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GEOLOGY AND GROUND-WATER RESOURCES
OF THE
HARNEY BASIN, OREGON

BY

A. M. PIPER, T. W. ROBINSON, AND
C. F. PARK, JR.

WITH A STATEMENT ON
PRECIPITATION AND TREE GROWTH
BY L. T. JESSUP

Prepared in cooperation with the
OREGON AGRICULTURAL EXPERIMENT STATION
W. A. Schoenfeld, Director
DEPARTMENT OF SOILS
W. L. Powers, Head

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GEOLOGY AND GROUND-WATER RESOURCES OF THE HARNEY BASIN, OREG.

By A. M. Piper, T. W. Robinson, and C. F. Park, Jr.

ABSTRACT

The Harney Basin covers about 5,300 square miles on the relatively high, semiarid plateau of southeastern Oregon, in Harney and Grant Counties. It constitutes the drainage area of the Malheur and Harney Lakes, which have no outlet to the sea. The average yearly rainfall is about 7.80 inches; the yearly mean temperature 44.6° F.

The basin may be divided into (1) a low central area that comprises playas and lake beds, extensive alluvial plains, cinder cones, and lava fields and (2) a higher marginal area that comprises erosion plains of intermediate altitude and a dissected upland eroded from a fault-block terrane. The Harney, Malheur, and Mud Lakes occupy the lowest part of the central area; together they cover about 125 square miles and range in altitude from 4,080 to 4,095 feet above sea level. Alluvial plains cover fully 800 square miles in addition to the playas. These plains are underlain by the shallowest water-bearing beds and include the arable land that can be irrigated economically by pumping from wells. The dissected upland attains a height of 9,600 feet above sea level in Strawberry Mountain, at the north, and of 9,400 feet in Steens Mountain, at the southeast.

The greater part of the basin is drained by the Silvies River and the Donner und Blitzen River, which rise on the highest parts of the upland to the north and south, respectively. Each stream varies widely in discharge, between a spring freshet of several thousand second-feet and an autumn run-off that may fail altogether; also, each discharges into Malheur Lake, which in turn drains westward to Harney Lake. Since 1895, the aggregate area of the lakes on these playas has ranged repeatedly from about 125 square miles to about 2 square miles.

In the Harney Basin nonmarine strata of the Tertiary and Quaternary systems rest upon crystalline and metamorphic rocks, part of which belong to the Lower Jurassic series. The Tertiary rocks include extrusive basalt, andesite, and rhyolite; ejectamenta that range from coarse scoria to compact massive tuff or breccia; also detrital sedimentary rocks of alluvial and lacustrine origin.

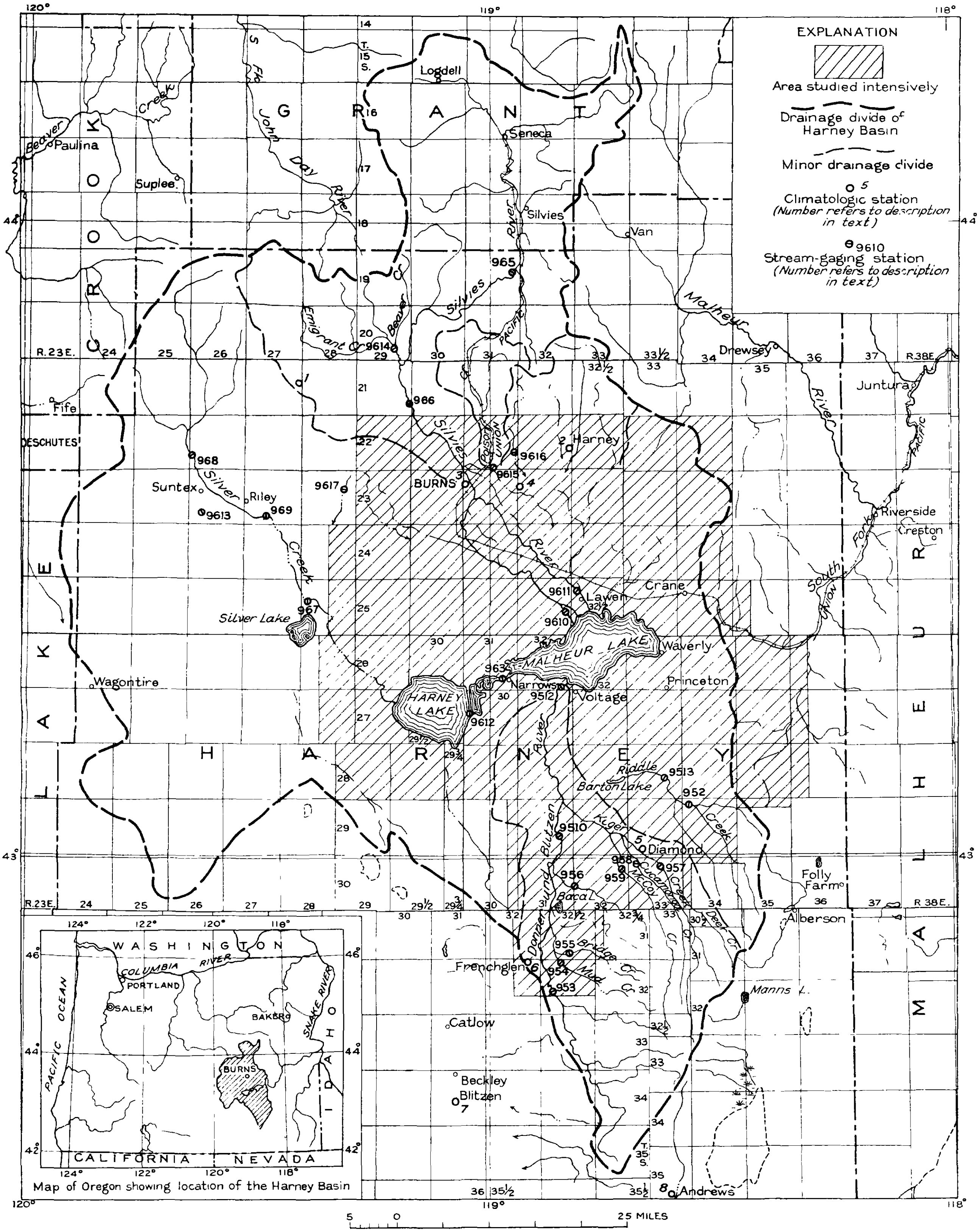
Five distinct stratigraphic units span the Miocene and Pliocene epochs. The oldest consists of siliceous extrusives of Miocene(?) age about 1,000 feet thick. These extrusives form a few scattered masses in the eastern half of the basin; in general they are loosely crumpled and faulted and have little water-yielding capacity. The Steens basalt, of Miocene age, rests unconformably on the older siliceous extrusives in the marginal upland along the east half of the basin. Its maximum known thickness, about 3,000 feet, is exposed in the eastward-facing escarpment of Steens Mountain. The component layers average 10 feet in thickness; scoriaceous and fragmental zones are common at the top of each layer and afford considerable water-yielding capacity. The Steens basalt is overlain un-

conformably by the Danforth formation, of Pliocene age, which crops out extensively over the whole dissected upland and ranges in thickness between 20 feet and about 800 feet. In the northwestern part of the basin the upper part of the Danforth formation comprises stratified siltstone, sandstone, tuff, and volcanic ash with a few intercalated layers of glassy rhyolite and one distinctive rhyolitic tuff-breccia member. Its lower part is massive rhyolite. In that area the stratified beds of the upper part yield considerable water at some places, and the lower part yields thermal water from fault conduits. In the southern part of the basin the Danforth formation displays four local facies—(1) the distinctive tuff-breccia member and associated stratified rocks; (2) an equally distinctive member of basaltic breccia and associated siltstone, sandstone, conglomerate, and two intercalated sheets of basalt; (3) stratified siltstone, sandstone, and ash; (4) spherulitic rhyolite. In that area the formation supplies several large thermal springs from fault conduits but generally is not extensively water-bearing. The succeeding stratigraphic unit, the Harney formation, of Pliocene (?) age, is about 750 feet thick and rests on the Danforth formation with angular and erosional unconformity. The Harney formation underlies an extensive plain of intermediate altitude in the west-central part of the basin and occurs in outliers along all margins of the central district except the northern. The formation includes massive basaltic tuff and breccia, sandstone, siltstone, some incoherent gravel, and a few layers of scoriaceous and massive basalt. The incoherent gravel yields water freely. A fanglomerate, also Pliocene (?), occurs locally along the north margin of the central area but lies above regional ground-water level.

The Quaternary formations include both volcanic and detrital deposits. In the southeastern part of the basin basaltic lava fields cover about 150 square miles. These disclose compact, scoriaceous, and fragmental extrusives; also lava domes, cinder cones, and cinder plains. The scoriaceous and fragmental facies are pervious; they supply one moderately large perennial spring and several flowing wells along the south margin of Malheur Lake. The youngest of these lava fields constitutes the Diamond Craters, which are of post-Pleistocene age. The Quaternary valley fill comprises alluvium, lake and playa deposits, and eolian sediments, all derived largely from the volcanic rocks of the upland. Along the principal streams at the outer margin of the central area the valley fill is largely clean sand and gravel, but toward the center of the basin these beds grade laterally and finger out into silt and clay. At least one thin layer of volcanic ash is intercalated from 3 to 6 feet below the land surface. It is inferred that alluviation followed promptly after the extrusion of a young basalt that dammed Malheur Gap, a former drainage outlet for the basin; also that the valley fill is thickest, about 300 feet, along the north edge of Malheur Lake. In the valley fill the members, lentils, and tongues of gravel and sand are pervious. Those which are shallow hold unconfined water; near the center of the basin this shallow water contains considerable alkali. The deep permeable beds in the valley fill hold confined water and supply several irrigation wells in the northwestern part of the central alluvial plain.

The Tertiary rocks of the upland are inclined toward the center of the basin from the north, east, and south, the dip ranging from 2° to 14°. In the main these rocks are not folded but are cut by faults that strike about N. 10° E. or N. 30°–60° W. The displacement along the principal fractures is about 1,000 feet. It is inferred that most of the faults were established at the end of the Steens epoch but were reopened and acquired their greatest displacement after the Danforth epoch. Some faulting occurred after the Harney epoch.

In the northwestern part of the central plain the water in the valley fill is derived largely by percolation from the Silvies River during the spring freshets.



MAP OF PART OF SOUTHEASTERN OREGON SHOWING EXTENT OF THE HARNEY BASIN.

Recharge of the shallow water-bearing beds takes place all along the stream. On the other hand, recharge of the deep pervious beds is inferred to take place largely within 5 miles from the head of the alluvial fan near Burns, where clean gravel and sand form about 90 percent of the fill. Farther from the head of the fan, confining beds prevent recharge of the deep pervious beds by downward percolation. From several lines of evidence it is estimated that the average annual recharge along the Silvies River is about 40,000 acre-feet, of which about 6,500 acre-feet could be pumped perennially from wells. In addition some water might be salvaged from the shallow pervious beds by growing alfalfa as a ground-water plant.

The water in the bedrock appears to fall into three distinct temperature ranges—slightly thermal water, 52° to 62° F.; water of intermediate temperature, 64° to 82° F.; and hot water, 90° to 154° F. The slightly thermal water has been encountered in bedrock wells of moderate depth in the northern part of the basin, where the safe yield of the aquifers appears to be at least equal to the safe yield of the valley fill. The water of intermediate temperature issues from relatively large springs in three small districts in the west half of the basin; the aggregate discharge by these springs in 1931 was about 40 second-feet. Water of intermediate temperature also issues from several flowing wells in the vicinity of the springs. The hot water issues from a few springs that are widely scattered over the basin, and their aggregate yield in 1931 was about 5 second-feet. It issues also from a deep flowing well in the southwestern part of the central alluvial plain. With few exceptions the thermal springs and the flowing thermal wells occur along or very near faults that cut the Tertiary rocks.

Six wells more than 500 feet deep have been drilled in the central plain in search of flowing water. The single deep well that was flowing in 1931 suggests that the artesian head is not large.

INTRODUCTION

Location and extent of the area.—The Harney Basin covers about 5,300 square miles in the relatively high and semiarid country of southeastern Oregon, in Harney and Grant Counties. As is shown on plate 1, it constitutes the drainage area of Malheur and Harney Lakes, which have no outlet. The largest community in the area is Burns, the county seat of Harney County and the commercial center of an extensive adjacent region.

Scope of the investigation.—The investigation upon which this report is based is one of a series that have been made in cooperation between the Federal Geological Survey and the Oregon Agricultural Experiment Station to evaluate the ground-water resources of Oregon. The cooperative program was begun in 1928 at the suggestion of J. T. Jardine, who was at that time director of the experiment station, and has been continued under the directorship of W. A. Schoenfeld.

The investigation covered the geology of the region in relation to the occurrence of ground water, an approximate ground-water inventory for a 3-year term, and the chemical character of the ground water. The field work was under the charge of A. M. Piper, who made a reconnaissance of the area October 4 to 7, 1928. Intensive field work was begun in August 1930 and ended in September 1932.

The greater part of the study of ground-water occurrence was made by T. W. Robinson; virtually all the geologic mapping was done by C. F. Park, Jr. Competent assistance was rendered by George Hibbard, Albert Hughet, and Mervin King.

Previous investigations.—The earliest reports that describe the general geologic and hydrologic features of the Harney Basin and the adjacent region are those by Russell,[1] who made reconnaissance surveys of ground-water resources in Idaho, Oregon, and Washington during the eighties and nineties. These surveys have been amplified through further reconnaissance by Waring.[2] Local geologic features have been studied in the last decade by Packard and Nelson,[3] Smith,[4] Fuller and Waters,[5] Gazin,[6] Lupher,[7] and Fuller.[8]

Acknowledgments.—Photographic copies of original topographic maps of the valley plain were furnished by the Bureau of Reclamation, United States Department of the Interior, and topographic maps of the beds of Malheur and Harney Lakes were made available by the Biological Survey, of the United States Department of Agriculture, in advance of general publication. Unpublished topographic maps and cultural maps were contributed by the United States Forest Service; by the State Engineer and the Department of Highways, State of Oregon; also by Baar & Cunningham, engineers, of Portland, and Cooper & Dodge, engineers, of Salem. The maps by Baar & Cunningham and Cooper & Dodge were received through C. B. McConnell, attorney, of Burns. The Oregon Short Line Railroad Co. supplied records of wells and pumping plants along their branch line within the basin. L. T. Jessup, of the United States Bureau of Agricultural Engineering, collaborated in gathering certain hydrologic data. Cooper & Dodge, engineers, and C. W. Pecore, of the United States Biological Survey, contributed unpublished data on the alti-

[1] Russell, I. C., A geological reconnaissance in southern Oregon: U. S. Geol. Survey 4th Ann. Rept., pp. 431–464, 1884; Notes on the geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Bull. 217, 83 pp., 1903; Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-Supply Paper 78, 53 pp., 1903; Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, 138 pp., 1905.

[2] Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, 86 pp., 1908; Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, 93 pp., 1909.

[3] Packard, E. L., and Nelson, R. N., Geologic occurrence of the Hardgrave Jurassic fauna of Burns, Oreg. [abstract]: Geol. Soc. America Bull., vol. 32, p. 148, 1921.

[4] Smith, W. D., Geology of Steens and Pueblo Mountains, southeastern Oregon [abstract]: Geol. Soc. America Bull., vol. 36, p. 202, 1925; Contribution to the geology of southeastern Oregon (Steens and Pueblo Mountains): Jour. Geology, vol. 35, pp. 421–440, 1927.

[5] Fuller, R. E., and Waters, A. C., The nature and origin of the horst and graben structure of southern Oregon: Jour. Geology, vol. 37, pp. 204–238, 1929; abstract and discussion by Smith, W. D., Geol. Soc. America Bull., vol. 40, pp. 187–188, 1929.

[6] Gazin, C. L., Miocene mammalian fauna from southeastern Oregon [abstract]: Pan-Am. Geologist, vol. 54, pp. 236–237, 1930; A Miocene mammalian fauna from southeastern Oregon: Carnegie Inst. Washington Contr. Paleontology, Pub. 418, pp. 37–86, 1932; abstract, Geol. Soc. America Bull., vol. 42, p. 367, 1931.

[7] Lupher, R. L., Geological section of Ochoco Range and Silvies Plateau [abstract]: Pan-Am. Geologist, vol. 54, p. 158, 1930.

[8] Fuller, R. E., The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: Washington Univ. Pub. in Geology, vol. 3, no. 1, 130 pp., 1931.

tudes of benchmarks established by them in the basin. L. A. MacArthur, of the Pacific Power & Light Co., also supplied unpublished data on altitudes of benchmarks compiled by his organization.

Orderly progress in the field investigation was assisted by the wholehearted cooperation of the residents of the area. The writers are especially grateful to T. A. Bayless, of the West Coast Power Co., for data on electric energy expended in pumping from wells; to G. M. Benson, warden of the Lake Malheur Reservation, for data regarding the history of Malheur and Harney Lakes and for cooperation in maintaining a staff gage in Malheur Lake in 1930 and 1931; to R. E. Cole and E. C. Hawkins, superintendents of municipal waterworks at Burns and Hines, respectively, for assistance in capacity tests of pumping plants in their charge; to J. S. Cook, R. W. Cozad, and William McLaren, irrigators, and to Obil Shattuck and R. E. Hutchison, of the Harney Branch Experiment Station, for cooperation in testing the capacity of their wells and in recording pumpage; and to J. J. Walsh, water master, for information on the utilization of surface water. Records of wells in the basin have been contributed freely by the well drillers who have operated in the basin; these include A. A. Durand, of Walla Walla, Wash.; Boyer & Koenemann and Hahn & Backus, of Burns, Oreg.; and the late P. S. Weitenhiller, of Crane, Oreg.

CLIMATE

The Harney Basin is semiarid, for ordinarily its rainfall is not sufficient to assure the growth of crops and occurs almost wholly in the winter and spring. Snow may fall on the valley plain during any month from October to June and on the surrounding mountains in any month of the year. The daily and seasonal range in temperature is unusually wide, relative humidity is low, evaporation is rapid, and in the summer the percentage of sunshine is high. Strong winds are common throughout the year, especially from March to June, but tornadoes are almost unknown.

Over a 25-year period the average length of the growing season or frost-free period at Burns has been 118 days. On the average, the latest killing frost of the spring has occurred on May 24 and the earliest killing frost of the autumn on September 19, but the latest and earliest of record occurred on July 6, 1895, and August 4, 1894, respectively. Thus, killing frosts or freezing temperature may occur in any month of the year. At the Harney Branch Experiment Station, the frost-free period is even shorter, the latest and earliest killing frosts for the 19-year term of record being July 7, 1924, and July 22, 1920, respectively.

Several tables follow to summarize the available climatologic data.

Summary of temperature records, in degrees Fahrenheit, for three climatologic stations in Harney Basin

[Data from publications of U. S. Weather Bureau and records of Harney Branch Experiment Station]

Burns (altitude, 4,157 feet; term of record, 1893 to 1920)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year (Oct. 1 to Sept. 30)
Mean	46.1	35.1	25.8	24.5	27.8	36.1	44.5	50.2	57.6	66.9	65.3	55.5	44.6
Mean of daily maximum	63.9	49.8	37.4	35.8	39.8	49.7	59.7	65.4	74.1	86.2	86.4	74.4	60.2
Mean of daily minimum	29.1	20.6	14.3	11.0	14.9	22.2	28.9	34.1	40.2	46.6	44.7	35.2	28.5
Highest of record	84	71	59	66	65	79	85	100	94	100	102	93	102
Lowest of record	6	−26	−23	−27	−32	−12	4	9	14	21	18	10	−32

Diamond (altitude, 4,300 feet; term of record, 1890 to 1900)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year (Oct. 1 to Sept. 30)
Mean	45.3	37.3	29.5	29.1	30.7	35.7	43.8	50.3	56.7	63.9	62.9	53.6	44.9
Mean of daily maximum	63.4	51.1	40.6	40.3	42.6	48.3	58.6	65.9	74.1	83.7	83.5	72.9	60.4
Mean of daily minimum	27.2	23.5	18.5	17.9	18.7	23.0	29.2	34.6	38.7	44.0	42.4	35.0	29.4
Highest of record	86	74	59	60	67	72	85	88	96	99	102	92	102
Lowest of record	9	−31	−11	−13	−22	3	12	17	22	26	28	17	−31

Harney Branch Experiment Station (altitude, 4,138 feet; term of record, 1914 to 1932)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year (Oct. 1 to Sept. 30)
Mean	43.8	33.6	21.8	20.5	27.2	36.3	43.2	50.9	57.7	64.6	63.4	53.4	43.2
Mean of daily maximum	62.2	47.2	33.0	32.4	38.3	48.7	58.6	68.3	76.7	87.1	85.2	73.8	59.3
Mean of daily minimum	25.5	19.6	10.3	8.8	16.3	23.4	28.4	34.0	39.1	44.3	41.8	33.2	27.1
Highest of record	88	70	58	59	68	76	83	93	102	105	101	95	105
Lowest of record	1	−14	−45	−44.5	−26	−17	11	12	19	27	24	2	−45

Annual rainfall and snowfall, in inches of water, at eight climatologic stations in or near Harney Basin

[By climatic years (Oct. 1 to Sept. 30). Data from publications of U. S. Weather Bureau and records of Harney Branch Experiment Station]

	Burns Mill	Camp Harney	Burns	Harney Branch Experiment Station	Diamond	Frenchglen	Blitzen	Andrews
No. on plate 1	1	2	3	4	5	6	7	8
Altitude, feet above sea level	5,000	4,150	4,157	4,138	4,300	4,100	4,300	4,100
1867–68		[1] 12.91						
1868–69		6.21						
1869–70		[2] 6.87						
1870–71		[2] 7.95						
1871–72		8.62						
1872–73		9.76						
1873–74								
1874–75		[2] 9.43						
1875–76		[2] 13.30						
1876–77		12.30						
1877–78		15.59						
1878–79		11.49						
1879–80								
1889–90								
1890–91					[1] 19.67			
1891–92			[3] 5.67		11.88			
1892–93			[3] 5.17		11.23			
1893–94			[1] 12.43		17.85			
1894–95					10.22			
1895–96					12.14			
1896–97			[1] 7.84		15.21			

See footnotes at end of table.

Annual rainfall and snowfall, in inches of water, at eight climatologic stations in or near Harney Basin—Continued

	Burns Mill	Camp Harney	Burns	Harney Branch Experiment Station	Diamond	Frenchglen	Blitzen	Andrews
No. on plate 1	1	2	3	4	5	6	7	8
Altitude, feet above sea level	5,000	4,150	4,157	4,138	4,300	4,100	4,300	4,100
1897–98	------	------	[2] 6.33	------	10.74	------	------	------
1898–99	------	------	------	------	14.44	------	------	------
1899–1900	------	------	12.25	------	16.51	------	------	------
1900–1	------	------	6.06	------	------	------	------	------
1901–2	------	------	------	------	------	------	------	------
1902–3	------	------	------	------	------	------	------	------
1903–4	------	------	16.20	------	------	------	------	------
1904–5	------	------	12.58	------	------	------	------	------
1905–6	------	------	16.98	------	------	------	------	------
1906–7	------	------	14.37	------	------	------	------	------
1907–8	------	------	9.86	------	------	------	------	------
1908–9	------	------	10.25	------	------	------	------	------
1909–10	20.20	------	12.81	------	------	------	------	------
1910–11	15.28	------	10.38	------	[1] 5.70	------	------	------
1911–12	18.60	------	12.19	------	9.44	------	------	------
1912–13	15.34	------	12.07	------	10.38	------	------	------
1913–14	------	------	13.07	[3] 9.77	7.34	------	------	------
1914–15	------	------	8.42	6.95	------	------	[2] 8.20	------
1915–16	------	------	------	8.12	------	------	8.45	7.52
1916–17	------	------	------	5.69	------	------	8.09	6.01
1917–18	------	------	9.88	7.00	------	------	3.54	4.57
1918–19	------	------	8.84	7.17	------	------	6.74	6.43
1919–20	------	------	8.46	7.85	------	------	[2] 10.96	7.93
1920–21	------	------	------	11.03	------	------	14.25	7.80
1921–22	------	------	------	7.43	------	------	6.69	6.29
1922–23	------	------	------	8.92	------	------	10.67	7.66
1923–24	------	------	------	5.24	------	------	5.35	4.21
1924–25	------	------	------	11.70	------	------	10.13	8.19
1925–26	------	------	------	8.19	------	------	7.57	6.86
1926–27	------	------	------	11.58	------	------	8.55	8.73
1927–28	------	------	------	7.40	------	9.69	9.75	5.93
1928–29	------	------	------	5.38	------	11.26	9.52	6.81
1929–30	------	------	------	5.43	------	8.76	8.58	6.44
1930–31	------	------	------	5.60	------	5.44	4.50	5.16
1931–32	------	------	------	7.73	------	12.10	11.40	7.20
Average	------	10.40	10.55	7.80	12.34	------	8.50	6.69

[1] Involves estimate for 2 months.
[2] Involves estimate for 1 month.
[3] Involves estimate for 3 months.

Monthly and annual rainfall and snowfall, in inches of water, at three stations in Harney Basin

[Data from publications of U. S. Weather Bureau and records of Harney Branch Experiment Station]

Camp Harney (altitude 4,150 feet)

Year (Oct. 1 to Sept. 30)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1867–68	------	------	3.90	1.88	0.57	0.91	0.78	2.01	2.29	0.27	0	0.30	[1] 12.91
1868–69	Tr.	0.40	.50	.97	.55	1.10	.86	1.11	.26	.31	Tr.	.15	6.21
1869–70	0	2.26	.90	1.50	.79	.59	.15	.10	------	0	.05	Tr.	[1] 6.87
1870–71	0	.09	.57	1.37	.48	2.20	.66	1.09	------	.64	.12	.11	[1] 7.95
1871–72	.03	1.05	2.83	1.69	1.68	.35	.10	.14	.11	0	.01	.63	8.62
1872–73	.82	.25	.53	3.15	1.24	.30	1.00	.27	.53	.96	.37	.34	9.76
1873–74	.25	1.08	2.41	------	------	------	------	------	------	------	------	------	------
1874–75	------	2.20	.34	1.14	.45	1.28	.28	1.15	1.64	.50	.02	Tr.	[1] 9.43
1875–76	1.26	3.00	3.19	1.01	.68	1.28	1.11	.54	.65	------	.12	.07	[1] 13.30
1876–77	1.05	.60	.48	1.30	1.35	3.60	.63	1.76	.81	.12	.54	.06	12.30
1877–78	.47	2.78	.40	2.00	3.12	1.61	1.72	.69	.84	.36	1.00	.60	15.59
1878–79	.76	.68	.22	1.50	1.75	2.04	2.74	1.01	.50	0	0	.29	11.49
1879–80	.70	3.34	4.42	.56	.62	.50	1.70	.72	------	------	------	------	------
Average	.49	1.48	1.59	1.51	1.11	1.31	.98	.88	.85	.32	.20	.23	10.40

[1] Missing months estimated.

Monthly and annual rainfall and snowfall, in inches of water, at three stations in Harney Basin—Continued

Burns (altitude 4,157 feet)

Year (Oct. 1 to Sept. 30)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1891-92	------	------	------	1.05	Tr.	0.25	0.25	1.65	0	0.10	Tr.	0.75	[1] 5.67
1892-93	------	------	0.16	1.35	0.50	.60	.10	------	Tr.	Tr.	0	1.25	[1] 5.17
1893-94	1.04	------	.80	1.90	1.70	.70	.70	1.80	1.30	.15	0	------	[1] 12.43
1894-95	1.85	------	------	1.20	------	------	------	------	------	0	------	------	------
1895-96	------	------	------	1.50	------	.93	1.30	------	------	.60	------	.70	------
1896-97	------	1.00	.60	1.10	1.10	.60	1.10	Tr.	------	.75	.25	.25	[1] 7.84
1897-98	.02	1.35	.95	1.45	------	Tr.	Tr.	1.52	.32	0	Tr.	Tr.	[1] 6.33
1898-99	Tr.	1.40	.20	1.90	.80	.61	.57	.16	------	------	------	------	------
1899-1900	1.32	4.55	1.80	Tr.	1.80	.54	1.15	.34	.34	0	.17	.24	12.25
1900-1901	.62	.47	.90	1.20	1.67	.30	.34	.12	.15	0	.22	.07	6.06
1901-2	.07	------	------	.72	3.31	.90	------	------	------	------	------	------	------
1902-3	------	------	------	------	------	------	------	------	------	------	------	------	------
1903-4	.34	3.53	.74	.77	2.52	2.88	1.50	[2] .81	.71	.58	.15	1.67	16.20
1904-5	.86	.37	2.84	1.93	.28	1.89	.65	.53	2.45	.01	.15	.62	12.58
1905-6	.55	.81	.57	4.24	1.38	3.94	.27	2.43	1.41	.36	.43	.59	16.98
1906-7	.23	.96	1.88	2.08	2.36	2.33	1.06	.51	1.59	.26	.10	1.01	14.37
1907-8	.27	.51	3.49	.99	.23	.34	.71	1.05	.73	.42	.31	.81	9.86
1908-9	1.35	.48	.59	3.86	1.52	.64	.10	.51	.23	.07	0	.90	10.25
1909-10	1.01	2.95	2.29	1.29	1.97	1.74	.32	.34	.04	.03	0	.83	12.81
1910-11	1.16	3.33	1.27	1.59	.50	.18	.36	.75	.56	.13	0	.55	10.38
1911-12	.13	.72	.71	1.94	1.35	.35	1.97	1.69	1.17	.91	.44	.61	12.19
1912-13	.16	1.66	1.19	1.55	.15	.86	.99	.25	2.93	1.99	.19	.15	12.07
1913-14	1.63	1.08	2.05	2.52	.80	.15	1.49	.94	1.41	0	0	[2] 1.00	13.07
1914-15	[2] .89	.03	.42	1.06	1.60	.90	1.18	.94	.40	.90	.06	.04	8.42
1915-16	------	1.26	------	------	------	.38	.44	------	------	------	------	------	------
1916-17	------	------	------	------	------	.84	.67	.90	.73	.30	0	.85	------
1917-18	0	2.27	.43	1.16	.75	.71	.20	.32	.92	.37	1.25	1.50	9.88
1918-19	.67	0	.15	1.25	2.58	.70	.67	0	0	.25	0	2.57	8.84
1919-20	.52	.04	2.58	.55	.16	.91	1.16	.36	.39	.61	.85	.33	8.46
1920-21	.56	2.68	2.10	------	------	------	------	------	------	------	------	------	------
Average	.66	1.43	1.25	1.61	1.26	.94	.74	.78	.81	.35	.20	.75	10.55

Harney Branch Experiment Station (altitude 4,138 feet)

Year (Oct. 1 to Sept. 30)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
1913-14	------	------	------	1.41	0.59	0.06	1.42	1.51	1.33	0.11	0	0.34	[1] 9.77
1914-15	1.39	0.12	0.36	.84	.73	.57	.75	1.52	.30	.30	.03	.04	6.95
1915-16	.03	1.16	.39	.50	1.90	.35	.81	.72	.96	.84	.33	.13	8.12
1916-17	0	.25	.38	.63	1.22	.58	.38	.80	.33	.19	.04	.89	5.69
1917-18	0	1.35	.62	.92	.53	.33	.12	.26	.64	.19	.51	1.53	7.00
1918-19	1.01	.20	.14	.67	1.45	.43	1.07	.32	0	.03	.07	1.78	7.17
1919-20	.78	.77	1.63	.35	.02	.71	.57	.51	.60	.53	.96	.42	7.85
1920-21	.86	1.77	1.26	1.46	.97	.98	.48	1.87	.29	.05	01	1.03	11.03
1921-22	.38	1.05	.45	.95	.75	1.03	.88	.36	.50	.01	1.06	.01	7.43
1922-23	.88	.78	1.51	.47	.09	.09	1.94	.86	1.52	.33	.06	.39	8.92
1923-24	1.38	.87	.44	.43	1.27	.18	.20	.06	.02	0	.18	.21	5.24
1924-25	1.03	.72	2.00	.96	1.07	.17	1.56	2.21	.34	.14	.44	1.06	11.70
1925-26	1.12	.97	1.16	.99	.86	.31	1.15	.53	.19	.46	.45	Tr.	8.19
1926-27	.25	2.96	1.07	.80	1.10	.82	.82	1.16	1.67	.01	.26	.66	11.58
1927-28	.44	1.83	.57	1.49	.88	1.02	.60	.04	.28	.15	0	.10	7.40
1928-29	.15	.66	.75	.50	.41	.28	1.20	.10	1.32	Tr.	Tr.	.01	5.38
1929-30	.04	.02	1.72	.87	.50	.72	.63	.22	.12	Tr.	.02	.57	5.43
1930-31	.18	.81	.23	.96	.62	1.05	.26	.38	.90	Tr.	Tr.	.21	5.60
1931-32	.59	.39	1.22	.86	.34	1.81	1.10	.97	.29	.15	Tr.	.01	7.73
Average	.58	.93	.88	.85	.81	.60	.84	.76	.61	.18	.23	.49	7.80

[1] Missing months estimated.
[2] Interpolated.

Average monthly and yearly snowfall, in inches, at five stations in southeastern Oregon

[Data from publication of U. S. Weather Bureau]

	Burns	Harney Branch Experiment Station	Frenchglen	Blitzen	Andrews
No. on pl. 1	3	4	6	7	8
Altitude, feet above sea level	4,157	4,138	4,100	4,300	4,100
Term of record	1893–1920	1922–32	1928–32	1914–32	1915–32
October	0.4	0.2	Tr.	0.4	Tr.
November	4.5	2.1	----	1.9	1.1
December	10.6	7.3	3.6	6.4	4.6
January	13.5	7.9	11.0	9.0	5.6
February	6.3	3.6	----	6.1	4.7
March	5.0	2.3	----	3.9	1.3
April	2.5	2.0	1.3	1.7	.7
May	.1	Tr.	0	.2	Tr.
June	.1	Tr.	Tr.	.2	Tr.
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	Tr.	0
The year	43.0	25.4	----	29.4	18.0

Evaporation, in inches, at Harney Branch Experiment Station

[Data from records of Harney Branch Experiment Station; 6-foot land pan blackened inside, rim 0.1 foot above land surface, water level 0.2 foot below land surface; altitude 4,138 feet]

Year	April	May	June	July	August	September	October	The period
1914	3.472	6.487	6.647	9.860	9.405	5.532	2.651	44.054
1915	4.352	4.971	7.714	8.820	9.036	5.871	3.525	44.289
1916	4.632	4.649	6.915	8.342	7.383	5.948	2.500	40.369
1917	1.750	5.226	7.895	10.190	8.140	5.257	3.647	42.105
1918	5.104	7.186	8.611	8.657	7.257	4.674	2.385	43.874
1919	4.509	6.838	8.435	9.801	8.210	5.163	2.544	45.500
1920	4.318	8.600	6.593	9.482	8.273	5.124	2.226	44.616
1921	3.636	6.092	6.080	9.330	8.208	4.948	2.849	41.143
1922	3.217	5.950	8.869	9.210	8.006	6.671	3.024	44.947
1923 [1]	----	----	----	----	----	----	----	----
1924	5.226	8.552	9.893	10.848	9.058	6.900	4.028	54.505
1925	3.915	5.286	6.358	9.392	7.499	4.445	2.300	39.195
1926	4.070	6.199	8.504	10.057	8.256	5.715	2.687	45.488
1927	3.378	5.159	6.276	8.063	6.758	3.730	2.425	35.789
1928	3.329	6.973	7.100	8.560	8.255	5.304	2.729	42.250
1929	2.580	6.268	6.040	9.185	7.888	5.063	2.881	39.905
1930	3.596	5.402	7.477	9.028	7.619	4.490	2.248	39.860
1931	3.954	7.093	6.639	9.503	7.750	4.183	2.379	41.501
1932	2.982	4.822	6.462	7.838	6.453	----	----	----
Average	3.826	6.290	7.414	9.313	8.059	5.236	2.766	42.905

[1] No record.

Monthly mean wind velocity, in miles an hour, at Harney Branch Experiment Station

[Data from records of Harney Branch Experiment Station; term of record, 1914 to 1932]

Month	Maximum	Minimum	Average	Percent of yearly wind movement
October	5.1	2.2	3.4	7.3
November	5.1	1.7	3.0	6.5
December	4.3	1.4	2.9	6.2
January	5.3	1.5	2.8	6.0
February	4.8	1.7	3.3	7.1
March	7.6	2.1	4.5	9.7
April	7.4	3.8	5.4	11.6
May	7.2	4.3	5.5	11.8
June	6.5	2.8	4.6	9.9
July	5.5	2.9	4.1	8.8
August	4.5	2.9	3.5	7.5
September	4.9	2.3	3.5	7.5
The year			3.9	

PRECIPITATION AND TREE GROWTH IN THE HARNEY BASIN

By L. T. Jessup [9]

Problems connected with water supply and its utilization commonly require some information relative to the general variations and trends of precipitation for a longer period than that covered by the usual climatologic records. One method that has been used in efforts to extend such records consists of the measurement of the rate of growth of trees as shown by the width of annual rings and comparing this rate with available precipitation records.[10] In the arid regions the available soil moisture may be the dominant physical factor in tree growth, and in some areas where the only source of soil moisture is local precipitation it is possible to establish a correlation.

Juniper trees were selected for making such an investigation in the Harney Basin, for the reason that they grow on the foothills close to the valley floor and at an altitude not far above that of the Harney Branch Experiment Station, where meteorologic observations are made. The experiment station is 4,138 feet above mean sea level.

The species of juniper growing in this basin tend to branch near the ground, and the trunks of the mature trees tend to become lobate in cross section, so that they have flutings. In many trees the several lobes grow at somewhat different rates, so that the width of a particular annular ring may not be constant. Also the older trees generally have extensive decayed sections, particularly at the heart or core. For these reasons a considerable number of trees were exam-

[9] Associate drainage engineer, Bureau of Agricultural Engineering, United States Department of Agriculture. This investigation was made by the writer while temporarily assigned to the Bureau of Biological Survey. The field work was done in September 1931, in collaboration with T. W. Robinson, of the Geological Survey, United States Department of the Interior.

[10] Douglass, A. E., Climatic cycles and tree growth, vol. 2: Carnegie Inst. Washington Pub. 289, 1928.

ined, but sections of only four were selected as satisfactory for study. These were full sections taken from isolated trees growing well above the bottom of any draw or depression. A brief description of the location of each follows:

1. Burns, 6 miles northwest of, on road to Izee, near rock ledge on steep slope with southern exposure; altitude 4,750 feet.
2. Burns, 21 miles west of, on highway to Bend; sandy soil on flat ridge; altitude 4,450 feet.
3. Frenchglen, 1½ miles southwest of, on road to Blitzen, near the pass from Blitzen Valley into Catlow Valley, on rocky shelf; altitude 4,840 feet.
4. Frenchglen, 5 miles north of, on road to Narrows, on steep rocky slope with western exposure on west side of Blitzen Valley; altitude 4,600 feet.

Transverse sections 2 inches thick were cut from the trunks about 1 or 2 feet above the land surface, and lines were drawn on each section to indicate the four cardinal directions of the compass in the position of growth. Some of these lines were shifted a few degrees in order to avoid indentations and other defects. Along each cardinal radius every tenth ring was marked and dated, and if possible it was completely traced out. Also the very small intervening rings of the four sections were compared in order to avoid improper dating that might have resulted from double or missing rings.

For the purpose of measuring ring widths a meter stick was fitted with a slide equipped with a fine pointer, a magnifying glass of 14 diameters, a vernier, and a slow-motion screw. The meter stick was fastened to the tree section so that the pointer could be moved along one of the radial lines and a reading to 0.1 millimeter was taken at the margin of each ring. Except where decay prevented, readings were taken along each of the four radii, and the four measurements of each ring were averaged.

For each tree the mean width of ring was determined for the period 1760 to 1930, and the deviation of each ring from this mean was determined and expressed as a percentage. An average of the four results for each year was taken to represent the percentage deviation from normal tree growth and was plotted on figure 1 for the years 1898 to 1930.

Measurements of rainfall and snowfall at Burns were started in 1892 and were continued until December 1921, although somewhat intermittently at first. At the Harney Branch Experiment Station, which is 6 miles due east of Burns, measurements were started during the later part of 1913 and continued to 1932 (p. 8). For the 72-month period of concurrent records, the average yearly precipitation at Burns was 9.89 inches, whereas at the Harney Branch Experiment Station it was 8.03 inches, or 81.2 percent of that at Burns. By applying this percentage to the earlier records at Burns the precipitation at the Harney Branch Experiment Station was estimated for 1898, 1900, 1901, and 1904 to 1913. A climatic year beginning with October 1 was used. These estimates, together with the measured precipitation, gave 8.6 inches as the probable magnitude of the long-term mean annual precipitation at the Harney Branch Experiment Station. The percentage of yearly deviation from this mean was determined and the results also plotted on figure 1.

On figure 1 the solid line represents the percentage deviation of tree-ring width or tree growth from the normal growth and the dotted line represents the corresponding deviation in precipitation. The close resemblance of the two curves is evident, even though the points were plotted without adjustment. Figure 2 is analogous to figure 1 except that each of its two curves has been smoothed by plotting the means of three successive determinations while giving

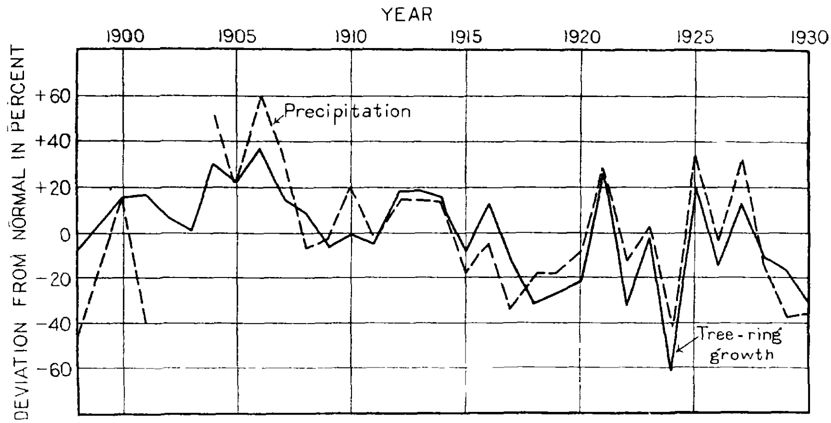


FIGURE 1.—Relation between tree growth and precipitation in the Harney Basin, 1898 to 1930.

double weight to the middle determination and except that the graph of tree-ring widths has been extended back to 1734.

Two of the four trees had rings extending back to 1734, but these two trees are hardly sufficient to give representative deviations. However, the average from the two showed tree-ring widths below normal from 1755 to 1759, and with but two exceptions they were above normal from 1734 to 1754.

The mean width for all the annular rings was 0.824 millimeter, the mean for the period 1760 to 1930 was 0.818 millimeter, and the mean for the period 1898 to 1930 was 0.820 millimeter. These figures indicate that the mean precipitation at the Harney Branch Experiment Station for the years during which records are available and computed is not materially different from the mean for the last 170 to 200 years. The curves of figure 1 agree more closely for the years in which measurements were made than they do for the years in which the precipitation was estimated by applying a coefficient to the records taken at Burns. Though it is evident from the curves that it would not be possible to determine accurately the precipitation for some particular past year of no record, yet the correlation appears to be sufficiently strong to indicate rather definite general trends and deviations.

The data from this study suggest that a precipitation of 8.6 inches is not far from the true long-term mean for the Harney Branch Experiment Station and that severe and protracted droughts may occur from 70 to 90 years apart. These relations and others of lesser import are shown on figure 2.

LAND FORMS

The Harney Basin may be divided into (1) a low central area whose land forms are relatively young and have been constructed by sedimentation and volcanism and (2) a higher marginal area which has been eroded from a fault-block terrane. In these general features the basin is typical of an extensive region in eastern Oregon and adjacent parts of Idaho, Utah, Nevada, and California.

In order of increasing age, the constructional land forms of the central area are playas and lake beds, dunes, and alluvial plains; also cinder cones and plains, lava fields, and other initial volcanic surfaces. The marginal area comprises erosion plains of intermediate altitude and an extensive dissected upland.

Three playas—flats which are covered periodically by ephemeral or intermittent lakes—dominate the central area of the Harney Basin; these are Harney, Malheur, and Mud Lakes. (See pls. 2 and 3, *A*.) These three playas are sumps to which excess surface water runs off and from which both surface water and ground

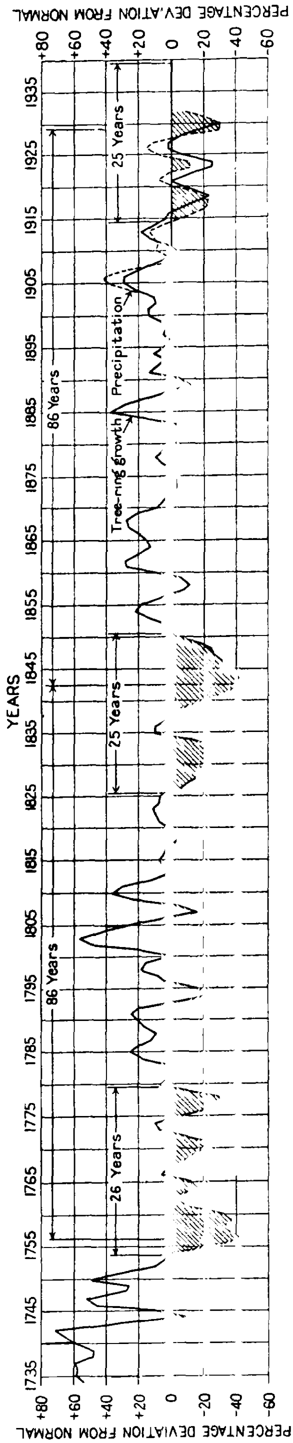


FIGURE 2.—General deviations of precipitation in the Harney Basin, as indicated by tree growth, 1734 to 1930.

water are dissipated by evaporation and to some extent by transpiration. Together, they cover about 125 square miles, but their relief is only about 15 feet. Pecore [11] determined the lowest point on the floor of Harney Lake to have been 4,079.7 feet above sea level in 1931; on Malheur Lake, 4,088.8 feet. Along the meander lines that surround the playas the mean altitudes were, on Harney Lake, about 4,095 feet; on Malheur Lake, about 4,093 feet.

Along the margin of Harney Lake the so-called "Sand Reef," a continuous and conspicuous ridge of dunes, rises gradually from the alluvial plain in sec. 29, T. 26 S., R. 30 E., and traces a smooth sweeping curve for about 10 miles toward the east and south. About a mile from its south terminus, in the unsurveyed portion of sec. 18, T. 27 S., R. 30 E., this ridge is pierced by a single channel, the so-called "Sand Gap," whose floor was between 4,086 and 4,087 feet above sea level in 1931, according to the survey by Pecore.[12] However, there is considerable historic evidence that the "gap" has been partly filled with dune sand at times and has been scoured intermittently when Malheur Lake has overflowed through it. (See p. 20.)

The eastern half of Malheur Lake is traversed by three abandoned beach ridges, of which the most easterly and westerly are known as Pelican Island and Cole Island, respectively. On the western half of the playa Graves Island forms a possible correlative of Cole Island. These ridges have stood above water when the playa has been extensively flooded in historic time. Each is breached by several gaps, which drain lagoons.

An older and higher beach ridge is imperfectly preserved at several places about the playas. East of Malheur Lake it extends almost to the portal of Malheur Gap (p. 18), where its crest is about 4,105 feet above sea level. Farther west it passes through the W½ sec. 11, T. 26 S., R. 33 E., skirts the southwestern flanks of Warm Spring Butte and Saddle Butte, and continues about to Lawen. Still farther west the ridge appears to lapse for several miles across the alluvial plain of the Silvies River, but it rises again about in sec. 26, T. 25 S., R. 32 E., and extends southwestward into the dunes northeast of Harney Lake. In the latter reach the crests of the principal beach remnants are about 4,100 feet above sea level. A possible correlative of the high-level beach ridge is the highest of four shingled beach terraces that occur south of Harney Lake in sec. 1, T. 28 S., R. 29¾ E. (See pl. 3, *B*.) No higher shore features are known to exist in the central area of the Harney Basin, although most other desert basins in eastern Oregon have prominent shore features at least 100 feet higher than their playas.

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[11] Pecore, C. W., Supreme Court of the United States, October term, 1932, The United States of America v. the State of Oregon, Joint abstract of record, vol. 1, pp. 105, 173–174, 263, 1932.

[12] Idem, vol. 2, pp. 850–851.

A. HARNEY PLAYA.

View southeastward from lot 3, sec. 28, T. 26 S., R. 30 E.

B. SHINGLED BEACHES ALONG THE SOUTHERN EDGE OF HARNEY LAKE.

A. PORTAL OF MALHEUR CAVE.
A lava tube in sec. 18, T. 27 S., R. 36 E.

B. EROSION TRENCH ON TONGUE OF VOLTAGE LAVA FIELD.
View eastward (downstream) from the SE¼ sec. 26, T. 27 S., R. 35 E.

A. GLACIATED VALLEY OF UPPER KIGER CREEK.
Viewed from the crest of Steens Mountain.

B. MALHEUR GAP.
Viewed from the central alluvial plain east of Malheur Lake.

Alluvial plains cover fully 800 square miles in the low central part of the Harney Basin (pl. 2), exclusive of the major playas. Chief among these are (1) the central alluvial plain east of Harney Lake and north of Malheur Lake, which covers about 500 square miles and is locally called the Harney Valley; (2) the Donner und Blitzen Plain, which covers about 125 square miles in the south-central part of the area; and (3) the plains along Warm Spring Creek and lower Silver Creek, which cover about 100 square miles between Harney and Silver Lakes. The latter two units are extensive tongues of the central plain which drown their respective valleys. The so-called "upper valley" of Silver Creek includes an alluvial plain of 40 square miles; this lies beyond the area shown on plate 2, largely in T. 23 S., R. 26 E. These alluvial plains absorb much water from the streams as well as from rain and snow; they also dissipate much water by transpiration and, to a minor degree, by evaporation (pp. 74–82). They are underlain by the shallowest productive water-bearing beds and include the arable land that can be irrigated economically by pumping from wells.

The central alluvial plain ranges between 4,165 feet above sea level near Burns and 4,093 feet along the margin of Malheur Lake. It originates in marginal alluvial tongues and vague fans that slope as much as 40 feet to the mile, whereas the main part of the plain slopes between 2 and 7 feet to the mile toward the playa. Upon this plain are superposed the shallow distributaries of the Silvies River and the "sloughs" and faint drains that converge from intermittent streams toward the playa.

Commonly the relatively flat alluvial plain abuts against a steep or even precipitous rock border. This condition is conspicuous along the flanks of Wrights Point, a narrow basalt-capped salient that projects nearly 8 miles into the plain from its western margin. There talus deposits are not extensive. Russell [13] and Waring [14] have concluded, respectively, that the precipitous slopes of Wrights Point were shaped by erosion and that the present topography was caused by gradual rise of base level and deposition of the present valley fill over the foot slopes of the erosion surface. With these conclusions the writers agree.

Surfaces of volcanic origin that are virtually unweathered and but little eroded are extensive in the Harney Basin, especially in its southeastern part. These are relatively permeable and probably allow an appreciable part of the rainfall to penetrate to the ground-water table. The youngest is a basaltic lava field, the Diamond Craters,[15] which

[13] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 40, 1905.

[14] Waring, G. A., Geology and water resources of the Harney Basin, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 29, 1909.

[15] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Bull. 217, pp. 54–57, 1903.

covers about 25 square miles in Tps. 28 and 29 S., R. 32 E. This field dams the basin of Riddle Creek and in all probability has diverted the lower part of Kiger Creek toward the west. Its dominant feature is a lava dome about 400 feet high whose crest is broken by a linear pit about 2,000 feet long, 600 to 700 feet wide, and about 50 feet deep. Small spatter cones are numerous along the eastern edge of the field. Satellitic cinder cones flank the central lava dome on the south and west, and from them a barren cinder plain extends southwestward. At some places the marginal lava field is hummocky with collapse pits and a few pressure ridges; at other places it is relatively smooth and composed of ropy (pahoehoe) lava; still elsewhere it is built from blocky (aa) lava with a jagged surface that is all but impassable. All these recent volcanic features stand unscarred by erosion. Very little soil has formed, but sagebrush and other desert plants grow here and there.

An older basaltic lava field, much more extensive, extends northward from the Diamond Craters nearly to Malheur Lake, eastward to the base of Riddle Mountain, and northward into the valley of the South Fork of the Malheur River. Altogether it covers about 125 square miles. It is unlike the Diamond Craters lava field in that it has a discontinuous thin mantle of eolian soil, its rocks are somewhat weathered at a few places, and locally it is overlain by alluvium. Lava domes from which this extensive field was extruded have been recognized in three places—(1) about 5 miles east and from 1 mile to 4 miles south of Voltage town site, in the eastern part of T. 27 S., R. 32 E.; (2) north of Riddle Mountain, near the Mule ranch, in T. 28 S., R. 35 E.; and (3) along the south flank of Malheur Gap in T. 27 S., R. 35 E. As the domes near Voltage are the most prominent, the name "Voltage lava field" is used in this report. In altitude, the Voltage lava field probably does not have a range of more than 500 feet. Generally it is relatively smooth, but locally it is spotted with pressure ridges and is strewn or paved with basaltic rubble.

Malheur Cave, in sec. 18, T. 27 S., R. 36 E., is a well-known landmark on the tongue of the Voltage lava that extends into the Indian Creek Valley;[16] it is a common lava tube whose roof has collapsed. (See pl. 4, *A*.) In 1932 the tube plunged below ground-water level about half a mile from its portal.

Although older than the lava field near Diamond, the Voltage lava field is relatively young in terms of the geologic time scale. It is inferred to have dammed the ancestral Malheur Gap and thereby to have cut off Harney Basin from the drainage area of the Malheur

[16] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 22, 1909.

River and to have started the epoch of alluviation that built the extensive central plain.

The most conspicuous of the erosion plains of intermediate altitude lies in the western part of the basin, between Sagehen Valley and Warm Spring Valley; it widens extensively farther west, beyond the vague drainage divide that bounds the Harney Basin (pl. 1). Its eastern margin is a somewhat lobate scarp about 200 feet high, which fronts on the central alluvial plain. This extensive plain has been cut from the little-deformed Harney formation by the stripping of weak rocks (pp. 28, 40) from above a common layer or zone of basalt. In its larger features the plain conforms to the initial lava surface, but pressure ridges and other volcanic features have been planed off. Dog Mountain rises about 250 feet above the plain in T. 25 S., R. 31 E.; it is composed largely of the weak members of the Harney formation that have been stripped elsewhere. Remnants of analogous erosion plains, some of them cut from rocks older than the Harney formation, occur along the eastern and southern margins of the basin.

On the north, east, and south the central alluvial plain is bordered by a well-drained upland of strong to high relief and relatively high altitude, which is composed largely of deformed volcanic rocks. These rocks are relatively resistant to erosion and are only slightly permeable; nevertheless the upland is the chief catchment area for the perennial streams that form the principal source of the ground water in the central area. (See pp. 63, 69.) This upland may be subdivided into (1) the Silvies Plateau, which borders the central alluvial plain on the north, whose southern part is a barren dip slope rising northward to 7,000 feet above sea level at King Mountain (T. 20 S., R. 32 E.), and whose northern part is timber-covered and rolling, has moderate relief, and culminates in Strawberry Mountain, at an altitude of 9,600 feet (T. 14 S., R. 33 E.); (2) the Crowcamp Hills and Indian Creek Buttes, which, with related terrane, bound the basin on the east; (3) Steens Mountain, to the southeast, whose crest is 9,354 feet above sea level,[17] whose eastern face is an impressive fault scarp about 5,500 feet high, and whose western face is a dip slope that declines 2° to 3° to the alluvial plain of the Donner und Blitzen River; and (4) finally, an unnamed barren plateau of low relief that lies west of the Donner und Blitzen River and south of Harney Lake. Commonly the upland streams occupy fault-line valleys, and many of the land forms, both large and small, have resulted from recent movement along faults or from stripping along inclined strata and not from planation in horizontal strata. Most of the dissection in these upland areas has been accomplished by streams, but in the northern part of

[17] Swick, C. H., First- and second-order triangulation in Oregon: U. S. Coast and Geodetic Survey, Special Pub. 175, p. 38, 1932.

Steens Mountain the upper reach of Kiger Creek flows in a bold U-shaped valley (pl. 5, *A*) which is the obvious product of a former valley glacier. Also, the highest parts of both Steens Mountain and Strawberry Mountain appear to have been glaciated locally.

Two low-level wind gaps pierce the dissected upland along the east side of the basin; these are Crane Gap, with a portal in sec. 7, T. 25 S., R. 34 E., and Malheur Gap (pl. 5, *B*), which opens from the central alluvial plain 11 miles farther south, in sec. 5, T. 27 S., R. 34 E. Russell [18] has inferred that each of these gaps has been a drainage outlet for the Harney Basin, although no drainage has passed through either within historic time or through Crane Gap in latest geologic time. The writers infer that Malheur Gap was the chief outlet of the basin during the epoch in which so large a volume of the Harney formation was stripped from the central area. The high-level beach ridge that passes around the east end of Malheur Lake swings within half a mile of the portal of Malheur Gap and is pierced by an ill-defined drain that can be traced well into the gap itself. These features suggest that Malheur Lake has spilled eastward through the Malheur Gap during the present geologic epoch, even though it has not done so within historic time. This suggestion, however, is not uncontroverted, for the alluvial floor of the gap rises toward the east and passes over a very low divide in the vicinity of the Gap School. There, 6 miles east of the portal and approximately on the line between Rs. 34 and 35 E., the alluvial floor stands 4,114 feet above sea level,[19] or about 25 feet above the floor of the Malheur Lake and 9 feet above the crest of the high-level beach ridge.

DRAINAGE SYSTEM

STREAMS

By far the greater part of the Harney Basin is drained by the Silvies River and the Donner und Blitzen River, which head on the highest parts of the dissected upland to the north and south, respectively, of the central alluvial plain. Each stream crosses an imperfectly drained plain of low or moderate relief and discharges onto the central alluvial plain. Each is flashy and varies widely in discharge, between a spring freshet that may be as much as 5,000 second-feet at the margin of the central plain and an autumn ground-water run-off that may fail altogether. The run-off likewise varies widely from year to year, that of the Silvies River having ranged recently from 2?9,000 acre-feet in 1903–4 to 21,800 acre-feet in 1929–30.

[18] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 38, 1905.

[19] Whistler, J. T., and Lewis, J. H., Harney and Silver Creek projects: U. S. Reclamation Service, [Report on] Oregon cooperative work, drawing 40, p. 76, 1916.

The Silvies River debouches upon the northwest corner of the central alluvial plain near Burns. At the apex of its alluvial fan it branches into a loosely braided plexus of distributaries and "sloughs" that traverse the central alluvial plain from northwest to southeast. (See pl. 2.) Each spreads widely beyond its channel during freshets.

Under natural conditions the greater part of the area within the plexus of distributaries was native meadow or swamp. However, much of the swampy land has been reclaimed to serviceable meadow, and the spring freshets have been spread widely to irrigate by "wild flooding." Donnelly [20] estimated that the area commonly irrigated in this manner between the apex of the alluvial fan and Malheur Lake was about 61,000 acres in 1912; it does not differ greatly today. Ordinarily, a relatively large percentage of the yearly run-off is dissipated from this area by consumptive use of plants (pp. 78–82); doubtless more water is dissipated under irrigation than under natural conditions. In the years of the larger freshets a considerable volume of water has run off into the Malheur Lake, but in other years the entire freshet has been dissipated on the alluvial plain. The latter condition existed in 1930 and 1931, when the yearly run-off was small, likewise in 1932, when the run-off was of average magnitude. By midsummer the discharge commonly becomes small and is entirely dissipated by diversion, evaporation, and infiltration within a few miles after reaching the central alluvial plain.

The Donner und Blitzen River does not ramify in its upland catchment area but has a few subparallel tributaries that descend the westward-sloping Steens Mountain block. Moreover, the valley of the trunk stream is drowned throughout by alluvium, so that under natural conditions the stream was sluggish and meandered through a swampy plain from the very head of its alluvial basin. However, this condition has been rectified by canalizing the stream for about 20 miles. Like the Silvies River, the Donner und Blitzen River has been spread widely upon its valley plain for irrigation by "wild flooding," but usually it has flowed perennially into Malheur Lake.

Without exception, the remaining streams of the Harney Basin are intermittent in their lower reaches, and many of their tributaries are ephemeral. Even Silver Creek and Warm Spring Creek, which together drain about 2,000 square miles in the western part of the basin and which nominally are tributary to Silver and Harney Lakes (pl. 1), commonly do not flow perennially. Likewise, the southwestern quadrant of the basin—the so-called Big Stick district of some 700 square miles—rarely has discharged water onto the alluvium of upper Warm Spring Valley.

[20] Donnelly, H. K., [Report to the Oregon State Water Board], quoted by Whistler, J. T., and Lewis, J. H., op. cit., p. 56.

LAKES

The Silvies River and the Donner und Blitzen River discharge into Malheur Lake, whence any surplus flows westward across Mud Lake to the Sand Gap and thence into Harney Lake. Harney Lake also receives the run-off from the western part of the basin by way of Silver Creek and Warm Spring Creek. Thus, Harney Lake is the ultimate drainage sump for the entire basin. Because neither it nor Malheur Lake has a functional drainage outlet, both dissipate water by evaporation and to some extent by transpiration. Thus each lake has varied widely in extent and volume from season to season and from year to year, according to the interplay between inflow (pp. 122–123) and evaporation (p. 9). Indeed, since 1895 their aggregate water-surface area has ranged repeatedly from about 125 square miles down to about 2 square miles.

The following table and the diagram in plate 6 indicate the water-surface area and capacity of the lakes. Plate 7 summarizes the available readings on staff gages in the lakes (pp. 128–131).

Water-surface area and capacity of Harney, Mud, and Malheur Lakes

Water-surface altitude (feet above sea level)[1]	Harney Lake		Malheur and Mud Lakes	
	Area [2] (acres)	Capacity [3] (acre-feet)	Area [2] (acres)	Capacity [3] (acre-feet)
4,080	3,600	360		
4,081	13,500	8,910		
4,082	19,900	26,200		
4,083	23,600	47,900		
4,084	26,400	73,100		
4,085	28,100	100,300		
4,086	29,000	129,000		
4,087	29,700	158,000		
4,088	30,200	188,000	120	60
4,089	30,700	218,000	800	430
4,090	31,300	250,000	12,200	5,230
4,091	31,700	281,000	19,400	23,400
4,092	32,100	313,000	33,600	46,400
4,093	32,400	345,000	49,000	91,000
4,094	32,700	378,000	59,300	143,000
4,095	[4] 33,100	411,000	[4] 64,300	208,000
4,100	[4] 36,600		[4] 122,000	

[1] Based on altitude 4,095.87 feet for the U. S. Geological Survey benchmark at Narrows. Leveling by C. W. Pecore, U. S. Biological Survey, 1931.
[2] By L. T. Jessup for the U. S. Biological Survey; measured by planimeter from topographic maps, scale 1:15,840.
[3] Computed by T. W. Robinson, U. S. Geological Survey.
[4] Estimated.

These two diagrams suggest the manner in which the area and volume of the lakes have varied in recent years under natural conditions,[21] although it should be kept in mind that (1) when the water-surface altitude is less than about 4,091.5 feet the three lakes are separate bodies of water, and under such conditions, the readings on the staff gage at Narrows have no relation to the water-surface altitude

[21] In 1935, the United States Biological Survey began the construction of dikes to reduce the area and volume of Malheur Lake by cutting off the lagoons east of Cole Island.

in either Malheur Lake or Harney Lake; (2) when the water-surface altitude is more than about 4,091.5 feet, water may be flowing from Malheur Lake into Mud Lake and possibly to Harney Lake, and under such conditions the water surface at the Narrows staff gage may stand somewhat lower than in Malheur Lake; (3) the water-surface altitude of Harney Lake is largely independent of the altitude of Malheur Lake and may stand as much as 10 feet lower; (4) the altitude of the water surface in the open lakes may differ somewhat, depending upon the rate of inflow, the intensity of the wind, and the disposition of tules; and (5) the altitude of the water surface in the lagoons east of Cole and Pelican Islands may lag behind that in the main lake, for the channels that join them to the main lake are relatively small. A rude cyclic fluctuation of the lakes over a term of years is suggested by the two diagrams.

In 1930 and 1931 no water ran off to Malheur Lake from the Silvies River and comparatively little from the Donner und Blitzen River. Consequently the lake receded steadily. In September 1930 it covered 2,000 acres, according to a stadia traverse, but a year later it had shrunk to its smallest known size—about 500 acres. This virtual desiccation culminated a progressive recession of the lake that began in 1921. In 1932 the lake again received no water from the Silvies River, but the freshet from the Donner und Blitzen River filled it to an altitude of about 4,092 feet. By May 23, 1932, it covered about 25,000 acres, but very little water passed through the gaps in Cole Island to the lagoons farther east. Throughout this 3-year term there was no water in Harney Lake except in the pools of several thermal springs upon its floor and about the mouth of Warm Spring Creek, at its western margin. For example, on September 11, 1930, Warm Spring Creek was flowing 11.8 second-feet at the margin of the playa but was dissipated by the time it had covered 500 to 1,000 acres. In May 1932, when the run-off to Malheur Lake had reached its peak for the year, two of the writers (Piper and Robinson) traversed the western part of Mud Lake and found no water in the channel leading to the Sand Gap and to Harney Lake.

Prior to 1931 Malheur Lake is known to have been small in the autumn of 1917 and to have been almost completely dry in 1889, after 3 years of deficient rainfall and deficient run-off. On the other hand, the lake was relatively extensive in 1921, repeatedly in the decade from 1895 to 1905, and commonly in the late seventies and early eighties. When largest, Malheur Lake commonly extended eastward within about half a mile of Windy Point.[22] All the early travelers in the region, beginning with Peter Skene Ogden in 1826, report an extensive saline lake (Harney Lake) but describe only a relatively small fresh-

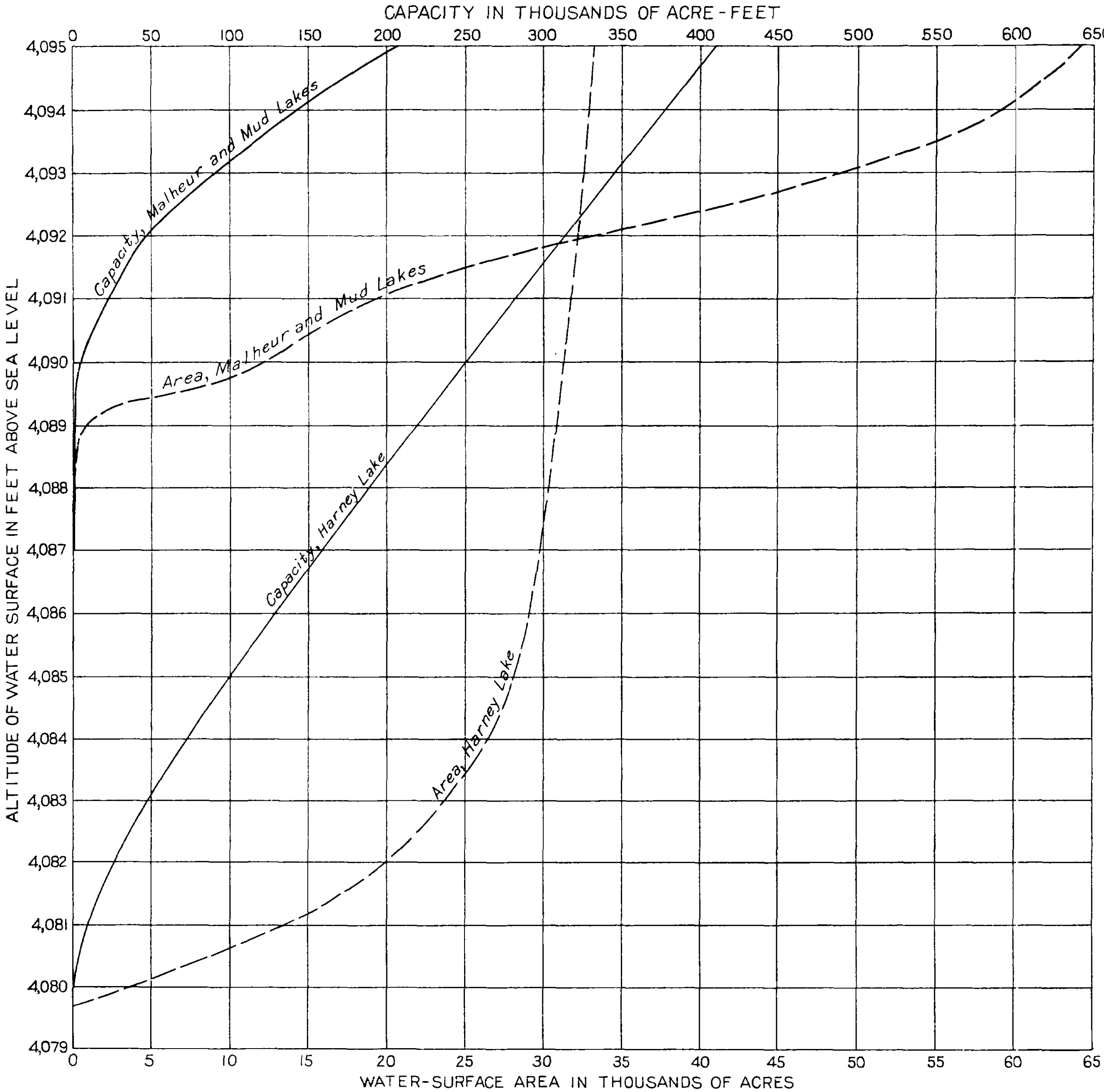
[22] Supreme Court of the United States, October term, 1932; The United States of America *v.* The State of Oregon, Joint abstract of record, vol. 1, pp. 348-621, 1932.

water lake to the east (Mud Lake or Malheur Lake). Not until 1864, apparently, did Malheur Lake command sufficient notice to be described separately and to be named in any of their journals. In June of that year Capt. George Currey and his troops entered Harney Basin from the east and arrived "at the southeast margin of Lake Malheur on the evening of June 24."[23] On the other hand, maps of the region published as early as 1846 show a chain of three lakes, which might be Harney, Mud, and Malheur Lakes.[24] These historical papers can be construed to indicate that Malheur Lake was relatively small prior to 1864, but they are far from conclusive in that respect. Thus, in historic time Malheur Lake has been so unstable in extent that it has been very nearly dry at least three times and has reached to or slightly beyond the meander lines of the official land surveys (pl. 2). Harney and Mud Lakes have doubtless varied in corresponding degree. Never, in this interval, have the lakes stood sufficiently long at any level to cut a prominent beach. That they have been similarly unstable for at least two centuries is suggested by the data on precipitation and tree growth in the basin (pp. 10–13). In at least four prehistoric epochs, however, Malheur Lake has been stable long enough to form as many typical beaches, which are now preserved in the dissected high-level beach ridge and in the three "islands" on the eastern part of its playa. Of these four features the high-level beach seems clearly the oldest. The pattern of the three "islands" suggests that they were formed subsequently during successive stages of a shrinking lake.

Even within historic time Malheur and Harney Lakes have not always been joined by a functional drainage channel. Peter Skene Ogden, on November 1, 1826, observed that "a small ridge of land, an acre in width, divides the fresh water [Mud Lake] from the salt lakes [Harney Lake]. These two lakes have no intercourse." The following year, on June 8, 1827, Ogden again reached the "salt lake" and found that "the water is very high. The waters of Sylvailles [Silvies] River and lakes [Malheur and Mud Lakes] discharge into it." In 1860 Lt. Joseph Dixon, topographic engineer attached to a military expedition commanded by Maj. Enoch Steen, prepared a map which indicates that the "Cricket" [Silvies] River flowed into Harney Lake. Again, in 1864, Captain Currey found "a deep quicksand-bottomed channel that connects the waters of Harney Lake with that of Stampede [Mud] Lake on its east, which in the early part of the summer is probably nothing but an arm of Malheur Lake." These repeated descriptions imply that a well-established but intermittent drain connected Harney and Mud

[23] Currey, George, in Report of the adjutant general of the State of Oregon, for the years 1865–66, pp. 40–41, Salem, Oreg., 1866.

[24] These and subsequent notes concerning the early history of the lakes are abstracted from Clark, R. C., Survey of the history of the Harney-Malheur Lakes region, 1825–72, in Supreme Court of the United States, op. cit., vol. 2, pp. 1014–1059.



AREA AND CAPACITY CURVES FOR MALHEUR, MUD, AND HARNEY LAKES, HARNEY COUNTY, OREG.

Lakes. In the seventies, however, the drain seems to have been closed by an extension of the "Sand Reef," over which cattle were commonly driven to avoid skirting the lakes. About 1880 Malheur Lake topped the "reef," overflowed into Harney Lake, and excavated the present "Sand Gap"; as the excavation started, the water surface of Harney Lake stood several feet lower that that of Malheur Lake.[25] The year in which the "reef" was breached is reported variously as 1877 [26] to 1881.[27] From spirit leveling about the gap in 1931, M. V. Dodge [28] estimated that the water in Malheur Lake attained an altitude of about 4,107 feet, as it topped the "reef" 50 years before. Obviously a large tolerance must apply to this estimate. In a general way, however, it confirms other evidence as to the maximum extent of Malheur Lake in historic time. During the nineties, and possibly at other times, several persons report [29] that the "gap" was cleaned out with teams and scrapers to quicken drainage.

The water of Harney Lake has been rather highly saline and ordinarily has been shunned by stock and by human beings alike, but the military expedition of Captain Currey used the water for its horses and men in 1864 for lack of another source. The saline water has been toxic to vegetation, so that the shores and bed of the lake are barren except about the thermal springs, whose dilute water has maintained local growths of tules and other water-using vegetation. On the other hand, the water of Malheur Lake is relatively fresh and has commonly been used for watering stock and even for cooking, although at times it is unpalatable. Russell [30] and Waring [31] both comment on this difference in salinity, and Russell ascribes it to the freshening of Malheur Lake by repeated overflow into Harney Lake. As Malheur Lake is shallow and not highly saline, tules have choked large areas about its margins and in its western part. In 1931, however, all the tules were dormant owing to complete desiccation of the lake.

GEOLOGY

SEQUENCE AND GENERAL FEATURES OF THE ROCKS

In the Harney Basin nonmarine strata of the Tertiary and Quaternary systems rest upon a basement of crystalline and metamorphic rocks that belong to the Lower Jurassic series, at least in part. Rocks of Middle Jurassic, Upper Jurassic, Cretaceous, or earlier Tertiary age are not known to occur.

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[25] Supreme Court of the United States, op. cit., vol. 2, pp. 829–842.

[26] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 46, 1909.

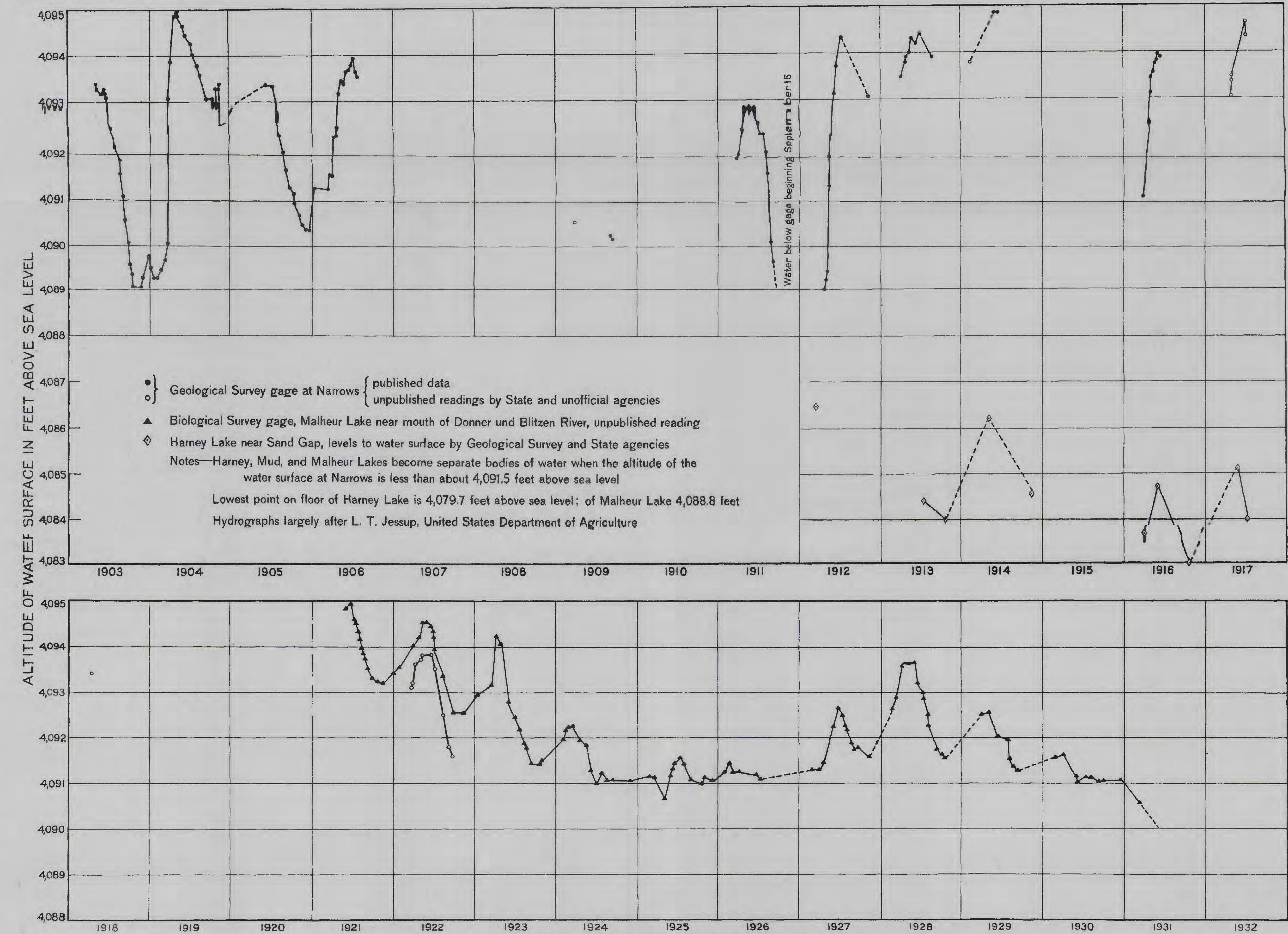
[27] Supreme Court of the United States, op. cit., vol. 2, pp. 829–842.

[28] Idem, vol. 2, p. 917.

[29] Idem, vol. 2, pp. 843–846.

[30] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Bull. 217, p. 31, 1903.

[31] Waring, G. A., op. cit., pp. 46–47, 1909.



ALTITUDE OF WATER-SURFACE OF MALHEUR AND HARNEY LAKES, 1903 TO 1931.

The strata of Tertiary age include (1) extrusive basalt, andesite, and rhyolite; (2) volcanic ejectamenta that range from scoria to compact massive tuff or breccia; and (3) detrital sediments of alluvial and lacustrine origin. Strata of the three classes are interlaminated and interfingered; also they grade laterally into one another in complex fashion. Five distinct stratigraphic units are discriminated in this report to span the Miocene and Pliocene epochs. Of these the oldest two are composed almost entirely of extrusives, one rhyolite and the other basalt. The youngest three, on the other hand, include relatively thick sections of sedimentary strata, although the intercalated extrusives seem to preponderate because they have been uncovered extensively by erosion.

The absence of marine strata among the Tertiary rocks of the Harney Basin was first noted by Russell [32] and later by Washburne [33] and Waring.[34]

The deposits of Quaternary age include (1) gravel and calcareous spring sinter in scattered patches on remnants of erosion terraces; (2) basaltic extrusives and ejectamenta from several epochs; and (3) unconsolidated valley fill, which comprises materials of alluvial, lacustrine, and eolian origin. In general the terrace deposits are oldest. The basaltic extrusives and the valley fill are contemporaneous in large part and presumably interfinger; each spans the late Pleistocene epoch and much if not all of the Recent epoch.

The sequence, physical character, and water-bearing properties of these stratigraphic units are summarized in the following table and are described at length on subsequent pages. The descriptions begin with the youngest unit and continue in the order that the units would be encountered in drilling a well; thus they invert the order that is usually followed in geologic reports. Formal names are initiated for three of the volcanic units that seem to be extensive in the region beyond the Harney Basin; these are the Steens basalt (p. 49), the Danforth formation (p. 43), and the Harney formation (p. 38).

[32] Russell, I. C., A geological reconnaissance in southern Oregon: U. S. Geol. Survey 4th Ann. Rept., pp. 438–441, 1884.

[33] Washburne, C. W., Gas prospects in Harney Valley, Oregon: U. S. Geol. Survey Bull. 431, pp. 56–67, 1909.

[34] Waring, G. A., op. cit., pp. 18–24.

Generalized stratigraphic section for the Harney Basin

Geologic age		Formation	Thickness within area represented by plate 2 (feet)	Character and extent	Water-bearing properties
Quaternary.	Pleistocene and Recent.	Valley fill and contemporaneous basalt near Diamond.	0–270+	Alluvium, lake and playa deposits, and eolian sediments derived from volcanic rocks of the upland; clean sand and gravel near the mouths of the principal canyons, grade laterally and feather fingerwise into silt and "clay" at the center of the basin. At least one thin layer of volcanic ash is intercalated from 3 to 6 feet below the land surface. A layer of peat as much as 30 inches thick covers most of Malheur Lake. Mantles about 900 square miles of central district. The basalt near Diamond, which is mapped separately, was extended after most of the valley filling had taken place and is either latest Pleistocene or Recent.	Pervious beds are the members, lentils and tongues of gravel and sand which finger between impermeable beds of silt and "clay." Shallow permeable beds hold unconfined water, which is highly concentrated in dissolved salts toward the center of the basin. Deep permeable beds hold confined water and are most practicable source of ground water for irrigation; safe yield limited by transmission capacity and by feasible pumping lift. The valley fill yields flowing wells locally near Hines and in the Warm Spring Valley.
Quaternary.	Pleistocene.	Basalt and basaltic ejectamenta near Voltage and near Hines.	750±	Extrusives with compact, scoriaceous, and fragmental facies forming lava domes and marginal lava fields; lapilli, cinders, and bombs in and about satellitic cones.	Scoriaceous and fragmental facies are pervious; the Voltage lava field supplies one moderately large perennial spring and several flowing wells along south margin of Malheur Lake.
Quaternary.	Pleistocene.	Terrace deposits.	0–20	Gravel that caps small terrace remnants along margin of central alluvial plain near Burns; calcareous spring sinter along lower Prater Creek and about 2 miles southeast of Windy Point.	Above regional ground-water level.
Tertiary (?).	Pliocene (?).	Harney formation	0–750±	Massive basaltic tuff and breccia, sandstone and siltstone, some incoherent gravel; scoriaceous and massive basalt intercalated at a few horizons. Basalt member caps extensive plain of intermediate altitude in west-central part of area: outliers of formation along all margins of central area except the northern. Rests unconformably on Danforth formation.	Incoherent gravel members would transmit water readily if in the zone of saturation; inferred to be water-bearing beneath much of the central alluvial plain but not distinguishable from other bedrock units.
Tertiary (?).	Pliocene (?).	Fanglomerate near Coffeepot Creek.	0–163	Semiconsolidated siltstone, sandstone, and fanglomerate; covers several square miles in north-central part of area but not discriminated elsewhere; stratigraphic horizon uncertain. May be younger than Harney formation.	Above regional ground-water level. Rests with unconformity (?) on Danforth formation.

Generalized stratigraphic section for the Harney Basin—Continued

Geologic age		Formation	Thickness within area represented by plate 2 (feet)	Character and extent	Water-bearing properties
....	....	-Unconformity?			
Tertiary.	Pliocene.	Danforth formation.	20-800+	In vicinity of Burns comprises (1) an upper part that includes a distinctive rhyolitic tuff-breccia member, also stratified siltstone, sandstone, tuff, and volcanic ash with layers of glassy or perlitic rhyolite at a few horizons; (2) a lower part made up of massive rhyolite, commonly spherulitic.	Upper part yields considerable water to municipal wells at Burns and Hines but was not water-bearing in a well near Prater Creek; lower part yields thermal water locally from fault conduits.
				In district south of Harney Lake comprises (1) the distinctive tuff-breccia member and associated rocks; (2) an equally distinctive basaltic-breccia member and associated siltstone, sandstone, and conglomerate and two intercalated layers of basalt; (3) stratified siltstone, sandstone, and ash; and (4) spherulitic rhyolite.	Yields considerable thermal water to large springs along fault conduits; sedimentary members inferred not to be water-bearing at a distance from the faults.
				All sedimentary members semiconsolidated; local unconformities between certain facies; crops out extensively in marginal upland.	
		-Unconformity-			
	Miocene.	Steens basalt.	0-1,500+	Basalt, layers average 10 feet thick, scoriaceous and fragmental zones common at top of each layer; andesitic facies locally; crops out in marginal upland along eastern half of the basin.	Scoriaceous and fragmental zones, together with fault fractures, have considerable water-yielding capacity locally; in Donner und Blitzen Valley supplies several perennial thermal springs along fault conduits.
	....	-Unconformity-			
	Miocene (?).	Older siliceous extrusive rocks.	1,000+	Rhyolite, commonly massive and spherulitic with glassy groundmass; generally crumpled and faulted; forms a few scattered masses, mostly in eastern half of basin.	Presumably pervious only along fractures.
		-Unconformity-			
Jurassic (in part).	Lower Jurassic (in part).	Pre-Tertiary rocks undifferentiated.	(?)	In northern part of basin fossiliferous limestone of Lower Jurassic age associated with shale, sandstone, schist, argillite, and greenstone. South of the basin andesitic porphyry, micaceous schist, and granitic rocks, all of unknown age.	

Figure 3 compares several representative columnar sections in the Harney Basin, arranged in two rude profiles across the basin from northwest to southeast.

SUMMARY OF GEOLOGIC HISTORY

The history of the Harney Basin seems to include the following stages: (1) Approximately in late Miocene time the site of the basin was a district of moderate or strong relief whose rocks included (*a*)

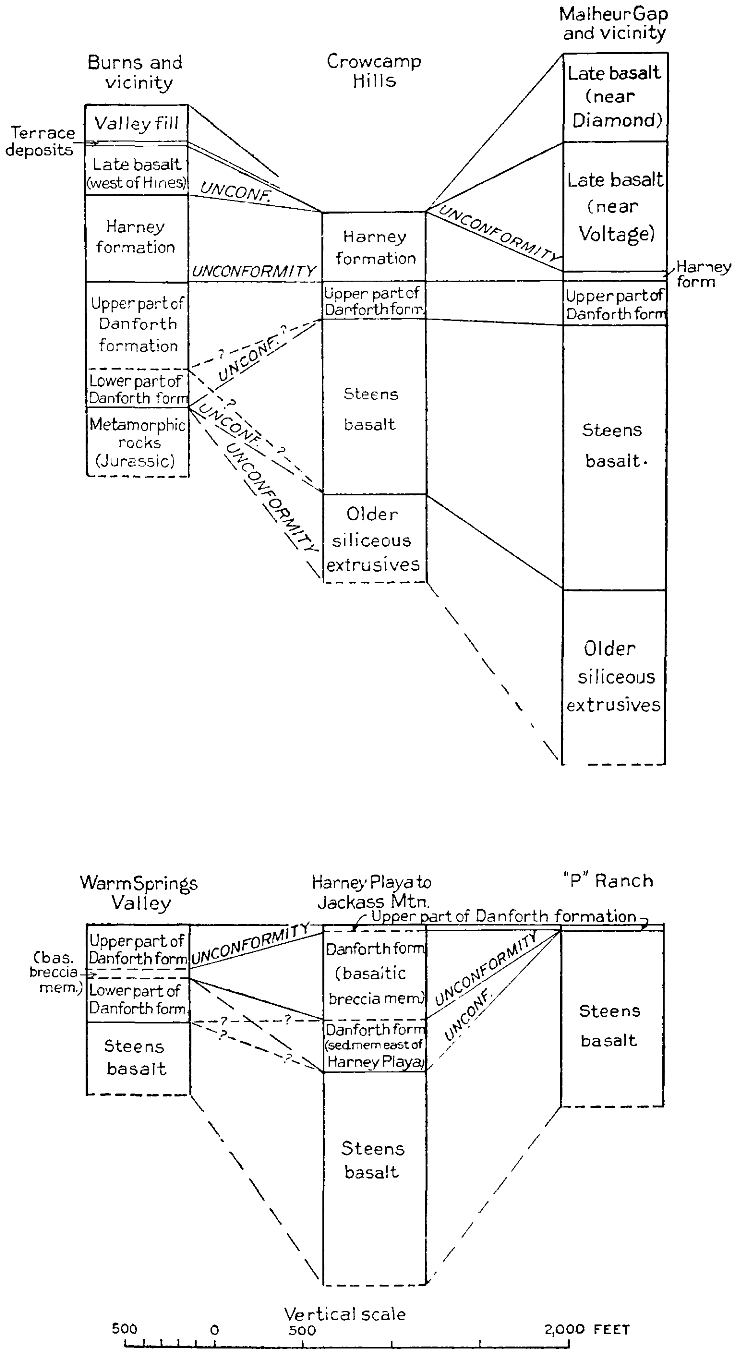


Figure 3.—Diagrammatic correlation of stratigraphic columns in the Harney Basin

metamorphosed sedimentary strata and crystalline plutonic rocks of several kinds, in part of Lower Jurassic age, which had been faulted and compressed; and (*b*) siliceous extrusives of Miocene (?) age, which had been faulted and loosely crumpled. (2) In Miocene time the Steens basalt was extruded in a series of thin but extensive sheets that buried the older rocks along the eastern margin of the basin with the exception of a few scattered peaks. North of Burns the whole series wedged out by overlap against the crystalline rocks. (3) The present structural basin was outlined in general form by faulting and by tilting of blocks. At that time certain of the present fault scarps were perhaps initiated and the major subdivisions of the present upland were outlined. (4) In Pliocene time the Danforth formation was deposited over most of the area; this formation comprised detrital sediments of lacustrine and alluvial origin, coarse and fine ejectamenta, massive spherulitic rhyolite and perlite, and thin discontinuous sheets of rhyolite and basalt. (5) The major faults of the pre-Danforth epoch were rejuvenated, the major fault scarps of the present land surface were formed or heightened, and, by further block tilting, the central part of the basin was depressed still more with reference to the bordering upland. (6) For a relatively long period the region was subject to erosion, and exterior drainage was established through Crane Gap or Malheur Gap, and possibly through both. (7) In late Pliocene (?) time the Harney formation was deposited throughout the central part of the basin and over an extensive area to the west; this formation comprised basalt scoria and pumice, detrital sediments, and some extensive but relatively thin layers of basalt. (8) Through a long fraction of the Pleistocene epoch erosion was again dominant, so that exterior drainage was once more established through Malheur Gap and perhaps briefly through Crane Gap. By stream planation the upper part of the Harney formation was stripped from the central area; it is inferred that ultimately the central area was reduced to a submature land surface which was adjusted to an outlet about 300 feet below the present alluvial tongue in the Malheur Gap. (9) Immediately prior to the epoch just described, or during the early part of that epoch, a few of the faults were reopened and some blocks were tilted further, particularly along the eastern margin of the basin near the two gaps; however, the major features of the structure are believed to have remained stable. (10) In late Pleistocene time basalt was extruded from vents west of Hines; also from vents east and south of Voltage. From the latter a relatively extensive lava field spread northward and eastward, entered Malheur Gap, and filled that drain up to the level of the present divide near the Gap School (p. 18). That lava dam has not been breached to this day. (11) The central basin was filled by lake and playa deposits, by alluvium, and by minor quantities of volcanic ash, peat, and wind-borne sand. It is not unlikely that some of the valley fill was deposited contemporaneously with the basalt. In the final stage of this epoch the central alluvial plain was aggraded to its present altitude and the lower reaches of the stream valleys were drowned by alluvium for several miles upstream from the central plain. (12) At some relatively late time in the epoch of valley filling the late basalt of the Diamond Craters was extruded.

PHYSICAL CHARACTER AND WATER-BEARING PROPERTIES OF THE STRATA

VALLEY FILL

PHYSICAL CHARACTER AND THICKNESS

As Waring [35] states, the alluvium that composes most of the visible valley fill is finer toward the center of the plain than around its borders, although some beds of coarse material occur at the very center and some of fine material occur locally at the borders. Thus, near the apex of the Silvies River fan the valley fill is composed largely of relatively clean gravel and sand. For example, the drillers' records of wells within 3 to 4 miles of the apex (Nos. 65, 73, 74; [36] p. 134), indicate that fine material ("clay") forms as little as 10 percent of the total thickness of the fill, at least from the land surface down to a depth of about 100 feet. Farther out on the central plain the "clay" beds make up more and more of the fill, although most wells north of Malheur Lake penetrate from two to four layers of gravel or sand. In six wells between 5 and 10 miles from the apex of the fan (Nos. 30, 56, 64, 94, 112, 171) the "clay" ranges between 35 and 75 percent of the aggregate thickness. Still farther away, near Lawen, it amounts to 80 to 90 percent in three wells (Nos. 197, 226, 246). Because the "clay" beds are relatively thick in the Lawen area, it is inferred that they are also relatively continuous and that the beds of sand and gravel tend to feather out fingerwise between them. It is probable that much of the valley fill at depth beneath Malheur and Harney Lakes resembles the playa deposits and, accordingly, includes rather massive beds of silt and clay with saline residues interspersed. It seems likely that the gradation from coarse to fine alluvial sediments extends fanwise over most of the plain from Burns and is broken only by small tongues of coarse sediment opposite some of the secondary streams.

Because the Donner und Blitzen Valley and the Warm Spring Valley are drowned by alluvium for many miles, it is inferred that sand and gravel have not been transported from either valley to the central

[35] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 23, 1909.

[36] The numbers used for wells and springs refer to descriptions and other records in the appendix (pp. 133–185), also to locations shown on pl. 2.

plain for a relatively long period. The intermittent streams of the Harney Basin have only small alluvial fans on which to assort their detritus. Accordingly, they have probably not formed extensive beds of clean gravel and sand in the fill beneath the central plain. Moreover, between the streams the extensive front of the upland that borders the central plain would contribute only ill-sorted slope wash and local talus to the valley fill. Peat forms the uppermost layer of the valley fill over most of Malheur Lake west of Cole Island, over much of Mud Lake, over a considerable area on the central plain between the distributaries of the Silvies River, and over much of the Donner und Blitzen Valley. Jessup [37] states that at least a considerable part of this material is derived from tules. He has found the peat as much as 22 inches thick along the south margin of Malheur Lake opposite the Donner und Blitzen Valley and from 12 to 30 inches thick "throughout a distance of several miles" in the northern part of the playa between Cole Island and Graves Island. The peat is underlain by fine detrital sediments. A layer of buried peat was penetrated between 3.2 and 4.4 feet below the floor of the Sand Gap in a boring (No. 371) opposite the axis of the Sand Reef at the eastern edge of Harney Lake. The top of this layer was 4 to 5 feet below the lowest of the surface peat in Malheur Lake.

Volcanic ash occurs in the valley fill in several areas. Within 4 miles of Burns, between the Silvies River and Poison Creek, a single layer from a few inches to a foot thick occurs from 3 to 6 feet below the valley plain. It crops out along Newman Slough (pl. 8, *A*) in sec. 16, T. 23 S., R. 31 E., and in borrow pits along the Burns-Crane highway; also, it was penetrated in borings made by T. W. Robinson. There the ash is compact, fine-grained, and white. It is composed almost wholly of microscopic curved fragments of tubular glass (index of refraction considerably less than 0.154), but locally it contains numerous diatoms. There are very few particles of foreign rock in the ash, although the layer of ash is bounded sharply by alluvium above and below. A similar thin layer of ash is exposed for a mile in borrow pits along the road near well 126, south of Harney town site; it was also found in borings 340 and 343, east of Malheur Lake. "Diatomaceous earth" or "hardpan" has been found in borings put down by Hutchison [38] at the Harney Branch Experiment Station, 6 miles east of Burns; by Greenslet [39] from Burns southward to Wrights Point and eastward as far as Harney town site; and by Jessup [40] on the Donner und Blitzen Plain near Rockford Lane. The writers

[37] Jessup, L. T., Malheur and Harney Lakes: Supreme Court of the United States, October term, 1932; United States of America *v.* State of Oregon, plaintiff's exhibit 52, pp. 80-82, 1932.

[38] Hutchison, R. E., oral communication.

[39] Whistler, J. T., and Lewis, J. H., op. cit., drawing 48.

[40] Jessup, L. T., oral communication.

believe the "diatomaceous earth" and "hardpan" at the foregoing localities to be largely volcanic ash.

Nowhere is the ash known to be more than a foot thick, although its widespread occurrences have a range of about 50 feet in altitude. It is inferred that the layer exposed near Burns was deposited from an ash fall in relatively late geologic time. The presence of diatoms within it suggests that the ash ponded some streams temporarily.

It is not unlikely that the lower part of the valley fill was deposited in an extensive and relatively deep lake, for the epoch of filling began when Malheur Gap was dammed by basalt, presumably before the end of the Pleistocene epoch, while rainfall was relatively great and while other closed basins in southeastern Oregon were occupied by lakes of considerable depth. If the hypothetical lake ever rose to the crest of the basalt dam (4,114 feet above sea level) it would have been only about 50 feet lower than the present land surface at Burns and, on the pre-fill topography, would have extended nearly if not entirely across the present alluvial plain. Thus, much of the "clay" that makes up the bulk of the valley fill in the vicinity of Lawen may be lacustrine. It is a corollary of this supposition that the coarse detritus of the Silvies River would not have been transported far offshore but would have been deposited in a delta near Burns. Presumably, corresponding deltas would have formed in the Donner und Blitzen Valley and possibly at the mouths of the secondary streams. Waring[41] seems to imply this condition for the Harney Basin, although it is not clear that the implication was intended.

The valley fill has buried a former land surface which comprised two elements—(1) the initial surface of the basalt dam in Malheur Gap and of the northern footslope along the Voltage lava field and (2) an erosion surface whose profiles were adjusted between the predam floor of Malheur Gap and the reaches of the present streams that are incised on the upland. Two useful inferences as to the form of the buried erosion surface can be drawn with fair assurance. First, over a considerable part of the central area, the surface had been eroded on soft tuff and sedimentary beds of the Harney formation and Danforth formation, which resemble the overlying fill in petrographic character. Second, the erosion surface probably had low but distinct relief, because (1) the bordering land forms whose footslopes were buried were youthful and still are youthful; (2) relatively weak salients along its margins, such as Wrights Point and Windy Point, were not smoothed off before the epoch of filling; and (3) the term of erosion was too brief for the outlet of the basin, Malheur Gap, to have been greatly widened, although it is inferred that a considerable volume of detritus was transported through it. On the other hand, surprisingly few outliers of the buried surface now rise above the central plain.

[41] Waring, G. A., op. cit. (Water-Supply Paper 231), p. 23.

Waring [42] estimates that the valley fill is less than 300 feet thick at most places, deriving his estimate partly from the fragmentary records of five wells on the central plain. These records are summarized in the following table, together with the available records of wells that have been drilled through the valley fill subsequently. The later records confirm the estimate made by Waring in 1909. Collectively the records indicate that the valley fill is roughly 100 feet thick within 5 miles of Burns and all along the northeastern margin of the valley plain; that it thickens steadily toward the south and the southeast; and that it is from 200 feet to about 270 feet thick from 2 to 5 miles north of Malheur Lake. South of the lake the valley fill feathers out against the Voltage lava field and is from 20 to 50 feet thick in several wells (Nos. 331, 332, 333, 334, 375) within half a mile of that field. None of the records indicate the depth to bedrock in the Donner und Blitzen Valley or the Warm Spring Valley.

Thickness of the valley fill in the Harney Basin, as shown by the records of drilled wells

No.	Altitude of land surface above sea level (feet)	Depth of bedrock below land surface (feet)	Remarks
5	4,153	67 to 143	See p. 133 for drillers' record.
30	4,144	80	See p. 133 for drillers' record.
35	4,150	62 to 122	Well bottoms on hard rock at 122 feet; dense clay and white sand between 62 and 122 feet in depth may be of the Danforth formation.
37	4,153	52(?)	Well penetrates "dark gray clay" (Danforth formation?) from 52 to 101 feet, then bottoms on hard rock.
53	4,139	100±	Well penetrates sand, gravel, and soft rock to depth 100 feet, then entered hard rock.[1 2]
73	4,146	100	See p. 134 for drillers' record.
95	4,137	100±	Well reached hard rock a little more than 100 feet in depth, penetrated it, then continued in granular material.
121	4,129	117+	Well does not reach bedrock.
------	4,135±	100	Well drilled in 1896 on property then belonging to Fred Haines, depth 507 feet, black lava and clay below depth 100 feet.[1 2]
143	4,132	109	See p. 135 for drillers' record.
171	4,128	86	See p. 135 for drillers' record.
201	4,120	235	Well bottomed on resistant rock at 235 feet.[2]
------	4,100±	200±	Well drilled in 1900 on land then belonging to G. L. Sitz, in the southern part of Lawen, depth 432 feet, encountered lava approximately at 200 feet.[2 3]
275	4,134	98	See p. 136 for drillers' record.
301	4,096	270±	Well reported to penetrate compact and partly lithified sediments from 270 to 1,430 feet in depth.
331	4,099	19	See p. 136 for drillers' record.
334	4,100	35	
------	4,125±	Less than 280	Well on property formerly owned by Smith, was in tuffaceous sediment at 280 feet.[3]

[1] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-Supply Paper 78, pp. 40–41, 1903.
[2] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, pp. 60–62, 1909.
[3] Russell, I. C., op. cit., p. 42.

An anomalous record has been received for one well (No. 65) on the central plain 2½ miles east and half a mile south from Burns. According to the record (p. 134), which is considered trustworthy, the well remained in unconsolidated material to its full depth, 300 feet,

[42] Waring, G. A., op. cit., pp. 23, 60–62.

districts the static level was lower than the water table—that is, the confined water was nonartesian and had subnormal pressure head, and the water table was semiperched. However, neither the districts of subartesian head nor the districts of subnormal head are constant in extent but change from season to season and from year to year. Also the pressure head in the deep water-bearing beds at a particular place may range from subartesian to subnormal. The effectiveness of this material as a confining bed is tested rigorously by data on pumpage effects, which suggest that over much of the central plain there are few permeable conduits that connect the deep and shallow water-bearing beds.

The foregoing statement applies particularly along the Silvies River between Burns and Malheur Lake. Analogous conditions may be inferred for the Donner und Blitzen Valley farther south, except that the valley plain was not built from a single apex of alluviation and that highly permeable beds may be less extensive (pp. 29–30).

The extent and transmission capacity of coarse-grained beds opposite the secondary streams can only be surmised. Tongues of sand and gravel may exist and function as ground-water arteries, but on the whole these are presumed not to be extensive nor to be as permeable as in the vicinity of the major streams. The talus that is inferred to be buried beneath the valley fill locally may form ground-water arteries with large aggregate capacity to transmit water.

The deep permeable beds in the valley fill—the "second" and deeper "flows"—constitute the most accessible source from which to recover ground water in quantities adequate for irrigation. Because their water is confined and moves under a pressure gradient, as if in a conduit, the quantity of water that can be recovered perennially from this source will be determined by the hydraulic gradient when the water levels have been drawn down to the economic limit of pumping lift. This quantity, the safe yield, is estimated on pages 89–90.

Locally, in the vicinity of Hines and in the Warm Spring Valley (p. 103), the valley fill contains water under sufficient head to yield flowing wells. However, that water is thermal and is derived from underlying Tertiary rocks by way of fault-plane conduits. It is distinct from the nonthermal water of the valley fill, which is not known to yield flowing wells at any place on the alluvial plain at the present time. On the other hand, Waring[43a] states that the Burke well, northeast of Lawen (no. 201), initially flowed about 10 gallons a minute from a water-bearing bed 235 feet beneath the alluvial plain and presumably just above the Tertiary bedrock. In 1931 the well was found to be open only to a depth of 66 feet and was not flowing; at that time the static level of its water conformed to that in adjacent wells entering deep pervious beds in the valley fill.

[43a] Waring, G. A., op. cit., pp. 59–61.

LATE BASALT AND BASALTIC EJECTAMENTA

The youngest volcanic rocks in the Harney Basin form the Diamond Craters, in Tps. 28 and 29 S., R. 32 E. (p. 15). These include compact olivine basalt and relatively large bodies of highly inflated scoria, lapilli, cinders, and bombs. Ordinarily the coarsest pyroclastic fragments are less than a foot in diameter. Most of the basalt has some disconnected gas holes or vesicles, the number and size being greater near the tops of the respective layers. In some hand specimens olivine is visible to the unaided eye; in general the olivine is fresh. The tops of some of the layers are blocky and fragmental, whereas others are relatively smooth but ropy.

The rocks of the Voltage lava field (p. 16) are also fresh olivine-bearing basalt. Because very little cinder or ejectamenta occurs, the material is believed to have flowed or welled quietly from numerous vents, chiefly southeast of Voltage and west of the Mule ranch. On the whole the massive facies are thin-bedded and moderately dense, but commonly the upper few feet of each layer is scoriaceous. Vesicles, in general less than 10 millimeters in diameter, are present throughout the rock but are disconnected. Pressure ridges are common. Because the initial volcanic surface has suffered little erosion (see pl. 4, *B*), the complete section of the late basalt is not exposed, but it is inferred that the base is not more than about 250 or 300 feet lower than the central alluvial plain. If this inference is correct, the maximum thickness is of the order of 750 feet, exclusive, of course, of the parent volcanic plug.

A third mass of young basaltic rocks flanks the central alluvial plain immediately west of Hines town site and adjoins the Danforth formation. This mass comprises several lava domes and cinder cones of typical symmetrical contour. The rocks include much highly inflated scoria and a profusion of volcanic bombs as much as 2 feet long. As a whole, the domes and cones are only slightly dissected.

The three masses of late basalt and basaltic ejectamenta just described occur along the projected trace of a zone or zones in which the older Tertiary rocks, particularly the Danforth formation and the Steens basalt, have been sliced by closely spaced faults (pl. 2, pp. 54–56). Presumably some detail of the fault pattern afforded an easy path for the ascent of volcanic material in each of the three areas and thereby localized the extrusions.

The age of the late basalt is known approximately. Because the rocks show little evidence of disintegration and decay, and because the lava domes and cinder cones have been little scarred by erosion, it is believed that none of the extrusions occurred before late Pleistocene time. On the other hand, at the Diamond Craters even the tenuous lips of minor spatter cones and small mounds of fine cinder have not disintegrated appreciably. Hence some of the volcanic activity may have taken place only a few hundreds or thousands of years ago; if so, it may have been in the Recent epoch. In each of the three areas the first extrusions of late basalt occurred after the upper members of the Harney formation had been stripped from the western part of the basin and after the central valley had been eroded. At Hines and near Voltage the late basalt is overlapped by the uppermost beds of the valley fill and therefore antedates those beds. It is not unlikely, however, that some of the late basalt in these two areas (or even much of it) was extruded while the central valley was being filled; according to that hypothesis, the volcanics—both flow rocks and ejectamenta—and the valley fill may interfinger in complex fashion. The late basalt near Diamond is clearly somewhat younger; in large part it was extruded after most of the valley filling had taken place. Accordingly, its age is taken to be latest Pleistocene or Recent.

The massive facies of the late basalt are essentially impermeable, for their pore spaces (vesicles) are not interconnected. Hence those facies probably receive little water by infiltration and have little or no capacity to transmit water under hydraulic pressures of ordinary magnitude. On the other hand, there is considerable perviousness in the blocky and fragmental zones that constitute the upper part of some layers, in the interspersed sheets and tongues of scoria and ejectamenta, and in fractured zones. Altogether, these permeable facies have considerable aggregate capacity to transmit water.

The late basalt near Voltage supplies the Sodhouse Spring (No. 317) and several flowing wells (Nos. 327, 332, 333, 334, 375, 376, 377) along the southern margin of the Malheur Playa. Altogether, the spring and the seven wells were discharging about 5,600 gallons a minute in 1932. The water is cool (54° F.), and therefore its sources are not deep-seated. Presumably the ultimate sources are rain that falls on the undrained lava field and run-off from the dissected upland to the southeast by way of drains that are dammed by the lava field. From both these potential sources the water must percolate northward to its low-level outlets. However, a considerable fraction of the rainfall probably runs off to small playas, which are numerous, and is ultimately dissipated by evaporation.

From scoriaceous facies of the late basalt near Hines issue several springs (Nos. 27, 28, 29), which together discharge about 1,100 gallons a minute and whose temperature at the principal orifices is 68° to 80° F. As this temperature is considerably more than the mean annual air temperature, the source of the water must be relatively deep-seated. Water of the same temperature and chemical character issues from a flowing artesian well (No. 143) on the central alluvial plain close at hand and from the Roadland Warm Spring, (No. 150) about 2 miles farther south. However, the well penetrates far below the buried erosion surface that is the common base for both the valley fill and the late basalt (p. 3). The Roadland Warm Spring does not issue from the late basalt but from jointed massive rhyolite of the Danforth formation. It is believed that all the thermal springs cited above and the flowing thermal well have a common ultimate source. If this source is in the late basalt, the water must be transmitted by the way of the parent basaltic plug and must percolate rather widely into the adjacent rocks. On the other hand, thermal ground water occurs at many places that are remote from the late basalt but are alined along faults in the Danforth formation (p. 106). Accordingly, it is postulated that the thermal water that issues from the late basalt near Hines does not originate in that formation but is transmitted from a relatively remote source through the faulted and jointed rocks of the underlying Danforth formation.

HARNEY FORMATION

The extensive erosion plain of intermediate altitude that borders the central alluvial plain on the west (p. 17) is underlain by flat-lying detrital and volcanic rocks, which are here named the Harney formation. The type section is in the east face of Dog Mountain, along the boundary between secs. 20 and 28, T. 25 S., R. 30 E.; this section is the thickest (468 feet) in the area represented by plate 2.

Type section of Harney formation, on east face of Dog Mountain

	Feet
Top of measured section, summit of Dog Mountain.	
14. Concealed; debris similar to unit 13	32
13. Tuff, tan, massive; fragments larger than 1 inch; angular basalt blocks as much as 3 feet long embedded in upper part	5
12. Concealed; debris similar to unit 13	42
11. Tuff and tuffaceous sandstone, light tan and gray, fine-grained; rude beds 4 inches to 3 feet thick	32
10. Concealed; debris similar to unit 11	68
9. Sandstone, largely basaltic, tan to buff, with some white tuffaceous (?) shale; most grains less than 3 millimeters in diameter but some as large as 15 millimeters; no tuff recognized with hand lens; strata rude, usually more than 3 feet thick, and finer toward the top	68
8. Basalt; scoriaceous flow-breccia forms base, and purple basalt scoria forms upper 3 feet (Wrights Point cap member)	5
7. Conglomerate and sandstone, dark gray, coarse-grained, with poorly rounded pebbles as large as 1 inch in diameter, also with some tuffaceous (?) shale and calcareous cement; rudely laminated	21
6. Poorly exposed; similar to unit 5	50

Type section of Harney formation, on east face of Dog Mountain—Continued

	Feet
5. Basaltic tuff, buff, decomposed (?); unoriented fragments of purple basalt scoria, clinker, and some dense white tuffaceous shale as much as 2 inches long; also angular blocks of dense basalt, mostly less than 4 inches long but some as much as 2 feet long	11
4. Sandstone, dense and earthy, deeply weathered and calcified; crystalline quartz in vugs; contact with unit 3 gradational and undulating in minor detail	1
3. Basalt scoria or breccia, buff, massive, decomposed; at base of bed pyroclastic fragments as large as 1½ inches; toward top, fragments smaller and partly of land waste; no apparent laminations	12
2. Sand and gravel, basaltic, poorly sorted, grains slightly rounded, calcareous (?) cement; laminations 2 to 6 inches thick, some of moderately clean medium-gray gravel; at the bottom contains fragments of small indeterminate shells; overlain by dense whitish tuff; all poorly exposed	29
1. Concealed	92
Bottom of measured section is level with central alluvial plain.	
Thickness of measured section	468

The basalt unit of the type section (no. 8) thickens southward and is 20 feet thick at the southeast point of Dog Mountain. Northward, the unit feathers out locally about the head of Sunset Valley, but still farther north basalt recurs at approximately (if not precisely) the same stratigraphic horizon and caps Wrights Point and the extensive plain south and west of the Sagehen Valley. Locally in the Sagehen area the basalt is nearly 50 feet thick and comprises more than one layer. It is a prominent horizon marker.

Altogether, pyroclastic and detrital rocks form the greater part of the Harney formation, but only at a few places do they crop out through the prevailing cover of nondescript slope wash. It is inferred that these members are characteristically inconstant in thickness and in physical character and that the type section probably does not disclose all facies. Noteworthy deviations from the type section are (1) incoherent and cross-bedded gravel, which is exposed in a small road-metal pit on the south face of Wrights Point, and (2) fine-grained stratified white volcanic ash (?) and an associated lentil of pumiceous basalt, which are exposed in cuts along the Burns-Bend highway in T. 24 S., R. 29 E.

The strata that are equivalent to the lower part of the Harney formation (units 1 to 8 of the type section) cover the entire district between the Sagehen and Warm Spring Valleys, extend to and far beyond the western margin of the area described in this report, and are inferred to form several outliers in the eastern part of the area. (See pl. 2.)

On the other hand, the strata that are equivalent to the upper part of the type section of the Harney formation (units 9 to 14) occur only in the vicinity of Dog Mountain and locally in the Sagehen Hills west and northwest of Burns. How far beyond those areas they extended initially is not known. At the localities in the Sagehen Hills patches of basalt cap several of the highest buttes and ridges; these patches appear to be correlative with an extensive basalt-capped plateau farther northwest. They are, however, stratigraphically distinct from several small slivers of basalt that underlie rhyolitic strata of the Danforth formation in upfaulted slices in the same district, and from the late basalt near Hines. Plateau, patches, and typical Harney formation are of about one age. Their rocks are similar in chemical and physical character. Thus, the basalt caps of the Sagehen Hills are correlated somewhat arbitrarily with the Harney formation in the adjacent area to the south, although they are displaced by faults that do not disturb the typical Harney formation.

The upper surface of the Harney formation comprises two segments—(1) its present youthful erosion surface, which is essentially coextensive with the erosion plain of intermediate altitude (p. 17); and (2) a part of the former land surface of low relief that was buried by the young volcanic rocks and the valley fill (p. 81). Essentially the two segments constitute one youthful or submature land surface, whose higher parts are virtually unmodified. The total relief on this surface is estimated as about 750 feet—that is, from the summit of Dog Mountain to the bottom of the valley fill near Lawen.

The sub-Harney surface or unconformity can be observed at a few places only, where the Harney formation laps upon older rocks. However, it may be inferred with fair assurance that the relief on that surface is determined largely by the level to which the pre-Harney rocks beneath the center of the basin were depressed after the Danforth epoch (p. 28). The magnitude of that relief is conjectural but probably is considerable. Hence, the stratigraphic thickness of the concealed portion of the Harney formation is not known from stratigraphic relations.

One deep well has been drilled on the Harney formation in search of petroleum. This well, the Oregon Oil & Gas Co.'s No. 1. (No. 212), is on the southwest flank of Dog Mountain, about in the SE¼ sec. 24 T. 25 S., R. 30 E. According to an incomplete driller's record (not given in this report) the well was initially 3,750 feet deep and penetrated "clay, sand, shale, and lime" in much of the space below 1,040 feet. The record does not afford any sound basis for estimating the thickness of the Harney formation at that place.

The exact age of the Harney formation is not known, as determinative fossils have not been found in its strata. It is inferred to be late Pliocene or early Pleistocene and is tentatively classified as Pliocene (?).

The capacity of the Harney formation to absorb water at the land surface or to transmit water in the zone of saturation varies widely because its component strata are diverse in physical character. Over extensive areas its topmost member is the prominent layer of basalt that caps Wrights Point (unit 8 of the type section). At most places this basalt is dense, contains only a few disconnected small vesicles, and is relatively impervious except as columnar joints afford openings for the percolation of water. Much of the rain that falls on it runs off to numerous small playas and is dissipated by evaporation. In some areas, however, the relatively impervious basalt feathers out. Whether strata of this character are present in the zone of saturation is not known; if present, they might act as confining beds. Much of the formation is tuff and breccia with a massive fine-grained matrix, probably not water-bearing. On the other hand, some strata that are composed of sand and gravel are relatively clean and only slightly indurated—for examples, unit 2 of the type section and the beds exposed in the road-metal pit on the south flank of Wrights Point. Strata of this character would absorb water readily and transmit it freely. That similar beds occur in the formation below the regional water table is suggested by the record of a well drilled on the central alluvial plain near Burns (No. 65). This well reached about 200 feet below the presumptive base of the valley fill (p. 32) and in that zone penetrated two water-bearing layers composed of fine gravel and coarse sand with an aggregate thickness of 138 feet. In part this sand is described as black, which suggests the basaltic Harney formation. If this suggested correlation holds, the formation may include a considerable volume of permeable material beneath the central alluvial plain. However, there seems to be no hope of discriminating any such permeable material from the underlying Danforth formation. Accordingly, the occurrence of water in the Harney formation is discussed jointly with water in the other bedrock formations. (See pp. 94–111.)

FANGLOMERATE NEAR COFFEEPOT CREEK

In the north-central part of the area represented by the geologic map (pl. 2), in T. 22 S., R. 32 E., semiconsolidated sediments form the divide between Coffeepot and Soldier Creeks for several miles immediately north of the central alluvial plain. The same material flanks Soldier Creek on the west, although it is not conspicuous there. The deposit occupies a small downwarped fold and terminates abruptly on the west by a fault-line contact against the older Danforth formation. Its physical character is indicated by the following section:

Section of fanglomerate near Coffeepot Creek, near east quarter corner of sec. 15, T. 22 S., R. 32 E.

	Feet
9. Conglomerate (fanglomerate) of poorly sorted subangular pebbles as large as 6 inches in diameter; most pebbles from rhyolite members of the underlying Danforth formation but a few from the tuff-breccia member	3
8. Sandstone, coarse, indurated; similar to unit 4	8¾
7. Conglomerate (fanglomerate) of subangular pebbles, most of which are silicified chert or rhyolite. Distinct and relatively coarse stratum at base, 3 inches thick, of subangular pebbles about 1 inch in diameter	1¼
6. Sand and gravel, indurated; similar to unit 4	9
5. Conglomerate	1
4. Gravel, sand, fine sand, and silt, indurated; locally the groundmass is glassy owing to secondary silicification and opalization. (This part of the section forms an overhanging ledge which is inaccessible for detailed study)	22–27
3. Gravel, with sand near the top; torrentially crossbedded and semiconsolidated; a typical stream deposit	0–5
2. Sandstone; lower part is medium gray and contains a few pebbles, also one 10-inch boulder from the tuff-breccia member of the underlying Danforth formation; upper part, 3 to 12 inches thick, fine-grained and mottled white	3
1. Concealed	110
Thickness of measured section	163

This sedimentary material is thought to be an indurated alluvial-fan deposit or fanglomerate. Some of its beds show torrential cross-bedding and contain coarse debris that is poorly sorted and water-rounded. Its exact age is unknown, but it overlies the Danforth formation (unconformably?), and some of its component pebbles have been derived from the distinctive tuff-breccia member of that formation. On the whole it is much more indurated than the sedimentary members of the Harney formation and so gives the impression of greater age. On the other hand, it seems to belong in the same general epoch as the Harney formation and so not to differ greatly in age.

So far as is known, the fanglomerate near Coffeepot Creek has no correlative at any other place in the Harney Basin, although it is similar lithologically to some facies of the older sedimentary strata east of Harney Lake (p. 46). It is perched above the regional water table and is inferred to be rather thoroughly drained.

A. EXPOSURE OF 10-INCH LAYER OF VOLCANIC ASH IN THE VALLEY FILL IN EAST BANK OF NEWMAN SLOUGH.

In the SW¼NW¼ sec. 16, T. 23 S., R. 31 E.

B. STRATIFIED SEDIMENTS UNDERLYING THE TUFF-BRECCIA MEMBER OF DANFORTH FORMATION.

Exposure in sand pit in the N½ sec. 13, T. 23 S., R. 30 E.

A. EXPOSURE OF BASALTIC-BRECCIA MEMBER OF THE DANFORTH FORMATION.
In the NW¼ sec. 23, T. 28 S., R. 30 E. Scale indicated by hammer.

B. BLUFF EXPOSING LACUSTRINE AND ALLUVIAL SEDIMENTS EAST OF HARNEY LAKE.
In sec. 30, T. 27 S., R. 30 E.

DANFORTH FORMATION

PHYSICAL CHARACTER

The greater part of the dissected upland that forms the margin of the Harney Basin is composed of relatively young siliceous volcanic rocks and associated tuffaceous sedimentary rocks that are distinct stratigraphically from the basaltic Harney formation, which overlies them, and from the older Steens basalt and siliceous volcanic rocks, which underlie them. The young siliceous extrusives and associated sedimentary rocks are named the Danforth formation in this report, from the Danforth ranch, in T. 22 S., R. 32½ E. where a conspicuous section is exposed along Cow Creek. The formation appears to be divisible into an upper part that is composed of sedimentary rocks with a few intercalated sheets of extrusive material and a lower part that is composed largely of extrusives. (See pls. 8, *B*, and 9, *A*, *B*.)

The four partial sections that follow suggest the character of the upper part of the Danforth formation in various parts of the basin. Few of the members that compose these sections are extensive; it is characteristic that they interfinger and grade laterally into one another. Some additional characteristics of the formation are shown by the drillers' records of four wells along the north edge of the central alluvial plain near Burns (Nos. 5, 6, 30, 32). Well 32 reaches the lowest stratigraphic horizon, at least 500 feet below the tuff-breccia member.

Section of tuff-breccia member and associated rocks in upper part of Danforth formation in bluff west of the Silvies River, in the SE¼ sec. 36, T. 22 S., R. 30 E.

	Feet
4. Tuff-breccia, purplish gray, massive; vitreous brownish-gray matrix (welded rhyolitic pumice?) enclosing abundant unoriented fragments of white pumice, black obsidian, and massive inflated rhyolite; fragments a fraction of an inch to a foot long	10–15
3. Glass, black, massive but granular; comprises feldspathic spherulites less than 1 inch in diameter, a slightly inflated matrix, and a few included fragments of banded glass as much as 12 inches long; grades upward into unit 4 with undulating contact	24–29
2. Transition zone; at base a light-gray massive tuff enclosing some fragments of pumice less than half an inch long; grades upward through dense purplish-gray tuff to black glass	6
1. Sediments, white, stratified, fine-grained; particles about half pumice and half glass, some waterworn; well assorted; laminae 1 to 10 inches thick	5
Base of section is alluvial plain of the Silvies River.	
Thickness of measured section	50

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Partial section of upper part of Danforth formation in bluff west of Cow Creek, in the SW¼ sec. 23, T. 22 S., R. 32½ E.

	Feet
16. Rhyolite, pink (cap rock)	10
15. Poorly exposed; powdery gray and brownish-gray slope wash that encloses small outcrops of (*a*) white ash at 60 feet above base of unit, (*b*) fine-grained gray tuff with many small pebbles of pumice at 120 feet, and (*c*) fragmental pumiceous light-gray tuff at 160 feet. Resembles units 4 to 6	160
14. Volcanic ash, white, fine-grained, poorly exposed	26½
13. Breccia, brownish; contains bits of obsidian, inflated basalt, and other volcanic rocks averaging ⅛ inch in diameter	3½
12. Ash, tuff, and tuffaceous sand, white, buff, and gray, fine-grained; lowest third dense but upper two-thirds highly inflated	10
11. Siltstone (?), brownish yellow, massive, indistinctly stratified; has conchoidal fracture	15½
10. Clay and pumiceous tuff, dark gray; weathers buff to yellow; middle third is leached and minutely cavernous; upper third contains fragments an inch long	11
9. Conglomerate, sandstone, and siltstone, gray; weathers buff; lower half contains pebbles of pumice and basalt scoria and is well stratified; finest-grained at top	3½
8. Ash and tuff, white and gray, in laminae 1 to 6 inches thick; upper part sandy, weathered, and poorly exposed	12
7. Pumice, loosely cemented, fragmental; a few angular pieces of compact white ash less than 3 inches long	3
6. Pumiceous ash, gray and white, also tuff, gray to cream; low specific gravity; several beds of massive compact ash 3 to 9 inches thick; upper half contains many subangular and angular pieces of pumice as much as half an inch through	44
5. Tuffaceous sandstone, light gray, fine-grained	½
4. Pumiceous tuff and ash, light gray and white, fine-grained; very low specific gravity; lower part poorly exposed; uppermost part has paper-thin bedding	15
3. Shale and coarse dirty sandstone, thin-bedded, indurated; bedding very irregular	3
2. Siliceous tuff, light to dark gray, poorly exposed; at top and bottom contains small fragments of basalt, pumice, black obsidian, and quartz; in center, contains many green chert concretions about a foot in diameter	22½
1. Concealed; slope wash	50
Base of section is alluvial plain of Cow Creek.	
Thickness of measured section	390

Section of basaltic breccia member of Danforth formation and associated rocks in the W½ sec. 18, T. 28 S., R. 31 E.

	Feet
13. Basalt, olivine-bearing, red, somewhat inflated, especially near its base	10
12. Concealed; slope wash of wind-blown sand and highly inflated red clinker	110
11. Basalt, olivine-bearing	8
10. Poorly exposed; lower third sand or silt, brownish, fine-grained; upper third vitrified (?) tuff and ash; 22 feet above base of unit is a 1-foot layer of sandy white clay; 47 feet above base is a 1-foot buff calcareous layer that contains shells of fresh-water gastropods	79
9. Sandstone or tuff, grayish, chalky, fine-grained but fragmental; lower part poorly exposed	23
8. Pumiceous conglomerate, pale yellow, very fine matrix	6
7. Silt or ash, gray and white, calcareous; laminae paper-thin to 1-foot thick; fine-grained but distinctly granular; upper two-thirds contains travertine (?) and numerous disconnected solution cavities as much as 6 inches long	24
6. Conglomerate, well cemented and cross-bedded; pebbles rounded, about 1 inch in diameter, and composed of white altered pumice; permeable	36
5. Ash, white, fine-grained; 3-inch beds	4
4. Siltstone, sandstone, and conglomerate, brownish; poorly exposed	60
3. Ash (?), white, fine-grained and dense	10
2. Basaltic breccia and very coarse tuff, comprising many inclusions of pumice and a light-gray fine-grained calcareous matrix; the whole is highly inflated but cemented and compact. In other exposures the inclusions are as much as 3 feet long and include basalt, rhyolite, and sedimentary rocks	25
1. Largely concealed; particles and small outcrops of (*a*) fine-grained cherty and calcareous material; (*b*) pumice; (*c*) glassy feldspar; (*d*) ash, grayish white, coarse and lumpy, containing particles as much as half an inch long; and (*e*) several 3-inch layers of dense white chert	65
Base of measured section is alluvial plain of the Donner und Blitzen Valley.	
Thickness of measured section	460

Section of sedimentary strata east of Harney Lake, in the SE¼NE¼ sec. 30, T. 27 S., R. 30 E.

	Feet
14. Rhyolite, altered, cherty	17½
13. Silt, brownish yellow, thermally altered	3
12. Conglomerate, mottled brown and white, fine-grained and highly altered	6
11. Sandstone or siltstone, yellow to buff, fine-grained but massive, with ferruginous concretions; largely semi-consolidated; two strata of reddish-brown dense calcareous sandstone at top and near base, each accompanied by a 6-inch layer of white calcareous silt or clay	33
10. Sandstone, buff, medium-grained, concretionary, pervious	1½
9. Conglomerate, fine-grained, calcareous, with pebbles of pumice as large as half an inch in diameter	4
8. Sand and silt, buff, in alternating layers; 2-foot stratum of dense fine-grained white volcanic ash (?) at center; upper part poorly exposed	39
7. Sandstone, buff to reddish brown, weakly consolidated; lower part generally fine and earthy; upper part coarse and cross-bedded. Encloses a 23-inch layer of soft buff silt and an 18-inch layer of fine white ash	13½
6. Ash (?), white, fine-grained, thinly laminated and dense	2½
5. Sandstone, grit, and conglomerate; white, gray, and brown; some of the sandstone is clean and pervious, but the unit as a whole is earthy; thin layers of clay and ash are enclosed. The conglomerate contains pebbles of pumice half an inch in diameter	58
4. Silt, brownish; ash, white, fine-grained, compact, and sandy; and one 15-inch layer of sandstone, coarse and poorly assorted. The ash contains some diatoms	7
3. Conglomerate, earthy; pebbles well rounded and about one-fourth inch in diameter, although some are about 1 inch; pebbles most abundant at the base; middle and upper thirds poorly exposed	30
2. Silt, brownish to white, loosely consolidated and massive; cliff-forming; resembles loess but contains many ferruginous concretions 10 inches in diameter which locally are alined horizontally. There are two intercalated layers of mottled fine-grained sandstone 3 to 6 inches thick; also, near the top, an 18-inch layer of dense iron-stained calcareous sandy silt	50
1. Slope wash	50
Base of section is alluvial plain adjacent to the Harney Playa.	
Thickness of measured section	315

In the northern part of the area, the lower part of the Danforth formation comprises thick extrusive sheets and masses of reddish-gray rhyolite. At some places its members are conspicuous owing to an abundance of evenly distributed spherulites and lithophysae ("stone bubbles") that are lined with opaline silica. These openings are usually discontinuous and do not impart perviousness to the rock. This facies of the lower part of the Danforth formation is well exposed in the canyon of Poison Creek along the highway that extends northward from Burns toward Seneca and Canyon City. At some places it is at least 300 feet thick.

In the Sagehen Hills, west and southwest of Burns, the rhyolite that has been classified as the lower part of the Danforth formation includes considerable black glass, is massive, and is jointed so closely that its initial layers cannot be readily discriminated. Certain spherulitic facies in that locality may belong with the older siliceous extrusive rocks (p. 51), which they resemble closely in petrographic character.

The uppermost member of the formation in the Silvies River section, the tuff-breccia member, is an invaluable horizon marker that can be traced from the type locality to and even beyond the remote parts of the area represented by plate 2. Locally, as in the upper basin of Cow Creek, the member is a brown translucent glass with few included fragments. In the eastern part of the basin the member is commonly underlain immediately by glassy rhyolite, which is coarsely spherulitic at some places and perlitic at others.

STRATIGRAPHIC RELATIONS, THICKNESS, AND AGE

As a whole, the sedimentary section that crops out along the Cow Creek Valley in the type area is considered tentatively to be a crude correlative of the section that overlies the basaltic breccia member east of Harney Lake. Thus, along the west margin of the Donner und Blitzen Valley in T. 28 S., Rs. 30 and 31 E., the basalt layer that caps the basaltic breccia section occurs directly beneath the tuff-breccia member of the type facies. Locally, however, there is a discordance of about 3° between the dips of the two horizon markers, particularly about 2 miles southwest of the Alkali Flat Playa. Because the discordance is local, the two rock units are considered essentially conformable. South of Harney Lake the basalt horizon marker underlies young rhyolite and overlies spherulitic rhyolite that is similar petrographically to rocks in the lower part of the Danforth formation in the type area. Still farther west, in the lower reach of Buzzard Canyon a few miles beyond the area represented by plate 2, Fuller [44] found two thin layers of basalt above spherulitic rhyolite and below the typical tuff-breccia member.

The small slivers of basalt that underlie rhyolitic strata of the Danforth formation in upfaulted slices in the Sagehen Hills (p. 40) are possible correlatives of some unit in the basaltic breccia member.

[44] Fuller, R. E., The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: Washington Univ. Pub. in Geology, vol. 3, No. 1, p. 130, 1931.

The sedimentary strata that crop out east of Harney Lake appear to underlie the basaltic breccia unconformably, at least at the locality southwest of the Alkali Flat Playa. There the strata of the basaltic breccia are nearly horizontal, whereas the sedimentary beds dip 3°–5° NW. However, this unconformity is also considered tentatively not to be regional. This interpretation has two corollaries—(1) the sedimentary strata east of Harney Lake are equivalent to a lower part of the Cow Creek section, and (2) all the sedimentary strata are somewhat higher stratigraphically than the massive spherulitic rhyolite that composes the lower part of the formation in the type district. It is inferred tentatively that the sedimentary strata east of the Harney Playa overlie the Steens basalt (p. 49), because they crop out in the lowest of a succession of down-faulted slices, whereas the Steens basalt crops out only in the higher slices to the south—that is, in the vicinity of Jackass Mountain.

In the type area, there is no obvious unconformity between the upper and lower parts of the Danforth formation, though the brief time available for the geologic investigation did not permit detailed study of the stratigraphic relations.

The Danforth formation varies greatly in thickness. In the northern part of the area the beds that crop out are at least 700 feet thick. Sections that are several hundred feet thick are exposed at many places along the north margin of the central alluvial plain, also between Harney Lake and the Donner und Blitzen Valley. On the other hand, a single sheet of rhyolite about 20 feet thick appears to be the only member of the formation in an extensive area on the west flank of Steens Mountain. The thickness of the formation beneath cover is unknown.

The Danforth formation rests unconformably upon all the older rocks of the region—that is, upon the Steens basalt, the older siliceous extrusives, and the pre-Tertiary rocks. The relief of the surface of unconformity is at least 500 feet, and both erosional and angular discordances are involved.

Within rather broad limits the age of the Danforth formation is indicated by five species of fresh-water shells that were found by C. F. Park, Jr., in the NW¼NW¼ sec. 18, T. 28 S., R. 31 E., in unit 11 of the basaltic breccia and associated rocks (p. 45). W. C. Mansfield states that the age may be either Pliocene or Pleistocene and reports the species to be as follows:

Pisidium sp.
Pompholix? sp.
Fossaria? sp.
Fluminicola fusca Haldeman.
Gyraulus parvus Say.

It is inferred that the age is more likely to be Pliocene, and the formation is here assigned tentatively to that epoch.

WATER-BEARING PROPERTIES

The capacity of the Danforth formation to transmit water varies widely. In general, the sedimentary facies that compose the greater part of the formation (see pl. 8, *B*) are not highly pervious, although there are pervious beds of sandstone and conglomerate, such as unit 9 in the Cow Creek section (p. 44), and units 5 and 10 in the section east of Harney Lake (p. 46). Even these beds are likely to finger or grade laterally into earthy material that is impervious.

The wide range in the water-yielding capacity of the sedimentary facies is shown by wells in the northwestern part of the basin. At one extreme are the two municipal wells at Burns (Nos. 17, 18), which bottom about 250 feet below the distinctive tuff-breccia member. In recent years their aggregate monthly pumpage has been as great as 44,000,000 gallons (p. 99). The municipal well at Hines, about 4 miles to the southwest (No. 22), bottoms about 340 feet below the horizon of the tuff-breccia member. Its monthly pumpage has been as great as 7,000,000 gallons. At the opposite extreme is a well (No. 1) near Prater Creek, about 6 miles northeast of Burns. This well, like the municipal wells at Burns, was started in the tuff-breccia member; it entered "shale" at a depth of 35 feet and continued in fine material to 490 feet. It is reported that the well failed to encounter ground water after it had picked up a small quantity of percolate at shallow depth. Evidently the stratum or strata that were pervious at Burns are not pervious at the Prater Creek locality.

In general, the extrusive members in the Danforth formation are compact and lack continuous primary pore space, but they have been extensively fractured and faulted (p. 53). Locally the secondary openings thus formed are ground-water conduits and transmit a large volume of water. For example, along certain of the faults in the Danforth formation are alined most of the large thermal springs in the basin (p. 106). Because no thermal springs issue from the Danforth formation at a distance from the faults, it is inferred that the formation is not generally pervious except for its fracture conduits. Otherwise, some of the ascending thermal water would almost inevitably be transmitted laterally to remote orifices.

If the inference just drawn is sound, it follows that the surface of unconformity at the base of the Danforth formation may control the circulation of the thermal ground water of moderate temperature, at least locally. (See p. 106.)

STEENS BASALT

In stratigraphic sequence the rhyolitic Danforth formation is underlain by a thick basalt series, for which the type section has been described and the name "Steens Mountain basalt" has been introduced by

Fuller.[45] In this report the series is designated the "Steens basalt," the name having been condensed to accord with the code of rules promulgated recently by the Committee on Stratigraphic Nomenclature.[46]

The type section of the Steens basalt occurs along the highest part of the bold east face of Steens Mountain, about 20 miles east of the head of the Donner und Blitzen Valley. There the basalt series is more than 3,000 feet thick and comprises many layers whose thickness varies widely but averages about 10 feet. Scoriaceous and fragmental zones are common at the tops of the successive layers; these zones are from a few inches to a few feet thick.

The Steens basalt crops out extensively in the eastern half of the area but only in the dissected upland that encloses the central alluvial plain. Its most northwesterly outcrop is in the valley of Rattlesnake Creek, but even there the exposed basalt strata are about 1,000 feet thick. In the southern part of the area the Steens basalt does not crop out west of Jackass Creek. Somewhat farther east, in the escarpment west of the Donner und Blitzen Valley and again in Riddle Mountain, the exposed sections also are about 1,000 feet thick, but none of these show the base of the series. In the Harney Basin the total thickness of the Steens basalt is inferred to range between a feather edge and about 3,000 feet, for the series does not crop out in the canyon of the Silvies River, to the north, and, so far as is known, it is thickest in the vicinity of the type section just described.

With respect to the age of the typical Steens basalt Fuller [47] says: "In general the evidence indicates that the Steens Mountain basalt * * * occurred either late in the Miocene or early in the Pliocene." His statement is based on the classification of a few flora and a few vertebrate fauna from associated strata.

Within the area mapped on plate 2 a few fresh-water shells were collected by C. F. Park, Jr., in sedimentary strata that are considered to be interbedded with the Steens basalt or to underlie it, although their stratigraphic position is not clear. The fossiliferous locality is along the west base of the Crowcamp Hills about 4½ miles north of Crane, in the NE ¼ SE ¼ sec. 18, T. 24 S., R. 34 E. W. C. Mansfield has determined the fossils as *Viviparus* cf. *V.* (*Callina*) *turneri* Hannibal and *Helisoma* aff. *H.* (*Perrinilla*) *cordillerana* Hannibal. He says: "The fauna lived in fresh water. The age of the fauna * * * appears at least not later than Miocene." This classification is in general agreement with that by Fuller.

The rock that makes up Jackass Mountain, in and about sec. 24, T. 29 S., R. 30 E., which has been mapped as Steens basalt, is strictly

[45] Fuller, R. E., op. cit., pp. 101–121.

[46] Ashley, G. H., and others, Classification and nomenclature of rock units: Geol. Soc. America Bull., vol. 44, pp. 433–434, 1933.

[47] Fuller, R. E., op. cit., pp. 114–114.

andesite. It is pinkish gray to glossy black, and most of it contains numerous disconnected vesicles, although some layers are massive and dense. Parting planes and platy textures are conspicuous in some layers. It is possible that the rock of Jackass Mountain is older than the Steens basalt and correlative with the andesite that underlies the basalt at its type section in the eastward-facing escarpment of Steens Mountain. On the other hand, Fuller [48] reports latites that are interbedded with the Steens basalt in the northeastern part of Steens Mountain. Moreover, along Jackass Creek some andesite layers are interbedded with basalt. Accordingly, it is believed that evidence for greater age is not sufficiently strong to justify discriminating the andesitic rocks of Jackass Mountain as stratigraphically distinct from the Steens basalt.

Many of the scoriaceous and fragmental zones in the Steens basalt are certain to be pervious. As a whole the basalt series is brittle and has been extensively jointed and faulted. Together, the pervious zones and certain of the fractures are presumed to transmit water rather freely. This presumption is confirmed by the relatively large springs, both thermal and nonthermal, that issue from the basalt along the west flank of Steens Mountain and the eastward-facing Donner und Blitzen escarpment. It is postulated that in the westward-tilted Steens Mountain block the water-bearing passages receive considerable water by infiltration from rain and melting snow and tend to transmit that water westward beneath the overlapping mantle of the Danforth formation. Analogous conditions may exist south of the Warm Spring Valley, where the volcanic rocks commonly dip northward.

OLDER SILICEOUS EXTRUSIVE ROCKS

In its type district the Steens basalt is underlain in turn by (1) a distinctive andesite series, (2) dacite and rhyolite, and (3) stratified sedimentary rocks.[49] Between these there are unconformities which appear to have little relief.

In the area represented by plate 2, however, neither the andesite series nor the stratified sedimentary rocks are known to crop out, and only the intervening unit—the siliceous volcanic rocks—has a possible correlative. This correlative is the only stratigraphic unit that is exposed beneath the Steens basalt within the area; it comprises rocks that are designated in this report older siliceous extrusives, to discriminate them from certain extrusives of the Danforth formation, which they resemble.

The older siliceous extrusives crop out in a few relatively small disconnected masses. In the hand specimen most of the rock is deep reddish brown and is not obviously crystalline but commonly contains

[48] Fuller, R. E., personal communication.
[49] Fuller, R. E., op. cit., pp. 43–45.

a few macroscopic angular fragments. The glassy matrix ranges from rhyolitic to andesitic; at some places it is almost completely devitrified. Both orthoclase and plagioclase feldspar are present, but the plagioclase is usually the more abundant. Most of the rocks contain chalcedony and opal; some contain also epidote, chlorite, and other secondary minerals.

Several masses of the older siliceous extrusives, especially those in the northern part of the Crowcamp Hills, north of Crane, are composed of coarse spherulitic layers that contain numerous lithophysae. This phase of the older siliceous extrusives resembles certain members in the lower part of the Danforth formation so closely that isolated masses of the two units may have been confused as this district was mapped. Likewise, in the Sagehen Hills, west of Burns, certain rocks that were mapped as Danforth formation may belong to the older siliceous extrusives and may be separated from the true Danforth formation by an unconformity that was not recognized and that cuts out the Steens basalt.

The Palomina Buttes, in T. 24 S., Rs. 28 and 29 E., are composed of extrusives which in petrographic character are unique among the rocks of the Harney Basin. These extrusives are light gray, are inflated throughout and even pumiceous at some spots, and commonly disclose conspicuous flow banding. Their matrix is largely siliceous glass (index of refraction less than 1.54) in which perlitic cracks and shards are common. The common feldspar ranges from oligoclase to acidic andesine, but some orthoclase (?) is present. Hornblende has been abundant as a primary mineral but is largely altered to biotite. A few small crystals of apatite are present, but no other accessory minerals were recognized in the thin section. The rock of the Palomina Buttes has been ascribed provisionally to the older siliceous extrusives.

Where the older siliceous extrusives and the Steens basalt are in contact they are separated by an unconformity that has strong relief and involves considerable erosion and local angular discordance. The angular discordance is disclosed in the northern part of the Crowcamp Hills, in the eastern part of Riddle Mountain, and in the area east of Malheur Gap. In the last-named area the older siliceous extrusives are crumpled and fractured, whereas the Steens basalt lies nearly flat, is faulted in a rather simple pattern, and is not crumpled.

PRE-TERTIARY ROCKS, UNDIFFERENTIATED

In the canyon of the Silvies River, from 20 to 25 miles north of Burns, fossiliferous strata of Lower Jurassic age crop out beneath the Tertiary rocks. Fossils from this general locality were first collected by a Mr. Huntington and were first studied by Thomas Condon.[50]

[50] Condon, Thomas, Oregon geology (edited by E. C. McCornack), p. 48, Portland, J. K. Gill Co., 1910.

Later, Packard and Nelson [51] reported a fauna of nearly 50 species, contained largely in impure red limestone. They also described the section as comprising light-colored limestone, fine-grained shale, arenaceous shale, arkosic sandstone, and basic intrusives. In 1932 a few fossils from the Donovan ranch were presented to C. F. Park, Jr., by Archie McGowan, of Burns. These Lower Jurassic fossils were identified by J. B. Reeside, Jr., as follows:

Parapecten acutoplicatus Gabb.
Gervillia sp.
Ostrea sp.
Pholadomya nevadana Gabb.
Pholadomya multilineata Gabb.
Pleuromya aff. P. concentrica Meek.

In the same vicinity, particularly where the Myrtle Creek road crosses the Silvies River, in sec. 29, T. 19 S., R. 31 E., greenstone crops out along the bottom of the canyon. This rock is highly altered and contains characteristic secondary minerals such as epidote, carbonates, and penninite. Quartz and plagioclase feldspar are present in broken and corroded grains, iron oxides are common, and the groundmass has begun to recrystallize.

Still farther north, in the Strawberry and Ochoco Mountains, which lie along and beyond the drainage divide of the Harney Basin, the correlative rocks are more metamorphosed and include schist and argillite. There intrusive rocks are also common.

Far south of the areas that have just been described, in the Pueblo Mountains, other crystalline rocks also crop out beneath the Tertiary lavas. According to Waring [52] these pre-Tertiary rocks include andesitic porphyry, micaceous schist, and granitic types, but their specific age is not known.

The unconformity that bounds the pre-Tertiary rocks at the top is the most profound stratigraphic break known in the region. Its relief amounts to several thousand feet, for the entire Tertiary volcanic sequence abuts against it at one place or another.

GEOLOGIC STRUCTURE

GENERAL FEATURES

The Tertiary rocks that border the central alluvial plain of the Harney Basin dip inward from all sides. Along the north border of the plain the Danforth formation dips 2°–3° S. (pl. 2). Along the whole east border and even farther south, along the Donner und Blitzen Valley, all the Tertiary rocks are present and dip inward from

[51] Packard, E. L., and Nelson, R. N., Geological occurrence of the Hardgrave Jurassic fauna of Burns, Oreg.: Geol. Soc. America Bull., vol. 32, p. 148, 1921.

[52] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 18, 1909.

2° to 14°. Farther west, in the quadrant south of Harney Lake and the Warm Spring Valley, the Danforth formation is exposed and again the dip is gentle, between 2° and 5°. Finally, along the west border of the central plain only the Harney formation crops out; its inward dip is only about 1°. Accordingly, the basin appears to be the broad, low fold or basin of downwarping that Russell [53] and Waring [54] have described.

The geologic structure of the Harney Basin is summarized in part as follows: (1) the Tertiary volcanic formations are not conformable and are deformed in different degree; (2) in general, the older formations are deformed most; (3) in all the Tertiary rocks except the oldest (older siliceous extrusives) the prevailing structural forms seem to be tilted fault blocks or horst and graben structure (raised and depressed blocks in alternation); (4) warps and folds are uncommon in the later Tertiary rocks except as they are caused by drag along major faults, by lapse of faults along the strike, and by local subsidence, as about the late basalt near Diamond; (5) the older siliceous extrusives are loosely crumpled as well as faulted, and the Lower Jurassic rocks that lie beneath the extrusives have been tightly compressed and are locally metamorphosed.

Owing partly to numerous faults in the Harney Basin, discontinuities in pervious strata are the rule rather than the exception in the Tertiary volcanics; also certain faults afford passages for the upward movement of thermal water in large volume. (See pp. 106–108.)

FAULTS

With few exceptions, the faults in the Harney Basin can be segregated into two sets that strike about N. 10° E. and N. 30°–60° W., and are arranged in a simple rhombic pattern. Most of them are grouped within a few wide zones and are disclosed on the land surface by conspicuous fault scarps. Few single faults persist more than 7 miles along the strike, but commonly several faults are arranged en échelon in a fault zone that extends much farther. In general, the fault surfaces are distinctly undulating or even angular.

Plate 2 shows the faults that have been traced with assurance or inferred from offset of the strata, from folds such as result from drag along faults, and from discordance in the dip of contiguous blocks, such as occurs east of Crane. Breccia, gouge, and slickensides have been accepted as corroborative evidence, although in a region of recurrent volcanism, such as the Harney Basin, these features commonly accompany minor collapse and in themselves are not considered evidence for mapping a fault. Also, certain land forms [55] have been

[53] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-Supply Paper 78, p. 22, 1903.

[54] Waring, G. A., op. cit., p. 25.

[55] Davis, W. M., The mountain ranges of the Great Basin: Harvard Coll. Mus. Comp. Zoology Bull., vol. 42, p. 151, 1903.

taken as corroborative, including (1) parallel escarpments that appear to be unrelated to the drainage pattern, (2) terminal ridge facets whose bases are alined, (3) prominent escarpments for which erosion does not seem a reasonable cause, and (4) prominent escarpments that are transverse to one or more structural units. However, certain prominent escarpments cannot rationally be inferred as of fault origin. Among these is the escarpment that bounds Wrights Point and fronts on the alluvial plain for miles farther west and south. On the other hand, certain land forms suggest faults where they have not been mapped. For example, several segments of the westward-facing footslope of the Crowcamp Hills are nearly straight and are parallel to one of the known sets of faults.

There appears to be no evidence for appreciable horizontal movement along any of the faults. In fact, many of the fault traces pass around promontories that would have been sheared off had there been material horizontal movement.

Although the faults that strike northwest are the more numerous, they produce neither the most persistent nor the most conspicuous of the fault escarpments. Commonly, the stratigraphic displacement along these faults is less than 100 feet, although along the faults that bound Steens Mountain on the north, near Riddle Mountain, it is somewhat more than 1,000 feet. Usually the strata are thrown down to the northeast, commonly stairlike across an entire fault zone. On the other hand, the northwestward-trending faults are involved in horst and graben structure in several areas. For example, the Sagehen Hills, west of Burns, overlook a small valley that trends N. 30°–35° W. and is a graben between a pair of dual-step faults. To the southeast, Riddle Mountain is an up-faulted sliver or horst, which is about 1 mile wide and 6 miles long. To the west, horst and graben structure recurs south of the Warm Spring Valley, although the stratigraphic displacement is moderate. In the area west and southwest from Weed Lake is a hinge zone where the stratigraphic displacement is negligible, although the faults may be continuous. For example, about 3 miles southwest of the lake a prominent southward-facing fault scarp decreases steadily in height as it approaches the hinge zone from the east, disappears for about 100 yards, then rises again but faces north as it continues westward.

Although the faults that strike northeast are less numerous, they are longer and commonly have the greater stratigraphic displacement. The most conspicuous example within the area is the fault (or fault zone) that forms the west flank of the Donner und Blitzen Valley. This fault is marked by a bold eastward-facing escarpment about 20 miles long. Its maximum stratigraphic displacement is about 1,000 feet. Locally, sharp drag folds take up fully half the displacement; in these the strata dip as much as 35°. This fault escarpment is rudely parallel to the better-known escarpment about 25 miles to the east that forms the east face of Steens Mountain. (See pl. 10.)

It is inferred that displacements have occurred concurrently along the faults that strike northeast and along those that strike northwest. Perhaps the most convincing demonstration lies in the structure along the Donner und Blitzen Valley. There the outstanding stratigraphic displacement follows a Z-shaped trace that comprises (1) the fault that strikes northwestward and passes near Frenchglen, (2) the Donner und Blitzen fault, and (3) the relatively broad zone of step faults that strikes northwest and passes just north of Jackass Mountain. East and north of this composite trace the Tertiary rocks have been depressed as a unit, although parted by some secondary fractures. Each of the two faults that form the southern salient of the Z-shaped trace is continued in the elevated block by a minor tear or flaw that dies out within a short distance.

FOLDS

In the Harney Basin the strata within each fault block or fault slice ordinarily are nearly plane, and the few folds are small. In the north-central part of the basin, in the vicinity of Coffeepot and Soldier Creeks, the Danforth formation is warped into a small depression that is shaped like half a spoon, abuts sharply against a fault on the west, and does not extend beyond that fault. In the southeast quadrant of the area another small structural basin and complementary anticline deform the Danforth formation and span the Kiger Creek Valley about 4 miles northwest of Diamond. These structural features adjoin the Diamond Craters; they are thought to be simple puckers formed by sagging of the roof above the magma chamber that supplied the late basalt. With the exception of the drag folds associated with faults, these two small basins are the most conspicuous folds in the area. At many places the strata are flexed gently about the termini of faults. Altogether, however, the few folds do not suggest that the Steens basalt and the overlying Tertiary rocks were ever folded extensively and independently of the faults.

EPOCHS OF DEFORMATION AND MECHANICS OF FAULTING

The Tertiary rocks in the Harney Basin appear to have been faulted and tilted at least thrice between late Miocene (?) and early Pleistocene time—that is, after the Steens, Danforth, and Harney epochs. The two unconformities within the Danforth formation (pp. 47–48) suggest that tilting took place during the Danforth epoch as well. Finally, the strata of Quaternary age—the terrace deposits, late basalt, and valley fill—are not known to have been faulted or deformed in the Harney Basin, although Fuller [56] has found

[56] Fuller, R. E., personal communication.

fault scarps in the alluvium of the Alvord Valley, which adjoins the Harney Basin on the east. Recurrent faulting in other districts of south-central and southeastern Oregon has been described by Waters,[57] Russell,[58] Fuller and Waters,[59] and Fuller.[60]

Further, the recurrent displacements in the Harney Basin have been in the same stratigraphic direction and along the same fault zones or, at some places, even along the identical faults. This is supported by the evidence that Davis [61] and Fuller [62] have presented for recurrent movements along the Steens Mountain fault zone. Thus, the fault pattern and general structural form of the Harney Basin appear to have been established before the Danforth epoch and may have been inherited from the rocks older than the Steens basalt. Furthermore, most elements of that fault pattern seem to have been reopened through each succeeding formation, although certain inferred faults in the Steens basalt do not extend into the overlying Danforth formation, and some faults in the Danforth do not extend into the overlying Harney formation.

The structural relations just described are disclosed particularly well in the western part of Riddle Mountain and in the Indian Creek Buttes, in T. 28 S., Rs. 34 and 35 E. There rhyolite of the Danforth formation rests on the Steens basalt in successive step-faulted slices, but the stratigraphic displacements in the rhyolite are materially less than in the basalt.

The writers concur in the belief that the conspicuous faults in the Harney Basin and elsewhere in south-central and southeastern Oregon are of the normal or gravity type—that is, they have resulted from tensional stress. On the other hand, Smith,[63] following the hypothesis of Wayland,[64] has advocated the idea that the fault along the eastern face of the Steens Mountain is a thrust fault—that is, it was caused by compressive stress. This theory of compression has been vigorously opposed by Fuller and Waters.[65] In his discussion, Smith cites a small anticline east of the Diamond Craters as competent evidence of compression. This anticline is a relatively small and gentle flexure which the writers have inferred was produced by

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[57] Waters, A. C., A structural and petrographic study of Glass Buttes, Lake County, Oregon: Jour. Geology, vol. 35, pp. 441–452, 1927.

[58] Russell, R. J., Basin Range structure and stratigraphy of the Warner Range, northeastern California: California Univ., Dept. Geol. Sci., Bull., vol. 17, pp. 417–418, 1928.

[59] Fuller, R. E., and Waters, A. C., The nature of the horst and graben structure of southeastern Oregon: Jour. Geology, vol. 37, pp. 204–239, 1929.

[60] Fuller, R. E., The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: Washington Univ. Pub. in Geology, vol. 3, no. 1, 1931.

[61] Davis, W. M., op. cit., pp. 168–169.

[62] Fuller, R. E., op. cit., pp. 28–29.

[63] Smith, W. D., Contributions to the geology of southeastern Oregon (Steens and Pueblo Mountains): Jour. Geology, vol. 35, pp. 421–441, 1927.

[64] Wayland, E. J., Some account of the geology of the Lake Albert rift valley: Geog. Jour., vol. 58, pp. 344–359, Royal Geog. Soc., 1921.

[65] Fuller, R. E., and Waters, A. C., op. cit., pp. 205–208, 221–238. Fuller, R. E., op cit., pp. 16–21.

sagging or slumping in the volcanics. Commonly the oldest Tertiary rocks of the basin (older siliceous extrusives) are loosely crumpled as if by compression, but even in those rocks no thrust faults have been observed.

WATER IN THE VALLEY FILL

UNCONFINED WATER IN THE SHALLOW PERVIOUS BEDS

FORM, DEPTH, AND FLUCTUATIONS OF THE WATER TABLE

Plate 2 shows the form of the water table beneath most of the central alluvial plain of the Harney Basin by contours for October 1931 and May 1932, these two sets of contours representing the lowest and highest stages in the climatic year 1931–32 and in the 3-year term of the present investigation as well. Each set of contours is based on altitudes of the water surface in about 160 wells that are too shallow to reach confined ground water. At about 75 wells the datum for altitudes was determined by spirit leveling; at the other wells it was estimated from a topographic map with 2½-foot contour intervals.[66]

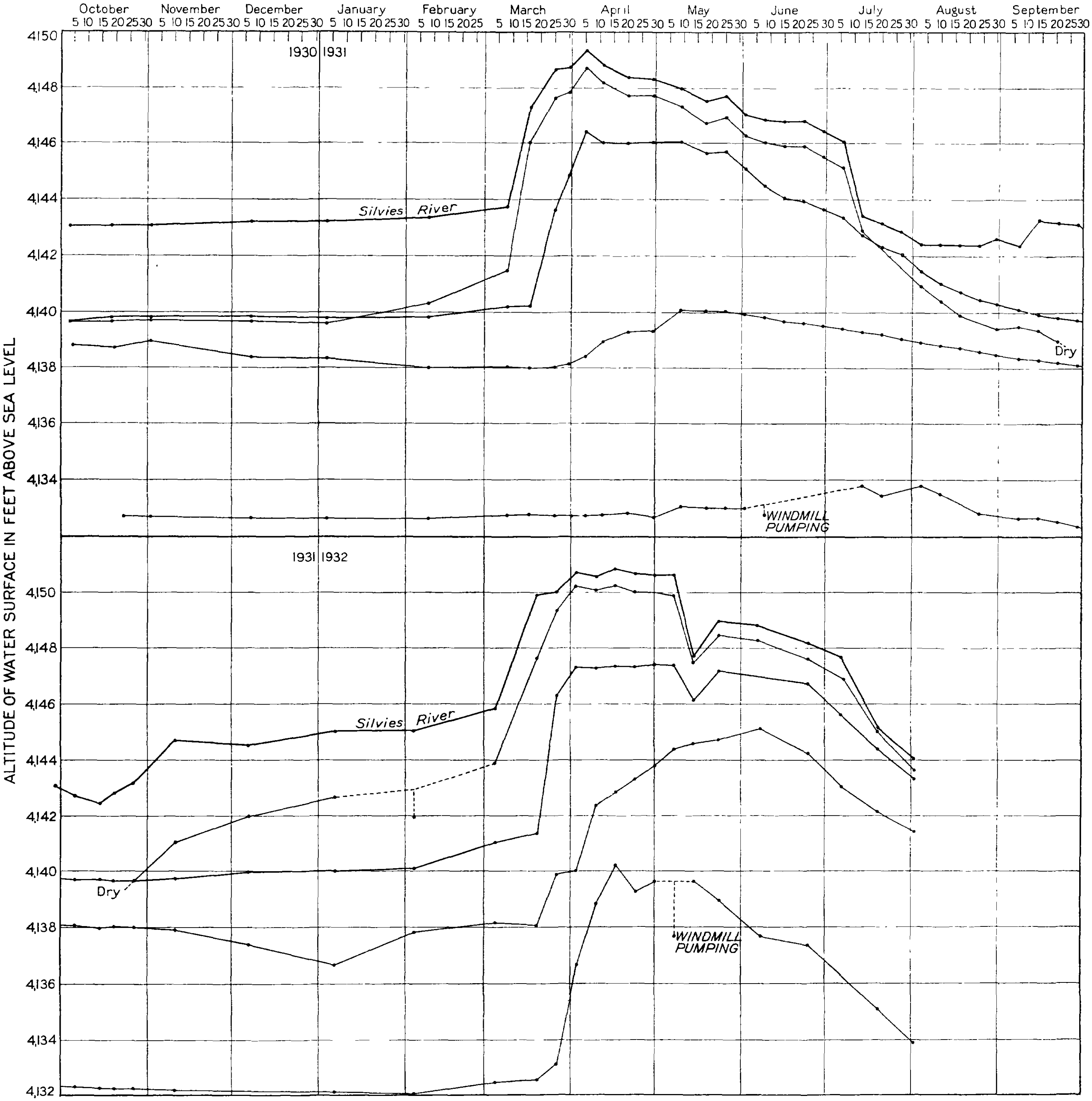
In general the water table, like the land surface, declines gradually from the northern, eastern, and southern margins of the central alluvial plain toward Malheur Lake, but it slopes somewhat more steeply than the land surface. So far as is known, the water table was lowest in the vicinity of Lawen, in Tps. 24 and 25 S., R. 32½ E., as is indicated by the closed 4,080-foot lines on plate 2. It is inferred, however, that the water table was about as low beneath Harney Lake, farther west.

The contours for October 1931 show the form of the water table after a succession of relatively dry years, but the form that would be assumed after a term of wet years can only be surmised. It is presumed that (1) the closed depression in the water table near Lawen would be obliterated, so that the water table would decline smoothly from the head of the alluvial plain near Burns to Malheur Lake; (2) in the southern part of the central alluvial plain the altitude of the water table would fluctuate according to the stage of Malheur Lake (see pl. 7); and (3) when the seasonal recession of the lakes was sufficient to separate them in the vicinity of the Sand Reef, the water table in the southern part of the plain would slope westward toward Harney Lake and would fluctuate in altitude according to the stage of that water body. These presumptions are supported by fragmentary data from several sources—(1) measurements of depth to the water table by E. R. Greenslet between August 1915 and April 1916, in connection

[66] Whistler, J. T., and Lewis, J. H., Harney and Silver Creek projects: U. S. Recl. Service, [Report on] Oregon cooperative work, maps 29, 30, 32, 1916. (Copies of the original drawings for these maps, scale 1:63,360, were made available by the U. S. Bureau of Reclamation.)

EAST FACE OF THE "HIGH" STEENS MOUNTAIN, AN ERODED FAULT SCARP.

Viewed from the Alvord alluvial plain, probably in sec. 2, T. 34 S., R. 34 E.



HYDROGRAPHS SHOWING FLUCTUATIONS OF THE WATER SURFACE IN THE SILVIES RIVER NEAR BURNS AND IN FOUR SHALLOW WELLS IN THE VALLEY FILL, 1930–31 AND 1931–32.

with soil-classification surveys;[67] (2) the driller's record of a well near Lawen (No. 197), which indicates that water-bearing sand and gravel were penetrated from 12 to 20 feet beneath the land surface in 1926, whereas in 1931 the water table at that place was about 32 feet below the land surface; and (3) comparative measurements of the depth to the water table made by Waring [68] in 1907 and by T. W. Robinson in 1931–32.

In October 1931 the water table was 6 to 10 feet below the land surface along the outer margin of the central alluvial plain opposite the streams and was 8 to 14 feet beneath Malheur Lake. Its greatest measured depth, 41.5 feet, was in well 178, near the head of the trough-like depression about Lawen. Farther west the water table was from 10 to 16 feet beneath Mud Lake, was only 5 feet deep in two wells at the north margin of Harney Lake, and ranged between 7 and 10½ feet deep in the northern part of the Warm Spring Valley. By May 1932 the water table had risen considerably in many parts of the valley, so that it stood at its highest level for the 3-year term of the investigation. At that time it was less than 1 foot beneath the land surface in some wells along the margin of the plain, and the greatest measured depth, 39.5 feet, was again in well 178 near Lawen. Several of the wells on the Malheur playa were under water in May.

In the Harney Basin the water table is known to have fluctuated owing to fluctuations in the discharge of streams and to transpiration by vegetation. Material fluctuations due to pumping have not been discriminated, because the draft from shallow beds in the valley fill is relatively small and the draft from deep beds has not affected the stage of the water table appreciably. (See p. 69.) However, it seems inevitable that the water table will tend to recede somewhat, at least locally, if the draft by pumps should increase materially.

The streams of the basin are flashy, and most of the year's run-off takes place in the spring; also, in years of relatively large run-off the streams commonly overflow extensive areas of the alluvial plain. Near the streams the water table generally rises in the spring in response to increased run-off and then declines until the end of the growing season, as is shown by plate 11.

For example, in 1930–31 the Silvies River did not spread materially beyond its banks, and the response of the water table extended eastward about a mile—that is, to and a little beyond well 48. In 1931–32, on the other hand, the river spread rather widely over the alluvial plain north of Burns, as did Foley, Newman, and Poison "Sloughs" and other intermittent distributaries. As a result, the water table in wells near

[67] Whistler, J. T., and Lewis, J. H., op. cit., maps 47 and 48, p. 20. Greenslet, E. R., unpublished data for the area from the Sand Reef to and 3 miles beyond Narrows.

[68] Waring, G. A., op. cit., pp. 58-59, 1909.

the river rose somewhat higher than in 1930–31; ultimately the rise was felt in well 57, about 4 miles to the east. The water table did not rise in wells far east of Poison Slough; in well 54, 1½ miles to the east, it varied only 0.3 foot in altitude during 1931–32 and seemed not to respond in any way to the freshet in the Silvies River. Fluctuations analagous to those mentioned occurred in other wells along the river—for example, in wells 77 and 245 (pl. 14).

Plate 12 shows the magnitude and extent of the rise of the water table beneath the central plain from October 1931 to May 1932. Essentially, this rise measures the net effect of the intervening freshet in the Silvies River, as well as the gross range in water-table stage in the 3-year term of the investigation. Ultimately the rise delineated on plate 12 should cause the water table to trend upward in the more remote parts of the central plain, although the short-term fluctuations would lag progressively and would be largely damped.

As White [69] and others have shown, certain species of plants commonly send their roots to the water table or to the capillary fringe and induce a diurnal fluctuation in water-table stage by their transpiration. These plants are the phreatophytes, or ground-water plants.[70] In the Harney Basin they include greasewood (*Sarcobatus vermiculatus*), salt grass (*Distichlis spicata*), certain meadow grasses that cover extensive tracts on the central plain, also the common tule or bulrush (*Scirpus*) and willow (*Salix*), which border the perennial reaches of the streams and the perennial ponds.

The three graphs that constitute figure 4 show daily fluctuations of the water table in well 77, which is at the edge of a native-grass meadow and about 25 feet from a clump of willows bordering the Silvies River. At the time both willows and grasses were growing vigorously. Graph A represents the period of most vigorous growth during 1931 and has a stairlike form owing to the net effect of daily transpiration draft and steady recession of the water table. Graph B indicates the smaller daily range of the water table after the lapse of a month, probably because the vegetation was transpiring less as the growing season waned and because the water table had fallen materially, possibly below the root zone. Graph C represents the period of vigorous growth in the following year when the daily average stage of the water table was nearly constant; thus, the graph has the sinelike form that White [71] infers to result from transpiration alone.

Transpiration by greasewood is inferred to explain a seasonal recession of the water table in certain widely separated wells. (See fig. 5.)

[69] White, W. N., A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U. S. Geol. Survey Water-Supply Paper 659, pp. 24–54, 1932.

[70] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, p. 1, 1927.

[71] White, W. N., op. cit., pp. 44–47.

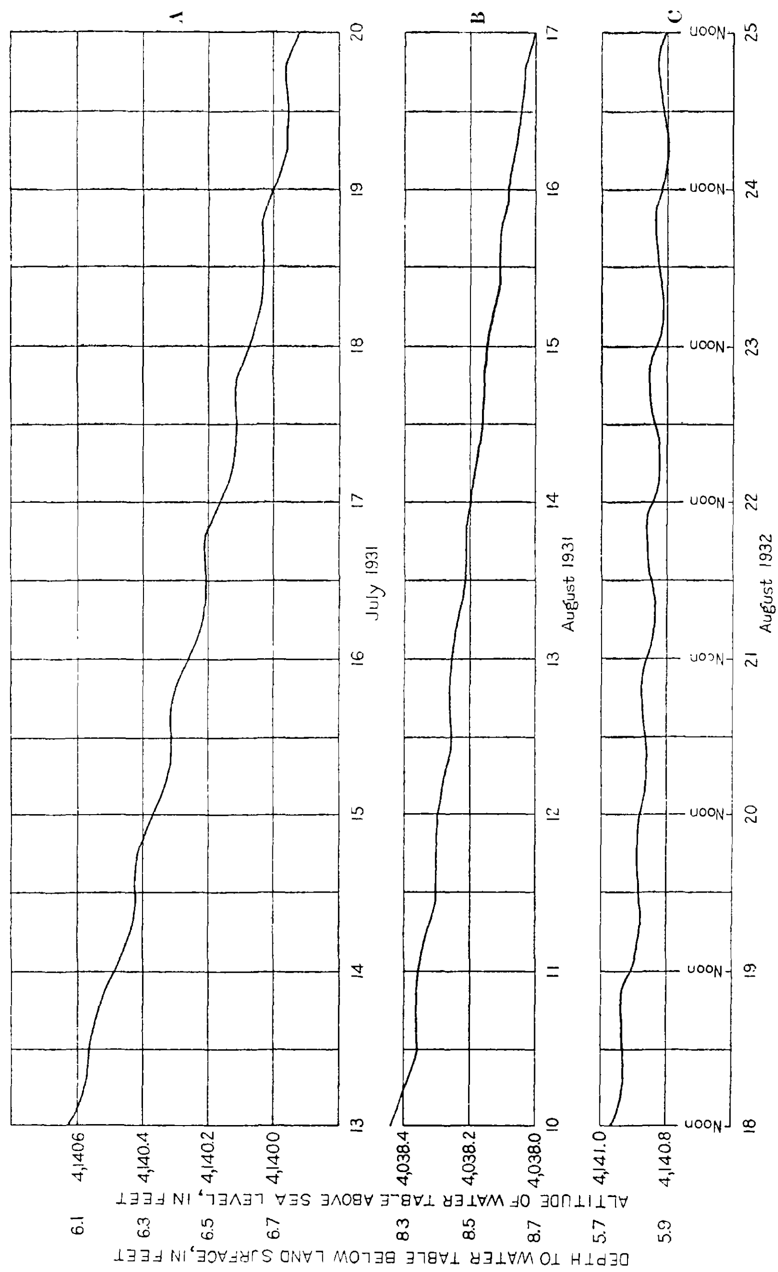


FIGURE 4.—Hydrographs showing daily fluctuations of the water table in well 77.

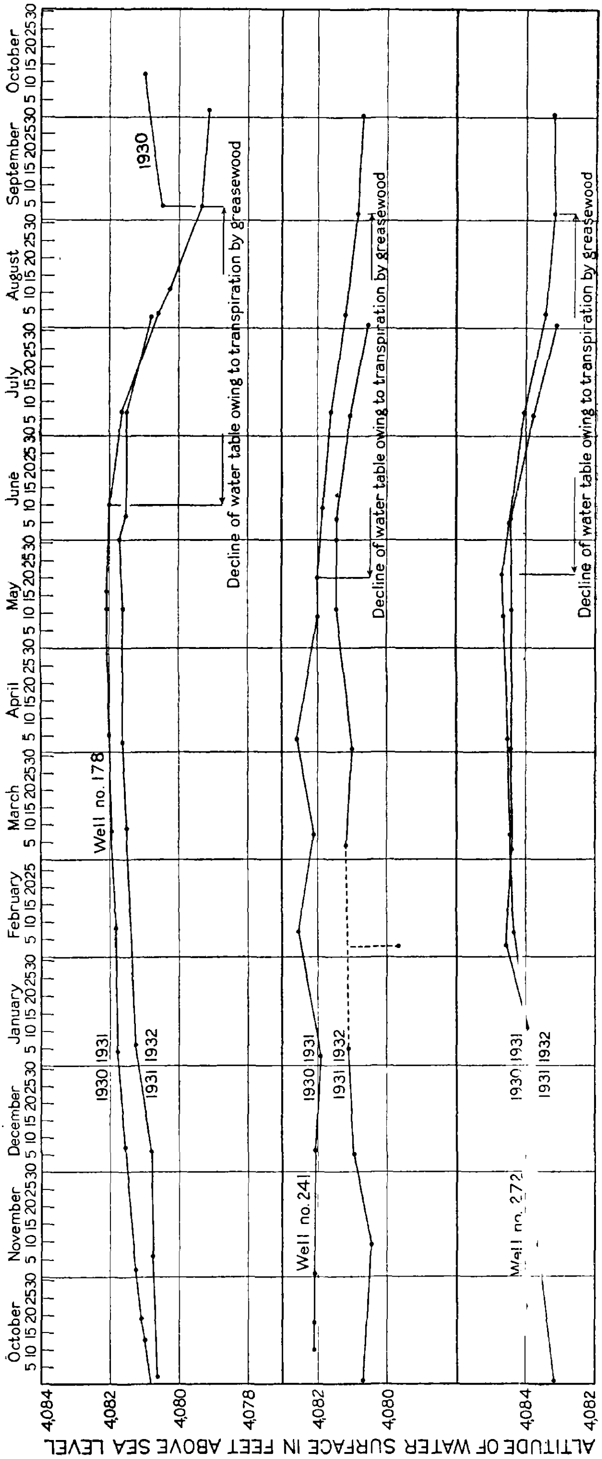


FIGURE 5.—Hydrographs for three shallow wells in the valley fill showing seasonal fluctuations of the water table due to transpiration by greasewood.

In addition to these fluctuations of relatively short term the water table no doubt rises or falls progressively during longer periods that correspond to terms of successive wet and dry years. For example, in three wells in the vicinity of Lawen (Nos. 200, 247, 250) the static level declined steadily from the beginning of the record until late May and early June 1932, when water from the Silvies River was being spread over adjacent meadows for irrigation; thereafter the water level resumed its downward trend. Further indication of the progressive decline of water levels in recent years is afforded by the dry wells listed in the following table.

Dry wells in the valley fill, Harney Basin

No.	Depth of well (feet)	Estimated depth to water table in October 1931 (feet)	No.	Depth of well (feet)	Estimated depth to water table in October 1931 (feet)
136	9	12	194	20	33+
137	9	12	196	28	31
139	12	12+	202	14	----------
175	34	35	214	21	----------
177	26½	29	215	22	----------
180	24	32+	251	14	15+
190	16½	26	269	20	----------
191	32	34	271	16	27
192	32	36+	341	19	----------
193	18	36			

SOURCE AND DISPOSAL OF THE UNCONFINED GROUND WATER

Ground water necessarily moves in the direction of the maximum hydraulic gradient—that is, at right angles to the contours of the water table or other pressure-indicating surface. Also, ground water is generally in constant motion from areas of recharge or intake toward areas of disposal; if the water-bearing material is homogeneous, the rate of movement is proportional to the hydraulic gradient. Thus, from the water-table contours on plate 2, the hydrographs of plate 11, and the water-table profiles of figure 6, it is inferred that so long as water flows in the Silvies River the water table is continuous with the surface of the stream and water percolates outward into the alluvium as a ground-water wave, the wavelike advance of the percolate being shown by the continuous rise of the water level until May 14 or later in well 49 (fig. 6), whereas a decline had begun soon after April 30 in the wells nearer the river. It is inferred further that ground water continues to percolate outward when the stream is not flowing over the alluvial plain and the water table is low, as in October 1931, after a succession of relatively dry years. Analogous conditions prevail along the south margin of Malheur Lake at the mouth of the Donner und Blitzen River.

Along the northern edge of the main alluvial plain water was entering the alluvium from Poison Creek in 1931–32 and merging with the percolate from the Silvies River. Farther east, an appreciable volume of water was percolating outward from Soldier, Coffeepot, and Rattlesnake Creeks, as is shown by the composite southward bulge of the water-table contours in that district. Of the other minor streams along the margin of the alluvial plain, none seemed to be contributing materially to ground-water storage in 1931–32, although they may do so in wet years.

Locally, the infiltration of rain probably adds somewhat to ground-water storage beneath the central alluvial plain, but the aggregate quantity so derived is much less than the percolate from the streams.

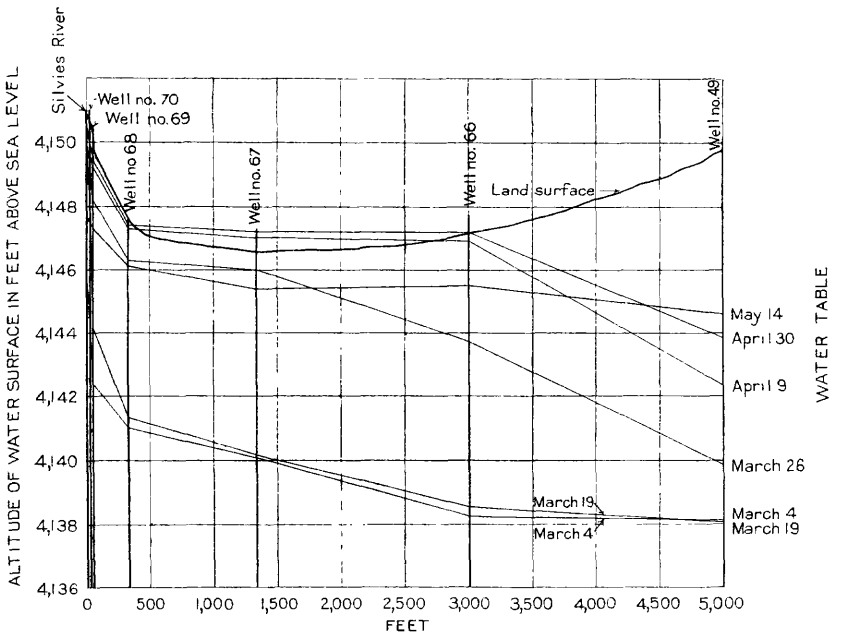


FIGURE 6.—Profiles of the water table east of the Silvies River along the Burns-Crane highway, 1932.

Over most of the plain, however, the rainfall is inferred not to penetrate below the belt of soil water. (See p. 80.)

The water-table contours for October 1931 and for May 1932 both indicate (1) that the shallow ground water beneath the main valley plain was converging toward the troughlike depression about Lawen and beneath Malheur Lake, (2) that the shallow ground water in the western part of the area was percolating radially toward Harney Lake, and (3) that no material volume of water was percolating outward beyond the margin of the topographic basin. Inasmuch as the two sets of lines represent, respectively, a low stage of the water table after a succession of dry years and a moderately high stage after the spring freshet of 1932, it is inferred that the three conditions just stated have prevailed commonly. It follows, therefore, that the ultimate disposal of the shallow ground water has commonly taken place from the vicinity of Lawen and from Malheur and Harney Lakes. Probably after a term of relatively wet years Harney Lake would become the chief sump from which ground water would be dissipated by evaporation; also some water might percolate eastward by way of Malheur Gap and pass beyond the topographic basin.

Evaporation and transpiration by ground-water plants probably dissipate a considerable volume of shallow ground water from the valley plain north of Malheur and Harney Lakes, especially during wet years. (See pp. 76–78.) Indeed, they probably dissipate most of the ground water that is discharged from the basin. Continued transpiration discharge during a succession of dry years is postulated as the cause of the peculiar troughlike depression in the water table near Lawen, for that trough is roughly coextensive with the most vigorous ground-water plants—greasewood and saltgrass. Its deepest part is overlain by vigorous greasewood, which is reported to send its roots as deep as 50 feet to reach ground water [72] and which is competent, in that respect, to have accomplished the unwatering. If the alluvium unwatered has a specific yield of 10 percent, about 28,000 acre-feet of ground water appears to have been withdrawn from storage to form the trough. It is a corollary of the postulate that the alluvium unwatered is relatively impermeable; otherwise ground water would have percolated freely toward the area of discharge, and the northern lobe of the trough could not possibly have been so much constrained as it was in 1931. The corollary is sustained by the drillers' record for well 197, which reports clay between 20 and 52 feet in depth below the land surface.

CONFINED WATER IN THE DEEP PERVIOUS BEDS

FORM AND DEPTH OF THE PIEZOMETRIC SURFACE

The pervious beds deep in the valley fill of the Harney Basin hold confined water whose pressure head commonly is distinctly different from the head of the unconfined water in the shallow pervious beds. Plate 13 shows the magnitude of this difference. It covers the two periods for which water-table contours are shown on plate 2 and is based largely on measurements of the static level in about 80 relatively deep wells that are cased tightly through the shallow pervious beds in the valley fill but do not reach the bedrock. (See pp. 137–151.) The available data of this sort are limited to the western part of the central alluvial plain.

These data afford two instructive comparisons between the form of the water table and the form of the piezometric surface (the imaginary surface that coincides everywhere with the static level of the confined

[72] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, pp. 37–42, 1927.

water in the deep aquifers [73]). Thus, the piezometric surface had the same general form as the water table, for in October 1931 and in the following May it sloped inward toward Malheur and Harney Lakes from all margins of the alluvial plain; nevertheless, the piezometric surface was notably smoother than the water table and contained no suggestion of a depression in the vicinity of Lawen.

In October 1931 the piezometric surface was lower at most places than at any other time from 1930 through 1932. At that time its depth below the land surface ranged between 1 foot in well 156, midway from Burns to Wrights Point, and 22 feet in well 246, near Lawen. Along the northern edge of the alluvial plain the depth to the piezometric surface was 14½ feet near the mouth of the Silvies River Canyon and 10 feet near Harney town site. On Malheur Lake the depth was less than at Lawen and ranged between 7½ and 15 feet. Only fragmentary data are available for the Warm Spring Valley, in the western part of the area; according to these, the piezometric surface ranged from 5½ feet below the land surface in one nonflowing well (No. 278) to 6 feet above the land surface in a flowing well (No. 350), which is about 2 miles west of Harney Lake.

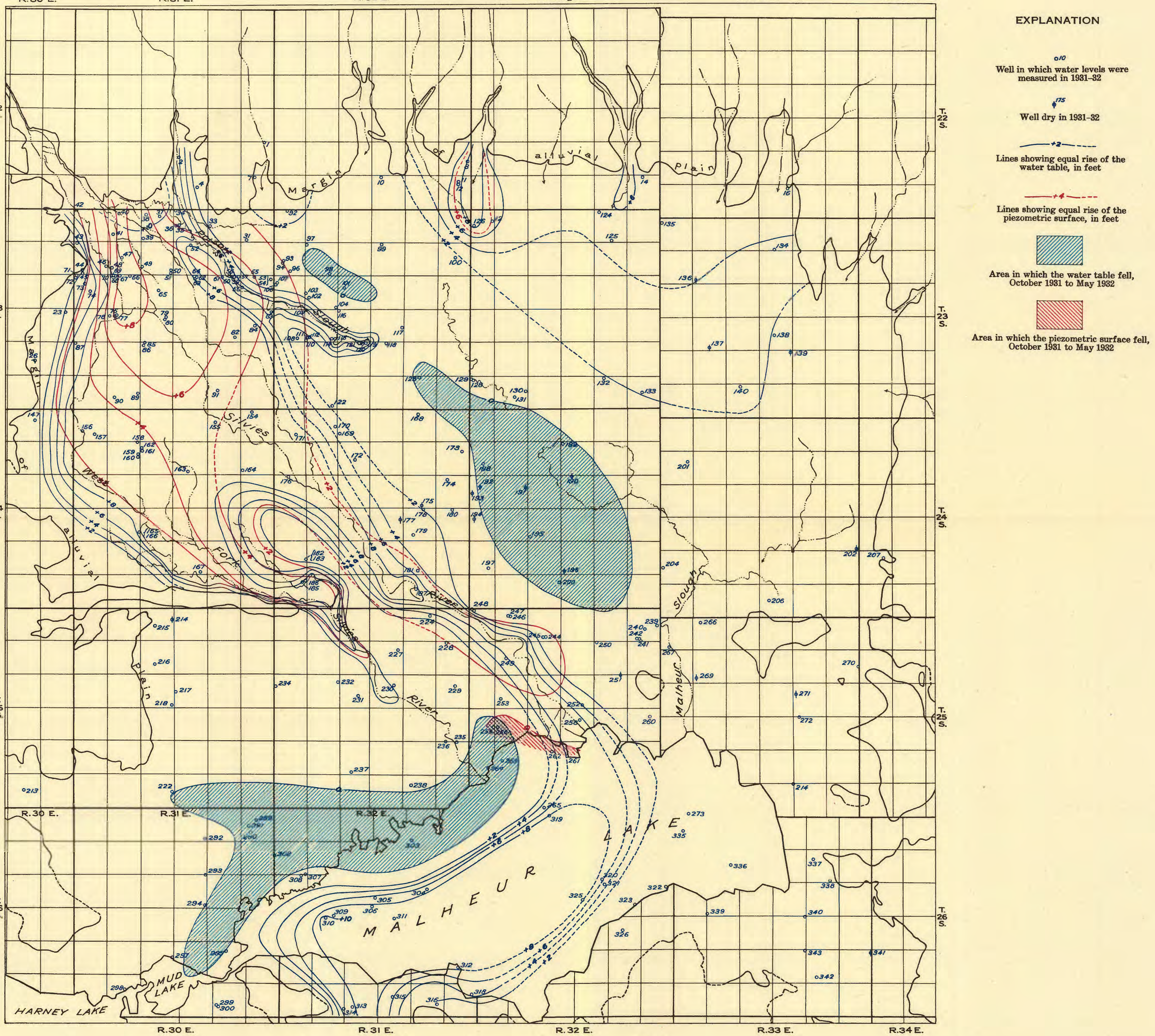
By the following May the piezometric surface for the confined water had risen as much as 8 feet in the vicinity of Burns and about 6 feet near the mouth of Rattlesnake Creek. Toward the south this rise diminished progressively to a feather edge somewhere near the north margin of Malheur Lake. (See pl. 12.) Owing to the rise just described, the piezometric surface ranged from 11½ feet to about 5 feet below the valley plain between Burns and Harney; it was 20½ feet below at Lawen and from 6 to 14 feet below much of Malheur Lake.

FLUCTUATIONS OF THE PIEZOMETRIC SURFACE

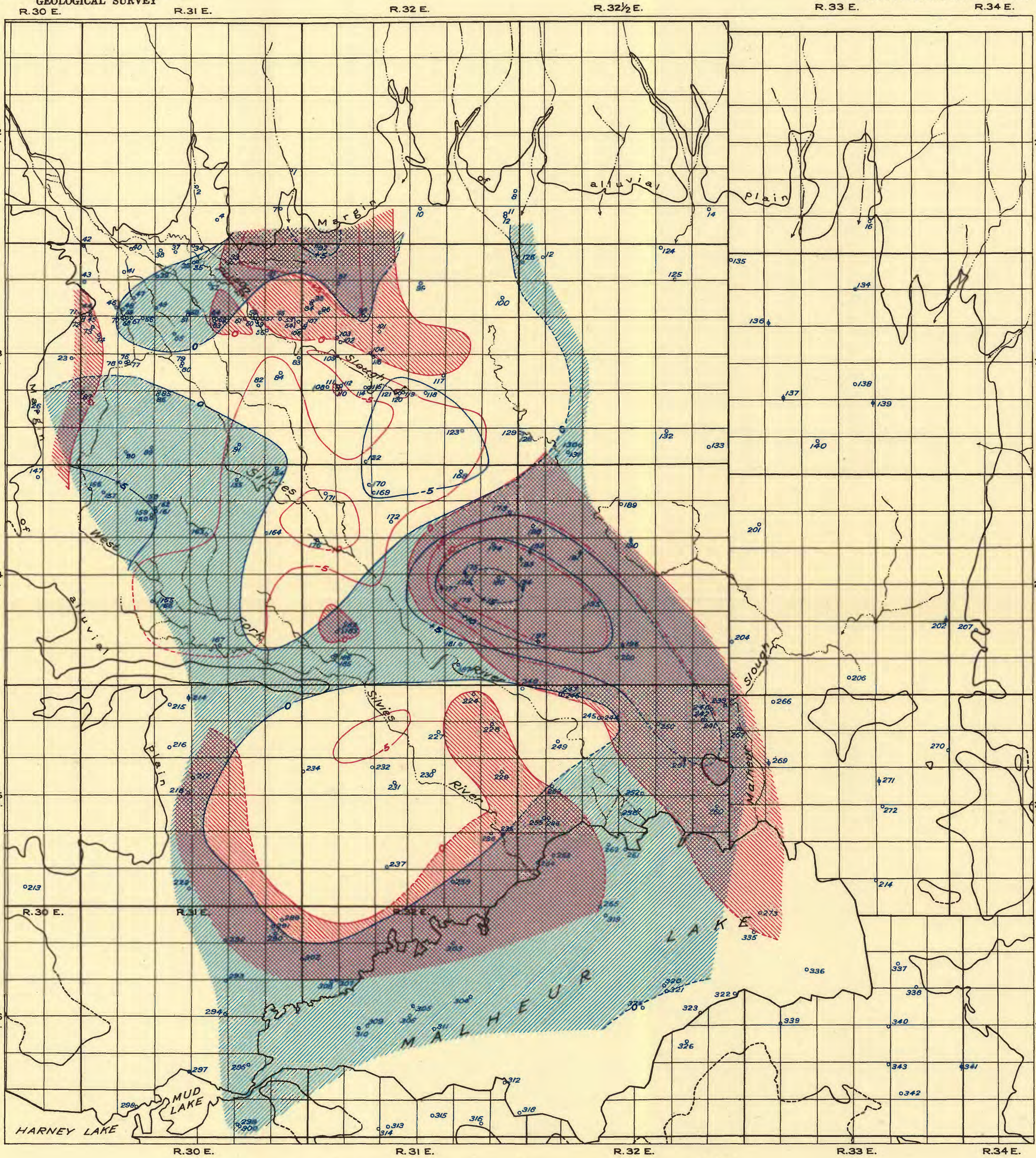
The static level of the confined water in the valley fill has been observed to fluctuate in response to run-off in the streams and to pumping from deep wells. Fluctuations from other causes have not been discriminated.

Plate 14 comprises hydrographs for three pairs of companion wells and shows typical fluctuations of the static level of the confined water in response to two freshets in the Silvies River; also, it compares those fluctuations with the concurrent fluctuations of the water table. Each of the three pairs comprises two wells a few feet or yards apart, one well being deep and tightly cased down to the confined water, whereas the other is shallow and does not reach far below the water table. Thus, the difference between the respective static levels indicates the true height of the piezometric surface above or below the water table at that place.

[73] Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, p. 38, 1923.



MAP SHOWING APPROXIMATE CHANGE IN GROUND-WATER LEVELS IN THE CENTRAL PART OF THE HARNEY BASIN, OREGON, FROM OCTOBER 1931 TO MAY 1932



EXPLANATION

o10
Well in which water levels were measured in 1931–32

175
Well dry in 1931–32

Lines showing head of the confined water above (+) or below (—) the water table, in feet:

—5—
in October 1931

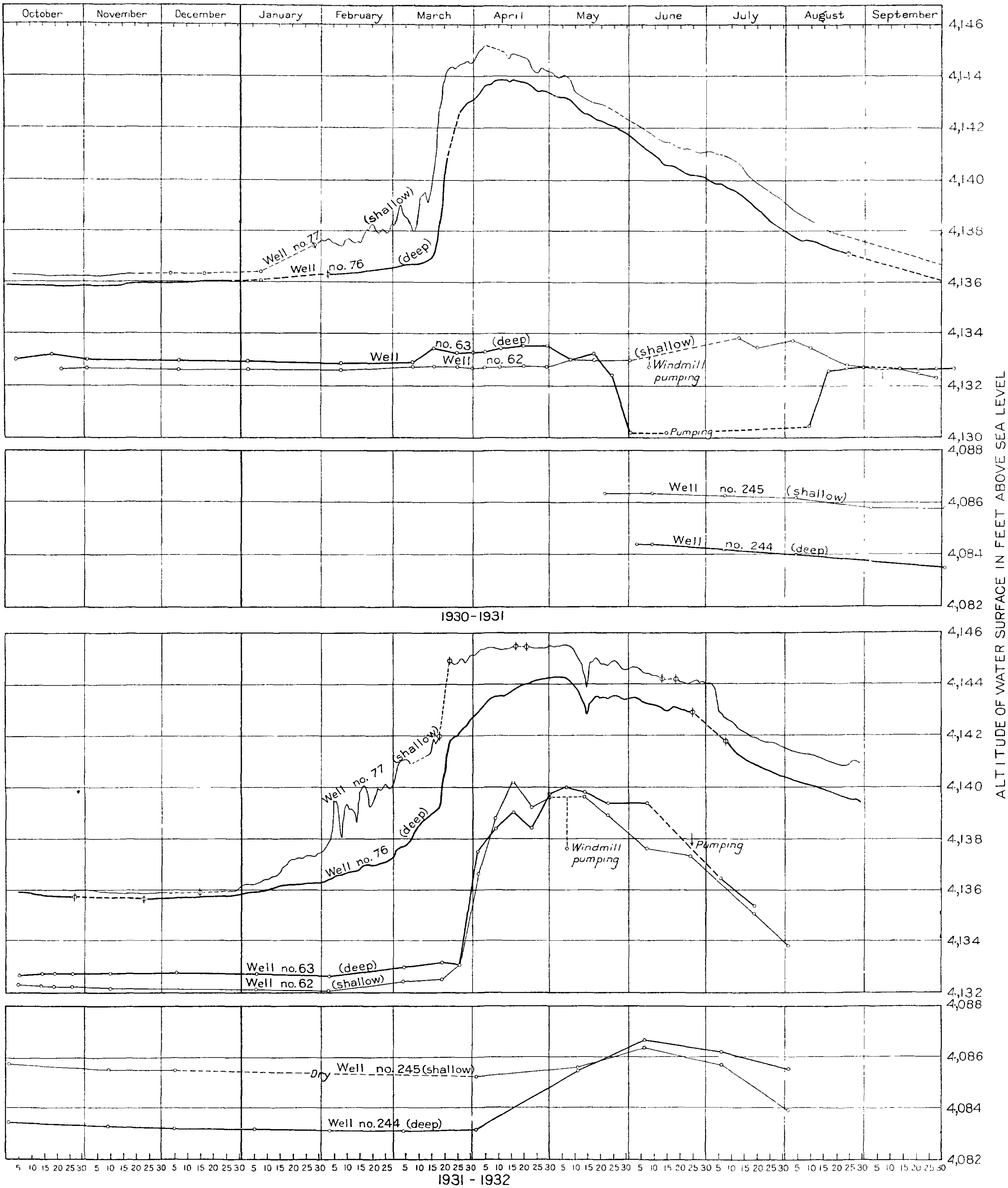
—10—
in May 1932

Area in which the static level of the confined water was above the water table:

in October 1931

in May 1932

MAP SHOWING APPROXIMATE DIFFERENCE IN HEAD BETWEEN THE UNCONFINED WATER AND THE CONFINED WATER IN THE VALLEY FILL IN THE CENTRAL PART OF THE HARNEY BASIN, OREGON, IN OCTOBER 1931 AND MAY 1932



HYDROGRAPHS SHOWING FLUCTUATIONS OF THE WATER LEVEL IN THREE PAIRS OF COMPANION WELLS IN THE VALLEY FILL, 1930-31 AND 1931-32.

[illegible]

It is inferred that the fluctuations in the static level of the confined water are due to changes in the load borne by the deep water-bearing beds as the shallow beds are saturated and unwatered and are not due primarily to recharge of the deep beds. Such fluctuations in response to changing load have been observed by many workers. For example, King [74] and Stearns [75] describe fluctuations caused by railroad trains passing near an observation well; Veatch [76] and Thompson [77] relate certain fluctuations in wells along the seacoast to the ocean tides. These fluctuations of pressure head have been analyzed by Meinzer [78] and ascribed to elastic deformation of the confined water-bearing bed, so that a part of the overlying load is transmitted to the confined water itself.

The inference that fluctuations of the static level in deep wells along the Silvies River are an effect of loading is drawn largely from the hydrographs from the water-stage recorders at wells 76 and 77. A critical section of these hydrographs constitutes figure 7; it shows the response of water levels to the impounding of water above the Culp diversion dam, which is about 150 feet downstream from the wells. After the peak of the spring freshet had passed, flashboards were placed in the dam early in the afternoon of May 15, 1932; within a few hours water was passing over the dam, the river stage opposite the wells having risen about 8 feet. The water table began to rise almost immediately at the shallow well and continued at a diminishing rate until 9 a. m. on the following day. Concurrently the static level in the deep well rose about 40 percent as much as in the shallow well and lagged about 4 hours. In other deep wells upstream the static level did not rise. Therefore, it appears that most if not all the increase of head in the deep aquifers was due to loading. After its initial rise, the water table was steady for about 26 hours, then rose about 0.2 foot in the succeeding 14 hours, again was nearly steady for 36 hours, and finally declined sharply about 11:30 a. m. May 19. These fluctuations are presumed to reflect manipulations of the flashboards at the dam. Concurrently, however, the piezometric surface rose steadily, although it responded somewhat to the fluctuations of the water table. The condensed hydrographs of plate 14 indicate that the piezometric surface continued to rise steadily with respect to the water table for at least 40 days; by that time the difference in static

[74] King, F. H., Observations and experiments on the fluctuations in the level and rate of movement of ground water on the Wisconsin Agricultural Experiment Station and at Whitewater, Wis : U. S. Dept. Agr. Weather Bureau Bull. 5, pp. 67–69, 1892.

[75] Stearns, H. T., Robinson, T. W., and Taylor, G. H., Geology and water resources of the Mokelumne area, California: U. S. Geol. Survey Water-Supply Paper 619, pp. 148–149, 1930.

[76] Veatch, A. C., Fluctuations of the water level in wells, with special reference to Long Island, N. Y.: U. S. Geol. Survey Water-Supply Paper 155, pp. 62, 63, 65–69, 74–75, 1906.

[77] Thompson, D. G., Ground-water problems of the barrier beaches of New Jersey: Geol. Soc. America Bull., vol. 37, p. 466, 1926.

[78] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology, vol. 23, pp. 275–276, 1928.

HYDROGRAPHS SHOWING EFFECT OF PUMPING FROM WELL 94 ON THE STATIC LEVEL IN THREE DEEP WELLS AND ONE SHALLOW WELL IN THE VALLEY FILL.

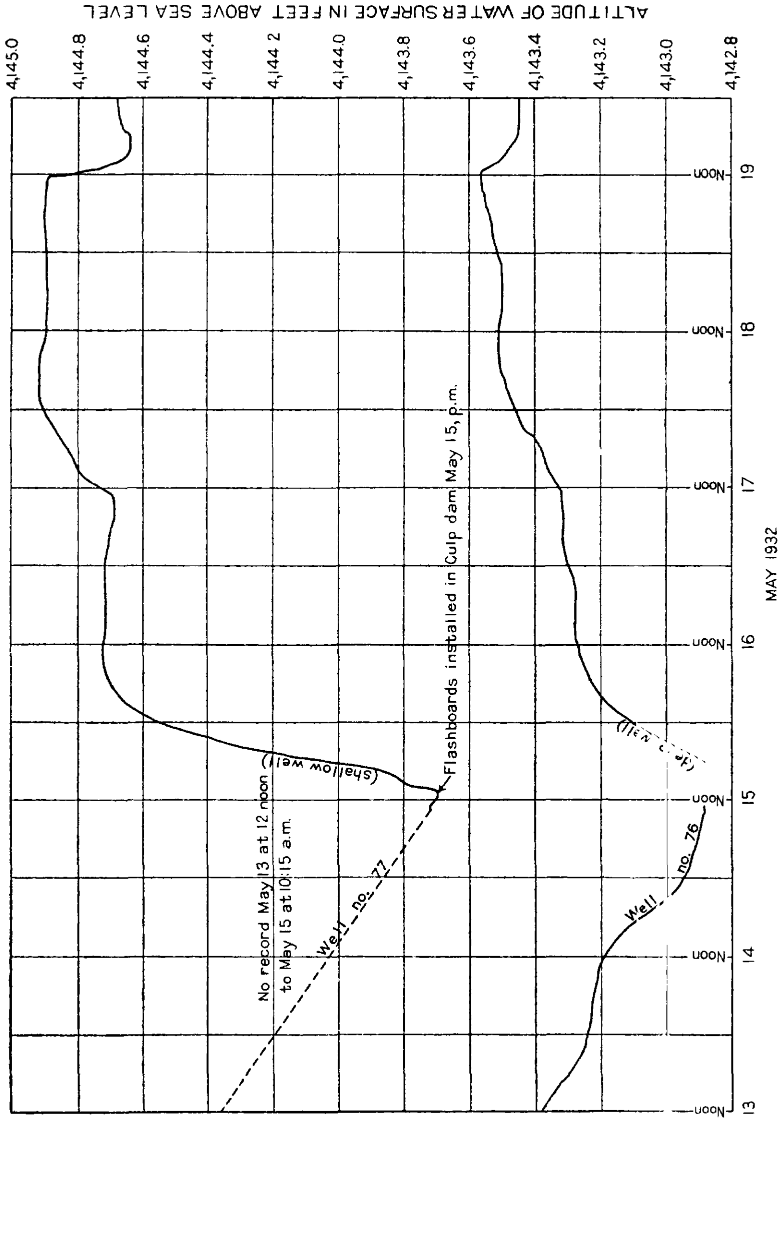


FIGURE 7.—Hydrographs showing fluctuations of the ground-water levels in two companion wells, nos. 76 and 77, in response to the impounding of water by the Culp dam.

levels had diminished to about 1 foot. Other fluctuations of the piezometric surface at this place have been 40 to 80 percent as large as the corresponding fluctuations of the water table and have lagged from 1 hour to 4 hours.

Altogether, 11 pairs of companion wells have shown fluctuations analogous to those just described, although the fluctuations are defined only by periodic measurements of depth to water and not by charts from water-stage recorders. Thus, they confirm the inference just developed. Further confirmation lies in similarity in the form of the zones through which the respective water levels rose from October 1931 to May 1932 (pl. 12).

Plate 15 assembles hydrographs for four wells in the vicinity of the Harney Branch Experiment Station and shows typical fluctuations of the static level in the deep valley fill in response to pumping. Three of the four wells (Nos. 53, 97, 107) tap the deep pervious beds in the valley fill from which water is pumped for irrigation at the experiment station (through well 94). Obviously, the recessions of water level in these deep wells are closely correlative with the pumping and are not reflected in a water-table well (No. 54) which is dug around the casing of one of the deep wells (No. 53). Thus, it is concluded that the recession in the deep wells is due wholly to loss of head in the aquifer. Even more convincing is the record from well 93, a shallow boring only 15 feet from the pumped well. In this shallow well also the water table did not recede in the least during the pumping season, although the pumped well was drawn down from 45 to 58 feet for 3½ months (pl. 16). Identical behavior of water levels was shown in the preceding year. This difference in head was approximately equal to the thickness of the impervious beds that intervene between the shallow and deep pervious zones. Thus, a hydraulic gradient of unity was insufficient to draw water downward from the shallow pervious zone. Analogous conditions existed about the irrigation wells operated by R. W. Cozad and William McLaren (Nos. 112, 64, respectively). At Mr. Cozad's well the difference in head during the pumping season was more than twice the aggregate thickness of the impervious beds reported by the driller (p. 135); at Mr. McLaren's well it was about one and a half times as great.

The foregoing data afford rather rigorous tests of the water-tightness of the confining beds that overlie the deep pervious zone in the valley fill. The three tests agree in indicating that the zone is tightly confined indeed.

SOURCE AND DISPOSAL OF THE CONFINED WATER

As the form of its piezometric surface indicates, in 1931–32 the water in the deep pervious beds of the valley fill was moving away from the Silvies River at an acute angle in two areas—(1) along an

8-mile reach beginning at the head of the alluvial fan near Burns and (2) near the north margin of Malheur Lake. The obvious implication is that water enters the deep beds by downward percolation from shallow water-bearing beds in the valley fill. However, three lines of evidence indicate that downward percolation along the Silvies River is restricted to a rather small district at the head of the alluvial fan.

First, wherever the static level of the water in the deep pervious beds stands above the water table, percolation tends to be upward rather than downward. In 1931–32 that condition prevailed over a considerable part of the alluvial plain—specifically, within the areas that are delineated on plate 13 by shading. Of course, those areas are not constant in extent; they appear to be most extensive in the autumn and after a succession of dry years, as in October 1931. The following May, while the Silvies River was in freshet, the static level of the water in the deep beds stood but slightly below the water table everywhere within 3 to 4 miles of the apex of the alluvial fan of the Silvies River, near Burns. That condition implies that water was percolating downward to the deep beds so readily that material differences in head could not long remain. Farther to the southeast, however, the static level for the deep beds was persistently from 5 to 10 feet below the water table. Although the pressure gradient favored downward percolation there, the inference follows that the valley fill was relatively impervious; otherwise, the difference in head would not have persisted.

Second, confining beds separate the shallow and the deep water-bearing zones beneath most of the central alluvial plain. Thus, near Lawen the confining beds are about 100 feet thick according to drillers' records for three wells (Nos. 197, 226, 246). The thickness and mode of origin (p. 31) of these beds both suggest that they are extensive in that vicinity, but it has been inferred that they tend to feather out fingerwise toward the northwest—that is, toward the apex of the alluvial fan of the Silvies River. Nevertheless, they are from 20 to 50 feet thick in wells between 5 and 8 miles from the apex of the fan (Nos. 56, 64, 94, 112). The data given above on the depression of water levels by pumping have shown that these beds are watertight. It is still closer to the apex of the alluvial fan that the confining beds constitute a minor fraction of the valley fill (wells 65, 73, 74).

Third, data on the chemical character of the ground water (pp. 114–119) indicate that the quantity of dissolved matter in the water from the shallow pervious beds increases steadily toward the southern part of the alluvial plain and becomes very large in the vicinity of Malheur and Harney Lakes. On the other hand, the water from the deep pervious beds at any particular place ordinarily contains less dissolved matter, especially near the playas. It seems that if the deep pervious beds were recharged by downward percolation in all parts of the alluvial plain, the water from the two pervious zones should be more alike in chemical character.

From the foregoing three lines of evidence it is inferred that effective recharge of the deep pervious zone by downward percolation from the Silvies River can take place only within about 5 miles of the apex of the alluvial fan near Burns—that is, largely in the northwest half of T. 23 S., R. 31 E. It is inferred further that a consequential volume of water does not reach the deep pervious zone by percolation from the minor streams along the north margin of the alluvial plain, nor from Sagehen and Sunset Valleys along the west margin. These streams have little run-off and inconspicuous alluvial fans. On the other hand, the Donner und Blitzen River, which drains the extensive southern part of the Harney Basin (pl. 1), is competent to have deposited coarse detritus beneath the western part of Malheur Lake. Thus it is altogether possible that the deep and shallow water-bearing zones are interconnected there, as at the apex of the Silvies River fan, although fragmentary data on ground-water levels imply that deep percolation was not taking place extensively opposite the Donner und Blitzen Valley in 1931–32.

The form of its piezometric surface indicates that in 1931–32 the water in the deep pervious zone of the valley fill was converging toward Malheur and Harney Lakes; thus it is implied that some of the water was dissipated there. The method of disposal, however, is not entirely clear. Over part of the playas the difference in pressure head would have permitted water to pass upward to shallow pervious beds, from which it might have been dissipated by evaporation and transpiration. However, only a few miles to the north the confining beds that separate the two water-bearing zones are competent to restrain percolation under much larger heads; thus the hypothesis of upward percolation is scarcely tenable unless the valley fill is preponderantly coarse-grained opposite the Donner und Blitzen Valley.

Fragmentary data on the form of the piezometric surface along the east margin of the alluvial plain indicate that in 1932 the water in the deep pervious zone of the valley fill was moving westward away from Malheur and Crane Gaps. Nevertheless, if the static level should rise considerably after a term of wet years, it is conceivable that some water in the deep pervious zone might percolate eastward through the gaps and out of the basin.

It seems unlikely that much water can percolate out of the alluvial basin through the enclosing bedrock, for the few deep wells along the margins and in the eastern part of the main alluvial plain indicate that generally the water in the bedrock has a higher head than the water in the valley fill. Under such conditions, water would tend to pass into the fill if any pervious conduits were available.

SUBDIVISIONS OF THE ALLUVIAL PLAIN

To facilitate discussion of the source, disposal, and recovery of ground water in the valley fill, four subareas that present distinct ground-water problems are discriminated. As shown on figure 8, these are (1) the Silvies subarea, (2) minor subareas north of Malheur Lake, (3) the Donner und Blitzen Valley, and (4) the Warm Spring Valley.

SILVIES SUBAREA

GENERAL HYDROLOGIC FEATURES

The Silvies subarea is essentially a natural ground-water province within whose boundaries the valley fill receives and discharges ground water independently of other subareas, although those boundaries are somewhat conventionalized. On the west and north the subarea is bounded by bedrock whose water is generally under greater head than the water in the valley fill. Hence ground water can cross that boundary only as it may percolate from the bedrock into the fill. On the east, its boundary in T. 23 S., R. 32 E., coincides approximately with the direction of natural percolation in both the shallow and the deep water-bearing beds in the valley fill in 1931–32; thus little or no ground water was percolating into the subarea or out of it in that township. Farther south, in T. 24 S., R. 32½ E., and T. 25 S., R. 32 E., water tended to percolate into the subarea, but the inflow is believed to have been offset by outflow toward the Malheur Playa.

There appear to be three sources for the water in the valley fill of the subarea—(1) seepage from the Silvies River and from Poison and Prater Creeks, (2) infiltration of rain, and (3) upward percolation of water from the bedrock. The third source is known to function only near Hines, in the northwestern part of the subarea, where thermal water from the Danforth formation is confined under artesian head in deep beds of the valley fill and where some recharge at shallow depth is effected by seepage from thermal springs. The volume of water contributed to the valley fill from the bedrock in this manner is not known. The recharge by seepage from the streams and by penetration of rain is discussed further on succeeding pages.

There are at least three lines of evidence showing that ordinarily the valley fill is recharged by substantial volumes of water each year. These are derived from data on ground-water storage, ground-water discharge, and source and disposal of soil water; each is developed separately on following pages.

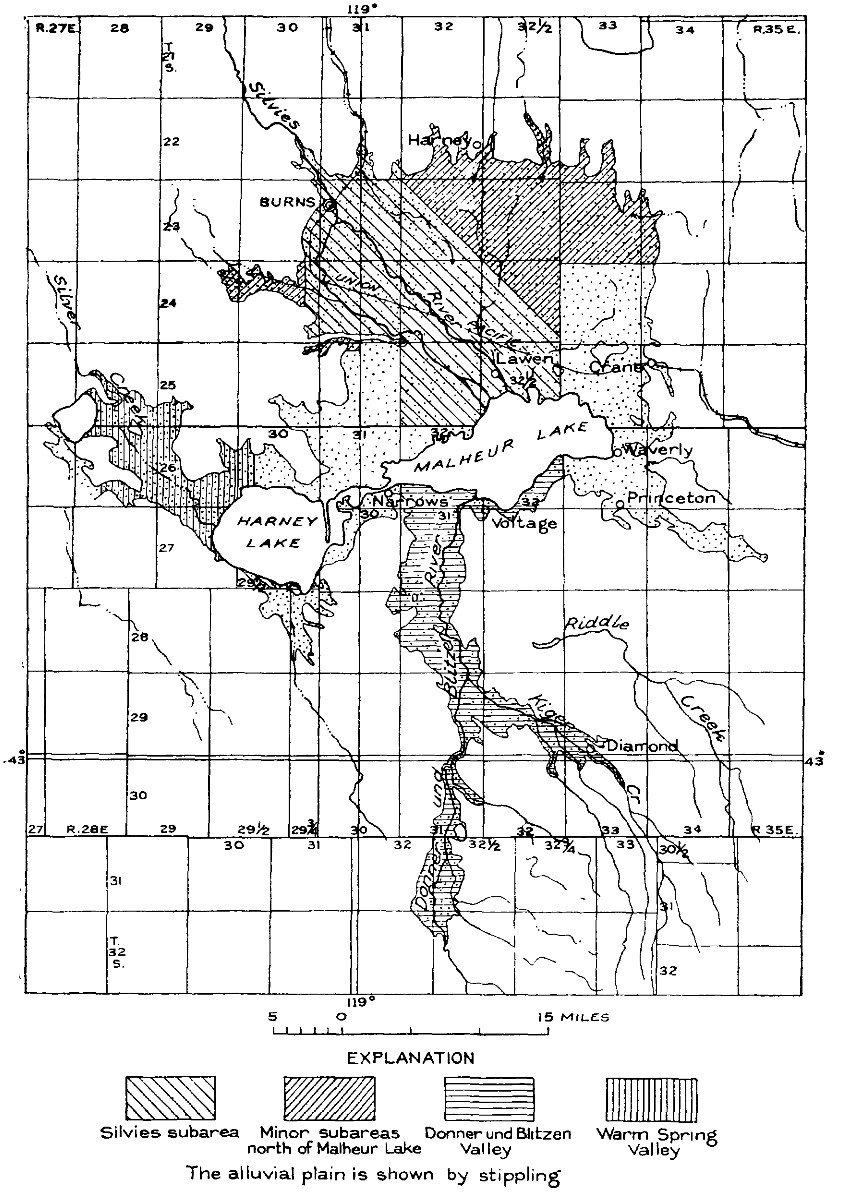


FIGURE 8.—Index map showing location and extent of subareas of the alluvial plain in the Harney Basin.

RECHARGE OF THE VALLEY FILL

ESTIMATES BASED ON GROUND-WATER STORAGE

The net rise or fall of the water table during any period may be taken as an index to the net volume of water that has been added to storage in the valley fill or withdrawn from storage during that period. If the water level is the same at the end as at the beginning of the period, it follows that there has been no net change in storage but that recharge and discharge have been equal.

In the Silvies subarea the water table is ordinarily lowest near the end of the growing season, usually in October, and is highest during the spring period of high water, usually in April or May. Nearly all the rise from autumn to spring is believed to be caused by seepage from the streams during their freshets.

Thus, in 1932 the high-water period began about mid-March;[79] ground-water recharge probably began soon afterward at the head of the Silvies River fan and extended gradually downstream. Plate 12 shows that by May, when the freshet had begun to wane, the water table had risen materially over an area of 75,000 acres and had risen 8 feet or more over some 35,000 acres. The corresponding volume of material saturated may be computed by the principle of average end areas; after measuring the area within each of the lines of equal rise it proves to be about 485,000 acre-feet. As the freshet waned, the water table fell near the river but continued to rise along the margin of the area of recharge. These subsequent changes in water-table stage do not indicate any increase or decrease in the net yearly recharge but merely a change in its distribution.

In 1931, on the other hand, the high-water period was relatively brief and the zone of recharge extended over about 36,000 acres. The volume of material saturated was about 64,000 acre-feet, or only 13 percent of the volume saturated a year later.

The average specific yield of the valley fill in the zone of water-table fluctuations in the Silvies subarea has not been measured. However, it may be estimated from the relative volumes of gravel, sand, and "clay" that compose the fill, taken in conjunction with data from Clark,[80] Lee,[81] Piper,[82] Stearns,[83] and White[84] as to the specific yield of materials of these classes.

[79] Daily gage height, in feet, and discharge, in second feet, of Silvies River near Burns, Oreg., for the year ending September 30, 1932, Office of the State Engineer, Water-Resources Department, State of Oregon, 1932.

[80] Clark, W. O., Ground water in Santa Clara Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 519, pp. 29–30, 1924.

[81] Ellis, A. J., and Lee, C. H., Geology and ground waters of the western part of San Diego County, Calif.: U. S. Geol. Survey Water-Supply Paper 446, pp. 121–123, 1919.

[82] Piper, A. M., Gale, H. S., Thomas, H. E., and Robinson, T. W., Geology and ground-water hydrology of the Mokelumne area, Calif.: U. S. Geol. Survey Water-Supply Paper 780, pp. 101–104, 1939.

[83] Stearns, H. T., Robinson, T. W., and Taylor, G. H., Geology and water resources of the Mokelumne area, Calif.: U. S. Geol. Survey Water-Supply Paper 619, pp. 151–172, 1930.

[84] White, W. N., A method of estimating ground-water supplies based on discharge by plants and evaporation from soil—results of investigations in Escalante Valley, Utah: U. S. Geol. Survey Water-Supply Paper 659, pp. 74–76, 102–105, 1932.

The relative volumes of the three classes of granular material in the Silvies subarea are indicated by the drillers' records of 19 wells, of which 14 representative records are tabulated on pages 133–136. Material reported by the driller as "gravel and sand" or "sand and gravel" has been considered half sand and half gravel, but, on the other hand, "clay and gravel," "sand and clay," or material reported by similar phrases has been classified as wholly "clay" on the presumption that fine particles are sufficiently abundant to occupy all the interstices between the coarse grains. That presumption seems well founded because the drillers, at least locally, commonly describe as "clay" only those materials that are sufficiently plastic to cling to the drilling tools. This method for correlating drillers' terms follows Clark.[85] The following table indicates the percentage volume of gravel, sand, and "clay" computed for successive 5-mile zones according to distance from the apex of the Silvies River fan.

Percentage volume of gravel, sand, and clay composing the valley fill of the Silvies subarea

Distance from apex of Silvies River fan (miles)	Number of well records	Percentage volume		
		Gravel	Sand	Clay
0 to 5	6	48	22	30
5 to 10	9	13	34	53
10 to 15	0			
15 to 20	4	4	23	73

The data on specific yield just cited show the following ranges: Gravel, 41.0 to 31.5 percent (by volume); the coarser grades of sand, 35.4 to 20.2 percent; sand of the finer grades, silt, and loam, 18.9 to 4.7 percent; clay and clay loam, 3.9 to 1.3 percent. For the three classes of material discriminated in the Silvies subarea, mean magnitudes have been adopted for the specific yield as follows: Gravel, 35 percent; sand, 20 percent; clay, 3.5 percent.

The following table applies the foregoing data to derive estimates of the volume of water added to storage in the valley fill in the springs of 1931 and 1932. The relative magnitudes of the recharge in 1930 and 1929 are suggested by measurements of depth to water in well 90 (p. 162). Even the foregoing fragmentary data suggest the relative magnitude of the long-term mean recharge, for 1931 and 1932 were, respectively, a year of very small run-off and a year of average run-off following a succession of dry years in which the water table had receded. Thus, the opportunities for recharge were, respectively, about the potential minimum and materially greater than the long-term mean. Accordingly, the average recharge in the two years,

[85] Clark, W. O., op. cit., p. 27.

36,500 acre-feet, may be taken as an approximate value for the long-term mean.

Estimated recharge in the Silvies subarea from the volumes of the valley fill saturated, 1931 and 1932

	1931	1932
Volume of material saturated during the spring rise..........acre-feet..	64,000	485,000
Average specific yield of the material saturated..........percent by volume..	18.5	12.5
Volume of water added to storage..........acre-feet..	12,000	61,000
Run-off in the Silvies River during the period of high water..........acre-feet..	15,200	94,900
Percentage of run-off represented by ground-water storage..........	79	64

ESTIMATES BASED ON GROUND-WATER DISCHARGE

Over a term of years the recharge to a body of unconfined ground water must equal the discharge except for net increase or decrease in storage. Thus, for an area in which the natural regimen has not been seriously disturbed by pumping, such as the Harney Basin, the discharge of ground water by natural processes may be estimated in lieu of a direct measure of the recharge. Within the Silvies subarea discharge is effected by underflow, return seepage to the streams, evaporation from the soil, and transpiration from vegetation. The net underflow from the subarea is believed to be negligible, and return seepage to the streams takes place only for a short time, as high water wanes in the spring, and is negligible; thus only evaporation and transpiration need be estimated to evaluate ground-water recharge.

With respect to the source from which they derive water, plants may be divided into three classes—(1) species that ordinarily do not depend upon ground water but utilize soil water almost exclusively, such as sagebrush (*Artemisia tridentata* and *Artemisia cana*) and some cultivated plants; (2) species such as alfalfa and certain grasses, which utilize ground water intermittently after the soil water has been depleted; and (3) species that habitually send their roots down to the capillary fringe or to the zone of saturation and draw upon ground water throughout their growth cycle. The third class comprises the true ground-water plants, such as greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnus nauseosus*), and saltgrass (*Distichlis spicata*). The plants that use ground water either habitually or intermittently differ greatly in their power to extend roots in the search for water. Thus, alfalfa and greasewood do not thrive where the water table is shallow but, on the other hand, may send their roots to a depth of 50 feet to reach the zone of saturation.[86] Thus, they can withstand a protracted drought. In contrast, even so vigorous a ground-water plant as saltgrass seems not to send its roots down more than about 12 feet for water [87]

[86] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, pp. 37, 54, 1927.
[87] Idem, p. 19.

and may become dormant if the water table falls to greater depth; much of the saltgrass in the Harney Basin did that in 1931.

The three tables that follow show (1) the distribution and aggregate extent of each plant species within the Silvies subarea in 1931, (2) the consumptive use by each type, and (3) the estimated yearly draft from ground water by each type. The data on consumptive use are estimates adapted to the climatic conditions of the Harney Basin from findings by other workers.[88] The estimates of ground-water draft are weighted averages that undertake, on the one hand, to make some allowance for areas in which the water table may be so shallow in wet years that evaporation is excessive, and, on the other hand, to make a corresponding allowance for areas in which during dry years the water table recedes below the root zone.

Distribution of plant species in the Silvies subarea, Harney Basin

[Quantities in acres; surveyed in 1931 by T. W. Robinson]

Township	Alfalfa and cereals, irrigated by pumped ground water	Alfalfa with small areas of cereals, irrigated by surface water [1]	Cereals and forage other than alfalfa, not irrigated	Meadow, irrigated by surface water [1]	Meadow, not irrigated	Saltgrass	Rabbitbrush	Greasewood	Sagebrush	Bare land, tules (dormant in 1931), and weeds	Total
T. 22 S., R. 30 E.				1,500							1,500
T. 22 S., R. 31 E.		900	70	1,340			60		450		2,820
T. 23 S., R. 30 E.				1,000	260		440		1,190		2,890
T. 23 S., R. 31 E.	430	3,790	470	13,200	190		700	950	3,100		22,800
T. 23 S., R. 32 E.	280		2,000		1,000		980		7,400		11,700
T. 24 S., R. 30 E.				1,860				540	10		2,410
T. 24 S., R. 31 E.		100		10,900			1,360	7,330	1,930		21,600
T. 24 S., R. 32 E.			40	2,190			2,480	9,160	8,830		22,700
T. 24 S., R. 32½ E.							160	2,210	8,810		11,200
T. 25 S., R. 32 E.				12,400		530	1,300	5,190	2,860	170	22,500
T. 25 S., R. 32½ E.			120	7,330		2,230	1,370	2,400	1,100	290	14,800
The subarea	710	4,790	2,700	51,700	1,450	2,760	8,850	27,800	35,700	460	137,000

1 Commonly only part of the area is irrigated if the year's run-off is small.

88 Blaney, H. F., Taylor, C. A., and Young, A. A., Rainfall penetration and consumptive use of water in Santa Ana River Valley and Coastal Plain: California Div. Water Resources Bull. 33, pp. 29-54 1930. Lee, C. H., An intensive study of the water resources of a part of Owens Valley, California: U. S. Geol. Survey Water-Supply Paper 294, pp. 53-64, 1912. Powers, W. L., and Johnston, W. W., The improvement and irrigation requirement of wild meadow and tule land: Oregon Agri. Exper. Sta., Bull. 167, pp. 36-41, 1920. Shattuck, Obil, and Ritchie, D. W., Growing irrigated crops in Harney Valley: Oregon Agri. Exper. Sta., Bull. 191, p. 21, 1922. Shattuck, Obil, and Hutchison, R. E., Progress report of the irrigated 80-acre demonstration farm unit of the Harney Branch Experiment Station, 1927-30: Oregon Agri. Exper. Sta., Bull. 270, pp. 16-17, 1930. White, W. N., op. cit., pp. 84-101.

Estimated yearly consumptive use and ground-water draft by vegetal types in the Harney Basin, Oreg.

[Depth of water in inches]

Class	Consumptive use (including evaporation from the soil)	Draft from ground water	
		Wet years	Dry years
Alfalfa and cereals, irrigated by pumped ground water	18 to 32	0	0
Alfalfa with small areas of cereals, irrigated by surface water [1]		12	15
Cereals and forage other than alfalfa, not irrigated	15 to 20	4	0
Meadow, irrigated by surface water [1]	15 to 18	9	1
Meadow, not irrigated		12	1
Saltgrass	24 to 30	18	0
Rabbitbrush	7½ to 12	5	2½
Greasewood			
Sagebrush	5 to 10	0	0
Bare land, tules (dormant in 1931), and weeds	5 to 50 [2]	6	0

[1] Commonly only part of the area is irrigated if the year's run-off is small.
[2] After a succession of wet years, much of the area would be swampy and would be recaptured by tules.

Estimated discharge of ground water from the Silvies subarea, Harney Basin

Ground-water vegetation	Area (acres)	Ground-water discharge (acre-feet)	
		Wet years	Dry years
Alfalfa with small areas of cereals, irrigated by surface water [1]	4,790	4,800	6,000
Cereals and forage other than alfalfa, not irrigated	2,700	900	0
Meadow, irrigated by surface water [1]	51,700	39,000	4,300
Meadow, not irrigated	1,450	1,400	100
Salt grass	2,760	4,100	0
Rabbit brush	8,850	3,700	1,800
Greasewood	27,800	12,000	5,800
Bare land, tules (dormant in 1931), and weeds	460	200	0
The subarea	137,000	66,000	18,000
Average		42,000	

[1] Commonly only part of the area is irrigated if the year's run-off is small.

This second line of evidence places two approximate limits on the average yearly recharge of the valley fill in the Silvies subarea. It is to be expected that over a long term of years the mean recharge would be equal to the average of these two limits—that is, it would be of the order of 42,000 acre-feet a year. In general, however, recharge does not balance discharge in any particular year and may lag progressively behind or forge steadily ahead for several consecutive years.

ESTIMATES BASED ON SOURCE AND DISPOSAL OF SOIL WATER

Within the Silvies subarea the principal sources of soil water are rain or snow and water diverted from the streams onto the meadows and fields for irrigation, chiefly by "wild flooding." Disposal of water takes place (1) by evaporation from free water surfaces so long as the streams are in freshet and water is held on the meadows; (2) by evaporation from the soil and transpiration by vegetation throughout the growing season (consumptive use); and (3) by deep percolation below the root zone, the deep percolate ultimately reaching the zone of saturation and becoming ground water. Available data afford passable estimates for infiltration and for consumptive use in 9 years of a 21-year period; corresponding estimates of ground-water recharge may then be computed by a simple soil-water inventory.

First, records of stream discharge afford nine yearly estimates of the diminution in run-off between the head of the subarea and the Malheur Playa. These estimates are derived in the table that follows. Ultimately they lead to estimates of infiltration from the streams and thus create the foundation for the soil-water inventory. As a background for the table, a few characteristics of the stream flow may be summarized to advantage. Thus, at the gaging station on the Silvies River near Burns (for all practical purposes the head of the subarea) the yearly run-off has ranged from 21,800 to 299,000 acre-feet during the 28 years of record. From 75 to 90 percent of the run-off takes place during a relatively brief freshet that ordinarily begins in March though sometimes in February and that lapses by the end of June. Thereafter the flow diminishes steadily until ordinarily by midsummer the stream channels are drained over most of the subarea. If the high-water period does not begin until March at the head of the subarea, as is usually the case, 4 to 9 weeks elapse before any run-off reaches the playa. This considerable lag is due largely to intervening diversions for "wild flooding" and to infiltration into the soil, which generally is thawed by March. On the other hand, if the high-water period begins in February a relatively large volume of water runs off from the subarea promptly, for in that month the soil is usually still frozen, so that infiltration takes place slowly if at all.

Estimated yearly diminution of run-off within the Silvies subarea

Year (Oct. 1 to Sept. 30)	Yearly run-off (acre-feet)[1]				Diminution of streamflow within the subarea (acre-feet)[4]
	Silvies River near Burns	Poison and Prater Creeks near Burns[2]	West Fork of Silvies River near Lawen[3]	East Fork of Silvies River near Lawen[3]	
	1	2	3	4	5
1911-12	173,000	10,000	70,000	10,000	103,000
1915-16	[5] 208,000	11,000	111,000	16,800	91,000
1916-17	[5] 189,000	10,000	89,000	15,000	95,000
1917-18	63,000	2,000	10,000	0	55,000
1918-19	114,000	6,000	16,300	6,000	98,000
1919-20	80,600	4,000	10,000		75,000
1921-22	[5] 127,000	6,220	[6] 40,000		93,000
1930-31	22,100	0	0	0	22,100
1931-32	98,600	5,000	(7)	(7)	104,000
Average	118,000	6,000	43,800		81,800

[1] From data on pp. 120-122 except as indicated.
[2] Except for 1921-22 and 1930-31, estimated from a run-off coefficient.
[3] Except as indicated, data are from Donnelly, H. K., Duty of water for Silvies River and its tributaries (typoscript report to the State engineer of Oregon), pp. 18-19, Sept. 22, 1915; and from Henshaw, F. F., Water supply of Malheur Lake, Harney County, Oreg. (typoscript report to the State engineer of Oregon), pp. 10, 14, January 1922.
[4] Sum from columns 1 and 2 less sum from columns 3 and 4.
[5] Estimate by Henshaw, F. F., idem.
[6] Estimated.
[7] In 1932 the East Fork and West Fork discharged an undetermined quantity at the gaging stations near Lawen but discharged nothing onto the Malheur Playa.

Second, the yearly rainfall on the Silvies subarea has been measured at the Harney Branch Experiment Station, where it ranged between 5.24 and 11.7 inches from 1913–14 to 1931–32 and averaged 7.8 inches (p. 8). Even the greatest yearly rainfall yet measured can be dissipated by evaporation from the soil and by transpiration of the native plants having the least consumptive use, such as sagebrush and rabbitbrush (p. 78). Thus, in the marginal parts of the subarea that are not irrigated, rain is ordinarily insufficient to cause deep percolation to the zone of saturation. Accordingly, these marginal areas can be excluded from the soil-water inventory. For the 9 years of the foregoing surface-water inventory, the following table indicates the yearly rainfall and snowfall on the part of the subarea that is overflowed naturally or by "wild flooding" during the freshets.

Rainfall and snowfall on the overflowed and irrigated portion of the Silvies subarea, Harney Basin

Year (Oct. 1 to Sept. 30)	Area overflowed or irrigated (acres)	Rainfall and snowfall: Depth [1] (inches)	Rainfall and snowfall: Quantity (acre-feet)	Year (Oct. 1 to Sept. 30)	Area overflowed or irrigated (acres)	Rainfall and snowfall: Depth [1] (inches)	Rainfall and snowfall: Quantity (acre-feet)
1911–12	[2] 57,600	[3] 9.90	47,500	1921–22	57,600	7.43	35,700
1915–16	[2] 57,600	8.12	39,000	1930–31	[4] 12,500	5.60	5,800
1916–17	[2] 57,600	5.69	27,300	1931–32	[3] 52,000	7.73	33,500
1917–18	[3] 36,000	7.00	21,000				
1918–19	57,600	7.17	34,400	Average		7.39	30,000
1919–20	[3] 40,000	7.85	26,200				

[1] From records for the Harney Branch Experiment Station (p. 8).
[2] Maximum area that has been irrigated according to maps by H. K. Donnelly in 1912 and by T. W. Robinson in 1931.
[3] Estimated.
[4] From map by J. J. Walsh, watermaster.

The three next tables show (1) the estimated evaporation from free-water surfaces during the period of freshet and "wild flooding," (2) the distribution of vegetation within the variable area that has been overflowed or irrigated, and (3) the estimated soil-water discharge by consumptive use. Each of these tables covers the 9 years of the soil-water inventory. The fourth table summarizes the foregoing data and derives figures for the deep percolate or ground-water recharge.

Estimated evaporation from free water surfaces in the Silvies subarea

Year (Oct. 1 to Sept. 30)	Maximum area overflowed or irrigated (acres) [1]	Evaporation: Approximate depth (inches) [2]	Evaporation: Volume (acre-feet)	Year (Oct. 1 to Sept. 30)	Maximum area overflowed or irrigated (acres) [1]	Evaporation: Approximate depth (inches) [2]	Evaporation: Volume (acre-feet)
1911–12	57,600	3.90	18,700	1919–20	40,000	4.26	14,200
1915–16	57,600	3.62	17,400	1921–22	57,600	3.61	17,300
1916–17	57,600	2.72	13,100	1930–31	12,500	4.31	4,500
1917–18	36,000	4.79	14,400	1931–32	52,000	3.04	13,200
1918–19	57,600	4.42	21,200				

[1] In irrigation by "wild flooding" water is spread widely during the spring freshet and is held on the land by dikes. All the area is not flooded at the same time, for the diversions are made progressively as the freshet advances downstream. Ordinarily the area overflowed increases from zero in March to a maximum in April or May and then declines to zero again in June.
[2] Half the evaporation measured in April and May at the Harney Branch Experiment Station multiplied by 0.78, a pan coefficient.

Area, in acres, occupied by vegetation within the overflowed and irrigated part of the Silvies subarea [1]

Year (Oct. 1 to Sept. 30)	Alfalfa	Cereals	Meadow	Rabbitbrush, greasewood, and sage-brush	Rushes, sedges and cattails ("tules")	Total
1911-12	3,900	900	34,300	8,500	10,000	57,600
1915-16	3,900	900	34,300	8,500	10,000	57,600
1916-17	3,900	900	34,300	8,500	10,000	57,600
1917-18	3,900	900	26,300	3,900	1,000	36,000
1918-19	3,900	900	36,300	8,500	8,000	57,600
1919-20	3,900	900	29,700	4,500	1,000	40,000
1921-22	3,900	900	36,300	8,500	8,000	57,600
1930-31	2,000	0	10,300	200	0	12,500
1931-32	3,900	0	39,800	8,300	0	52,000

[1] Areas based on distribution in 1931, there being considerable evidence that the areas have not changed materially since 1912 except in low-lying meadows that revert to "tules" in wet years.

Estimated yearly consumptive use by vegetation within the overflowed and irrigated part of the Silvies subarea

	Alfalfa	Cereals	Meadow	Rabbitbrush, greasewood, and sage-brush	Rushes, sedges and cattails ("tules")	Total
Coefficient of consumptive use (inches)[1]	20	16	9	7	50	
Year (Oct. 1 to Sept. 30)	Consumptive use (acre-feet)					
1911-12	6,500	1,200	26,000	4,900	42,000	81,000
1915-16	6,500	1,200	26,000	4,900	42,000	81,000
1916-17	6,500	1,200	26,000	4,900	42,000	81,000
1917-18	6,500	1,200	20,000	2,300	4,200	34,000
1918-19	6,500	1,200	27,000	4,900	33,000	73,000
1919-20	6,500	1,200	22,000	2,600	4,000	36,000
1921-22	6,500	1,200	27,000	4,900	33,000	73,000
1930-31	3,300	0	7,700	100	0	11,000
1931-32	6,500	0	30,000	4,800	0	41,000
Average						56,800

[1] Estimated mean derived from the limits shown on p. 78.

Estimated yearly percolate from the belt of soil water to the zone of saturation in the Silvies subarea

[Quantities in acre-feet]

Year (Oct. 1 to Sept. 30)	Diminution of stream flow 1	Rainfall and snowfall 2	Evaporation from water 3	Consumptive use 4	Deep percolate [1] 5
1911-12	103,000	47,500	18,700	81,000	51,000
1915-16	91,000	39,000	17,400	81,000	32,000
1916-17	95,000	27,300	13,100	81,000	28,000
1917-18	55,000	21,000	14,400	34,000	28,000
1918-19	98,000	34,400	21,200	73,000	38,000
1919-20	75,000	26,200	14,200	36,000	51,000
1921-22	93,000	35,700	17,300	73,000	38,000
1930-31	22,100	5,800	4,500	11,000	12,000
1931-32	104,000	33,500	13,200	41,100	83,000
Average	81,800	30,000	14,900	57,000	40,000

[1] Sum of columns 1 and 2 less sum of columns 3 and 4, without allowance for changes in soil-water storage. However, it is believed that each growing season soil water is depleted about to the wilting percentage; thus the errors from soil-water storage should be moderate and should be largely compensated in the 9 year average.

It will be noted that the minimum and maximum figures for deep percolate are those for 1930–31 and 1931–32, respectively. In 1930–31 the yearly run-off was next to the lowest on record, whence it follows that the infiltration from the streams and the deep percolate were also near their respective long-term minima. In 1931–32 the run-off was of average magnitude but the computed deep percolate seems inordinately large. This may result from neglecting the net yearly change in soil-water storage, because 1931–32 followed a succession of dry years and may have opened with a soil-water deficiency that was appreciably greater than the ordinary. The 9-year average, 40,000 acre-feet, should be a passable figure for the long-term mean, for it involves average run-off and rainfall.

SUMMARY OF ESTIMATES OF RECHARGE

The three averages given above for yearly recharge to the valley fill of the Silvies subarea are 36,500, 42,000, and 40,000 acre-feet. As they have been derived independently, their relatively close agreement tends to be mutually substantiative, although of necessity several postulates are involved, so that the agreement may be somewhat fortuitous. The estimates derived by the first two methods would measure the aggregate recharge by infiltration and by upward percolation of thermal water near Hines (pp. 102–104), whereas the estimate derived by the third method would measure only the recharge by infiltration. However, the recharge from thermal water is believed to be relatively small. Thus, the long-term average recharge of the valley fill in the subarea under natural conditions is taken to have been equal to the mean of the three averages—that is, about 40,000 acre-feet a year.

The foregoing estimate of the long-term average recharge to the valley fill covers, of course, the common source for the unconfined water in the shallow pervious beds and the confined water in the deep pervious beds. Over a term of years this common recharge tends to be offset by natural ground-water discharge from the shallow and deep water-bearing beds. However, as water is recovered from the valley fill for beneficial use, the ground-water levels will inevitably be depressed somewhat and each recharge season will tend to open with an unnaturally large deficiency in ground-water storage. Thus, like an emptied reservoir on a stream, the valley fill can absorb more water by infiltration and store it for subsequent use; in this way, the natural yearly recharge may be increased materially.

RECOVERY OF GROUND WATER

ECONOMIC REQUIREMENTS

Where unconfined ground water occurs at shallow depth, as in the valley fill of the Silvies subarea, there are at least two methods for salvaging water that otherwise would be discharged without economic benefit—(1) uprooting worthless native ground-water plants and growing a ground-water plant of large worth, such as alfalfa; (2) pumping in sufficient volume to depress the water table below the roots of ground-water vegetation. Of course, if the venture is to be economically sound, the cost of salvage must not exceed the additional return from the land.

If salvage is effected by pumping, the venture involves the economic limit of pumping lift, which is the maximum depth from which water may be raised before the pumping cost exceeds the additional value or yield of the crop due to irrigation. This cost should include operation, maintenance, depreciation, interest on the initial investment, taxes, and insurance of the pumping plant. For crops that cannot be raised without irrigation, the economic pumping limit depends upon the value of the crop; for other crops it depends upon the added return derived through irrigation. Thus the depth from which water may be raised to irrigate one crop with profit may be prohibitive for some other crop. Other factors also have a material influence on the cost of pumping, such as the method of constructing and developing the well,[89] the type and capacity of pump and motive power, and the arrangement of ditches and works for applying the water to the land.

In the Harney Basin the growing season is relatively short, the climate is rigorous, and markets are somewhat remote. Consequently the practicable crops appear to be the hardy cereals and forage, which are relatively low in market value and do not afford a large margin above the cost of production. Accordingly, the success or failure of irrigating from wells depends in large measure upon the good judgment of the farmer in choosing the crop that affords the widest margin of profit, upon his enterprise and skill, and upon the efficiency of his pumping plant.

RECOVERY OF WATER FROM THE SHALLOW PERVIOUS BEDS

In the Silvies subarea of the Harney Basin the climate and conditions of ground-water occurrence appear to be similar to those in the Escalante Valley, Utah, where alfalfa has been grown as a ground-water plant with some measure of success since 1919, as described by White.[90] There the alfalfa is irrigated until its roots have penetrated to the capillary fringe; thereafter growth is maintained by ground water, provided the soil and subsoil are so fine in texture that the capillary fringe is relatively thick. Where the subsoil is gravelly the capillary fringe is presumably thin and does not yield

[89] *Adequate methods of construction are necessary to assure permanence of the well.* See notes for wells 56, 94, 113 (p. 86).

[90] White, W. N., A method of estimating ground-water supplies based on discharge by plants and evaporation from soil—results of investigations in Escalante Valley, Utah: U. S. Geol. Survey Water-Supply Paper 659, pp. 9–10, 1932.

sufficient water for growth of the alfalfa; further, the root system does not extend itself readily. White[91] brings out the essential requirements by the following statement:

> Measurements of about 15 fairly evenly spaced wells in this area [lands producing alfalfa as a ground-water plant] in the fall of 1923 showed depths to water ranging from 9 to 15 feet. The water table rises 1½ to 2½ feet in the late winter and early spring. On lands where natural subirrigation has proved feasible the soil and subsoil down to the water table is a dark-gray clay loam or sandy loam and a black loam derived largely from decomposed peat. Attempts to extend the cultivation of subirrigated alfalfa to adjoining areas where the subsoil is gravelly have not proved successful, although the depths to ground water in these areas are no greater than in the area where success has been attained.

The development in the Escalante Valley has not been without misfortune. At first the alfalfa was grown largely for its seed, a crop of high value. However, experience seems to show that growth for seed cannot long endure.[92] By 1935 the water table had receded 6 to 10 feet in the lower parts of the valley—a recession anticipated by White.[93] It had become necessary to irrigate much of the alfalfa that formerly had depended upon the ground water,[92] presumably because the zone of unwatering contained numerous lentils of sand and gravel that thwarted downward extension of the root system.[94]

Conditions in parts of the Silvies subarea of the Harney Basin also seem to favor substituting alfalfa for the native ground-water plants and growing crops of hay or seed with slight irrigation or none, although the experience in the Escalante Valley indicates the wisdom of further investigation before extensive developments are undertaken. However, it seems inevitable that a considerable part of the ground water discharged by native plants cannot be salvaged in this manner, because in some areas both the soil and the water in the shallow pervious beds of the valley fill—that is, the "first flow"—contain considerable "alkali." Also, in some areas the water table is so deep that it would be difficult to establish alfalfa as a ground-water plant, although deep-rooted native plants thrive.

It is believed that except in the vicinity of Burns comparatively little of the ground-water now discharged by native vegetation can be salvaged by pumping from the "first flow," for the water-yielding capacity of those pervious beds is commonly rather small. Near Burns, in the relatively small recharge area that is common to the shallow and the deep pervious beds of the valley fill—that is, at the head of the Silvies River fan and in the northwest half of T. 23 S., R. 31 E.—the "first flow" yields water freely and promises wells of sufficient yield for effective irrigation. For example, in July 1930,

[91] Idem, p. 10.
[92] Clyde, G. D., written communication, Dec. 6, 1935.
[93] White, W. N., op. cit., p. 90.
[94] White, W. N., written communication, Oct. 19, 1935.

about 2,200,000 gallons of water was pumped daily from C. E. Silbaugh's gravel pit in the SE¼NW¼ sec. 18, T. 23 S., R. 31 E.; in August the pumpage was about 1,400,000 gallons a day. These quantities are equivalent to a steady inflow of 1,500 and 1,000 gallons a minute, respectively. At that time the pit was about 200 yards long, 100 yards wide, and 12 to 18 feet deep; its floor was 3 to 9 feet below the water table. Farther from the apex of the fan, however, the shallow pervious beds are thinner and have less capacity to transmit water. Dug wells that tap them as much as 8 miles from the apex are adequate to irrigate gardens covering half an acre or less or to water as many as 50 horses or cattle; however, these uses require far less water than would be necessary for effective irrigation. Still farther from the apex of the fan all the stock wells in the larger meadows (each of which pastures several hundred cattle) pass through the "first flow" to reach the deeper water-bearing beds, whence it is inferred that commonly in these areas the "first flow" is inadequate.

Where the water table is higher than the static level of the confined water (p. 65), the casings of deep wells might be perforated from top to bottom, so that some water might be drawn from the "first flow," provided the "first flow" did not contain a prohibitive percentage of alkali. On the other hand, where the water table is lower than the static level of the confined water it would be inadvisable to perforate well casings opposite the "first flow" lest the head of the confined water should be dissipated.

RECOVERY OF WATER FROM THE DEEP PERVIOUS BEDS

Pumpage, 1927 to 1931.—From 1927 to 1931 moderately large volumes of water have been pumped from six wells that tap the deep pervious beds in the valley fill within the Silvies subarea. The following tables assemble pertinent data on these wells and their pumping plants, and plate 16 shows the performance of the well that was pumped most heavily in 1931.

Discharge tests of pumping plants on deep wells in the valley fill of the Silvies subarea

[Tests by T. W. Robinson except as indicated]

No.	Owner	Date of test	Total lift (feet)	Draw-down (feet)	Discharge		Energy input	
					Second-feet	Gallons a minute	Kilowatts	Kilowatt-hours to the acre-foot pumped
56	J. S. Cook	June 11, 1931	78.2	66	1.29	580		
		July 5, 1931	70.0	58	1.34	600		
64	William McLaren	June 6, 1931	[1] 49		1.06	475		
		June 26, 1931			1.04	465	10.1	118
		July 11, 1931	49+		.89	400	10.6	144
		July 25, 1931			1.07	480	10.9	123
74	C. E. Silbaugh	Aug. 13, 1930			[2] 2.45	[2] 1,100		
94	Harney Branch Experiment Station (87-foot well) [3]	Mar. 5-15, 1927	[1] 60	[4] 49.5	[5] 1.59	[5] 715		
		June 22-July 29, 1931.	[1] 67	[6] 58	[6] 1.18	[6] 530	12.6	129
112	R. W. Cozad	May 25, 1931	45.7	34.5	1.05	475		
		July 11, 1931	55.0	43.8	.96	435		
		July 20, 1931	55.7	44.5	.97	440		
		Aug. 10, 1931			1.05	475		

[1] Approximate.
[2] Estimated.
[3] Tests by Obil Shattuck, superintendent.
[4] Maximum drawdown at end of 244-hour test.
[5] Average for 244-hour test.
[6] Steady after about 175 hours' operation.

56. Well drilled in 1930-31, 18 inches in diameter, 105 feet deep; galvanized stovepipe casing to 84 feet, perforated from 67 to 79 feet. Deep-well turbine belt-driven by 25-horsepower semi-Diesel engine. Considerable sand pumped throughout 1931, indicating incomplete development after drilling. Well deepened to 330 feet in 1934, also recased in an attempt to curb influx of sand.

64. Well 18 inches in diameter, 87 feet deep; galvanized stovepipe casing to 53 feet, perforated from 41 to 53 feet with slots about ⅜ inch wide by 1 inch long. Kimball turbine pump driven by a belt-connected Fordson tractor until June 19, 1931; thereafter by a direct-connected 15-horsepower electric motor.

74. Well 12 inches in diameter, 106 feet deep, standard screw-joint casing to 106 feet, drilled in a gravel pit close to its southern bank. Turbine pump set with its base about 5 feet below natural land surface and actuated by a direct-connected 15-horsepower electric motor.

94. Well drilled initially in 1926, 18 inches in diameter, 86½ feet deep; galvanized 12-gage stovepipe casing to 60 feet, perforated 42½ to 55 feet with ½-inch drilled holes 1½ inches apart. Kimball turbine pump belt-driven by a 25-horsepower semi-Diesel engine. After caving below the initial casing, the well was re-drilled to 82 feet in August 1930 and 16-inch perforated casing was set from 42 to 82 feet, so that it overlapped the initial casing for a space of 18 feet; perforations were slots about 1/16 inch wide, ¾ inch long, spaced 1½ inches apart in staggered rounds. The dual casings appear to have increased the entrance head materially and reduced the specific capacity of the well about 25 percent. In June 1931 the initial pumping plant was replaced by a Price turbine direct-connected to a 15-horsepower electric motor. In March 1935 the 16-inch inner casing was pulled, and 90 percent of its narrow perforations were found clogged. The well was then cleaned to 93 feet and fitted with standard 12-inch casing from ½ foot to 93 feet (4 feet into clay), the casing having been perforated from 36 to 86 feet by torch-cut slots about ¼ inch wide, 6 inches long, and 3 inches apart horizontally and vertically. This inner casing having been set, the annular space between it and the initial 18-inch casing was filled with screened gravel (¼-inch to ¾-inch in size) as the well was swabbed.

112 and 113. Two wells have been drilled at this site. The first well (No. 113) was 24 inches in diameter and 78 feet deep and was cased to 60 feet with 14-gage perforated stovepipe casing. It was equipped with a "Parma water lifter" belt-driven by a 25-horsepower semi-Diesel engine; its yield is reported to have been 925 gallons a minute, with a drawdown of 26 feet. After about a year's use this well caved at 30 feet, and its casing was crushed. In May 1929 the present well (No. 112) was drilled about 10 feet to the north, 24 inches in diameter, 72 feet deep, cased to 64 feet with 10-gage galvanized stovepipe casing, of which the lower 12 feet is perforated. It is equipped with a Byron-Jackson turbine belt-driven by a 25 horsepower semi-Diesel engine.

Yearly pumpage in acre-feet, from the deep valley fill of the Silvies subarea, 1927–31

No.	Use	Pumpage				
		1927	1928	1929	1930	1931
56	Irrigation					43.0
64	do				80	119
[1] 73	Railroad	5	5	5	5	5
74	Pit drainage and irrigation				200	0
94	Irrigation	36.5	90.4	118	90.5	201
112	do		[1] 90	[1] 100	[1] 100	114
	Domestic, stock, and miscellaneous [1]	20	20	20	20	20
	Total pumpage for irrigation	36.5	180	218	470	477
	Total pumpage for all uses	61.5	205	243	495	502

[1] Estimated.

Permeability and transmission capacity of the deep pervious beds.—The capacity of a water-bearing stratum to transmit water is approximately proportional to (1) the gradient of the hydraulic pressure head, measured in the direction of flow; (2) the thickness of the stratum; and (3) the hydraulic permeability or perviousness of the stratum, which is the rate at which it will transmit water through a unit cross section under a unit pressure gradient. This rate is expressed by a coefficient of permeability, which is defined on page 34.

Fairly accurate figures for the mean permeability of the deep pervious beds in the vicinities of two irrigation wells (Nos. 94, 112) can be computed after the method proposed by G. Thiem,[95] which depends upon the rate of draft from the pumped well, the corresponding drawdown in a pair of observation wells close at hand, and the thickness of the pervious stratum. For each of the two wells in the Silvies subarea, available data afford three independent figures for the coefficient of permeability; the average coefficients are 450 for well 94 and 490 for well 112. These coefficients indicate that the deep water-bearing beds in the valley fill have a moderately large capacity to transmit water away from the area of recharge.

The coefficient of permeability may be computed also from the transmission capacity of the water-bearing beds in the Silvies subarea according to the formula $q=Phwm$, or, in modified form,

$$P=\frac{q}{hwm}$$

in which q=the quantity of water conducted, in gallons a day.

[95] Thiem, G., Hydrologische Methoden, Leipzig, 1906. For a discussion of the Thiem method and for certain simplifications of Thiem's formula, see Meinzer, O. E., Outline of methods for estimating ground-water supplies: U. S. Geol. Survey Water-Supply Paper 638, pp. 134–135, 1932; Wenzel, L. K., Recent investigations of Thiem's method for determining permeability of water-bearing materials: Am. Geophys. Union Trans. 13th Ann. Meeting, p. 313, 1932; The Thiem method of determining permeability of water-bearing materials and its application to the determination of specific yield: U. S. Geol. Survey Water-Supply Paper 679–A, 1936.

P= the coefficient of permeability.
h= the hydraulic gradient, in feet to the mile.
w= the width of the segment of the water-bearing stratum under consideration, in miles.
m= the thickness of the stratum, in feet.

All these variables except the coefficient of permeability may be evaluated directly for the vicinity of well 94 at the end of the pumping season in 1931. Thus, the quantity of water conducted (q) is taken as the average daily pumpage from July 27 to August 3, or 419,000 gallons a day. The width of the segment that was yielding water to the well (w) and the corresponding hydraulic gradient (h) are evaluated from plate 17; they are 6.0 miles and 6.3 feet to the mile, respectively, for the 4,118-foot contour of August 3, 1931. The thickness of the water-bearing stratum (m) is taken as 24.5 feet. From these data the coefficient of permeability is computed as 450, a virtual check on the result already computed from Thiem's formula.

In principle the aggregate underflow to the remote parts of the Silvies subarea through the deep pervious beds in the valley fill is equal to the underflow passing beneath the feather edge of the impervious confining beds along the outer margin of the area of recharge that is common to the shallow and the deep pervious zones. Data given above afford estimates of the natural rate of that underflow and the accelerated rate that conceivably can be maintained by pumping from wells. These estimates involve several inferences. (1) The form of the piezometric surface in late August 1931 (pl. 17) indicates that the four irrigation wells then active (nos. 56, 64, 94, 112) were intercepting essentially all the underflow in the deep beds within a segment about 3 miles wide, bounded on the north by the margin of the central alluvial plain and on the south by an imaginary line represented on plate 17 by the line A–A′. (2) The rate of pumping, 5.5 acre-feet a day, was sensibly equal to the rate of underflow from that area, although there was a negligibly small flow toward well 94 from the north. (3) The 4,130-foot lines on plate 17 approximately mark the outer boundary of the common recharge area; there, in August 1931, the average hydraulic gradient was about 6.2 feet to the mile across the 3-mile segment that was supplying the wells. (4) Finally, the thickness and perviousness of the water-bearing beds are essentially constant along those lines because they are circular about the apex of the alluvial fan.

Just before pumping started in May the average hydraulic gradient along the full length of the 4,130-foot line was 4.0 feet to the mile. Accordingly, the natural underflow across the outer margin of the area of common recharge at that time is estimated to have been about 10 acre-feet a day—that is, at the rate of 3,600 acre-feet a year. However, competent data are not available to estimate the long-term average rate. It is not considered feasible to steepen the average hydraulic gradient to more than 10 feet to the mile by pumping from wells, lest economic pumping lifts be exceeded or some of the deep pervious beds be unwatered. Therefore, the potential maximum underflow away from the recharge area is estimated to be about 25 acre-feet a day. If all that underflow were recovered by pumping from wells beyond the outer margin of the common recharge area, the draft would amount to about 3,000 acre-feet in the ordinary 120-day irrigation season—that is, about from April 15 to August 15. That potential seasonal draft is 1,800 acre-feet more than the natural underflow during the 120 days, if the average natural gradient is presumed to be the same as that which prevailed in May 1931.

SAFE YIELD OF THE VALLEY FILL IN THE SILVIES SUBAREA

The safe yield of a ground-water province is the rate at which water can be withdrawn perennially without depleting the supply to such an extent that withdrawal at that rate becomes uneconomic or physically impossible. It may be considered as comprising two items—(1) the portion of the natural ground-water discharge that can be salvaged and (2) the increased recharge that may result as ground-water levels are drawn down by pumping or as water is spread artificially over potential recharge areas. If all the natural discharge can be salvaged (pp. 76–78), the ultimate limit to the safe yield is the gross recharge; ordinarily, however, salvage is not complete. If the volume of water available for recharge exceeds the capacity of the water-bearing beds some water may be rejected. However, if the water-bearing beds have been depleted to an unnatural extent by pumping from wells, they can absorb additional water to replace that withdrawn by pumping. Thus, the water-bearing beds may be utilized to absorb and store water that otherwise would be rejected, and their safe yield can be increased by use.

In the Silvies subarea the safe yield of the valley fill may be limited by (1) the facilities for intake and storage; (2) the transmission capacity of the water-bearing beds, particularly of the deep beds; or (3) the pumping lift.

The area of recharge that is common to the shallow and to the deep pervious beds comprises the alluvial fans of the Silvies River and Poison Creek and is estimated to cover about 6,500 acres. If, as seems feasible, the ground-water level can be lowered 5 feet throughout that area by pumping from wells, about 32,500 acre-feet of water-bearing material would be unwatered and about 6,500 acre-feet of water would be removed from storage. The facilities for infiltration seem to assure replenishment in that volume each year. Accordingly, that volume is taken as an approximate estimate of the safe yield from both shallow and deep pervious beds within the common recharge area and from the deep pervious beds in the outlying parts of the subarea. The latter fraction of the safe yield has already been estimated as about 3,000 acre-feet during the irrigation season The remainder—3,500 acre-feet a season—would perforce be recovered by pumping from wells within the recharge area. Obviously, the aggregate safe yield would be influenced by the spacing and arrangement of wells not yet drilled, but the foregoing estimates are believed to be of the proper order of magnitude for the particular conditions assumed.

In addition, some water can doubtless be recovered from the shallow water-bearing beds in the outlying parts of the subarea by pumping from wells or by cultivating ground-water plants of large worth (pp. 83–84). However, so many little-known variables are involved that no estimate of added yield seems warranted.

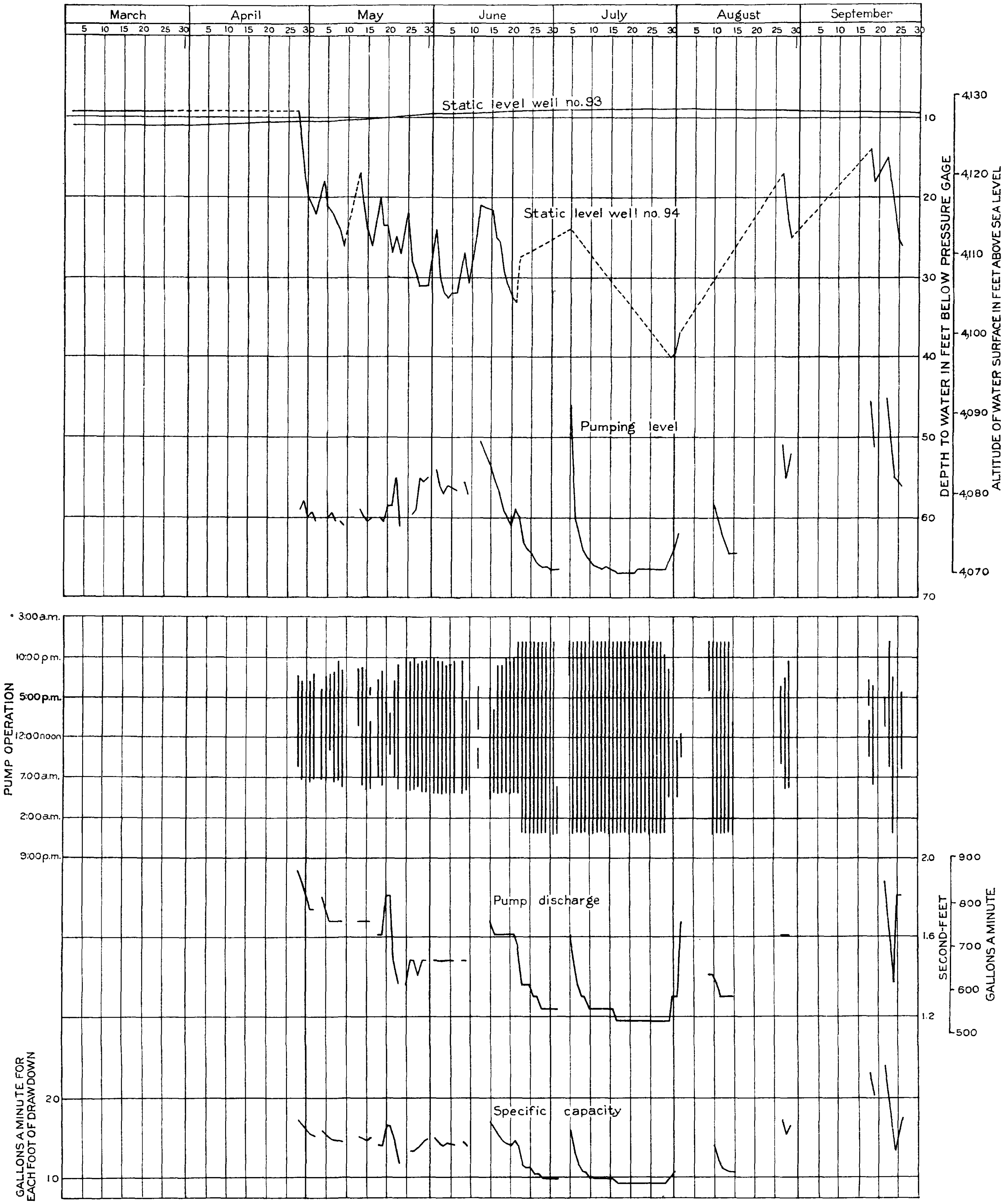
In the development of any ground-water province by wells, some decline of water levels is inevitable, otherwise percolation toward the area of artificial discharge would not be accelerated above the natural rate, and large withdrawals could not be made continuously. In 1931 the water level in irrigation wells 94 and 112 was drawn down by pumping about to the lowest practicable level. Accordingly, further recession of the pumping level in those wells might properly cause concern.

FLOWING WELLS IN THE SILVIES SUBAREA

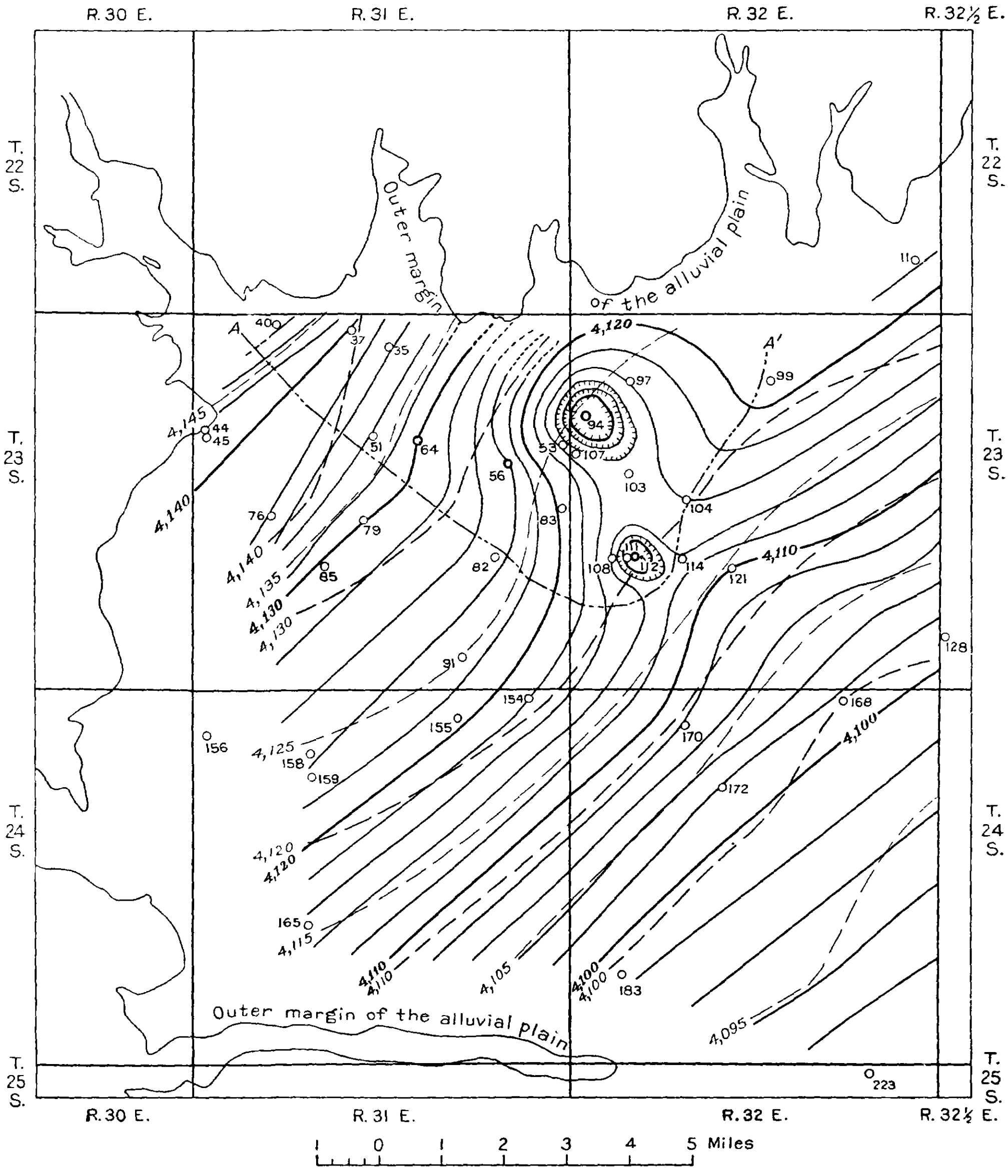
At the western margin of the Silvies subarea, near Hines, certain deep pervious beds in the valley fill confine water under sufficient artesian pressure to overflow at the land surface—for example, in wells 24, 143, and 144. Presumably these beds are supplied by lateral percolation from the conduits that transmit thermal water from depth (pp. 106–108). Accordingly they are not recharged by infiltration of surface water, and their safe yield is not included in the quantities just estimated. It is not expected that flowing wells will be obtained from the valley fill in other parts of the subarea.

MINOR SUBAREAS NORTH OF MALHEUR LAKE

Along the northern margin of the central alluvial plain the valley fill is inferred to include tongues and lentils of pervious material beneath the faint alluvial fans that lie opposite the several creeks east of the Silvies subarea (fig. 8). In that respect the ground water in the fill occurs under conditions analogous to those of the Silvies subarea. However, it is probable that the pervious beds are decidedly less extensive and thinner than in the Silvies subarea. A moderate number of shallow wells are available to disclose the form of the water table (pl. 2) but only three wells (Nos. 11, 97, 128) are known to reach deep pervious beds in the valley fill. All three deep wells are pumped



DIAGRAMMATIC SUMMARY OF OPERATION OF THE 87-FOOT WELL AT THE HARNEY BRANCH EXPERIMENT STATION, 1931.



EXPLANATION

— — Contours for May 11 to 15, 1931 (interval 5 feet)

——— Contours for August 3, 1931 (interval 2 feet; not shown below 4,110 feet near the irrigation wells)

○99 Observation well

●94 Irrigation well

—··—··— Margin of the area of influence for the irrigation wells

MAP OF THE NORTHWESTERN LOBE OF THE CENTRAL ALLUVIAL PLAIN, SHOWING CONTOURS ON THE PIEZOMETRIC SURFACE FOR THE WATER IN THE DEEP VALLEY FILL, 1931.

lightly. Accordingly, data are not available to indicate (1) where the water in the deep beds may be confined under artesian head, (2) where the water table may be semiperched, (3) what the water-yielding capacity of the pervious beds may be, or (4) whether the deep and the shallow pervious beds are essentially distinct sources of water, as in the outer parts of the Silvies subarea.

The water in the valley fill of this subarea appears to be derived chiefly through infiltration from the streams and from rain. All the streams are intermittent, although together they drain about 200 square miles along the moderately rugged flank of the dissected upland. Their channels are well defined at the mouths of the canyons but disintegrate on the alluvial plain and finger out within 1 or 2 miles. During years of small rainfall, such as 1930 and 1931, the run-off onto the subarea is very small; on the other hand, in years of large rainfall the run-off is considerable and the streams spread widely beyond their channels, as is attested by the coarse debris that has been deposited. Under these conditions there is ample opportunity for infiltration, and ordinarily the entire run-off is dissipated by infiltration or evaporation within the subarea. Only infrequently is the run-off so large that water flows entirely across the subarea into Malheur Slough and thence into Malheur Lake.

In the spring of 1931 the increase in ground-water storage in the subarea was negligible. In 1932, however, the water table rose beneath some 55,000 acres (pl. 12), about 190,000 acre-feet of material being saturated and about 20,000 acre-feet of water being added to storage. Because 1932 was a year of average run-off and because it followed a succession of dry years in which the water table had receded steadily, the recharge of that year probably was somewhat greater than the average.

Rough estimates of ground-water discharge by vegetation indicate that the long-term average recharge in the subarea is about 17,000 acre-feet a year. This figure is a rude confirmation of the quantity added to storage in 1932.

Competent data are not available to afford an estimate of the safe yield from the valley fill in the subarea that has just been described. Presumably it is a relatively small fraction of the average yearly recharge, as in the Silvies subarea.

The remaining two subareas north of Malheur Lake—Sagehen Valley and Sunset Valley—together drain about 175 square miles of territory that is intermediate in altitude and low in relief. No stream-flow records for these subareas are available, but the indistinct channels suggest that the run-off to the square mile is decidedly less than that from other parts of the basin. Accordingly, the facilities for recharge by infiltration are not good. Furthermore, the tongues of fill that occupy the two valleys are inferred to be composed largely of fine material with small water-yielding capacity. Altogether, conditions in the two valleys appear not to favor the recovery of large volumes of water from wells.

Sagehen Valley contains several relatively large springs (Nos. 148 to 151; see p. 182), which issue from the Tertiary rocks along the northern margin of its alluvial plain. Conceivably the spring conduits would charge pervious beds in the valley fill by lateral percolation, as in the vicinity of Hines, although the volume of water so stored cannot be estimated.

DONNER UND BLITZEN VALLEY

The Donner und Blitzen Valley (fig. 8 and pl. 2) comprises three parts—(1) the P-ranch field, a southern segment of the alluvial tongue that covers about 15,000 acres in Tps. 30 to 32 S.; (2) a rock-cut gorge about 4½ miles long that heads in sec. 15, T. 30 S., R. 31 E.; and (3) a northern segment of the alluvial tongue that covers some 45,000 acres and extends onward about 18 miles to join Malheur Lake.

In the southern segment of the valley the fill may enclose coarse-grained pervious beds near the mouths of the creeks that descend the westward-facing slope of Steens Mountain, but nothing is known as to the lateral extent and thickness of those beds nor as to their capacity to transmit water. Whether such beds occur widely in the northern segment of the subarea below Kiger Creek is unknown.

Under natural conditions the greater part of the P-ranch field and much of the area between the rock gorge and Rockford Lane were perennial swamps—obvious evidence that ordinarily the valley fill was saturated and had no capacity for additional water. By canalizing that reach of the river, however, those areas have been drained and reclaimed into meadows. Ordinarily the meadows are irrigated by "wild flooding" during each yearly freshet, so that the opportunity for infiltration is large; thus the water table is inferred to have remained at relatively shallow depth. For the P-ranch field, at least, relative stability in water-table stage is brought about by the small underflow capacity of the rock gorge. In contrast, the part of the subarea that lies north of Rockford Lane is not swampy, although in years of large run-off a considerable part of it is overflowed naturally or is watered by "wild flooding." There the opportunity for infiltration is moderately large, at least in wet years.

The spring freshet in the Donner und Blitzen River commonly reaches the valley plain 4 to 6 weeks later than that from the Silvies River, but it continues longer and discharges somewhat more water onto the plain. (See pp. 121–123, also pl. 1.) In some years a considerable fraction of the run-off passes over the entire length of the subarea and is wasted into Malheur Lake. The following table summarizes the 5-year record that is available.

Inflow to and outflow from the alluvial plain of the Donner und Blitzen Valley, in acre-feet

Station	1916	1917	1918	1919	1921
Measured inflow:					
Donner und Blitzen River near Diamond	96,100	[1] 118,000	63,200	76,700	139,000
Mud Creek near Diamond	3,920				
Bridge Creek near Diamond	9,830				
Kiger Creek near Diamond	[2] 16,900	[2] 26,000	[2] 8,870	20,300	[2] 11,700
Cucamonga Creek near Diamond	[2] 1,620	[2] 17,600	10,100	13,200	25,800
McCoy Creek near Diamond	[2] 13,800	[2] 20,500	[1] 4,300	[2] 4,260	[2] 9,000
Total measured inflow	[2] 142,000	[2] 182,000	[2] 86,500	[2] 114,500	[2] 185,500
Measured outflow:					
Donner und Blitzen River near Voltage	43,800	119,000	12,400	22,700	76,300
Quantity of surface water dissipated	98,200	63,000	74,100	91,800	109,200

[1] Low-water run-off not measured and not represented in the year's total.
[2] Estimated.

WARM SPRING VALLEY

Two intermittent streams—Silver Creek and Big Stick Creek—enter the Warm Spring Valley from the west (fig. 8), and a third stream—Warm Spring Creek—rises within the subarea in perennial thermal springs (p. 104); all three streams trend eastward across the alluvial plain and nominally discharge onto the Harney Playa. Silver Creek alone is of consequence, its drainage area to the northwest of the subarea being estimated [96] as 900 square miles and its run-off at the gaging station near Narrows (p. 127) having been as much as 33,900 acre-feet in 1921. In 1930 and 1931 its run-off was zero; in 1932, the third year of the investigation, it was appreciable but was not measured. Of the other exterior stream, Whistler and Lewis [97] say: "Big Stick has an area of more than 700 square miles tributary to it, but the character of the watershed is such that the run-off is very low in average years, while in minimum years none whatever reaches Warm Spring Valley."

Under its former natural regimen Silver Creek swerved westward as it entered the subarea and discharged into Silver Lake (pl. 1), although in wet years a considerable fraction of the run-off passed onward to Harney Lake. In late years, however, most of the run-off has been diverted above Silver Lake and has been applied to meadows for irrigation. Accordingly, there has been a material opportunity for infiltration to the zone of saturation. Evidence of recharge is shown by the water level in well 278, which rose 1.5 feet between July 1931 and May 1932. Although the features just described imply that the mean yearly recharge in the northwestern part of the subarea may be mate-

[96] Whistler, J. T., and Lewis, J. H., Harney and Silver Creek projects, irrigation and drainage, p. 78, U. S. Recl. Service, 1916.
[97] Idem, p. 79.

rial, neither the safe yield nor the water-yielding capacity of the valley fill is known.

In the southern part of the subarea the valley fill appears to receive water from the bedrock by percolation from thermal-spring conduits. The volume of water so received each year is not known but is undoubtedly considerable. Several drilled wells that tap pervious beds in the valley fill in that part of the subarea flow by artesian head, their discharges ranging from 2 to 100 gallons a minute. It is estimated that the aggregate discharge by all wells of that sort is about 300 gallons a minute, or nearly 500 acre-feet a year. Here also the safe yield of the valley fill is not known.

WATER IN THE BEDROCK

GENERAL FEATURES

In the Harney Basin certain of the bedrock formations (pp. 36–53) yield water copiously to perennial springs and to flowing and nonflowing wells, although the water-yielding capacity of a particular formation is by no means constant from place to place. Rather, there are in the bedrock several bodies of water that are distinct and of somewhat small extent. For convenience, these bodies may be segregated into three classes according to distinctive conditions of ground-water occurrence and according to the water temperatures of representative wells and springs, as follows: (1) Slightly thermal water (52° to 62° F.); (2) water of intermediate temperature (64° to 82° F.); and (3) hot water (90° to 154° F.). The slightly thermal water is inferred to be derived largely if not entirely by local infiltration of rain and snow to relatively shallow depth; the water of intermediate temperature and the hot water are inferred to originate by deep percolation from relatively remote meteoric sources or in part by upward percolation of juvenile water.

Certain features of ground-water occurrence in the bedrock are suggested forcefully by the depth-temperature curve determined by Van Orstrand [98] in a deep oil-test well (the so-called Dog Mountain well, No. 212). This curve is reproduced in figure 9. It is unique in that (1) it indicates uncommonly high earth temperatures for the shallow depths; (2) it comprises three isothermal segments in each of which the temperature varies little, the approximate respective depths of these segments below the land surface being (*a*) from 375 to 500 feet, (*b*) from 1,250 to 2,125 feet, and (*c*) from 2,250 to 3,250 feet; and (3) the mean depth-temperature gradient is steep—1° F. in 39.8 feet. Commonly the temperature of ground water is about the same as the temperature of the rock from which it is derived and

[98] Van Orstrand, C. E., Temperature in some springs and geysers in Yellowstone National Park: Jour. Geology, vol. 32, p. 221, 1924.

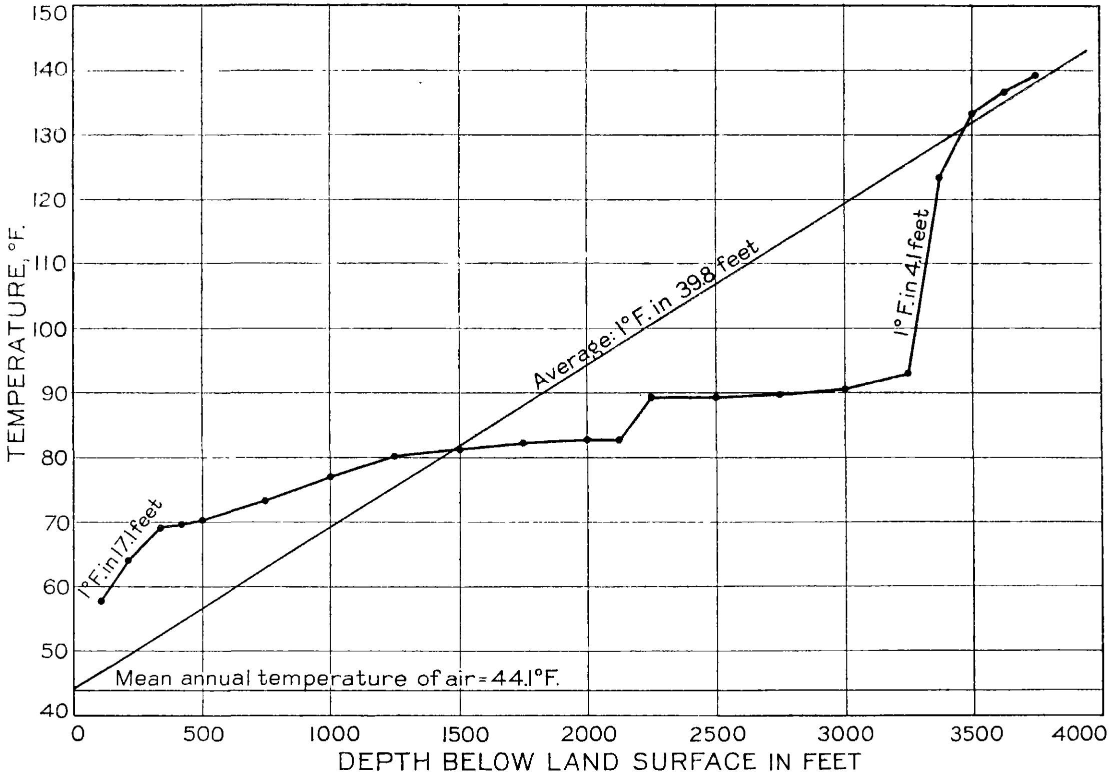


FIGURE 9.—Depth-temperature curve for the Dog Mountain oil-test well, Harney Basin. (After Van Orstrand.) Unfortunately, the corresponding depth-temperature curve as previously shown by Van Orstrand is in error in that the scale of temperatures is 10° F. too low (Van Orstrand, C. E., personal communication). The error is corrected in this figure.

depends largely upon the depth of the source rock beneath the land surface. Accordingly, Van Orstrand explains the isothermal segments of the depth-temperature curve as probably due to distinct bodies of ground water of different temperatures circulating freely through distinct bedrock units,[99] although it seems that they may result in part from convection within the well. From Van Orstrand's explanation, at least three distinct water-bearing zones would be expected in the bedrock. Analogous conditions may exist in other parts of the basin, although the particular zones of the Dog Mountain locality may not extend laterally to great distances.

In a general way, the depth-temperature curve of the Dog Mountain well may be taken as representative for the Harney Basin, because its average gradient agrees fairly well with gradients deduced from 211 observations in mines and in flowing and nonflowing wells within the adjacent region of Tertiary lavas.[1] In strictness, therefore, even the water that circulates in the bedrock only 100 to 250 feet beneath the land surface is thermal, for its temperature may be expected to range between 57° and 66° F.—that is, between 13° and 22° F. above the mean annual air temperature, which is about 44° F. On the other hand, this range is only 5° to 10° F. above the temperature range for the water in the valley fill. Thus the slightly thermal bedrock water may have acquired its temperature by circulating only about 250 feet beneath the land surface; the limit in depth of circulation so derived is confirmed in a general way by geologic conditions. Likewise, the bedrock water of intermediate temperature and the hot bedrock water, if derived wholly from meteoric sources, could acquire their highest temperatures by circulating to respective depths of about 1,750 and 4,500 feet beneath the land surface. However, some heat would doubtless be dissipated from the water as it ascended to the surface; this heat loss might well be appreciable if the path of ascent were circuitous. Hence, the actual depth of circulation is inferred to be somewhat greater than the figure interpolated from the depth-temperature curve.

The geologic structure of the Harney Basin (p. 53) favors the circulation of meteoric water to moderate depth and thus is compatible with the bedrock-water temperatures of the intermediate range. Ordinarily, however, water does not circulate freely at depths so great as 4,500 feet—a fact which implies that the hottest water has acquired some heat in another way.

The abundance of Tertiary and Quaternary volcanic rocks in the Harney Basin suggests that igneous magma or uncooled rocks probably underlie the region even now, although probably not within several thousand feet of the land surface. Materials of that sort

[99] Van Orstrand, C. E., personal communication.

[1] Van Orstrand, C. E., op. cit., pp. 218-221.

commonly contain considerable water, which may be expelled as steam but not as liquid water.[2] This generalization is based, at least in part, on the experimental work of G. W. Morey, who found that the vapor pressure of water in a magma would be so reduced by dissolved constituents that a pressure sufficient to condense the vapor would serve only to drive water into the magma. In other words, if water is to leave the magma at all, it must do so as steam. A simple calculation shows that 1 kilogram of steam at 100° C. (212° F.) and atmospheric pressure would heat about 25 kilograms of water from a temperature of 6.7° C. (44° F.) to 27.8° C. (82° F.)—that is, from the mean annual atmospheric temperature of the Harney Basin to the upper limit of the intermediate temperature range for bedrock water. The resulting solution would contain only about 4 percent of magmatic water. Likewise, the same quantity of steam would heat nearly 9 kilograms of water to 67.8° C. (154° F.), and the solution would contain about 10 percent of magmatic water. However, the depth-temperature gradient for the Dog Mountain well implies that steam ascending from magma beneath the Harney Basin would condense into water while still many hundred feet beneath the land surface. Indeed, the heat evolved by such condensation may account for a large measure of the unusual steepness of that gradient. Accordingly, the foregoing ideal case of admixture of meteoric water and of magmatic steam at shallow depth is unlikely to occur. Nevertheless, the intermediate case—that is, magmatic steam condensing to juvenile water and ascending to mingle at moderate depths with water from meteoric sources—seems a rational explanation for the temperature of much of the hot bedrock water and even for some water of intermediate temperature. Whatever may be the source of its heat, the thermal ground water of the Harney Basin is probably derived largely from meteoric sources—a conclusion that is substantiated in a general way by the chemical character of the water.

SLIGHTLY THERMAL WATER NEAR BURNS

OCCURRENCE

Within 6 miles of Burns slightly thermal water issues from the bedrock in at least two perennial springs along the margin of the alluvial plain (Nos. 148, 149) and is pumped from several wells on the plain or on an adjacent bedrock terrace (Nos. 5, 17, 18, 22, 30, 32, 65, 88, 95). Certain other valley springs along the south margin of the Silvies Plateau may also be supplied from the bedrock, although their immediate source is in alluvium or slope wash. In depth the wells just enumerated range between 251 feet (Nos. 17, 18) and 400 feet (No. 30); in temperature they range between 57° F. (No. 17) and

[2] Day, A. L., and Allen, E. T., The source of the heat and the source of the water in the hot springs of the Lassen National Park: Jour. Geology, vol. 32, pp. 178–190, 1924.

62° F. (No. 22). Some of these wells tap pervious beds in the Harney formation, and others tap the upper part of the Danforth formation, but collectively they are presumed to draw from a common body of ground water. However, wells 1 and 6 have been drilled into the upper part of the Danforth formation to depths of 490 feet and 228 feet, respectively, yet they failed to find water below the zone of rock weathering. Obviously, therefore, the pervious zones in the bedrock strata are discontinuous.

The form of its piezometric surface suggests that the slightly thermal bedrock water near Burns originates by infiltration on the Silvies Plateau and possibly on other parts of the dissected upland to the north and west, although the catchment area cannot be bounded specifically. Furthermore, the slightly thermal water percolates southeastward, and some may percolate upward into the overlying valley fill, for ordinarily its pressure head is 1 foot to 3 feet higher than that of the deep water-bearing beds in the valley fill and its aquifers are probably in contact with the pervious beds in the valley fill at some places, as in the vicinity of well 65. That well penetrates only gravel, sand, and clay to a depth of 300 feet, a depth so great that the well has been inferred to pass through the valley fill into the Harney formation. The inference is substantiated by the temperature of the water from the well, 58½° F., which corresponds to that of the bedrock water but is 4° to 7° F. warmer than the water from adjacent wells that tap the valley fill. The drillers' record (p. 134) indicates a 38-foot stratum of "blue clay" between the valley fill and the next deeper pervious bed, which is presumed to belong to the Harney formation. However, it seems probable that this intervening stratum of clay is discontinuous. The rate at which water may be supplied to the valley fill in this way is not known.

There is a suggestion that the body of ground water just described extends far beyond the small district near Burns, for several wells on the outlying parts of the central alluvial plain draw water from the bedrock at moderate depth. Among these are the railroad well at Crane (No. 275) and two wells on the Island ranch of the Pacific Live Stock Co. (Nos. 184, 225). In these wells, as in those near Burns, the static level for the bedrock water ordinarily is slightly higher than that for the water in the valley fill; nowhere, however, is the slightly thermal bedrock water known to have sufficient head to rise above the land surface. Thus it is unlikely to yield flowing wells.

RECOVERY BY PUMPING FROM WELLS

In the vicinity of Burns the slightly thermal water has been pumped in relatively large volume from three wells for municipal purposes

(Nos. 17, 18, 22) and from two wells for irrigation (Nos. 65, 95). The next four tables give data from capacity tests on these five wells in 1930–31, also computed pumpage.

Discharge tests of pumping plants on bedrock wells near Burns

No.	Owner	Date of test	Total lift	Draw-down	Discharge: Sec-ond-feet	Discharge: Gal-lons a min-ute	Energy input: Kilo-watts	Energy input: Kilo-watt-hours to the acre-foot pumped
			Feet	*Feet*				
18	City of Burns	Aug. 18, 1931	184	4.8	0.81	362		[2] 450
		Oct. 28, 1931					30.0	
22	City of Hines	Aug. 8, 1930		43	1.34	600		[2] 564
		Oct. 23, 1931					62.3	
65	Pacific Live Stock Co.	June 6, 1931			2.10	940		
95	Harney Branch Experiment Station.[1]	1931				340–470		
		1932	[2] 45	33.8	.88	395	6.9	95.7

[1] 218-foot well. Tests by R. E. Hutchison, assistant superintendent; data for 1932 are averages from daily observations throughout the 93-day irrigation season.
[2] Approximate.

Monthly pumpage, in gallons, from the two municipal wells at Burns (Nos. 17 and 18), 1930–33

Month	1930	1931	1932	1933
January	8, 490, 000	5, 740, 000	4, 720, 000	5, 510, 000
February	7, 640, 000	5, 040, 000	5, 470, 000	5, 020, 000
March	6, 840, 000	4, 600, 000	4, 800, 000	4, 470, 000
April	9, 770, 000	5, 300, 000	5, 770, 000	9, 060, 000
May	12, 600, 000	9, 230, 000	6, 970, 000	11, 600, 000
June	16, 200, 000	15, 700, 000	10, 830, 000	11, 000, 000
July	20, 400, 000	19, 700, 000	16, 500, 000	13, 900, 000
August	19, 400, 000	20, 800, 000	12, 800, 000	12, 100, 000
September	14, 000, 000	13, 800, 000	9, 560, 000	10, 700, 000
October	8, 930, 000	7, 700, 000	6, 170, 000	5, 790, 000
November	5, 850, 000	4, 530, 000	4, 420, 000	5, 490, 000
December	5, 060, 000	4, 310, 000	4, 450, 000	5, 900, 000
The year	135, 200, 000	116, 400, 000	92, 400, 000	100, 600, 000

17 and 18. Two wells, each 12 inches in diameter and 251 feet deep, cased to 151 feet with standard screw-joint casing; deep-well turbines driven by 25-horsepower direct-connected electric motors. Pressure and draft are equalized by 100,000-gallon elevated tank. No. 17 is the northerly of the two wells. The two pumping plants can be operated independently or simultaneously; ordinarily they are controlled by automatic switches so as to maintain the water level in the elevated tank.

22. Drilled well 12 inches in diameter and 340 feet deep; kind and amount of casing unknown. Deep-well turbine with rated capacity of 600 gallons a minute, driven by a 100-horsepower direct-connected motor.

65. Well 12 inches in diameter and 300 feet deep; drilled in October 1930. Casing: (1) 18-inch single stovepipe, to 53 feet, perforated with longitudinal slots ¼ by ½ inch spaced 16 to the round, the rounds staggered and 4 inches apart; (2) 12-inch standard screw-joint to 117 feet, perforated in place between 37 and 117 feet by slots ¼ inch by 1¼ inches spaced 4 to the round, the rounds 12 inches apart; (3) 8-inch standard screw-joint 155 to 300 feet, perforated in place between 160 and 240 feet by slots ⅛ inch by 1½ inches spaced 8 to the round, the rounds 9 inches apart. Byron-Jackson deep-well turbine belt-driven from a 25-horsepower semi-Diesel engine.

95. Well 8 inches in diameter and 218 feet deep; standard screw-joint casing to about 170 feet; drilled in 1917; measured depth 160 feet in 1920. From 1920 until May 1932, Kimball deep-well pump belt-driven by a 15-horsepower semi-Diesel engine; thereafter, by a Byron-Jackson turbine and electric motor. Water distributed by wood flume and earth ditch for irrigation.

Monthly pumpage, in gallons, from the municipal well at Hines (No. 22), 1930–33

Month	1930	1931	1932	1933
January		550,000	741,000	863,000
February		573,000	620,000	1,042,000
March		515,000	602,000	718,000
April		909,000	1,150,000	961,000
May		2,580,000	1,720,000	2,620,000
June		3,990,000	3,290,000	4,480,000
July		4,790,000	5,130,000	6,850,000
August		4,800,000	4,590,000	5,730,000
September	197,000	2,500,000	2,720,000	4,420,000
October	596,000	1,130,000	1,350,000	1,370,000
November	753,000	758,000	747,000	1,094,000
December	579,000	793,000	897,000	886,000
The year	2,125,000	23,890,000	23,560,000	31,020,000

Yearly pumpage, in acre-feet, from the slightly thermal bedrock water in the vicinity of Burns, 1926–32

Number	Use	1926	1927	1928	1929	1930	1931	1932
17, 18	Municipal	11.1	99.8	222	325	415	357	284
22	do					6.5	73.3	72.3
65	Irrigation						57	0
95	do	[1] 60	[1] 60	[1] 60	[1] 60	67	87	94
	Domestic and stock	[1] 2.5	[1] 2.5	[1] 2.5	[1] 2.5	[1] 2.5	[1] 2.5	[1] 2.5
Total pumpage for irrigation		60	60	60	60	67	144	94
Total pumpage for all uses		74	162	184	388	491	578	453

[1] Estimated.

Plate 18 shows the performance of the 218-foot well at the experiment station in 1931, as plate 16 shows the performance of the adjacent 87-foot well. These diagrams show that the specific capacities of the two wells are very nearly equal, although the bedrock well is less than half as large in diameter as the other and would be expected to have materially larger entrance head. From the foregoing data it is concluded that the water-yielding capacity of the pervious zone in the bedrock about the experiment station is about equal to that of the deep pervious beds in the valley fill. This conclusion is substantiated by a relatively large draft from the other bedrock wells that have been described.

SLIGHTLY THERMAL WATER IN THE SOUTHERN PART OF THE BASIN

Along the southern margin of the central alluvial plain water issues from two perennial springs (Nos. 317, 328) and from seven flowing wells (Nos. 327, 332 to 334, 375, 376, 377) presumably from the late basalt near Voltage. For the wells, the aggregate discharge in 1931 was about 375 gallons a minute and the temperature ranged between 52° and 54° F. For the larger spring, the so-called Sodhouse Spring (No. 317, pl. 19, *A*), the temperature was 54° F. and the discharge 5,200 gallons a minute (11.6 second-feet) on September 9, 1930. However, the discharge fluctuates with the seasons and is known to have been as small as 1,800 gallons a minute (p. 184). The relatively low temperature and the seasonal variation in discharge indicate that the ultimate source of the spring is shallow. It is believed that most if not all the water is derived by infiltration of rain on the late basalt near Voltage and near Diamond and is confined by the fine-grained playa deposits that overlap the basalt from the north.

The water-yielding capacity of the late basalt probably varies widely from place to place, for its pervious zones are inherently discontinuous (p. 37). As the artesian head is relatively small in the wells just mentioned, the area of artesian flow is probably confined to a narrow strip along the edge of Malheur Lake. Moreover, it is to be expected that the head will fluctuate commensurately with the discharge of the Sodhouse Spring. The ultimate capacity of pumped wells in those rocks is unknown.

In the southern lobe of the Donner und Blitzen Valley, about 5 miles northeast of Frenchglen, the Knox Spring (No. 380) issues from the Steens basalt at the base of the western dip slope of Steens Mountain. The average discharge of that spring was 450 gallons a minute from March to July 1930.[3] Moreover, the larger perennial streams in the adjacent area—in particular, Riddle, Kiger, and Krumbo Creeks—are formed by or receive water from other perennial springs that issue from the Steens basalt. Presumably the springs are supplied by water that percolates at relatively shallow depth through porous zones of the basalt and is replenished by local infiltration of rain on the dip slope of the mountain. This condition implies that wells in the Steens basalt would commonly be successful, although the texture of that volcanic formation is extremely variable.

Still farther west, in the northern part of Warm Spring Valley, slightly thermal bedrock water issues from the "OO cold spring" (No. 279, p. 182) and was encountered in one drilled well (No. 283), but so far as is known, all other springs and wells in that well-watered district find warmer water. Presumably the OO cold spring is fed by relatively shallow percolation from the north and west. From geologic conditions it is inferred that the bedrock of the Silver Creek Valley might afford wells of sufficient capacity for irrigation, but that inference is yet to be proved by exploratory drilling. The safe yield of the slightly thermal water in this district is unknown.

Possibly the slightly thermal bedrock water in the vicinity of the Silver Creek Valley is part of a relatively extensive body that extends northward as far as Burns and across much of the area north of Malheur, Mud, and Harney Lakes. If so, its source lies to the northwest. It is believed that this water cannot transgress the Warm Spring Valley nor Harney Lake except as it may mingle with the water of intermediate temperature that rises through the conspicuous spring

[3] Water resources of the State of Oregon, 1925–30: Oregon State Engineer, Bull. 8, p. 483, 1931.

conduits along the south margin of the valley (p. 104). Further, this water is believed to be distinct from the water in the late basalt near Voltage, being separated from that body of water by playa deposits of low permeability and having a somewhat lower head. The few pertinent data on ground-water levels suggest that slightly thermal bedrock water may percolate eastward in the area about Crane and Malheur Gaps and there pass beyond the drainage divide of the Harney Basin.

THERMAL WATER OF INTERMEDIATE TEMPERATURE

The thermal water of intermediate temperature (64° to 82° F.) issues from a number of large perennial springs and is tapped by a few wells. Brief descriptions of these springs and wells appear in the two tables that follow. With a single exception, they are found in one of three relatively small districts in the western half of the area—(1) at the western margin of the central alluvial plain near Hines, in Tps. 23 and 24 S., R. 30 E.; (2) along the southern margin of the Warm Spring Valley, for the most part in T. 27 S., R. 29E.; and (3) in the vicinity of Mud Lake, in T. 27 S., R. 30 E. The one exception is an outlying spring (No. 13) on the west branch of Cow Creek. In 1931 the aggregate discharge of the springs was about 18,000 gallons a minute (40 second-feet, or 29,000 acre-feet a year).

Thermal springs of intermediate temperature in the Harney Basin

No.	Temperature	Discharge, gallons a minute		Water-bearing formation
		1930	1931	
	°F.			
13	72	225	225	Alluvium overlying Danforth formation.
Central plain near Hines				
27	80	[1] 500	[1] 500	Highly inflated and jointed late basalt along contact with valley fill.
28	--------	[1] 300	[1] 300	Do.
29	78	[1] 300	[1] 300	Do.
149	64	[1] 75	[1] 5	Jointed rhyolite (Danforth formation).
150	72	485	370	Do.
153	70	[1] 50	[1] 50	Slope wash of Harney formation.
Warm Spring Valley				
280	74	--------	[2] 5,350	Jointed rhyolite (Danforth formation).
281	72	--------	1,730	Do.
285	74	--------	1,200	Do.
347	72	--------	850	Jointed rhyolite and tuff (Danforth formation).
349	68	--------	5,700	Do.
351	67	--------	1,160	Do.
354	66	--------	410	Danforth formation.
355	--------	--------	[1] 25	Valley fill.
Mud Lake and vicinity				
357	70	--------	--------	Valley fill (overlying Danforth formation).
365	70	--------	[1] 25	Do.
366	--------	--------	[1] 10	Do.
369	66	--------	[1] 5	Do.
372	66	--------	[1] 25	Do.
Total	--------	--------	18,200	

[1] Estimated. [2] May 30, 1932.

Wells in Harney Basin that tap thermal water of intermediate temperature

No.	Depth	Temperature	Estimated yield, gallons a minute [1]	Water-bearing formation
Central plain near Hines	*Feet*	*°F.*		
24	174	76	200; [2] 800	Late basalt near Hines.
25	152		[3] 400	Do.
143 [4]	478	80	300-400	Late basalt near Hines (?).
144	60	64	Trickle	Valley fill (?).
145	83½		([5])	Late basalt near Hines (?).
146	80	82	([6])	Do.
Warm Spring Valley				
345	47	68	2	Valley fill.
348	63	64	100	Valley fill (?).
350	43	60	20	Valley fill (black sand).
353	103	64½	½	Danforth formation (?).
Mud Playa				
368	315	65½	35	Danforth formation.

[1] By artesian flow except as indicated.
[2] Maximum capacity when pumped.
[3] Well does not flow; estimated capacity when pumped.
[4] Flow surges; drillers' log on p. 135.
[5] Flowed slightly prior to July 1930; hand pump.
[6] Hand pump.

In the area near Hines the aggregate natural discharge of the springs of intermediate temperature in 1930 and 1931 was about 1,500 gallons a minute (3½ second-feet or 2,400 acre-feet a year); however, it is not known whether the discharge is variable over a term of years. The natural discharge of one spring (No. 27) was increased somewhat by a turbine pump (capacity 500 gallons a minute) which drew the water level down below the natural orifice. The few wells in the same area suggest that the static level for the thermal water is nowhere more than a few feet above the land surface, so that flowing wells of large yields are not likely. The potential area of flowing wells is inferred to be a relatively narrow belt along the west margin of the alluvial plain.

In this area near Hines the water temperature is greatest (82° F.) in well 146, whence it diminishes progressively in all directions. This condition suggests a focal point at which excess heat is transmitted to the ground water, by ascending magmatic steam or juvenile water (p. 97). This hypothetical focal point would fall near the southern edge of the late basalt and close to an outlier of the upper part of the Danforth formation that has been hydrothermally altered. Thus it is suggested, though by no means proved, that the transmission of heat is a continuing stage of the late basaltic volcanism. Conceivably the groundwater temperature gradients could be extended northward to well 22 (62° F.), possibly even to wells 17 and 18 (58° F.) at Burns, also westward to spring 148 (56° F.) in the Sagehen Valley. In other words, they might be extended to accepted components of the slightly thermal ground water. Accordingly, in the area near

Hines there may be no real distinction between the slightly thermal water and the water of intermediate temperature.

The thermal springs of intermediate temperature in the Warm Spring Valley are by far the most conspicuous springs in the Harney Basin. They are alined along the base of the fault-line escarpment that bounds the valley plain on the south, each issuing from numerous small orifices in the bottom of a sizable pool. Near some of them the rocks of the escarpment (Danforth formation) are prominently jointed, but at others there are no obvious secondary openings in the rocks. In 1931 these springs together discharged about 16,500 gallons a minute (37 second-feet, or 27,000 acre-feet a year). This quantity is about 90 percent of the discharge from all springs of intermediate temperature and 80 percent of the discharge from all thermal springs in the Harney Basin. The greatest discharge from any one spring measured in 1931–32 was 5,700 gallons a minute (12.6 second-feet) from spring 349 (pl. 19, *B*). However, the so-called "OO warm spring" (No. 280) has the greatest recorded discharge of all in the district—9,400 gallons a minute (20.9 second-feet) on August 23, 1913. The discharge of these thermal springs has been measured at irregular intervals beginning in 1907 (p. 184), and the variability among the largest five springs is from 43 to 103 percent of the respective averages. A considerable part of the variability may have been caused by intermittent diversions for irrigation, which is accomplished by regulating the stage in the spring pools over a moderate range. Nevertheless, the measurements suggest that the discharge has tended to decline progressively. It seems likely that the discharge would not vary greatly in any one year if the stage in the pool were held constant, yet equally likely that it would vary over a term of years in response to long-term fluctuations in rainfall.

The wells in the Warm Spring Valley indicate a triangular area of potential artesian flow from the valley fill and from the bedrock, bounded on the north by the wagon road between Narrows and the OO ranch and on the south by the line of thermal springs. Toward the east it may extend to and beyond the margin of Harney Lake. To this area slightly thermal water is inferred to percolate from the north and west and water of intermediate temperature from the spring conduits to the south.

In the Warm Spring Valley, as in the area near Hines, the ground-water temperatures show a decided gradient. The maximum (74° F.) is at the westernmost of the thermal springs, the OO warm spring (No. 280); thence the temperature decreases eastward to 66° F. at spring 354. It also decreases northward among the flowing wells and by inference grades ultimately into the slightly thermal range. These features suggest that a focal conduit for the transmission of heat lies near the OO ranch or farther west, and (2) that some thermal water percolates northward from the spring conduits through pervious facies of the bedrock and through the valley fill, ultimately to mingle with nonthermal or slightly thermal water from the north and west.

Plate 20, *A*, shows one of four "sulphur" springs near Mud Lake. Among these springs, the water temperature ranges between 66° and 70° F. In 1931 the aggregate discharge was relatively small, only about 65 gallons a minute. In the same area one 315-foot well was flowing about 35 gallons a minute in June 1931 and its water temperature was 65½° F. The relation of this ground-water body to those near Hines and in the Warm Spring Valley is unknown, as is its relation to the cooler ground water close at hand. Neither can its area of artesian flow be bounded.

HOT WATER

The hot ground water (90° to 154° F.) issues from a few springs that are widely scattered over the Harney Basin, also from one flowing well in the southwestern part of the central alluvial plain. The springs are listed in the following table, and the hottest spring (No. 361) is pictured in plate 20, *B*.

Hot Springs (90° to 154° F.) in the Harney Basin

No.	Temperature	Approximate discharge, 1930–31, gallons a minute	No.	Temperature	Approximate discharge, 1930–31, gallons a minute
	° F.			° F.	
205	126	180	361	154	150
358	[1] 104	(3)	379	[2] 80	900
359	[1] 92	(3)	381	[2] 89	500
360	[1] 108	20	382	[2] 83	100

[1] Main spring orifice inaccessible; temperature taken in slack water close to edge of spring pool and probably too low.
[2] Isolated spring in the Donner and Blitzen Valley; temperature distinctly higher than for springs of intermediate temperature in the Warm Spring Valley, to the north, but somewhat less than the hot-spring range.
[3] Small.

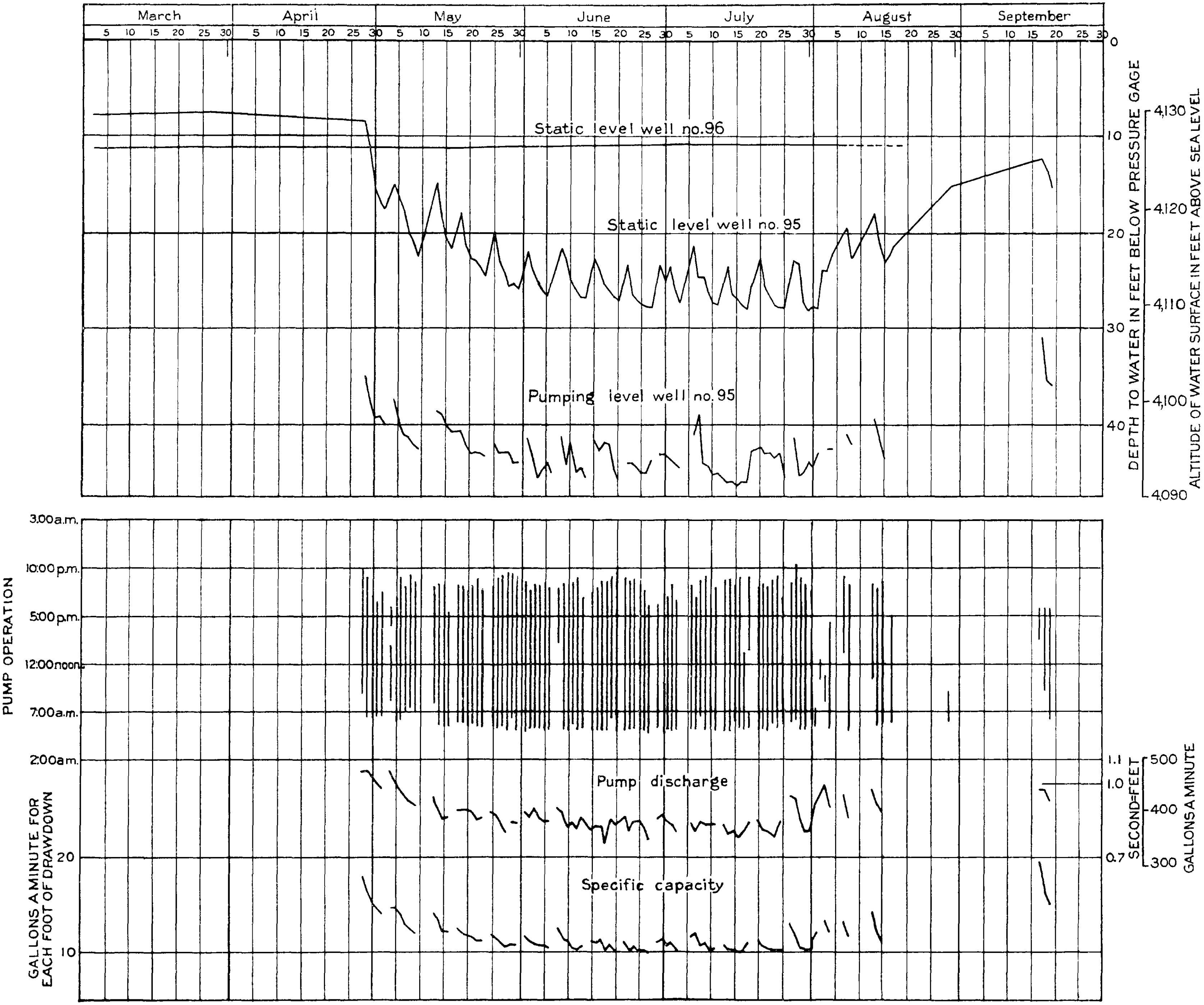
The lone well that yields hot water is the so-called Howell oil-test well (No. 301), about 5½ miles northeast of Narrows. According to report, that well was drilled 1,430 feet deep. It penetrated two water-bearing beds in the valley fill, seven water-bearing beds in the bedrock between 430 and 659 feet in depth, no water-bearing beds from 659 to 1,330 feet, and finally encountered the hot water in two strata between 1,330 and 1,402 feet. From the depth-temperature curve for the Dog Mountain well (fig. 9), which is 8 miles farther west and 2½ miles farther north, it is inferred that the seven water-bearing beds at intermediate depth contained water at about 75° to 80° F.—that is, in the intermediate-temperature range. Whether any of those seven beds confined water under sufficient pressure to flow at the land surface is not reported. The 670-foot dry zone between 659 and 1,330 feet corresponds rudely with the interpolated depth of the Danforth formation. In 1930 the well was flowing about 30 gallons a minute, presumably from the deepest water-bearing beds; however, there is an unconfirmed report that the yield was materially greater before casing was placed in the well. The position of the static level with reference to the land surface is not known for any of the water-bearing beds, so that the extent of the area of artesian flow cannot even be surmised.

RELATION OF THE THERMAL WATER TO GEOLOGIC STRUCTURE

Two features in the occurrence of thermal water in the Harney Basin are striking—namely, (1) most of the natural discharge falls within a narrow temperature range, 64° to 82° F., and takes place in a few small but widely spaced areas; and (2) nearly all the thermal springs are alined along certain known or inferred faults or issue from the valley fill along the projected traces of faults. The definite exceptions to the second of these generalizations are the Crane hot spring (No. 205), on the central alluvial plain near its eastern margin and a quarter of a mile north of Warm Springs Butte; the thermal springs near the Mud Playa and certain of those on the Harney Playa, farther west; and spring 382, at the eastern flank of the Donner und Blitzen Valley. Even these may be on or close to faults that have not been recognized. Certain of the springs near Hines issue from the late basalt (p. 102), but that volcanic mass itself was extruded along a conspicuous fault zone, which may provide the spring conduits. In this connection, Meinzer[4] has pointed out that the great majority of thermal springs in the neighboring States of Nevada, Utah, and Idaho arise along faults.

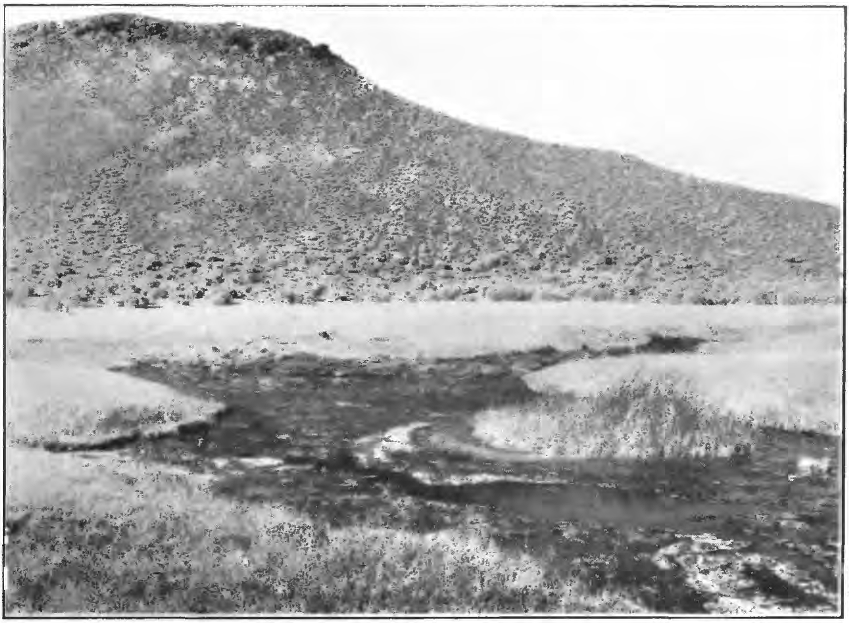
It seems obvious that the circulation of thermal ground water in the Harney Basin is controlled largely by faults, which locally afford conduits transverse to the strata and which set impervious beds against pervious beds. Accordingly, certain major fault blocks become distinct ground-water provinces so far as the thermal water is concerned. Within each of these blocks the circulation is inferred to be controlled also by stratigraphic nonconformities. An example is furnished by the relatively large springs of intermediate temperature in the Warm Spring Valley. From the average depth-temperature gradient of figure 9, the source rock for these springs may be interpolated to extend from 850 to 1,200 feet below the land surface; if the actual depth-temperature graph is taken rather than the average gradient the interpolated depth of the source rock would not exceed 800 feet and

[4] Meinzer, O. E., Origin of the thermal springs of Nevada, Utah, and southern Idaho: Jour. Geology, vol. 32, pp. 295–303, 1924.



DIAGRAMMATIC SUMMARY OF OPERATION OF THE 218-FOOT WELL AT THE HARNEY BRANCH EXPERIMENT STATION, 1931.

A. "SULPHUR" SPRING WEST OF MUD LAKE.



B. UNNAMED HOT SPRING SOUTHEAST OF HARNEY LAKE.
In the SE¼ sec. 36, T. 27 S., R. 29½ E.

A. SODHOUSE SPRING, NEAR THE SOUTH MARGIN OF MALHEUR LAKE.
In the SE¼ sec. 35, T. 26 S., R. 31 E. ("south of Malheur Lake").

B. CRANE CREEK, OR HUGHET SPRING.
In the NE¼ sec. 8, T. 27 S., R. 29 E.

might be as little as 300 feet. It is, therefore, inferred that the functional aquifers for the springs lie within the Steens basalt and that the confining beds are in the overlying Danforth formation. Possibly the unconformity between the two formations is the precise horizon at which the water is confined. Whatever the horizon may be, it is thrown down to the north by the fault along which the springs are alined, that fault being the western limb of a major Z-shaped fracture separating two of the larger crustal blocks in the Harney Basin (p. 56). Accordingly, some or all of the aquifers in the upfaulted block to the south would abut against the confining beds in the downfaulted block to the north and, if the pressure head were adequate, their water would be deflected upward to the land surface through chance conduits along the fault. It is inferred further that the catchment area for the meteoric fraction of the water is not remote and lies to the south, the direction from which the Tertiary rocks generally dip toward the center of the basin. No part of the Harney Basin other than the Warm Spring Valley is likely to afford a catchment area equally large or artesian circulation equally free.

Geologic conditions near Hines would permit much the same mechanism for the catchment, circulation, and discharge of thermal water of intermediate temperature. The water temperatures are somewhat higher than in the Warm Spring Valley, and suggest that the depth of circulation is on the order of 1,000 to 1,500 feet beneath the land surface (fig. 9, average gradient). On the other hand, heat may be transmitted to the water as a continuing stage of the late basaltic volcanism.

By implication, the circulation and discharge of the hot ground water is controlled by faults in a fashion similar to that set forth above, at least for the fraction of the water that is derived from meteoric sources. However, the interpolated depth of circulation is greater—so great that in certain areas it involves the deeper rocks, which have been faulted more extensively than those cropping out. Hence, the hot water may ascend through fault conduits that do not extend to the land surface, and it may reach the ultimate spring orifices by devious paths. As would be expected, the hot water usually does not give rise to springs in the areas that yield water of intermediate temperature, for there any ascending hot water presumably would be intercepted by the shallower water. The extent to which heat may be transmitted in this way to water of intermediate temperature is problematic.

A certain fraction of the ascending thermal water—of the intermediate- and high-temperature ranges alike—escapes from its fault-plane conduits and percolates laterally into the wall rocks at relatively shallow depth. In the area near Hines, for example, water of intermediate temperature enters deep beds in the valley fill, for locally the pressure head in those deep beds is built up so much that flowing wells can be obtained (p. 90). In the Warm Spring Valley water of intermediate temperature percolates northward from the spring conduits into the valley fill and the bedrock alike (p. 104).

RECOVERY OF THERMAL WATER FROM SPRINGS AND WELLS

Altogether, a major fraction of the discharge from the thermal springs of intermediate temperature is used for irrigation, and at Hines one spring (No. 27) is used for industrial purposes. The Crane Hot Spring (No. 205) has been developed for a small natatorium. At most springs, however, only rude diversion works have been provided, and the full capacity is not utilized. At some springs more water could probably be salvaged by cleaning the orifices and sinking cut-off walls into the soil to restrain shallow percolation. Because most of the springs issue under low head, the discharge is highly sensitive to changes of stage in the spring pool; thus, the discharge decreases if diversions are made at higher levels but may be increased if the water level is drawn down below its natural stage. Conservation of the spring discharge during the nongrowing season is difficult, though waste would be minimized by imposing a back pressure on the orifice through dikes and gates by which the pool could be held at high stage. However, this might force the spring into a new low-level orifice outside the control works or might cause waterlogging of arable land near the spring.

Wells can recover the water of intermediate temperature and the hot water only as they enter one of the devious fault-plane conduits or as they tap one of the pervious strata in the bedrock or valley fill that are fed by those conduits. In general, the chance of the well being successful is greatest if it is near a known conduit, a thermal spring, or a known body of thermal water, although the stratigraphic horizon and extent of all the pervious zones cannot be foretold. Also, the safe yield of a thermal-water body is determined by the transmission capacity of the conduit that feeds it, and that capacity cannot readily be gaged. Accordingly, the few existing thermal wells that have been cited are far from an adequate basis for judging the aggregate safe yield of the thermal ground water.

Two of the drilled wells that tap water of intermediate temperature near Hines (Nos. 24, 25) have been pumped rather heavily, it being reported that each will yield about 800 gallons a minute when drawn down 20 feet. Thus, their specific capacities are roughly three times those of the two irrigation wells at the Harney Branch Experiment Station. The rock which they penetrate, a scoriaceous facies of the late basalt, is decidedly more pervious than most other Tertiary rocks in the Harney Basin and promises other wells of large capacity in that vicinity. So far as the writers are aware, no other thermal wells in the basin have ever been pumped heavily, so that the capacities of potential wells in other parts of the basin are yet to be demonstrated.

The data available to the writers indicate that wells more than 500 feet deep have been drilled at six widely spaced localities on the central alluvial plain. The history of these wells retraces the effort that has been made to bring in deep flowing wells. The oldest is an exploratory well (No. 53) put down in 1893 at the expense of Harney County. In describing it Russell [5] says:

> A well drilled at the expense of Harney County in 1893, at a locality about 6 miles east of Burns, in sec. 13, T. 23 S., R. 31 E., was continued to a depth of 848 feet. The well at the top has a diameter of 6 inches but narrows near the bottom to 4 inches. At the depth of 350 feet water was reached which rose and overflowed at the surface, but after an attempt to improve the well, made in the spring of 1902, it ceased to flow. The water in August 1902 stood 3 feet below the surface and had a temperature of 49° F. The first 100 feet of material passed through was sand, gravel, and soft rock, and at a greater depth hard rock was penetrated, but no record as to its nature, etc., is available. Two water-bearing strata are said to have been reached, one at 350 feet from the top and the other at the horizon where drilling was discontinued—namely, 840 feet. The outflow from the first water-bearing layer is said to have been small. The well is cased with iron tubing, 6 inches in diameter, to a depth, as reported, of 450 feet * * *. Work is said to have been abandoned on account of the loss of drilling tools in the well.

Waring [5b] reports that during the summer of 1907 the water level in the well stood about 5 feet below the land surface and little, if any, above the water table. At that time, therefore, the water level was some 2 feet lower than at the time of Russell's visit. In 1928 the well was sounded by Obil Shattuck, superintendent of the Harney Branch Experiment Station, and found to be partly bridged from 110 to 148 feet, and closed tightly at 411 feet. On October 5 of that year the water level was found by A. M. Piper to be 6.8 feet below the top of the casing, or 4.9 feet below the land surface—that is, it was approximately the same as when observed by Waring 21 years earlier. In August 1930 an effort was made to recondition the well by redrilling and bailing to a depth of 420 feet and then "shooting" with 35 sticks of 40 percent dynamite at 350 feet and with 50 sticks at 326 feet. As a result the casing was ruptured thoroughly; also, sand and gravel ran in so freely that the well could not be kept open for more than 325 feet. Subsequently, the water level in the well has ranged between 10.8 and 25.7 feet below the top of the casing (p. 155) and, in spite of the difference in the depth of the wells, seems to have fluctuated with the confined water in the deep valley fill and to have been drawn down intermittently by pumping in the 87-foot well at the experiment

[5] Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-Supply Paper 78, pp. 40–41, 1903.

[5b] Waring, G. A., Geology and water resources of the Harney Basin region, Oregon: U. S. Geol. Survey Water-Supply Paper 231, p. 62, 1909.

station (pl. 15). This condition implies a casing failure above the 325-foot level.

The second deep well was drilled in 1896 about 10 miles farther east. This well was not found during the investigation of 1930–32, but Russell [6] describes it as follows:

> About 5 miles east of Harney, on land belonging to Fred Haines, in sec. 2, T. 23 S., R. 32½ E., a well 3 inches in diameter, drilled in 1896 to a depth of 507 feet, struck water at a depth of between 200 and 300 feet, which rose to the surface. The well is not cased, and the water now stands 6 feet below the surface and has a temperature of 49° F. The material passed through was soft to a depth of 100 feet and below that depth consisted of black lava, clay, etc., but no definite record is available. This well at first yielded a true artesian flow, but, as nearly as can be judged, has caved in, owing to lack of casing, and the water supply at present is from percolation through porous beds near the surface. The temperature of the water now being pumped indicates that it comes from about 50 feet below the surface.

About a quarter of a mile southeast of the so-called County well, a 3-inch well (No. 105) has been drilled on the property of Fred Denstedt. It is reported that the well is 565 feet deep, is cased to 240 feet, and has never flowed at the land surface. During the irrigation season its water level is depressed by pumping in the 218-foot well at the experiment station, but at other times it intermittently overflows the top of its casing, which is 9.0 feet below the land surface, and discharges into a surrounding pit.

About 2¼ miles farther east a 6-inch well (No. 101) has been drilled to a reported depth of 800 feet. From 1930 to 1932 its static level ranged between 6.0 and 5.6 feet below the top of the casing, which was about 0.5 foot above the land surface (p. 168).

The remaining two deep wells on the central plain are located in the alcove between Wrights Point and Malheur Lake. One, the Howell oil-test well (No. 301) was the only flowing hot-water well in the Harney Basin during the present investigation. The other well (No. 233) was drilled about 4½ miles to the north in 1930, also in search for petroleum. According to report, it was 1,000 feet deep, did not find water under sufficient pressure to flow, and was finally plugged. The casing is now removed and the well abandoned.

Of the six wells just described, only one (No. 301) was flowing in 1930–32, three (Nos. 53, 101, and the Haines well) were not flowing at that time but are known or inferred to have flowed previously. and two (Nos. 105 and 233) have never flowed. Satisfactory casing records are not at hand for any of these wells, and accordingly it is not known whether the lapse of artesian flow has been due primarily to caving in the well, to local temporary dissipation of pressure head through leaky casing, or to regional permanent diminution of head. In part, the lapse is believed due to permanent diminution of head, for

[6] Russell, I. C., op. cit., p. 40.

water under sufficient pressure to flow was found at a depth of 350 feet in 1893 in well 53, but subsequently not in well 105, a quarter of a mile away. Even from the fragmentary data available it is clear that wells on the central alluvial plain from 500 to 1,000 feet deep are likely not to flow by artesian pressure, although flowing wells of shallower depth are common in the three areas along the western margin of the plain. Still deeper wells, such as No. 301, which flowed first when 1,330 feet deep, may flow from bodies of hot water beneath the central alluvial plain relatively close to Malheur Lake. The boundaries of the area of artesian flow for the hot water cannot be traced specifically from the data at hand.

CHEMICAL CHARACTER OF THE GROUND WATER IN RELATION TO USE FOR IRRIGATION [7]

As an index to the chemical character of the ground water in the Harney Basin, samples for analysis were taken in 1931 and 1932 from 100 wells and 7 perennial springs. Three of the wells (Nos. 50, 51, 344) were sampled twice, once in each year. In addition, five samples were taken from the streams in May 1932, and one sample had been collected from the Harney Lake by I. C. Russell in 1902.[8] All these samples (except the one taken from Harney Lake in 1902) were analyzed by E. W. Lohr and S. K. Love, of the Geological Survey, according to the methods regularly used by the Survey.

Samples of water for analysis were taken from 65 shallow wells in the valley fill and from 27 wells whose measured depth was so great that obviously they reached the deep pervious beds in that unconsolidated material. These deep wells were chosen with a view to comparing the chemical composition of the water in shallow and deep beds. Accordingly the sampling was limited to those wells whose casings appeared to be in good condition and thus adequate to effect a real separation of the two water-bearing zones. However, some wells were necessarily accepted for the purpose without full information as to the depth reached by the casing. Others were accepted though they were not fitted with pumps and had not been used for several years, the samples being withdrawn by a small pump attached to ordinary garden hose. Deep wells of either sort may not have yielded samples that represented the water in the deep pervious beds, owing to insufficiency or leakiness of the casing.

The successful use of water for irrigation depends on a number of factors in addition to the chemical character of the water. Among these are the character of the soil, the amount of water used, rainfall,

[7] By W. D. Collins in large part.

[8] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Bull. 217, p. 31, 1903.

and drainage. A recent publication [9] has suggested limits for certain characteristics of irrigation water. The lower set of limits is such that in general waters within the range specified are not likely to be harmful when used in ordinary irrigation. The upper limits represent concentrations that are very likely to make the waters unfit for irrigation because of their effects on the soil or on the plants. Concentrations between the upper and lower limits may or may not cause injury to crops and soils, their effect depending on the concentrations of the various constituents of the water, the characteristics of the land, and the way the water is used. The following table shows the suggested limits:

Suggested limits for safe and unsafe waters for irrigation

[Parts per million except as indicated]

Constituents	Safe	Unsafe
Total dissolved solids [1]	700	2,000
Percent sodium	50	60
Sulphate (SO_4)	192	480
Chloride (Cl)	142	355

[1] Reported by Scofield as "specific electrical conductance."

The percentage of sodium is calculated from analytical results expressed in milligram equivalents per kilogram. These results are obtained by dividing the parts per million of sodium, calcium, and magnesium by 23, 20, and 12.24, respectively; then 100 times the milligram equivalents of sodium is divided by the sum of the milligram equivalents of sodium, calcium, and magnesium. In milligram equivalents $\frac{100\ Na}{Na+Ca+Mg}$=percentage of sodium.

The following table shows the suitability for irrigation of the ground waters of Harney Basin:

Suitability for irrigation of the ground waters of Harney Basin

[Number of samples from each source that fall into each of Scofield's classifications]

Constituents	Shallow valley fill (65 samples)			Deep valley fill (27 samples)			Bedrock (16 samples)		
	Safe	Intermediate	Unsafe	Safe	Intermediate	Unsafe	Safe	Intermediate	Unsafe
Total dissolved solids	31	20	14	19	4	4	15	1	0
Percent sodium	23	5	37	6	3	18	4	2	10
Sulphate (SO_4)	40	9	16	22	3	2	16	0	0
Chloride (Cl)	48	6	11	21	4	2	15	0	1

[9] Scofield, C. S., South Coastal Basin investigation, quality of irrigation waters: California Dept. Public Works, Div. Water Resources, Bull. 40, pp. 21–24, 1933.

This table shows that water from the shallow valley fill is less suitable for irrigation than the water from the deep valley fill and from the bedrock. In every respect except percentage of sodium the water from deep valley fill and bedrock is better. Water from the shallow valley fill is likely to be more toxic to growing plants than that from the other two sources, whereas the water from the deep valley fill and bedrock is more likely to injure the physical character of the soil.

APPENDIX

Chemical constituents of representative waters from the Harney Basin, Oreg.

[E. W. Lohr and S. K. Love, analysts, U. S. Geological Survey. See tables, pp. 137 and 181, for description data for wells and springs]

Samples from wells and springs

No. on pl. 2	Location	Date of collection	Temperature (°F.)	Sum of constituents [1]	Analyses (parts per million)										
					Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K) [2]	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness (as $CaCO_3$) [3]
	T. 22 S., R. 32 E.														
8	NE¼SE¼ sec. 25	Sept. 5, 1931	53	97			[4] 14		16	0	102	[4] 4	2.5	2.0	[5] 57
10	NE¼NW¼ sec. 34	May 31, 1932	46	315			24	14	83	0	291	31	20		117
	T. 22 S., R. 32½ E.														
13	NE¼SW¼ sec. 14	Sept. 2, 1931	72	72			[4] 16		12	0	86	[4] 4	1.9	1.0	[5] 51
	T. 23 S., R. 30 E.														
18	NE¼SE¼ sec. 12	Aug. 27, 1931	58	[6] 167	59	0.01	14	6.0	18 4.9	0	108	7.5	3.8	2.5	60
22	NE¼SW¼ sec. 23	Aug. 16, 1931	62	112			[4] 12		15	0	86	[4] 13	10	4.6	[5] 69
27	NE¼NE¼ sec. 35	Aug. 26, 1931	78	121			[4] 14		37	0	109	[4] 11	8.0	1.1	[5] 33
	T. 23 S., R. 31 E.														
33	NW¼SW¼ sec. 2	May 9, 1932		621			109	36	92	0	650	[4] 5	59		420
37	Lot 2, sec. 4	May 31, 1932	52	156			28	13	15	0	160	14	7.0		123
42	Lot 8, sec. 6	Sept. 7, 1931	50½	174			[4] 30		26	0	180	[4] 10	3.1	4.6	[5] 109
50	SE¼SE¼ sec. 9	Aug. 26, 1931	49	191			[4] 35		29	0	180	[4] 20	6.0	2.4	[5] 136
		June 1, 1932	42	369			107	22	3.6	0	363	38	20		358
51	SE¼SE¼ sec. 9	Aug. 26, 1931	51½	140			[4] 24		21	0	145	[4] 12	1.8	.10	[5] 87
		June 1, 1932		147			28	7.4	19	0	147	18	2.0		100
	T. 23 S., R. 31 E.														
59	NW¼NE¼ sec. 14	May 14, 1932		114			20	10	9.8	0	109	18	3.0		91
69	Lot 6, sec. 17	do		134			24	12	12	0	129	25	2.0		109
73	Lot 2, sec. 18	June 1, 1932		107			18	6.6	14	0	100	14	5.0		72
76	Lot 1, sec. 20	May 29, 1932		148			32	9.2	13	0	154	15	3.0		118
77	do	do		145			30	9.6	13	0	149	15	4.0		114

79	SE¼NE¼ sec. 21	May 14, 1932	50	192			26	14	32		0	214	12	3.0		122
80	do	do	47	150			20	7.2	31		0	164	9.1	2.0		80
	T. 23 S., R. 32 E.															
92	Lot 3, sec. 6	May 31, 1931	46	836			66	26	250		0	950	[4] 2	24		272
94	NE¼SW¼ sec. 7	Sept. 1, 1931	48	[6] 652	51	0.01	64	22	117	4.0	0	151	175	138	.70	250
95	SW¼SE¼ sec. 7	do	56	[6] 188	55	.01	11	2.7	38	2.9	0	141	4.7	3.6	1.1	39
98	SE¼SE¼ sec. 8	May 13, 1932	54	280			21	12	77		0	278	16	17		102
99	NE¼NW¼ sec. 10	May 31, 1932	50	212			12	7.6	62		0	185	26	13		61
100	SW¼NE¼ sec. 12	May 9, 1932		478			19	10	168		0	470	[4] 3	47		88
106	Lot 2, sec. 18	May 13, 1932		1,196			164	62	159		0	330	470	178		664
110	SW¼SW¼ sec. 20	Aug. 31, 1931	52	1,303			154	43	234		0	498	387	109	131	561
111	do	Sept. 9, 1931	50	281			[4] 12		102		0	321	[4] 2	2.8	4.7	[5] 51
118	NW¼NE¼ sec. 27	May 13, 1932	50	251			36	13	38		0	168	73	8.0		143
122	SE¼SE¼ sec. 32	May 28, 1932		168			32	13	17		0	191	10	2.0		133
	T. 23 S., R. 32½ E.															
124	Lot 4, sec. 2	May 9, 1932		322			8.5	7.0	116		0	312	18	19		50
128	Lot 1, sec. 31	Sept. 5, 1931	51	481			[4] 2		198		0	438	[4] 60	17	3.7	[5] 18
129	do	do	50	[6] 219	54	0.01	29	9.2	21	8.1	0	176	11	4.2	.8	108
131	NW¼SE¼ sec. 32	May 13, 1932	52	210			14	15	51		0	229	12	5.0		96
132	NE¼NW¼ sec. 35	May 31, 1932	49	1,045			38	31	343		0	910	102	83		222
	T. 23 S., R. 33 E.															
138	NE¼SW¼ sec. 22	Sept. 2, 1931	52	715			32	14	219		0	453	88	64	75	137
140	NE¼NW¼ sec. 33	May 9, 1932		1,540			46	22	483		12	299	490	340		205
	T. 24 S., R. 30 E.															
143	Lot 2, sec. 1	Aug. 26, 1931	80	[6] 159	51	.01	9.6	1.7	30	2.4	0	95	13	5.2	1.2	31
147	SE¼NE¼ sec. 2	May 14, 1932	54	215			9.0	7.0	70		0	224	16	3.0		51
150	SE¼SW¼ sec. 11	Aug. 26, 1931	72	113			[4] 7		40		0	104	[4] 13	5.0	.30	[5] 18
152	NE¼NE¼ sec. 18	May 28, 1932		123			14.0	2.4	31		0	100	17	9.0		45
	T. 24 S., R. 31 E.															
159	SE¼NE¼ sec. 8	May 14, 1932	54	112			5.0	4.4	35		0	107	6.6	8.0		31
160	do	May 10, 1932	46	649			29	18	188		0	298	175	92		146
163	SE¼SW¼ sec. 10	Sept. 8, 1931	51	348			45		77		0	358	[4] 24	12	1.1	[5] 169
164	SW¼SW¼ sec. 12	May 14, 1932		352			51	20	63		0	380	24	7.0		210
165	NE¼SE¼ sec. 20	Sept. 4, 1931	51	1,182			73	33	317		0	307	274	334		318
166	do	May 10, 1932	46	417			34	15	126		0	339	49	26		146

See footnotes at end of table.

Chemical constituents of representative waters from the Harney Basin, Oreg.—Continued

[E. W. Lohr and S. K. Love, analysts, U. S. Geological Survey. See tables, pp. 137 and 181, for description data for wells and springs]

Samples from wells and springs—Continued

No. on pl. 2	Location	Date of collection	Temperature (°F.)	Sum of constituents [1]	Analyses (parts per million)										
					Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)[2]	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness (as $CaCO_3$)[3]
	T. 24 S., R. 32 E.														
170	NE¼SE¼ sec. 5	May 28, 1932	50	427	--------	--------	10	7.9	161	25	426	6.2	7.0	--------	57
172	NW¼SE¼ sec. 9	May 14, 1932	--------	816	--------	--------	8.5	6.6	312	61	538	126	37	--------	48
178	NW¼NE¼ sec. 23	May 11, 1932	52	1,046	--------	--------	18	23	383	20	909	61	93	--------	139
179	SE¼SW¼ sec. 23	May 11, 1932	52	1,826	--------	--------	46	56	550	0	925	633	85	--------	345
181	SE¼SW¼ sec. 26	May 31, 1932	49	1,404	--------	--------	19	22	496	19	841	314	120	--------	138
184	SE¼NE¼ sec. 31	Sept. 4, 1931	55	465	--------	--------	[4] 7	--------	195	0	524	[4] 4	14	.40	[5] 30
186	do	do	48	663	--------	--------	[4] 25	--------	230	45	596	[4] 8	49	.20	[5] 140
	T. 24 S., R. 32½ E.														
188	NW¼SE¼ sec. 7	May 13, 1932	--------	3,230	--------	--------	106	129	871	0	1,154	1,166	375	--------	794
189	NW¼NW¼ sec. 10	do	54	388	--------	--------	19	9.4	130	9.8	389	16	12	--------	86
198	SW¼NW¼ sec. 32	Sept. 4, 1931	57	1,205	--------	--------	[4] 12	--------	492	0	1,034	[4] 3	212	.25	[5] 80
200	NE¼NE¼ sec. 33	May 11, 1932	--------	1,366	--------	--------	63	68	408	0	1,302	[4] 14	172	--------	436
	T. 24 S., R. 33 E.														
205	NW¼SE¼ sec. 34	Aug. 30, 1931	120	427	--------	--------	[4] 2	--------	171	22	173	[4] 80	82	1.4	[5] 6
206	NE¼SW¼ sec. 34	May 11, 1932	54	1,193	--------	--------	15	5.2	429	16	531	347	119	--------	59
	T. 25 S., R. 31 E.														
216	SE¼SW¼ sec. 9	Sept. 4, 1931	51	413	--------	--------	[4] 14	--------	158	0	410	[4] 35	14	.30	[5] 48
222	NE¼SE¼ sec. 33	May 18, 1932	56	1,421	--------	--------	144	65	351	0	1,539	48	55	--------	626
	T. 25 S., R. 32 E.														
223	Lot 1 sec. 2	May 31, 1932	--------	859	--------	--------	31	44	234	79	418	222	43	--------	258
224	do	do	--------	2,126	--------	--------	225	108	313	0	425	1,230	41	--------	1,005
238	Lot 3 sec. 35	Sept. 8, 1931	52	1,731	--------	--------	45	98	490	0	1,292	358	104	--------	514

	T. 25 S., R. 32½ E.															
242	SE¼SW¼ sec. 1	May 25, 1932		448			7.0	5.5	172		21	317	5.3	81		40
247	Lot 3 sec. 5	Sept. 2, 1931	52	1,568			85	72	392		0	903	499	68	7.4	508
249	NE¼SW¼ sec. 8	May 10, 1932	52	1,769			38	71	498		31	769	740	12		386
250	NW¼NW¼ sec. 11	May 11, 1932		5,810			34	58	2,157		368	2,560	1,141	790		323
255	Lot 5 sec. 19	May 19, 1932	49	1,628			111	140	278		0	919	559	87		852
257	Lot 1, sec. 20	May 19, 1932	52	6,139			212	322	1,396		0	1,081	3,160	505		1,850
258	Lot 7 sec. 22	May 24, 1932		404			65	22	53		0	273	104	25		253
259	do	do		454			22	27	103		48	90	165	45		166
265	(7)	do		1,564			123	107	327		0	1,284	331	43		746
	T. 25 S., R. 33 E.															
267	SE¼SW¼ sec. 6	May 11, 1932		687			36	20	212		0	565	79	62		172
272	NW¼NW¼ sec. 23	do		712			5.5	6.1	265		76	117	91	211		39
	T. 26 S., R. 28 E.															
278	NW¼NE¼ sec. 14	May 30, 1932	54	237			9.5	3.9	85		0	241	4.9	15		40
	T. 26 S., R. 29 E.															
283	NW¼SE¼ sec. 27	do	52	437			8.0	7.4	166		0	425	4.9	41		50
285	Lot 4 sec. 31	Aug. 21, 1931	68	[6] 230	60	0.01	14	7.5	41	4.2	0	134	14	24	1.1	66
	T. 26 S., R. 31 E. "North of Malheur Lake" and T. 26 S., R. 30 E. "South of Malheur Lake"															
292	SE¼SE¼ sec. 3	May 17, 1932		27,500			717	341	8,510		153	3,770	11,060	4,850		3,190
294	SE¼SE¼ sec. 15	May 26, 1932		6,370			4.5	25	2,640		511	4,990	299	428		114
295	SW¼NE¼ sec. 26	May 18, 1932	52	1,694			50	137	453		0	1,800	102	65		687
298	Lot 2 sec. 32	do	52	11,490			327	348	3,150		0	1,172	5,020	2,065		2,244
299	NW¼SW¼ sec. 35	Sept. 8, 1931	52½	4,138			[3] 14	[4] 58	1,630		0	1,804	570	1,148	.25	[5] 154
300	do	do	54	485			[3] 3	[4] 0	207		13	353	[3] 3	101	1.5	[5] 7.5
	T. 26 S., R. 32 E. "North of Malheur Lake" and T. 26 S., R. 31 E. "South of Malheur Lake"															
303	(7)	May 19, 1932	51	2,458			30	162	650		0	1,346	795	158		739
304	(7)	Sept. 8, 1931	50	2,626			76	133	744		0	1,624	560	311	2.0	735
305	(7)	May 19, 1932	51	4,480			468	291	615		0	1,140	2,204	335		2,363
307	NE¼NE¼ sec. 18	May 18, 1932	51	2,371			10	18	964		40	1,936	[3] 5	380		99
308	do	do	52	7,100			7.0	2.0	2,840		449	4,370	1,221	425		26
310	(7)	Sept. 8, 1931	50	746			87	67	122		0	864	[3] 32	12	.70	492
315	Lot 6 sec. 34	May 20, 1932		311			34	27	55		0	348	12	12		196
317	Lot 6 sec. 35	Aug. 22, 1931	55	[6] 226	44	.01	20	13	34	3.9	0	195	8.6	7.4	.62	103

See footnotes at end of table.

Chemical constituents of representative waters from the Harney Basin, Oreg.—Continued

[E. W. Lohr and S. K. Love, analysts, U. S. Geological Survey. See tables, pp. 137 and 181, for description data for wells and springs]

Samples from wells and springs—Continued

No. on pl. 2	Location	Date of collection	Temperature (°F.)	Sum of constituents [1]	Analyses (parts per million)										
					Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K) [2]	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness (as $CaCO_3$) [3]
	T. 26 S., R. 32 E. "South of Malheur Lake"														
322	(7)	May 16, 1932	56	634			44	11	180	15	227	133	139		155
325	(7)	May 25, 1932	51	243			16	5.9	75	18	175	17	25		64
332	NW¼SE¼ sec. 34	Aug. 22, 1931	54	168			[3] 18	[4] 12	42	0	163	[3] 8	13	.50	[5] 70
	T. 26 S., R. 33 E.														
335	(7)	Sept. 8, 1931	52	2,502			24	86	863	63	1,761	280	318	1.0	413
336	(7)	do	50	2,374			17	48	878	124	1,396	202	417	.50	239
339	Lot 3 sec. 17	May 16, 1932	52	272			20	7.2	78	0	187	26	49	.50	80
340	Lot 13 sec. 22	do	50	20,930			5.0	6.1	8,270	2,168	7,510	3,530	3,250		38
342	SE¼SW¼ sec. 26	do	54	282			1.5	2.4	111	55	131	33	15		14
343	NE¼NE¼ sec. 27	do	51	63,000			2.9	44	21,810	546	4,020	30,100	8,560		188
	T. 27 S., R. 29 E.														
344	SW¼SW¼ sec. 3	Aug. 21, 1931	53	193			[3] 16	[4] 17	47	0	143	[3] 24	25	.05	[5] 75
		May 30, 1932	52	194			19	10	42	0	137	29	27		88
345	Lot 4 sec. 5	Aug. 21, 1931	68	212			13	4.1	67	16	134	20	26		49
	T. 27 S., R. 29½ E.														
361	NE¼SE¼ sec. 36	do	139	[6] 1,782	92	.03	13	3.0	622 12	0	601	140	562	.50	45
	T. 27 S., R. 30 E.														
368	Lot 4 sec. 4	do	65½	680			[3] 1	[4] 0	298	89	428	[3] 20	90	.25	[5] 0
370	Lot 7 sec. 8	May 18, 1932	54	5,460			5.0	4.6	2,100	227	1,343	962	1,500		31
	T. 27 S., R. 31 E.														
374	NE¼NE¼ sec. 5	May 10, 1932	51	246			24	12	60	0	268	12	6.0		109

Samples from streams and from Harney Lake

	T. 23 S., R. 31 E.														
A	Lot 8 sec. 6	May 12, 1932	....	122	....	....	29	6.8	8.3	0	121	17	1 0	....	100
	T. 24 S., R. 31 E.														
B	NW¼NW¼ sec. 21	May 10, 1932	66	165	....	....	21	7.9	35	0	177	11	3.0	....	85
	T. 24 S., R. 32 E.														
C	NW¼NW¼ sec. 21	May 14, 1932	....	172	....	....	34	11	18	0	179	19	2.0	....	130
	T. 25 S., R. 32 E.														
D	SE¼SW¼ sec. 24	May 10, 1932	66	172	....	....	36	10	17	0	175	21	2.0	....	131
	T. 26 S., R. 31 E., "South of Malheur Lake"														
E	Lot 6 sec. 35	May 20, 1932	....	88	....	....	16	5.0	12	0	94	7.0	2.0	....	60
F [8]	Harney Lake	Aug. 5, 1902	....	8,851	29	0	0	6.8	3,604 193	0	3,007	773	2,771	....	....

[1] Silica (SiO_2), iron (Fe), and nitrate (NO_3) not included.
[2] Calculated except for analyses in which sodium (Na) and potassium (K) are entered separately.
[3] Calculated except as indicated.
[4] By turbidity.
[5] By soap method.
[6] Total dissolved solids at 180° C.
[7] Unsurveyed land within meander line of Malheur and Harney "lakes."
[8] Russell, I. C., Notes on the geology of southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Bull. 217, p. 31, 1903; George Steiger, analyst.

A. Silvies River near apex of alluvial fan.
B. West Fork of Silvies River 6½ miles south of Burns, opposite Sagehen Valley.
C. East Fork of Silvies River, 5½ miles northwest of Lawen.
D. West Fork of Silvies River. 5 miles south of Lawen.
E. Donner und Blitzen River near mouth, 6 miles east of Narrows.
F. Sample taken by I. C. Russell.

Records of discharge by streams in the Harney Basin, 1903–32 [1]

No. on pl. 1	Station	Location	Period of record	Drainage area [2] (square miles)	Maximum discharge: Date	Maximum discharge: Second-feet	Minimum discharge (second-feet)
965	Silvies River near Silvies	NE¼ sec. 14, T. 20 S., R. 31 E.	1903–16	510	Apr. 16, 1904	2,320	0
966	Silvies River near Burns	SE¼ sec. 25, T. 21 S., R. 29 E.	1903–33	925	Apr. 15, 1904	4,730	.1
9610	West Fork of Silvies River near Lawen	SW¼ sec. 24, T. 25 S., R. 32 E.	1916–22	...	Apr. 16–18, 1916	1,250	0
9611	Silvies River near Lawen	Sec. 5, T. 25 S., R. 33 E.	1916		Apr. 21, 1916	272	0
9614	Emigrant Creek near Burns	SW¼ sec. 26, T. 20 S., R 29 E.	1921	...	...	...	...
953	Donner und Blitzen River near Diamond	SW¼ sec. 8, T. 32 S., R 32½ E.	1910–21	200	May 3, 1921	2,200	23.0
9510	Donner und Blitzen River near Narrows	NE¼ sec. 26, T. 29 S., R. 31 E.	1915–20	...	March 1917	780	.3
9512	Donner und Blitzen River near Voltage	Sec. 35, T. 26 S., R. 31 E.	1916–22	...	May 21, 1917	800	0
954	Mud Creek near Diamond	NW¼ sec. 4, T. 32 S., R. 32½ E.	1911–16	30	May 3, 1915	154	.1
955	Bridge Creek near Diamond	SE¼ sec. 34, T. 31 S., R. 32½ E.	1911–16	35	do	166	7.0
956	Krumbo Creek near Diamond	Sec. 19, T. 30 S., R. 32 E.	1911	...	...	...	...
957	Kiger Creek near Diamond	NW¼ sec. 10, T. 30 S., R. 33 E.	1909–21	75	May 9, 1912	330	3.2
958	Cucamonga Creek near Diamond	NE¼ sec. 7, T. 30 S., R. 33 E.	1911–16	15	May 25, 1916	77	0
959	McCoy Creek near Diamond	Sec. 12, T. 30 S., R. 32 E.	1909–29	45	June 6, 1912	300	.7
9615	Poison Creek near Burns	Sec. 34, T. 22 S., R. 31 E.	1921–22	88	Apr. 21 or 22, 1922	476	0
9616	Prater Creek near Burns	Sec. 25, T. 22 S., R. 31 E.	1921–23	16.6	Apr. 6, 1922	115	0
952	Riddle Creek near Smith	Sec. 7, T. 29 S., R. 34 E.	1911	...	...	...	...
9513	Riddle Creek near Diamond	Sec. 23, T. 28 S., R. 33 E.	1917–21	...	March 1917	330	.2
968	Silver Creek above Suntex	NW¼ sec. 30, T. 22 S., R. 26 E.	1904–23	260	Apr. 14, 1904	1,760	0
969	Silver Creek below Suntex	NE¼ sec. 14, T. 24 S., R. 27 E.	1912–23	...	Apr. 28, 1922	764	0
967	Silver Creek near Narrows	NW¼ sec. 21, T. 25 S., R. 28 E.	1917–23	...	Apr. 29 and 30, 1922	538	0
9613	Chickahominy Creek near Suntex	Sec. 29, T. 23 S., R. 26 E.	1917–22	...	Apr. 22, 1922	264	0
9617	Rock Quarry Creek near Suntex	T. 23 S., R. 28 E.	[3] 1922	...	Apr. 6, 1922	432	0
963	Malheur Lake outlet at Narrows	Sec. 26, T. 26 S., R. 30 E. ("south of Malheur Lake").[4]	1916	...	May 14, 1916	203	0
9612	Mud Lake outlet near Narrows	Sec. 17, T. 27 S., R. 30 E.[4]	1916–22	...	June 6, 1921	245	0

[1] Summarized from water-supply papers of U. S. Geological Survey and bulletins of State engineer of Oregon.
[2] Measured on maps prepared by U. S. Bureau of Reclamation, U. S. Forest Service, and Garfield Stubblefield.
[3] Total run-off in the period Mar. 30 to Apr. 20, only, 1,030 acre-feet.
[4] Unsurveyed area; location for convenience only.

Monthly run-off, in acre-feet, of streams in the Harney Basin

[Summarized from published records]

Silvies River near Silvies

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1902-3	----	----	----	----	----	----	----	[1] 4,610	3,090	553	184	238	8,680
1903-4	799	1,900	2,030	3,040	16,500	21,800	73,900	32,600	7,860	1,780	381	262	163,000
1904-5	1,220	1,430	2,680										5,330
1908-9	----	----	----	8,920	11,000	10,000	13,700	8,480	3,590	408	181	264	56,500
1909-10	500	1,160	1,780	[2] 1,840	[2] 2,460	40,600	19,200	6,080	429	144	44	75	74,300
1910-11	244	541	1,120	[2] 738	[2] 722	6,640	17,000	8,790	2,790	----	----	----	38,600
1911-12	----	----	----	----	----	----	[1] 21,600	51,000	[1] 7,770	----	----	----	80,400
1915-16	----	----	----	----	----	----	59,100	24,400	[1] 5,320	----	----	----	88,800
1920-21	----	----	----	----	----	25,600	70,200	40,500	[1] 4,230	----	----	----	141,000
1921-22	----	----	----	----	----	----	[1] 23,400	30,200	[1] 5,120	----	----	----	58,700
1922-23	----	----	----	----	----	----	20,800	10,300	[1] 1,380	----	----	----	32,500

Silvies River near Burns

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1902-3	----	----	----	----	----	----	----	[3] 13,700	6,010	1,410	492	[3] 129	21,700
1903-4	246	2,320	[3] 1,030	1,470	16,400	48,600	146,000	65,000	12,600	3,080	1,340	970	299,000
1904-5	1,860	1,960	1,890	[3] 1,600	[3] 500	----	[3] 17,800	12,600	4,390	1,400	627	542	45,200
1905-6	861	1,100	965	1,320	1,370	4,770	75,000	25,600	25,500	[3] 3,130	----	----	140,000
1908-9	----	----	[3] 346	12,000	9,890	18,100	32,000	14,600	4,670	1,290	492	476	93,800
1909-10	1,170	2,260	1,750	2,200	2,370	92,800	37,400	9,960	1,040	504	344	643	152,000
1910-11	1,080	1,750	2,050	1,790	1,790	13,200	32,500	13,500	3,020	1,350	461	476	73,000
1911-12	1,040	1,580	1,580	3,790	5,810	6,270	42,500	78,700	27,300	[2] 3,040	[2] 615	[2] 536	173,000
1912-13	----	2,380	----	----	----	[3] 7,800	58,000	[3] 28,300	----	----	----	----	96,500
1913-14	----	----	----	----	----	46,600	73,200	22,900	[2] 7,140	[4] 2,620	[2] 922	----	153,000
1914-15	----	----	----	----	----	[3] 10,600	18,200	11,100	----	----	----	----	39,900
1915-16	----	----	----	----	[2] 4,660	45,900	92,800	37,600	[3] 10,900	----	----	----	192,000
1916-17	----	----	----	----	----	[3] 2,780	45,100	94,700	25,200	2,660	1,500	934	173,000
1917-18	----	----	----	----	----	13,800	20,100	6,060	1,080	412	246	411	[5] 42,100
1918-19	861	1,270	1,150	824	2,920	12,300	67,300	20,900	2,510	799	584	1,930	114,000
1919-20	2,630	1,740	1,400	9,410	5,560	8,120	23,100	23,800	3,330	799	369	357	80,600
1920-21	----	----	----	----	----	52,100	103,000	65,200	15,800	----	----	----	236,000
1921-22	----	----	----	----	----	3,810	44,100	59,900	8,750	1,210	----	----	118,000

[1] Part of month only, as follows: 1903, May 9-31; 1912, Apr. 11-30, and June 1-9; 1916, June 1-13; 1921, June 1-11; 1922, Apr. 16-30 and June 1-20; 1923, June 1-9.
[2] Estimated.
[3] Part of month only, as follows: 1903, May 10-31, Sept. 1-12 and 17, and Dec. 1-26; 1905, Jan., 17 days only, Feb. 1-6, and Apr. 9-30; 1906, July 1-24; 1908, Dec. 14-31; 1913, Mar. 9-31, and May 1-26; 1915, Mar. 8-31; 1916, June 1-19; 1917, Mar. 25-31.
[4] Based on mean of five determinations.
[5] Total run-off for 1917-18 estimated as 63,000 acre-feet.

Monthly run-off, in acre-feet, of streams in the Harney Basin—Continued

[Summarized from published records]

Silvies River near Burns—Continued

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1922-23	1,380	1,800	1,980	3,870	3,000	9,720	34,500	15,000	6,430	1,990	842	678	81,200
1923-24	1,410	1,400	1,430	1,510	14,500	4,320	7,680	2,050	690	244	237	183	35,700
1924-25	461	1,040	1,050	6,400	16,000	26,700	41,800	18,000	6,550	1,400	449	518	120,000
1925-26	1,380	1,850	2,370	[2] 1,860	11,300	14,100	12,700	3,030	649	160	92	286	49,800
1926-27	388	875	3,600	3,410	5,240	19,900	43,600	38,100	13,400	2,280	775	684	132,000
1927-28	1,020	1,430	2,960	4,960	3,640	40,500	42,000	23,400	3,720	1,250	508	506	126,000
1928-29	824	1,130	1,320	3,160	4,410	15,600	13,100	8,790	3,430	1,140	529	791	54,200
1929-30	935	1,180	2,340	1,860	5,490	4,670	2,580	1,660	539	220	154	205	21,800
1930-31	462	503	947	2,370	2,320	6,030	7,380	1,400	379	140	68	98	22,100
1931-32	239	308	[2] 615	[2] 615	[2] 1,150	15,700	50,200	24,500	4,520	407	213	148	98,615
1932-33	448	898	689	[2] 922	[2] 1,110	3,010	16,500	21,000	6,430	806	137	143	52,100

West Fork of Silvies River near Lawen

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1915-16							57,600	27,700	7,620				92,900
1916-17							[5a] 9,490	61,200	18,100	[5a] 1,010			89,800
1918-19							8,030	7,440					15,470
1921-22							[5a] 850	1,270	2,350				4,470

Silvies River near Lawen

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1915-16							9,100	3,790	[6] 931				13,800

Emigrant Creek near Burns

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1920-21						[7] 13,100	[7] 22,400						35,500

Donner und Blitzen River near Diamond [8]

1908-9				[2] 4,920	[2] 4,100	[2] 7,070	[2] 11,000	[2] 18,300	[2] 23,100	[2] 5,840	[2] 2,520	[2] 2,380	79,200
1909-10	[2] 3,820	[2] 6,130	[2] 4,720	[2] 5,660	[2] 6,890	[2] 25,300	[2] 21,600	[2] 18,600	[2] 10,300	[2] 4,380	[2] 2,520	[2] 2,380	112,300
1910	[2] 3,070	[2] 2,980	[2] 3,690										9,740
1911						[9] 13,300	8,930	11,000	19,100	5,560	2,200	2,040	62,100
1911-12	2,510	1,950	2,180	[10] 5,630	7,420	11,300	17,600	34,500	34,600	5,770	3,920	[10] 2,740	130,000
1912-13	3,070	3,600	2,410	2,060	2,510	7,810	18,300	22,100	15,100	7,810	4,460	2,830	92,100
1913-14						[11] 9,160	14,200	29,600	15,800	7,500	3,140	[11] 3,450	82,800
1914-15	3,740	2,950	1,810	1,600	1,690	2,630	6,900	39,900	12,000	6,050	2,340	2,500	84,100
1915-16	1,830	1,730	1,600	1,560	4,000	23,000	10,700	17,400	18,300	7,810	4,670	3,470	96,100
1916-17							[9] 15,400	37,100	47,700	11,300	3,650	3,040	118,000
1917-18	2,890	2,800	2,890	2,840	4,540	7,260	10,200	12,900	10,400	2,600	1,920	1,910	63,200
1918-19	2,430	2,140	2,460	2,460	2,780	8,550	19,000	23,400	7,320	2,800	1,710	1,690	76,700
1919-20	2,060	2,040	2,770	3,900	2,660	5,960	10,600	29,100	16,200	6,460	2,660	2,410	86,800
1920-21	3,520	5,550	6,460	5,670	17,200	20,900	11,800	30,900	23,000	6,270	4,140	3,870	139,000

Donner und Blitzen River near Narrows [8]

1914-15						[12] 2,210	6,960	17,400	11,100	4,480			42,200
1915-16							[12] 8,320	11,600	12,500	[12] 5,400			37,800
1916-17							[12] 11,700	25,200	25,500	9,870	[12] 1,210		73,200
1917-18	3,070	[2] 3,490	[2] 4,180	[2] 4,480	[2] 3,940	[2] 6,960	7,290	9,970	6,760	[2] 1,930	[2] 820	619	53,500
1918-19	1,770	2,390	2,910	2,770	2,770	[2] 7,130	[2] 14,900	[2] 19,900	[2] 2,450				57,000
1919-20	2,130	3,550	6,700	7,750	3,950	8,730	11,100	21,300	12,600	4,280	3,140		85,300

Donner und Blitzen River near Voltage

1915-16							[13] 6,100	8,920	15,000	7,810	[14] 3,150	[15] 2,830	43,800
1916-17	2,580	2,780	[2] 2,460	[2] 2,150	[2] 1,390	5,500	27,100	29,200	26,800	12,300	3,380	3,360	119,000
1917-18						[16] 5,530	[13] 5,180	1,690					12,400
1918-19						[13] 2,050	7,440	10,600	[13] 2,630				22,700
1920-21						[2] 25,000	[2] 12,000	14,100	21,300	3,750	[13] 182		76,300
1921-22						[13] 3,660	11,700	6,210	[13] 8,810				30,400

[2] Estimated.
[5a] Part of month only, as follows: 1917, Apr. 8-30 and July 1-11; 1922, Apr. 3-30.
[6] June 1-15 only.
[7] Part of month only, as follows: Mar. 11-31 and Apr. 1-25.
[8] Includes diversions by canal.
[9] Part of month only, as follows: 1911, Mar. 16-31; 1917, Apr. 15-30.
[10] Based on mean determined from days on which gage was read.
[11] Based on mean of 6 determinations.
[12] Part of month only, as follows: 1915, Mar. 21-31; 1916, Apr. 7-30 and July 1-17; 1917, Apr. 16-30 and Aug. 1-12.
[13] Part of month only, as follows: 1916, Apr. 6-30; 1918, Apr. 17-30; 1919, Mar. 20-31 and June 1-6; 1921, Aug. 1-5; 1922, Mar. 17-31 and June 1-26.
[14] Based on mean of 8 determinations.
[15] Based on mean of 4 determinations.
[16] **From records of the State engineer of Oregon.**

Monthly run-off, in acre-feet, of streams in the Harney Basin—Continued

[Summarized from published records]

Mud Creek near Diamond

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1910-11						[17] 294	625	916	[2] 750	[2] 68	[2] 15	[2] 12	2,680
1911-12	[2] 12	[2] 12	[2] 12	278	101	57	916	3,630	1,360	62	55	48	6,540
1912-13	85	86	69	77.5	65.5	256	1,370	1,950	456	224	76.2	59.5	4,770
1913-14	[2] 61	55	58	92	54	178	982	836	296	98	23	30	2,760
1914-15	46	48	30	25	22	49	195	1,640	393	116	6	9	2,580
1915-16	14	17	12	15	134	540	575	1,540	833	199	22	18	3,920

Bridge Creek near Diamond

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1910-11						[17] 372	922	1,050	815	633	615		4,410
1911-12				1,060	656	603	1,550	2,510	1,460	867	818	774	10,300
1912-13	812	774	799	812	678	812	1,180	1,780	904	842	885	833	11,100
1913-14	[2] 861	857	861	972	778	910	1,190	1,380	702	676	738	714	10,600
1914-15	738	714	664	492	444	492	488	1,090	643	615	615	595	7,590
1915-16	461	446	461	461	851	1,050	851	1,830	1,090	873	738	714	9,830

Krumbo Creek near Diamond

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1910-11						[18] 610	348	216	196	[18] 103			1,470

Kiger Creek near Diamond

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1908-9					1,040	1,620	4,890	7,990	9,040	1,910	646	595	27,700
1909-10	701	1,300	1,800	1,760	1,730	3,710	5,210	4,780					21,000
1910-11						[19] 1,730	4,210	4,910	6,130	1,410	615		19,000
1911-12					[19] 793	1,750	5,840	13,200	11,800	2,770	1,990	952	39,100
1912-13	1,510	1,680						7,620	4,590	1,780	744		17,900
1915-16							[19] 2,580	3,500	5,090	2,930	830		16,900
1916-17							[19] 2,780	9,780	11,400	[19] 2,130			26,100
1917-18							[19] 1,010	3,780	2,820	588	312	356	[20] 8,870
1918-19	406	474	[2] 553	[2] 430	[2] 500	953	5,110	7,500	2,600	916	379	433	20,300
1919-20								8,060	4,270	1,840	701	726	15,600
1920-21	[19] 598					[19] 1,560	3,710	5,840					11,700

Cucamonga Creek near Diamond

1915–16							[21] 337	689	368	188	33		1,620

McCoy Creek near Diamond

1908–9					[22] 862	1,130	1,990	4,920	4,830				13,700
1909–10								[22] 1,290	1,260	238	69	111	2,960
1910–11	232	293	315	[2] 430	[2] 222	[2] 1,080	1,510	3,340	6,550	1,200	272	234	15,700
1911–12	399	412	[2] 235	658	788	461	2,040	6,640	8,210	916	368	195	21,300
1912–13	375	375	226	372	360	363	1,560	6,580	[22] 4,270				14,500
1913–14	793	494	[2] 369	553	333	762	2,970	5,740	2,150	646	92	179	15,100
1915–16							[22] 1,240	4,330	5,160	2,690	366		13,800
1916–17							[22] 1,140	4,070	8,690	2,870	518	355	17,600
1917–18	365	393	342	278	228	389	1,540	3,600	2,520	259	132	90	10,100
1918–19	97	106	144	137	200	447	2,220	7,320	1,760	400	184	206	13,200
1919–20							1,200	4,960	4,150	1,480	306	425	12,500
1920–21	589	904	1,010	898	1,660	1,550	1,890	7,320	7,140	1,640	695	515	25,800

Poison Creek near Burns

1920–21						[23] 4,610	1,990	[23] 126					6,730
1921–22							[23] 3,920	[23] 524					4,440

Prater Creek near Burns

1920–21						[24] 1,110	869	148	[24] 28.7				2,160
1921–22						[24] 33.3	1,130	577	[24] 39.9				1,780
1922–23						133	380	73	[24] 8				594

Riddle Creek near Smith

1910–11						[25] 2,160	1,680	879	369				5,090

[2] Estimated.
[17] Mar. 18–31 only.
[18] Part of month only, as follows: Mar. 17–31 and July 1–18.
[19] Part of month only, as follows: 1911, Mar. 14–31; 1912, Feb. 14–29; 1916, Apr. 11–30; 1917, Apr. 14–30 and July 1–17; 1918, Apr. 22–30; 1920, Oct. 1–17; 1921, Mar. 18–31.
[20] Total run-off for the year 1917–18 estimated as 11,800 acre-feet.
[21] Apr. 11–30 only.
[22] Part of month only, as follows: 1909, Feb. 2–28; 1910, May 23–31; 1913, June 1–22; 1916, Apr. 11–30; 1917, Apr. 14–30.
[23] Part of month only, as follows: 1921, Mar. 7–31, and May 1–27; 1922, Apr. 2–30 and May 1–21.
[24] Part of month only, as follows: 1921, Mar. 8–31 and June 1–18; 1922, Mar. 29–31 and June 1–24; 1923, June 1–23.
[25] Mar. 10–31 only.

Monthly run-off, in acre-feet, of streams in the Harney Basin—Continued

[Summarized from published records]

Riddle Creek near Diamond

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1916–17						[26] 2,520	7,970	6,700	1,870	455	566	411	20,500
1917–18						[26] 1,040	893	69 5	47.4	120	102	[26] 44.7	2,320
1918–19						824	2,800	564	60	[26] 7			4,260
1919–20						[26] 714	2,800	1,530	527				5,570
1920–21					[26] 3,430	3,440	1,080	935	[26] 118				9,000

Silver Creek above Suntex

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1903–4				[2] 615	[2] 1,150	[2] 27,700	[2] 55,600	12,700	2,300	[2] 3,330	[2] 357	[2] 155	104,000
1904–5	141	369	885	3,610	2,320	7,870	6,540	3,130	922				25,800
1905–6					2,150	5,690	25,900	5,070	7,320	[27] 805			46,900
1908–9					2,080	3,580	10,800	1,910	613	258	33	0	19,300
1909–10	248	462	429				6,360	1,410	444	106	0	0	9,460
1910–11	[2] 107	[2] 238	278			7,990	[27] 7,940						
1911–12						[27] 1,760	22,100	14,800	1,980				40,600
1913–14						23,600	13,200	[27] 720					37,500
1914–15						[27] 5,710	10,800	[27] 438					16,900
1915–16						[27] 14,200	16,500	[2] 3,260					34,000
1916–17							11,400	16,500	2,290				30,200
1917–18						[27] 4,820	4,000	498					9,320
1918–19						[27] 3,880	20,100	2,710					26,700
1919–20				[27] 3,530	1,650	1,960	10,200	4,040					21,400
1920–21					[27] 1,780	17,500	19,800	[2] 5,530	[2] 2,380				47,000
1921–22							19,300	14,900	1,540				35,700
1922–23					[2] [27] 40	2,380	10,900	2,900					16,200

Silver Creek below Suntex

Year	October	November	December	January	February	March	April	May	June	July	August	September	The year or period
1911–12						[28] 674	12,100	13,200	940				26,900
1912–13								1,230	12				1,240
1913–14					[28] 1,120	17,600	11,200	1,300	[28] 127				31,300
1918–19						[28] 4,360	15,900	[28] 1,100					21,400
1920–21						15,200	18,200	5,340	1,720				40,500
1921–22							17,900	14,900	[28] 139				32,900

Silver Creek near Narrows

1916–17							6,070	14,000	696				20,800
1918–19						[29] 2,640	14,800	[29] 772					18,200
1919–20						[29] 163	3,660	[29] 1,510					5,330
1920–21						12,200	15,500	4,760	[29] 1,410				33,900
1921–22							[29] 12,700	13,500	[29] 378				26,600

Chickahominy Creek near Suntex

1916–17						102	739						850
1921–22						[30] 17.5	2,510	[30] 19.8					2,550

Rock Quarry Creek near Suntex

1921–22													[31] 1,030

Malheur Lake outlet at Narrows

1915–16							[2] 1,550	[2] 10,900	[2] 8,690	[2] 3,700			[2] 24,800

Mud Lake outlet near Narrows

1915–16								[32] 3,260	4,930	1,460			9,650
1916–17							[32] 714	9,280	11,700	3,630	1,140	1,170	27,900
1917–18							[2] 2,980	[2] 1,350	[2 32] 99				[2] 20,000
1920–21								[32] 2,980	10,900	3,030	1,380		18,300
1921–22								2,920	2,200	123			5,240

[2] Estimated.
[26] Part of month only, as follows: 1917, Mar. 27–31; 1918, Mar. 17–31 and Sept. 1–16; 1919, July 1–5; 1920, Mar. 14–31; 1921, Feb. 10–28 and June 1–4.
[27] Part of month only, as follows: 1906, July 1–14; 1911, Apr. 1–22; 1912, Mar. 22–31; 1914, May 1–10; 1915, Mar. 14–31 and May 1–5; 1916, Mar. 11–31; 1918, Mar. 17–31; 1919, Mar. 21–31; 1920, Jan. 18–31; 1921, Feb. 11–28; 1923, Feb. 27–28.
[28] Part of month only, as follows: 1912, Mar. 12–31; 1914, Feb. 23–28, and June 1–20; 1919, Mar. 21–31 and May 1–17; 1922, June 1–17.
[29] Part of month only, as follows: 1919, Mar. 23–31 and May 1–5; 1920, Mar. 30–31 and May 1–16; 1921, June 1–13; 1922, Apr. 4–30 and June 1–15.
[30] Part of month only, as follows: 1922, Mar. 30–31 and May 1–5.
[31] Mar. 30 to Apr. 20, 1922.
[32] Part of month only, as follows: 1916, May 10–31; 1917, Apr. 25–30; 1918, June 1–10; 1921, May 17–31.

Staff gages in Malheur Lake

Designation	Agency [1]	Location	Gage datum: Term of use	Gage datum: Altitude (feet)[2]	Adjustment of previous altitude (foot)
Narrows Bridge [3]	G, O	County bridge across the Narrows, a quarter of a mile west of former post office of Narrows	May 14, 1903, to July 21, 1906.	4,087.67	−0.33
			Mar. 27, 1909, to Sept. 16, 1911.	4,088.55	−.33
			Mar 9, 1912, to June 13, 1914.	4,088.73	−.33
			Mar. 31, 1916, to Sept. 26, 1922.	4,088.53	−.33
Near Voltage	B	About 2 miles northeast of headquarters of Lake Malheur Reservation and 2½ miles north of Voltage.	June 5, 1921, to July 9, 1926.	[4] 4,090.29	
			On and after Mar. 3, 1927.	4,089.80	
Showen Bridge, near Lawen.	O	NW¼NE¼ sec. 31, T. 26 S., R. 32 E., 5 miles south of Lawen, on north side of Showen Bridge.	Mar. 22, 1922	[5] 4,091.17	+.17
			May 3, 1922	4,091.27	+.17
			Sept. 24, 1922	4,091.37	+.17
Near Voltage	O	Northeast of George Benson's cabin, about 1¼ miles northeast of headquarters of Lake Malheur Reservation and 2 miles northwest of Voltage.	Mar. 24 to Sept. 29, 1922.	4,091.09	−.27
Graves Ranch, near Lawen.	O	About 6½ miles southeast of Lawen and 1 mile south of dwelling on Graves ranch.	Mar. 26 to Sept. 24, 1922.	4,091.06	+.04
Pelican Point, near Lawen.	O	About 7 miles southeast of Lawen.	June 23 to Sept. 30, 1922.	4,091.35	+.34
Near Voltage	G	About 2½ miles northeast of headquarters of Lake Malheur Reservation and 2¾ miles north of Voltage.	Sept. 12, 1930, to Mar. 13, 1931.	4,090.42	

[1] G, U. S. Geological Survey, data published in water-supply papers; B, U. S. Biological Survey, data not published; O, Oregon State Land Board, data from Cooper, R. D., Malheur Lake Survey, 1922 (typewritten report), 1923.
[2] Adjusted to datum of U. S. Geological Survey benchmark at Narrows, altitude 4,095.87 feet. See Pecore, C. W., Supreme Court of the United States, October term, 1932, United States of America v. State of Oregon, Joint abstract of record, vol. 1, p. 174, 1932.
[3] Water at gage disconnected from the lake when water-surface altitude is less than 4,091.5 feet (approximately); altitude of bottom of channel at gage 4,089.1 feet.
[4] Datum of gage determined by comparison with gages of the Oregon State Land Board near Voltage and at Graves ranch.
[5] Showen Bridge unstable; water-surface altitudes (after Cooper) assumed to have been adjusted for rising gage.

Altitude of water surface at staff gages in Malheur Lake, 1903–32

Narrows Bridge

Date of measurement	Altitude of water surface (feet)[1]
1903	
May 14	93.4
June 1	93.3
June 15	93.3
July 1	93.0
July 15	92.7
Aug. 1	92.3
Aug. 15	91.9
Sept. 1	91.0
Sept. 15	90.3
Oct. 1	89.6
Oct. 15	89.2
Nov. 1	89.1
Nov. 15	89.1
Dec. 1	89.3
Dec. 15	89.6
1904	
Jan. 1	89.5
Jan. 15	89.4
Feb. 1	89.3
Feb. 15	89.5
Mar. 1	89.6
Mar. 15	89.9
Apr. 1	93.3
Apr. 15	94.1
Apr. 30	94.9
May 15	95.0
June 1	94.7
June 15	94.6
July 1	94.4
July 15	94.2
Aug. 1	94.0
Aug. 15	93.7
Sept. 1	93.4
Sept. 15	93.1
Oct. 1	93.1
Oct. 15	93.1
Nov. 1	93.3
Nov. 15	93.3
Nov. 20	92.8
1905	
June 16	93.35
July 8	93.30
July 15	93.15
July 22	93.00
July 29	92.85
Aug. 5	92.65
Aug. 12	92.45
Aug. 19	92.25
Aug. 26	92.05
Sept. 2	91.85
Sept. 9	91.65
Sept. 16	91.50
Sept. 23	91.25
Sept. 30	91.15
Oct. 7	91.10
Oct. 14	90.95
Oct. 21	90.85
Oct. 28	90.75
Nov. 4	90.65
Nov. 11	90.55
Nov. 18	90.45
Nov. 25	90.4
Dec. 2	90.35
Dec. 9	90.3
Dec. 16	90.3

Date of measurement	Altitude of water surface (feet)[1]
1906	
Jan. 6 to Mar. 3	91.25
Mar. 10	91.4
Mar. 17–24	91.55
Mar. 31	92.1
Apr. 7	92.4
Apr. 14	92.45
Apr. 21	92.65
Apr. 28	93.15
May 5	93.3
May 12	93.4
May 19	93.35
May 26	93.35
June 2	93.55
June 9	93.60
June 16	93.65
June 23	93.75
June 30	93.85
July 7	93.9
July 14	93.6
July 21	93.5
1909	
Mar. 27	90.55
Sept. 4	90.25
Sept. 5	90.25
Sept. 6	90.15
Sept. 7	90.15
Sept. 8	90.05
1911	
Mar. 22	91.8
Mar. 25	91.9
Mar. 28	91.9
Mar. 31	91.9
Apr. 2	92.0
Apr. 4	92.0
Apr. 6	92.1
Apr. 9	92.55
Apr. 11	92.55
Apr. 14	92.65
Apr. 17	92.7
Apr. 20	92.75
Apr. 23	92.8
Apr. 26	92.8
Apr. 29	92.85
May 1	92.85
May 3	92.9
May 6	92.9
May 9	92.9
May 12	92.9
May 15	92.9
May 18	92.85
May 21	92.85
May 24	92.85
May 27	92.9
May 30	92.9
June 1	92.8
June 4	92.8
June 6	92.75
June 9	92.75
June 12	92.75
June 15	92.75
June 18	92.7
June 21	92.7
June 24	92.65
June 27	92.6

Date of measurement	Altitude of water surface (feet)[1]
1911	
June 30	92.6
July 1	92.55
July 8	92.55
July 15	92.55
July 22	92.55
July 29	92.35
Aug. 2	92.15
Aug. 5	91.95
Aug. 12	91.65
Aug. 19	91.35
Aug. 26	91.3
Sept. 2	90.15
Sept. 9	89.65
Sept. 16	(2)
1912	
Apr. 13	[3] 89.05
Apr. 20	89.25
Apr. 27	89.45
May 4	[4] 89.65
May 6	90.05
May 7	90.65
May 8	91.35
May 9	92.05
May 10	92.25
May 11	92.45
May 13	92.55
May 15	92.60
May 18	92.65
May 20	92.75
May 22	92.85
May 25	92.95
May 28	93.05
June 1	93.15
June 8	93.55
June 11	93.75
June 15	93.85
June 22	94.05
June 29	94.35
1913	
Apr. 2	93.55
Apr. 5	[5] 93.55
Apr. 12	93.65
Apr. 19	93.85
Apr. 26	93.95
May 3	93.95
May 10	94.05
May 17	94.25
May 24	94.35
May 31	94.35
June 7	94.25
June 14	94.25
June 21	94.35
June 28	94.45
July 14	[6] 94.24
Aug. 17	94.05
Aug. 23	94.0
Aug. 28	93.95
1914	
Feb. 11	[6] 93.78
June 1	94.90
June 8	94.90
June 13	94.90

Date of measurement	Altitude of water surface (feet)[1]
1916	
Mar. 31	91.10
Apr. 6	91.10
Apr. 25	92.74
May 1	93.21
May 6	93.43
May 14	93.53
May 22	93.73
May 26	93.78
June 7	93.93
June 13	93.88
Oct. 25	92.25
1917	
Apr. 13	93.01
Apr. 20	93.37
Apr. 21	93.48
Apr. 22	93.47
Apr. 25	93.43
Apr. 27	93.43
June 16	94.63
July 20	94.33
1922	
Mar. 24	93.1
Apr. 2	93.1
Apr. 9	93.6
Apr. 16	93.6
Apr. 24	93.7
Apr. 26	93.7
May 3	93.7
May 6	93.7
May 7	93.7
May 8	93.8
May 9	93.7
May 11	93.7
May 14	93.7
May 18	93.8
May 20	93.8
May 21	93.8
May 22	93.8
May 24	93.8
May 27	93.8
June 1	93.8
June 4	93.7
June 5	93.8
June 7	93.8
June 9	93.8
June 11	93.8
June 13	93.8
June 16	93.8
June 19	93.7
June 22	93.7
June 24	93.7
June 26	93.7
June 29	93.6
July 1	93.6
July 4	93.6
July 7	93.5
July 11	93.5
July 28	93.0
July 29	92.9
Aug. 15	92.5
Aug. 18	92.4
Sept. 12	91.8
Sept. 16	91.7
Sept. 20	91.7
Sept. 26	91.6

[1] In excess of 4,000 feet above sea level.
[2] Channel dry.
[3] Water seeping into channel near gage from Apr. 13 to May 4.
[4] Malheur Lake broke through natural dike, and water in channel rose rapidly.
[5] Considerable ice in channel.
[6] Altitude by Cooper & Dodge by leveling.

Altitude of water surface at staff gages in Malheur Lake, 1903–32—Continued

Near Voltage

[United States Biological Survey gage]

Date of measurement	Altitude of water surface (feet) [1]	Date of measurement	Altitude of water surface (feet)	Date of measurement	Altidute of water surface (feet)	Date of measurement	Altitude of water surface (feet)
1921		1923		1925		1928	
June 5	94.87	May 6	94.08	Oct. 13	91.04	May 20	93.63
June 23	94.95	June 4	92.79	Nov. 4	91.16	May 25	93.63
July 4	94.62	June 10	92.75	Dec. 5	91.12	June 12	93.17
July 14	94.58	June 24	92.54	1926		June 26	92.96
July 22	94.37	June 30	92.49	Jan. 31	91.29	July 7	92.84
July 29	94.21	July 22	92.21	Feb. 18	91.49	July 27	92.50
Aug. 7	94.04	Aug. 9	91.91	Mar. 4	91.29	Aug. 6	92.26
Aug. 14	93.91	Aug. 18	91.83	Apr. 6	91.29	Sept. 9	91.72
Aug. 21	93.77	Sept. 11	91.45	June 26	91.21	Sept. 23	91.63
Aug. 28	93.67	Oct. 17	91.45	July 9	91.12	Oct. 13	91.55
Sept. 4	93.58	Nov. 1	91.54		([4])	1929	
Sept. 25	93.37	1924		1927		Mar. 27	92.50
Oct. 17	93.29	Jan. 31	91.99	Mar. 3	91.30	Apr. 10	92.50
Nov. 7	93.25	Feb. 16	92.21	Apr. 7	91.30	Apr. 25	92.55
Dec. 27	93.49	Feb. 23	92.25	Apr. 24	91.42	June 5	92.05
1922		Mar. 2	92.29	June 5	92.22	July 16	91.92
Jan. 24	93.62	Apr. 26	91.95	June 24	92.55	July 27	91.55
Mar. 24	94.08	May 11	91.87	June 28	92.63	Aug. 12	91.38
Apr. 2	94.08	May 30	91.41	July 13	92.46	Aug. 31	91.30
Apr. 23	94.21	June 22	[3] 91.04	July 22	92.30	1930	
May 14	94.58	July 13	91.29	July 28	92.22	Feb. 25	91.59
May 24	94.58	July 21	91.21	Aug. 4	92.13	Mar. 26	91.63
June 11	94.49	Aug. 11	91.12	Aug. 9	92.09	May 23	91.13
June 20	94.37	Sept. 3	91.13	Aug. 26	91.88	May 27	91.05
June 25	94.25	Nov. 20	91.08	Sept. 7	91.72	July 12	91.13
July 6	93.99	1925		Sept. 14	[5] 91.76	July 24	91.13
Aug. 16	[1a] 92.41	Feb. 25	91.18	Nov. 5	91.55	Sept. 20	91.05
Sept. 30	92.62	Mar. 11	91.18	1928		Sept. 22	91.09
Nov. 16	92.58	Apr. 21	90.71	Feb. 17	92.63	Oct. 21	91.00
1923		May 22	91.21	Mar. 2	92.88	Dec. 3	91.09
Jan. 11	92.95	June 4	91.37	Apr. 7	93.55	1931	
Feb. 17	([2])	June 17	91.45	Apr. 13	93.63	Feb. 10	90.96
Mar. 25	93.21	July 12	91.62	Apr. 24	93.63	Mar. 13	[6] 90.59
Apr. 8	94.25	Aug. 5	91.45	Apr. 29	93.63		
		Aug. 27	91.12				

Showen Bridge, near Lawen

1922		1922		1922		1922	
Mar. 22	94.2	Apr. 18	94.6	May 3	94.5	June 11	94.6
Apr. 2	94.1	Apr. 20	94.4	May 7	94.6	June 17	94.6
Apr. 3	94.2	Apr. 23	94.4	May 10	94.7	June 27	94.3
Apr. 8	94.4	Apr. 24	94.4	May 14	94.8	July 3	94.2
Apr. 9	94.4	Apr. 25	94.4	May 17	94.8	July 6	94.1
Apr. 11	94.5	Apr. 27	94.3	May 21	94.8	July 28	93.5
Apr. 13	94.6	Apr. 28	94.3	May 24	94.7	Aug. 4	93.4
Apr. 14	94.7	Apr. 29	94.3	May 28	94.7	Aug. 15	92.8
Apr. 16	94.7	Apr. 30	94.4	May 31	94.6	Sept. 24	91.1
Apr. 17	94.6	May 1	94.4	June 4	94.6		

[1] In excess of 4,000 feet above sea level.
[1a] Probably 1 foot low.
[2] Ice 12 inches thick.
[3] Maximum depth of water in lake about 20 inches.
[4] In late July and in August 1926 water level was near zero of gage; nowhere in the lake was the water more than 6 inches deep.
[5] Rise due to increased discharge of the Donner und Blitzen River.
[6] Stage falling because water cut through mud dike beyond mouth of river; water level rising in central part of lake.

Altitude of water surface at staff gages in Malheur Lake, 1903–32—Continued

Near Voltage

[Oregon State Land Board gage]

Date of measurement	Altitude of water surface (feet) [1]	Date of measurement	Altitude of water surface (feet)	Date of measurement	Altidute of water surface (feet)	Date of measurement	Altitude of water surface (feet)
1922		1922		1922		1922	
Mar. 24	94.1	May 4	94.2	June 20	94.5	July 29	93.5
Apr. 2	94.1	May 14	94.5	July 5	94.1	Aug. 16	93.2
Apr. 9	94.1	June 7	94.5	July 6	94.0	Sept. 29	92.7
Apr. 23	94.2	June 11	94.5				

Graves ranch, near Lawen

1922		1922		1922		1922	
Mar. 26	94.1	May 21	94.5	June 5	94.4	July 2	94.0
Apr. 2	94.1	May 23	94.5	June 7	94.4	July 6	93.9
Apr. 9	94.0	May 24	94.5	June 10	94.4	July 28	93.5
Apr. 17	94.2	May 28	94.5	June 14	94.3	Aug. 5	93.4
Apr. 23	94.2	May 31	94.5	June 20	94.3	Aug. 13	93.2
Apr. 29	94.2	June 2	94.5	June 25	94.2	Aug. 20	93.0
May 12	94.4	June 3	94.5	June 28	94.1	Sept. 24	91.9

Pelican Point, near Lawen

1922		1922		1922		1922	
June 23	94.6	July 21	94.0	Aug. 11	93.6	Sept. 8	93.1
June 28	94.5	July 29	93.8	Aug. 25	93.3	Sept. 30	92.9

Near Voltage

[United States Geological Survey gage]

1930		1930		1931		1931	
Sept. 12	90.72	Oct. 21	90.67	Feb. 10	90.97	Mar. 13	90.57
Sept. 20	90.72	Dec. 3	90.77				

Altitude of water surface in Harney Lake, 1912–18

[Based on leveling from temporary bench marks assumed to be tied to the United States Geological Survey bench mark at Narrows; altitude reduced to the common datum by a correction of −0.33 foot]

Date	Altitude of water surface (feet)[1]	Authority
Mar. 12, 1912	86.48	U. S. Geological Survey Water-Supply Paper 330, p. 246, 1914.
July 14, 1913	84.4	Report to Oregon State Land Board by R. D. Cooper.
Sept. 13, 1913	84.0	Do.
May 4, 1914	86.2	Do.
Oct. 24, 1914	84.6	Do.
Mar. 31, 1916	83.5	Levels by M. V. Dodge and F. F. Henshaw.
May 31, 1916	84.7	Report to Oregon State Land Board by R. D. Cooper.
Oct. 24, 1916	83.0	
May 22, 1917	85.1	Levels by F. F. Henshaw and R. D. Cooper.
July 13, 1917	84.0±	Levels by R. C. Briggs and —— Barron.
May 21, 1918	83.7−	Report to Oregon State Land Board by R. D. Cooper.

[1] In excess of 4,000 feet above sea level.

Altitude of water surface at staff gages on streams in the Harney Basin, 1930-32

Silvies River gage

[NW¼NW¼ sec. 17, T. 23 S., R. 31 E., on south side of highway bridge, east bank of river. Zero of gage, 4,142.72 feet above sea level]

Date	Gage height (feet)	Date	Gage height (feet)	Date	Gage height (feet)	Date	Gage height (feet)
1930		1931		1931		1932	
Sept. 22	0.30	Apr. 20	5.68	Aug. 24	−0.34	Mar. 4	3.08
Sept. 27	.30	Apr. 29	5.62	Aug. 31	−.12	Mar. 19	7.20
Oct. 3	.30	May 9	5.28	Sept. 7	−.37	Mar. 26	7.30
Oct. 18	.34	May 18	4.82	Sept. 14	.56	Apr. 2	8.00
Nov. 1	.34	May 25	4.99	Sept. 21	.44	Apr. 9	7.85
Dec. 7	.48	June 1	4.34	Sept. 28	.38	Apr. 16	8.12
		June 8	4.14	Oct. 5	.00	Apr. 23	7.95
1931		June 15	4.08	Oct. 14	−.28	Apr. 30	7.90
		June 22	4.08	Oct. 19	.10	May 7	7.90
Jan. 3	.48	June 29	3.72	Oct. 26	.46	May 14	5.00
Feb. 8	.62	July 6	3.35	Nov. 10	1.98	May 23	6.22
Mar. 8	.94	July 13	.68	Dec. 6	1.80	June 6	6.08
Mar. 16	4.67	July 20	.44			June 24	5.42
Mar. 25	5.96	July 27	.14	1932		July 6	4.90
Mar. 31	6.02	Aug. 3	−.31			July 19	2.40
Apr. 5	6.66	Aug. 10	−.30	Jan. 6	2.30	Aug. 1	1.35
Apr. 11	6.12	Aug. 17	−.33	Feb. 3	2.30		

Donner und Blitzen River gage

[NE¼SW¼ sec. 35, T. 26 S., R. 31 E. ("south of Malheur Lake"), on south side of highway bridge, east bank of river. Zero of gage, altitude unknown]

1930		1931		1931		1932	
Sept. 9	0.80	Feb. 8	1.60	July 23	(2)	Mar. 9	0.60
Sept. 15	.80	Mar. 8	2.50	Sept. 4	0.04	Apr. 3	1.80
Sept. 27	[1] 1.50	Apr. 5	2.82	Oct. 2	.50	May 10	3.00
Oct. 19	.76	May 11	3.26	Nov. 11	(2)	June 7	2.09
Nov. 2	1.36	May 26	3.10	Dec. 6	(2)	July 7	2.60
Dec. 7	1.48	June 4	2.86			Aug. 3	1.10
		June 10	2.50	1932			
1931		June 20	2.58				
		July 3	2.30	Jan. 6	(2)		
Jan. 4	2.24	July 7	2.30	Feb. 4	.90		

[1] Gage moved; vertical displacement unknown.
[2] Channel dry at gage.

Poison Slough gage

[NW¼NE¼ sec. 14, T. 23 S., R. 31 E., on south side of highway bridge, east bank of river. Zero of gage 4,136.18 feet above sea level]

1932		1932		1932		1932	
Mar. 26	[1] 2.48	Apr. 23	2.68	May 23	1.40	July 19	(2)
Apr. 2	2.80	Apr. 30	2.86	June 6	.49	Aug. 1	(2)
Apr. 9	2.40	May 7	2.76	June 24	(2)		
Apr. 16	3.00	May 14	2.14	July 6	(2)		

[1] Channel dry at gage from Sept. 30, 1930, until March 1932.
[2] Channel dry at gage.

Drillers' records of wells in the Harney Basin

[Stratigraphic correlations by A. M. Piper]

No. 5, pl. 2. Frank Whiting. Land-surface altitude 4,153 feet; drilled by Boyer & Koenemann in 1930; diameter 18 inches to 82 feet, 8 inches from 82 to 155 feet, unknown 155 to 288 feet; cased to 68 feet; reported yield 300 gallons a minute when 155 feet deep, 400 gallons a minute with draw-down about 50 feet when 255 feet deep

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Danforth formation:		
Soil	10	10	Pumice or sandstone, fine, white	5	148
Gravel and sand, fine; water-bearing; static level −8 feet	15	25	Rock, black (basalt)	27	175
Clay, blue, sticky	4	29	Shale, green	30	205
Gravel, coarse, and sand	18	47	Clay, gravel, and sand in alternating layers from 2 feet to 3 feet thick	42	247
Clay, yellow and sticky, and sand	4	51	Gravel, waterworn, and sand	8	255
Gravel, fine, and sand	6	57	Clay, yellow, and sand	28	283
Clay, brown, hard	4½	61½	Sand, fine, yellow; some pebbles, white, glassy; static level −9 feet	5	288
Sand, fine, brown	5½	67			
Unclassified:					
Clay, blue	15	82			
Clay, yellow, blue, and brown; some waterworn gravel	61	143			

No. 7, pl. 2. Chas. Walker. Land-surface altitude 4,152 feet; drilled by P. S. Weiterhiller and Smitzer & Crews in 1930; diameter 24 inches to 30 feet, unknown below 30 feet; reported as "dry hole"

Valley fill:			Danforth formation—Continued.		
Soil, sand, and gravel	30	30	Lava, black, very dense and glassy	65	108
Danforth formation:			Shale, blue	120	228
Stone, pink, similar to building stone at Burns (rhyolite or tuff-breccia)	13	43			

No. 30, pl. 2. Oregon Western Colonization Co. Land-surface altitude, 4,144 feet; drilled by Hahn & Backus

Valley fill:			Danforth formation—Continued.		
Clay	16	16	Sand, black, "paraffin"	20	175
Gravel, water-bearing	9	25	Sand, gray and black	13	188
Clay	15	40	Gravel, pumiceous	22	210
Gravel, water-bearing	5	45	Shale, blue, sticky	38	248
Sand	7	52	Sand, gray and black	11	259
Gravel, water-bearing	3	55	Shale, blue to green, sticky	111	370
Quicksand	25	80	Shale, gray, and sand; little water	30	400
Danforth formation:					
Soapstone	35	115			
Gravel, pumiceous, and sand, water-bearing	40	155			

No. 32, pl. 2. P. G. Williams. Land-surface altitude 4,150 feet; drilled by P. G. Williams in 1930; diameter, 6 inches; uncased. Driller reports no water-bearing beds below zone of weathering

Danforth formation:			Danforth formation—Continued.		
Limerock	232	232	Sand, black (tuffaceous); contains many black particles	40	310
Porphyry, brown	8	240	Sand, with clay, brownish gray	40	350
Sand, light gray	20	260			
Sandstone, red	10	270			

No. 56, pl. 2. J. S. Cook. Land-surface altitude 4,143 feet; drilled by O. L. Gasch in 1931; redrilled in 1934–35; diameter 18 inches to 95 feet, 12 inches 95 to 330 feet; casing 18-inch stovepipe to 83 feet, perforated from 67 to 79 feet; 12-inch to 200 feet, perforated in place; in 1931, tested capacity 600 gallons a minute with draw-down 57 feet

Valley fill:			Harney and Danforth formations (?):		
Soil	12	12	Sand and clay, mixed	25	175
Gravel, "first flow" of water	11	23	Clay	110	285
Clay	26	49	Rock	8	293
Gravel	12	61	Clay, yellow	7	300
Clay	8	69	Gravel	3	303
Sand	4	73	Clay, black	7	310
Clay	22	95	Clay, yellow	20	330
Sand	55	150			

Drillers' records of wells in the Harney Basin—Continued

No. 64, pl. 2. William McLaren. Land-surface altitude, 4,142 feet; drilled by P. S. Weitenhiller in 1930; diameter 18 inches; casing to 53 feet, perforated 41 to 53 feet with slots 1 inch by about ½ inch; tested capacity 480 gallons a minute; draw-down unknown

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Loam, black	6	6	Muck, blue	17	38
Gravel, waterworn, pebbles up to 2 inches in diameter, some sand	15	21	Hardpan	1	39
			Gravel and sand, red	13	52
			Clay, blue	35	87

No. 65, pl. 2. Pacific Live Stock Co. Land-surface altitude, 4,146 feet; drilled by P. S. Weitenhiller and A. A. Durand; diameter 12 inches to 117 feet, 8 inches 155 to 300 feet; plugged at bottom; casing perforated from 37 to 117 feet with slots 1¼ inches by ¼ inch spaced 4 rounds to the foot, also from 160 to 240 feet with slots 1½ inches by ⅛ inch spaced 8 to the round with rounds 9 inches apart; capacity reported 150 gallons a minute while drilling and 155 feet deep, tested 940 gallons a minute when completed, draw-down unknown

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Harney formation (?):		
Soil	9½	9½	Clay, blue	38	155
Gravel, loose; cemented layers 1 foot thick at 50 and 75 feet	74½	84	Gravel, fine, or sand, coarse	105	260
Clay	6	90	Clay	8	268
Gravel, coarse, black, loose; coarser toward bottom	27	117	Sand, grains as large as ⅛ inch in diameter, black; some pebbles as large as 2 inches in diameter; considerable fine silt	32	300

No. 73, pl. 2. Oregon Short Line Railroad Co., at Burns. Land-surface altitude 4,146 feet; drilled in 1924; diameter 12 inches; cased to 100 feet; reported yield 150 to 200 gallons a minute

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Clay	5	5	Sand and clay	19	100
Sand and gravel	20	25	Danforth formation (?):		
Clay	10	35	Gravel, pumiceous	3	103
Gravel	36	71	(?); water-bearing, static level −5 feet	7	110
Sand	10	81			

No. 74, pl. 2. C. E. Silbaugh. Land-surface altitude 4,144 feet; drilled in 1930; diameter 12 inches; cased to 106 feet; reported yield 1,100 gallons a minute with draw-down 19 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Sand and gravel	30	30	Clay	3	95
Clay	8	38	Quicksand	11	106
Sand and gravel	54	92			

No. 94, pl. 2. Harney Branch Experiment Station. Land-surface altitude 4,135 feet; drilled by P. S. Weitenhiller in 1926; diameter 18 inches; initial casing to 60 feet, perforated from 42½ to 55 feet with ½-inch drilled holes 1½ inches apart; in 1930 well cleaned after caving and 16-inch casing set from 42 to 82 feet, perforated with slots 1/16 by ¾-inch spaced 1½ inches in staggered rounds. Average capacity for 20-day test in 1931, 540 gallons a minute with draw-down about 55 feet. In March 1935 16-inch casing removed and well redrilled to 93 feet; cased to 93 feet with standard 12-inch pipe perforated from 36 to 86 feet with torch-cut slots ¼ inch wide by 6 inches long spaced 3 inches horizontally and vertically

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Silt loam, sandy	1½	1½	Gravel, waterworn, and coarse sand, grading to fine sand and clay at base	12½	55
Adobe, black, angular	3½	5	Sand, fine, red	1	56
Clay, yellow	4½	9½	Clay, yellow with gray	5	61
Sand, fine, blue	1	10½	Sand, gravel, and clay	2	63
Gravel, fine; water table, static level −11 feet	1½	12	Sand, fine, blue	1	64
Gravel, fine, grading to coarse sand	2	14	Clay, blue, with blue sand layers	11	75
Clay, blue, and fine sand	1½	15½	Clay, fine, blue, coarser toward bottom, with some gravel; "third flow" of water	11	86
Clay, blue, grading to fine sand at base	6½	22	Clay, blue	½	86½
Clay, blue	17	39			
Clay, blue, and gravel, hardpan	3½	42½			

Drillers' records of wells in the Harney Basin—Continued

No. 112, pl. 2. R. W. Cozad. Land-surface altitude 4,132 feet; drilled by P. S. Weitenhiller in 1929; diameter 24 inches; casing to 64 feet, perforated from 56 to 64 feet; tested capacity 435 to 525 gallons a minute in 1931, with draw-down about 40 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Loam	6	6	Quicksand, water-bearing	5	38
Hardpan, cement	1½	7½	Clay, blue, hard and sandy	2	40
Sand, grades to gravel	2	9½	Gravel, cement	4	44
Gravel, rounded, little sand; water table, static level −9 feet	4½	14	(?)	7	51
Clay, blue, compact, with some sandy layers	19	33	Gravel, loose, water-bearing	19	70
			Clay, blue	2	72

No. 143, pl. 2. J. C. Clemens. Land-surface altitude 4,132 feet; drilled by Boyer & Koenemann in 1930; diameter 12 inches to 52 feet, 10 inches 52 to 478 feet; cased to 117 feet; artesian flow estimated 300 to 400 gallons a minute

Valley fill:			Late basalt scoria or Danforth formation—Continued.		
Soil	60	60	Clay, yellow	10	255
Sand and gravel; first artesian flow	22	82	Clay, blue, hard	58	313
Clay, blue	15	97	Shale, green	39	352
Gravel; second artesian flow	12	109	Sandstone; third artesian flow	106	458
Clay, blue, soft	98	207	Rock, red	19	477
Late basalt scoria or Danforth formation:			Soapstone; fourth artesian flow	1	478
Clay, yellow	10	217			
Clay, blue, soft	28	245			

No. 171, pl. 2. Pacific Live Stock Co. Land-surface altitude 4,128 feet; drilled by William Switzer in 1932; diameter 10 inches; cased to 121 feet

Valley fill:			Valley fill—Continued.		
Soil	8	8	Clay, blue, harder than above	30	85
Sand, water-bearing	12	20	Sand, water-bearing	1	86
Clay, blue, soft and sticky	10	30	Clay, blue (shale)	8½	94½
Sand, brown, with pea-sized gravel; water-bearing	3	33	Sand and gravel, water-bearing	3±	97½
Clay, blue, soft and sticky	15	48	Harney formation (?): Shale	207½	305
Sand, grading to marble-sized gravel	7	55			

No. 197, pl. 2. Ralph Catterson. Land-surface altitude 4,106 feet; drilled by P. S. Weitenhiller; diameter 18 inches; cased to 80 feet

Valley fill:			Valley fill—Continued.		
Soil, sandy	12	12	Quicksand, fine, black, water-bearing	18	70
Sand, very fine, and gravel, water-bearing	8	20	Clay, blue	60	130
Clay, blue	32	52	Sand and gravel	(?)	130+

No. 226, pl. 2. Pacific Live Stock Co. Land-surface altitude 4,103 feet; drilled by Boyer & Koenemann in 1931; diameter 8 inches; reported as "dry hole"

Valley fill:			Valley fill—Continued.		
Soil	2	2	Lava rock	½	49
Hardpan	6	8	Clay, yellow	2	51
Sand; little water	20	28	Sand, black, and clay	9	60
Clay, yellow	6	34	Clay, green, and sand	46½	106½
Clay, green	14½	48½			

No. 246, pl. 2. Fred Timm. Land-surface altitude 4,105 feet; drilled by Fred Timm in 1931; diameter 4 inches at top, 1½ inches at bottom; uncased

Valley fill:			Valley fills—Continued.		
Clay	52	52	Quicksand	--------	------
Sand, black, water-bearing	8	60			
Clay, variegated (black, gray, green and blue)	125	185			

Drillers' records of wells in the Harney Basin—Continued

No. 275, pl. 2. Oregon Short Line Railroad Co., at Crane. Land-surface altitude 4,134 feet; drilled by Ray Smith in 1916; diameter 10 inches; cased to 92 feet; reported yield 125 gallons a minute during a 5-hour test

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Valley fill:			Valley fill—Continued.		
Soil	22	22	Gravel, cement	8	98
Quicksand	20	42	Harney formation (at least the upper part): Shale, hard; water from rock at 410 feet	317	415
Clay	8	50			
Quicksand	40	90			

No. 331, pl. 2. Mrs. Frank Dunn. Land-surface altitude 4,099 feet; drilled by Hahn & Backus in 1930; diameter 6 inches; cased 20 feet

Valley fill: Dirt and clay (sediments)	19	19	Late basalt near Voltage—Con.		
Late basalt near Voltage:			Shale, red, broken (probably scoria)	5	75
Rock (vesicular basalt)	51	70	(?)	8½	83½

No. 332, pl. 2. Hahn & Backus. Land-surface altitude about, 4,100 feet; drilled by Hahn & Backus in 1931; diameter 8 inches at top, 6½ inches at bottom; artesian flow estimated 120 gallons a minute

Valley fill: Soil and subsoil	22½	22½	Late basalt near Voltage—Con.		
Late basalt near Voltage:			Lava, gray, hard	25	75
Lava, broken, loose	4½	27	Lava, vesicular and broken; vesicles filled with white talcose material	55	130
Lava, brownish black, hard	17	44			
Rock, broken	½	44½			
(?)	5½	50			

Hydrologic data for representative wells in the Harney Basin, Oreg.

[Use of water—D, domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Altitude above sea level (feet)	Observed extremes of ground-water stage, 1930 (feet below measuring point): Lowest	Observed extremes of ground-water stage, 1930 (feet below measuring point): Highest	Use	Temperature (°F.)	Remarks
	T. 22 S., R. 31 E.												
1	NW¼NE¼ sec. 25	Charles Richmond	490	10 in	[2]	Top of casing	+0.5	4,180	24.65	10.05	None		"Dry hole"; penetrates "shale" of Danforth formation from 35 feet to 490 feet.
2	SW¼NW¼ sec. 27	Unknown	10	5 ft	Qal	Top of platform	.0	4,173	8.40	[3] 2.55	S		
4	SW¼NE¼ sec. 34	—— Baker	9		Qal	do	+1.0	4,157	8.05	[5] 6.45	S		
[4] 5	SW¼SW¼ sec. 34	Frank Whiting	288	18 to 8 in	Td	Top of casing	+1.0	4,154	13.15	3.35	S		
6	NW¼NE¼ sec. 36	Charles Walker	228	24 to 18 in	Td	do	+1.5	4,153	6.90	[3] 5.60	None		
7	NE¼NW¼ sec. 36	L. S. Hebener	36	18 in	Qal	do	+1.0	4,155	15.25	12.25	S		
	T. 22 S., R. 32 E.												
[4, 6] 8	NE¼SE¼ sec. 25	Alex Rogers	11	5½ ft	Qal	Top of platform	+.5	4,147	10.25	3.50	D	53	Uncased.
[4, 6] 10	NE¼NW¼ sec. 34	William Krzeska	14	6 ft	Qal	do	.0	4,144.5	11.75	10.70	None	46	Do.
[4] 11	NW¼NE¼ sec. 36	Frank Triska	44	6 in	Qal	Top of casing	+.6	4,133	10.85	4.45	D		Cased 44 feet.
[4] 12	do	do	16	8 in	Qal	do	+2.0	4,134	11.35	11.15	None		Casing pulled and well filled up in May, 1931.
	T. 22 S., R. 32½ E.												
[4] 14	NE¼NW¼ sec. 36	I. L. Poujade	14	5 ft	Qal	Top of platform	.0	4,143	13.40	9.30	do		Uncased.
	T. 22 S., R. 33 E.												
16	NE¼NE¼ sec. 34	Unknown	22	6 by 6 ft	Qal	[2]	+1.0	4,166	14.75	9.25	D		Measuring point, top of 12- by 12-inch timber.

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point			Observed extremes of ground-water stage, 1930 (feet below measuring point)		Use	Temperature (°F.)	Remarks
						Description	Above or below land surface (feet)	Altitude above sea level (feet)	Lowest	Highest			
	T. 23 S., R. 30 E.												
17	NE¼SE¼ sec. 12	City of Burns	251	12 in	Td	Pressure gage	+4.5	4,233.7			P	57	Cased 151 feet.
[6] 18	do	do	251	12 in	Td	do	+4.5	4,233.7			P	58	Do.
19	do	Unknown	115	4 in	Td	Top of casing	−5.0	4,215.70	74.55	73.65	None		Cased 40 feet.
21	NE¼SE¼ sec. 23	Stafford, Derbes & Roy. Co.	170	6 in	Td	(2)	+.8	4,159.45			P		Cased 100± feet. Measuring point, top of casing collar.
[6] 22	NE¼SW¼ sec. 23	City of Hines	340	12 in	Td	Pressure gage	.0	4,314.9			P	62	
23	NE¼NE¼ sec. 24	Harney County fair grounds.	16	2 in	Qal	Top of casing	+1.8	4,149	6.40	4.35	None		Filled within 5 feet of the top during winter of 1930–31.
24	NE¼SE¼ sec. 26	Edward Hines Western Pine Co.	174	10 in	Qbh						Ind	76	Cased 100 feet. Flowed 200 gallons a minute when drilled.
25	do	do	152	10 in	Qbh						Ind		
26	do	do	78	18 in	Qal	do	+1.0	4,148			None		Filled up to 53 feet.
	T. 23 S., R. 31 E.												
[4] 30	SW¼SW¼ sec. 1	—— Davidson	400	8 in	Td?	do	−8.4	4,135.28	7.54	2.90	S		
[4] 31	do	do	22	5 ft	Qal	(2)	.0	4,144.28	14.05	13.30	None		Measuring point, top of 6-inch casing in dug portion.
32	Lot 4, sec. 2	P. G. Williams	350	6 in	Td	Top of platform	.0	4,150	11.50	[7] 11.00	S		No casing.
[4 6] 33	NW¼SW¼ sec. 2	Unknown	13	4 by 6 ft	Qal	Top of curb	+1.5	4,145	11.70	10.00	None		Do.
34	Lot 4 sec. 3	Unknown	33	18 in	Qal	Top of casing	+1.0	4,154	9.30	9.30	do		
35	NW¼SW¼ sec. 3	R. E. Peabody	123	18 in	Qal	do.	.0	4,150	9.40	6.45	Ir	55	Cased 45 feet. Irrigates 2-acre garden.
36	do	do	122	4 in	Qal	do	+.2	4,149	8.50	8.50	D		Cased 67 feet.
[4 6] 37	Lot 2 sec. 4	L. M. Hamilton	98	18 in	Qal	do	+1.0	4,153	13.43	8.45	None	52	Cased 50 feet.

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38	Lot 4 sec. 4	S. Hoeg	41		Qal	Top of platform	+1.0	4,156	15.35	10.10	D		
39	SW¼SW¼ sec. 4	L. M. Hamilton	15	4½ ft	Qal	do	.0	4,152	11.50	[8] 1.95	Ir		Irrigates small garden.
[4] 40	Lot 3 sec. 5	William Hanley Co.	42	3 feet	Qal	(2)	+2.0	4,162	16.88	8.65	D		Measuring point, copper washer in top of well cover.
41	SW¼SW¼ sec. 5	A. B. Cooley	12	3 by 5 ft	Qal	Top of platform	+.5	4,153	8.90	[8] 3.55	S		No casing.
[6] 42	Lot 8 sec. 6	Charles Frazier	14	3 in	Qal	Top of pump support.	+1.8	4,166	12.65	5.65	D	50.5	Do.
[4] 43	Lot 8 sec. 7	—— Hansen	14	4 in	Qal	Top of casing	+2.3	4,157	13.12	9.40	None		
44	SE¼SW¼ sec. 7	Archie McGowan	125	3 in	Qal(?) or Td.	(2)	.0	4,150	8.93	7.72	do		Measuring point, concrete floor of garage.
45	do	Unknown	31	2 in	Qal	Top of casing	+4.0	4,153	12.45	11.00	do		
46	Lot 4 sec. 7	Matt Riggs	10	8 in	Qal	Top of pump support.	.0	4,150	[9] 10.2	4.50	do		No casing.
47	NE¼SW¼ sec. 8	Unknown	10	1½ in	Qal	Lower valve seat	+3.0	4,152	10.20	3.75	do		
48	Lot 2 sec. 8	H. B. Mace	140	6 in	Qal						D		Cased 126 feet.
[4] 49	SW¼SW¼ sec. 9	Burns Airport	25	4½ in	Qal	Top of casing	+.3	4,150.19	13.55	5.06	D		
[6] 50	SE¼SE¼ sec. 9	George Whiting	12		Qal	Top of platform	+.2	4,144.59	[3] 10.68	[3] 1.72	S	49	No casing.
[6] 51	SE¼SE¼ sec. 9	do	43	1½ in	Qal	Lower valve seat	+2.5	4,147.45	12.60	12.60	D	51.5	
52	NE¼NW¼ sec. 10	Unknown	13	10 in	Qal	Top of casing	+2.0	4,148	[10] 13.53	[10] 8.00	S		
[4] 53	NE¼NE¼ sec. 13	Obil Shattuck	325	6 in	Qal and Th (?).	do	+1.9	4,141.15	[11] 25.72	10.80	None		So-called County well. Flowed at original depth of 848 feet.
[4] 54	do	do	28	6 by 6 ft	Qal	(2)	+1.9	4,141.15	14.90	14.15	do		Dug around well 53; cribbed 18 feet with wood. Measuring point, top of casing of well 53.
[4] 55	NE¼NW¼ sec. 13	Unknown	16		Qal	Top of pump flange	+2.3	4,141	17.25	16.65	S		
[4] 56	SW¼NW¼ sec. 13	J. S. Cook	105	18 in	Qal	Top of pump base	.0	4,142.80	[12] 77.9	12.00	Ir	52	Cased 84 feet.
[4] 57	NE¼NE¼ sec. 14	Geological Survey	12½	4 in	Qal	Top of casing	+.7	4,140.70	11.50	9.92	None		Cased 3 feet.
[4] 58	do	do	12	4 in	Qal	do	+.4	4,142.83	13.00	8.83	do		Do.
[4,6] 59	NW¼NE¼ sec. 14	do	12½	4 in	Qal	do	+.5	4,142.83	13.00	4.97	do		Do.
[4] 60	do	do	12	4 in	Qal	do	+.7	4,141.96	12.05	3.57	do		Do.
[4] 61	NE¼NW¼ sec. 14	Unknown	28	6 in	Qal	do	+1.0	4,144.50	14.01	11.64	S	50	
[4] 62	NW¼NE¼ sec. 15	William McLaren	16	18 in	Qal	do	+.2	4,141.90	9.81	1.70	D		Irrigates small garden.
63	do	do	52	18 in	Qal	Top of girder	+.5	4,141	9.50	9.20	None		Well filled up in September 1930.
[4] 64	do	do	87	18 in	Qal	(2)	+.1	4,141.92	11.48	1.90	Ir	51.5	Cased 53 feet. Measuring point, bottom of ½-inch drilled hole in casing.
[4] 65	SW¼NE¼ sec. 16	Pacific Live Stock Co.	300	12 to 8 in	Th (?)	Top of pump base	.0	4,145.58	13.36	5.19	Ir	58.5	Cased 300 feet.
[4] 66	NW¼NE¼ sec. 17	Geological Survey	10	3 in	Qal	Top of casing	+.6	4,147.75	10.73	.57	None		Cased 3 feet.
[4] 67	NE¼NW¼ sec. 17	do	11	4 in	Qal	do	+.8	4,147.26	8.40	.04	do		Do.
[4] 68	Lot 6 sec. 17	do	10	4 in	Qal	do	+.8	4,147.42	8.68	.01	do		Cased 7 feet.
[4,6] 69	do	do	12	4 in	Qal	do	+1.0	4,150.49	11.05	.88	do		Cased 3 feet.
[4] 70	do	do	14	4 in	Qal	do	+.5	4,151.05	11.92	.81	do		Do.
71	Lot 1 sec. 18	L. Vickers	13		Qal	Top of cover	.0	4,152	9.05	8.35	S		
[4] 72	do	C. H. Voegtly	13	6 by 6 ft	Qal	do	+.7	4,152	10.82	8.89	D		
[6] 73	Lot 2 sec. 18	Oregon Short Line R. R. Co.	110	12 in	Qal						R		Cased 100 feet.
74	SE¼NW¼ sec. 18	C. E. Silbaugh	106	12 in	Qal						Ir	54	Cased 106 feet.

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Altitude above sea level (feet)	Observed extremes of ground-water stage, 1930 (feet below measuring point): Lowest	Observed extremes of ground-water stage, 1930 (feet below measuring point): Highest	Use	Temperature (°F.)	Remarks
	T. 23 S., R. 31 E.												
75	NE¼NE¼ sec. 20	Charles Culp	195±	6 in		Top of casing	+3.5	4,148	11.15	10.20	None		
[6] 76	Lot 1 sec. 20	do	63½	24 in	Qal	do	+.8	4,147.79	3.46	12.13	do		
[4, 6] 77	do	Geological Survey	15	18 in	Qal	do	+1.0	4,147.67	2.12	11.81	do		Cased 3 feet.
78	SW¼NW¼ sec. 20	Charles Culp	16½	6 in	Qal	(2)	+1.3	4,147.04	10.00	3.70	D		Measuring point, top of plank on 8- by 14-inch timber.
[6] 79	SE¼NE¼ sec. 21	William Hanley Co.	54	4 in	Qal	Top of casing	.0	4,139	7.70	.55	D	50	Cased 54 feet.
[6] 80	do	do	13	1½ in	Qal	Lower valve seat	+2.7	4,143	11.80	4.20	D	47	
81	do	do	97	2 in	Qal	do	+2.7	4,143	11.00	4.00	D		
[4] 82	SE¼SE¼ sec. 23	do	55½	4 in	Qal	Top of casing	+.5	4,136.44	11.80	9.63	S		
83	NE¼NE¼ sec. 24	——— Brown	78	2 in	Qal	do	−4.4	4,135	12.00	12.00	S		
84	SE¼NW¼ sec. 24	Unknown	10½	4 by 5 ft	Qal	Top of cover	.0	4,137	Dry	1.65	S		No casing.
[4] 85	NW¼NW¼ sec. 28	Charles Culp	45	8 in	Qal	Top of casing	+1.7	4,139.20	10.40	2.65	S		Land-surface altitude 4,137 feet at well No. 86 used as datum.
[4] 86	do	do	9	4 by 4 ft	Qal	(2)	−.5	4,137	8.80	.10	None		Measuring point, copper washer in top of 2- by 12-inch plank.
87	Lot 1 sec. 30	——— Hotchkiss	11½	1½ in	Qal	Top of casing	+3.0	4,142	5.50	2.00	do		
88	NW¼NE¼ sec. 32	C. W. Mace	295	6 in		(2)	+1.0	4,134	7.40	2.50	S		Cased 295 feet. Measuring point, copper washer in top of wooden pump clamp.
89	NE¼SE¼ sec. 32	Newton Hotchkiss	38	2 in	Qal	Top of casing	+4.1	4,137	12.20	11.05	D		Cased 38 feet.
[4] 90	NW¼SW¼ sec. 32	O. D. Hotchkiss	10	1¼ in	Qal	Lower valve seat	+2.2	4,134	10.55	3.10	None		
91	SE¼NW¼ sec. 35	William Hanley Co.	72	4 in	Qal	Top of casing	+1.0	4,134	10.15	9.25	do		

	T. 23 S., R. 32 E.												
[4][6] 92	Lot 3 sec. 6	Unknown	19½	5 ft	Qal	Top of girder	.0	4,138	15.60	12.45	do	46	No casing.
[4] 93	NE¼SW¼ sec. 7	Harney Branch Experiment Station.	11½	4 in	Qal	Top of casing	+.4	4,135.6	9.70	6.50	do		
[4][6] 94	do	do	87	18 in	Qal	Pressure gage	+1.4	4,136.8	[13] 40.00	6.00	Ir	48	Cased 60 feet.
[4][6] 95	SW¼SE¼ sec. 7	do	218	8 in	Th	do	+.7	4,137.4	[13] 28.20	7.60	Ir	58	Cased 170± feet.
[4] 96	do	do	11	4 in	Qal	Land surface	.0	4,136	10.40	8.20	None		No casing.
[4] 97	NW¼NW¼ sec. 8	Unknown	45	1½ in	Qal	Top of casing	+1.5	4,134.95	[11] 18.39	8.68	do		
[6] 98	SE¼SE¼ sec. 8	F. O. Jackson	14	2 in	Qal	Lower valve seat	+2.5	4,133	13.65	13.30	do	54	
[4][6] 99	NE¼NW¼ sec. 10	Unknown	33	6 in	Qal	Top of curb	+1.5	4,133	12.19	11.24	do	50	
[4][6] 100	SW¼NE¼ sec. 12	do	18½	4 by 6 ft	Qal	Top of girder	.0	4,128	11.00	9.80	do		
[4] 101	SW¼NW¼ sec. 16	Dr. Horton	800±	6 in		Top of casing	+.5	4,132	6.00	5.55	do		
102	NW¼SW¼ sec. 17	B. L. Allen	59	24 in	Qal	do	+1.0	4,132	12.47	11.90	None		
[4] 103	do	do	53	8 in	Qal	do	.0	4,135.70	[11] 21.11	11.35	do		
104	SE¼SE¼ sec. 17	do	52	8 in	Qal	do	+1.0	4,134	18.26	12.75	D		
[4] 105	Lot 2 sec. 18	Fred Denstedt	565	3 in		(²)	+.5	4,137.89	[11] 24.27	9.34	None		Measuring point, copper washer in top of curb.
[6] 106	do	do	24	18 in	Qal	Top of casing	.0	4,138.65	12.80	12.80	S		
[4] 107	do	do	60	6 in	Qal	(²)	+.5	4,138.85	[11] 23.40	8.72	None		Measuring point, copper washer in top of curb.
[4] 108	SE¼SE¼ sec. 19	R. W. Cozad	39	6 in	Qal	Top of casing	+.3	4,132.98	[11] 21.17	9.72	D		
109	NW¼NW¼ sec. 20	Curtis Smith	15	4 by 5 ft	Qal	Top of platform	+1.2	4,134	13.75	13.75	S		
[4][6] 110	SW¼SW¼ sec. 20	R. W. Cozad	15½		Qal	Top of cover	+.5	4,132.60	11.40	10.40	D	52	Irrigates lawn.
[4][6] 111	do	do	44	2 in	Qal	Lower valve seat	+4.0	4,135.27	[11] 31.70	16.22	D	50	
[4] 112	do	do	72	24 in	Qal	Top of pump base	−.4	4,132.75	[13] 22.85	9.90	Ir	52	
[4] 114	SE¼SE¼ sec. 20	D. N. Varien	47	2 in	Qal	(²)	−8.5	4,124.39	[11] 10.87	7.37	D		Measuring point, top of tee joint of casing.
115	do	do	12½	6 by 8 in	Qal	Top of casing	+3.0	4,137	14.30	7.30	S		
116	NW¼NW¼ sec. 21	—— Woods	12½	8 in	Qal	Top of pump base	+2.3	4,135	13.80	13.30	S		
117	NE¼SE¼ sec. 22	Unknown	20	6 by 6 ft	Qal	Top of cover	+.5	4,127	16.25	16.25	S		
[6] 118	NW¼NE¼ sec. 27	do	11	4 by 4 ft	Qal	Top of curb	+2.0	4,130	13.65	13.00	D	50	
119	NE¼NE¼ sec. 28	Duhaime Bros	12	4 by 4 ft	Qal	Top of cover	+.8	4,130	13.25	5.75	S		
120	do	do		18 in	Qal								
[4] 121	NW¼NW¼ sec. 28	do	135	24 in	Qal	Top of casing	.0	4,129	21.40	15.65	None		Cased 90 feet.
[4][6] 122	SE¼SE¼ sec. 32	Unknown	12½	8 in	Qal	(²)	+.2	4,128	Dry	11.30	do		No casing. Measuring point, top of bucket in top of well.
123	NE¼NW¼ sec. 35	do	13	6 ft	Qal	Top of curb	+.7	4,125	13.30	12.85	D		Do.
	T. 23 S., R. 32½ E.												
[4][6] 124	Lot 4 sec. 2	do	15	6 by 6 ft	Qal	Top of cover	+1.2	4,134	[14] 14.10	4.95	S		
125	SW¼SE¼ sec. 2	do	19	6 by 6 ft	Qal	do	+.8	4,130	13.15	13.15	D		Cased 10 feet.
126	Lot 4 sec. 6	Unknown	15	5 ft	Qal	do	.0	4,129	13.00	4.75	S		No casing.
127	SE¼NE¼ sec. 6	Jim Gibson	16	6 ft	Qal	Top of curb	+2.4	4,131	16.20	15.95	D		Cased 10 feet.
[6] 128	Lot 1 sec. 31	Henry Anderson	52	2 in	Qal	Top of cover	+.1	4,119	19.05	19.05	S	51	
[4][6] 129	do	do	18		Qal	Lower valve seat	+.7	4,120	18.00	16.60	D	50	
130	SE¼NE¼ sec 32	—— Haines	21	6 by 6 ft	Qal	Top of pump support.	+.8	4,118	16.55	16.55	S		
[6] 131	NW¼SE¼ sec. 32	H. C. Bush	24	2 in	Qal	Lower valve seat	+2.6	4,121	21.50	19.70	D	52	Cased 24 feet.
[6] 132	NE¼NW¼ sec. 35	Unknown	20	6 by 6 ft	Qal	Top of platform	+1.0	4,120	[14] 14.30	12.35	S	49	
133	NE¼SW¼ sec. 36	do	22	6 in	Qal	Top of plank	.0	4,121	11.90	11.50	S		

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Altitude above sea level (feet)	Observed extremes of ground-water stage, 1930 (feet below measuring point): Lowest	Observed extremes of ground-water stage, 1930 (feet below measuring point): Highest	Use	Temperature (°F.)	Remarks
	T. 23 S., R. 33 E.												
[4] 134	SE¼SW¼ sec. 3	Unknown	11½	8 ft	Qal	Top of cover	.0	4,134	11.40	4.25	S		No casing.
135	Lot 4 sec. 6	State Board Land Co.	18	10 ft	Qal	do	+1.0	4,135	11.35	11.35	S		
[4] [6] 138	NE¼SW¼ sec. 22	State of Oregon	18½	8 ft	Qal	do	+.2	4,130	[5] 18.15	11.70	S	52	
[6] 140	NE¼NW¼ sec. 33	do	16	6 by 6 ft	Qal	do	.0	4,128	14.40	11.10	S		
	T. 24 S., R. 30 E.												
[6] 143	Lot 2 sec. 1	J. C. Clemens	478	12 to 10 in.	Qb or Td						Ir	80	Cased 117 feet. Flowing when visited. Flow estimated between 300 and 400 gallons a minute.
144	Lot 4 sec. 1	—— Brown	60	3 in	Qal						S	64	Flows a trickle 2½ feet above land surface.
145	Lot 1 sec. 2	Unknown	83½	2 in	Qb (?)	Lower valve seat	+.9	4,136	2.40	1.15	Ir		Irrigates garden. Flowed until about July 1, 1930.
146	Lot 2, sec. 2	H. Wumbsgan	80	2 in	Qb or Td	Top of platform	+4.0	4,142	10.25	10.25	D	82	
[6] 147	SE¼NE¼ sec. 2	do	15	10 in	Qal	Top of cover	.0	4,135	7.45	6.90	None	54	No casing.
[6] 152	NE¼NE¼ sec. 18	Unknown	33	5 ft	Qal						S		Water turbid with suspended matter. No casing,
	T. 24 S., R. 31 E.												
154	Lot 6 sec. 1	do	44	2 in	Qal	Lower valve seat	+3.0	4,134	13.35	13.30	None		
155	Lot 4 sec. 2	William Hanley Co.	60½	2 in	Qal	do	+3.2	4,134	13.50	12.30	S		

156	SE¼SW¼ sec. 6	Unknown	47	2 in	Qal	Top of casing	+2.5	4,133	3.15	2.45	None		
157	SW¼SE¼ sec. 6	do	10	8 in	Qal	Bottom of pump base.	+1.2	4,131	9.55	6.20	S		No casing.
158	NE¼NE¼ sec. 8	do	48	4 in	Qal	do	.0	4,128	4.95	3.00	None		
[4,6]159	SE¼NE¼ sec. 8	do	44½	2 in	Qal	do	+1.6	4,129.85	6.95	3.80	D	54	Land-surface altitude 4,128 feet at well No. 160 used as datum.
[4,6]160	do	do	10	3 in	Qal	Top of cover	.0	4,128	10.00	1.30	None	46	Well found caved July 7, 1932.
161	SW¼NW¼ sec. 9	do	52	2 in	Qal	Top of casing	+2.2	4,130	7.10	7.10	do		
162	do	do	42	2 in	Qal	do	+1.0	4,128	6.40	4.85	S		
[6]163	SE¼SW¼ sec. 10	Mrs. John Creasman.	11	6 by 6 ft	Qal	Top of cover	+1.0	4,127	12.95	3.65	S	51	
[4,6]164	SW¼SW¼ sec. 12	Unknown	11	6 by 6 ft	Qal	(2)	+.3	4,126	10.05	1.55	S		Measuring point, copper washer in top of log girder.
[4,6]165	NE¼SE¼ sec. 20	Larsen ranch	53	2 in	Qal	Top of casing	+2.5	4,126.50	12.50	9.70	S	51	Land-surface altitude 4,124 feet at well No. 166 used as datum.
[4,6]166	do	do	11	3 by 5 ft	Qal	Top of wood curb	+1.0	4,125	Dry	3.25	None	46	
167	SE¼SE¼ sec. 27	Unknown	10½	6 by 6 ft	Qal	Top of cover	.0	4,116	9.40	8.85	do		No casing.
	T. 24 S., R. 32 E.												
168	Lot 3, sec. 2	Unknown	73	4 in	Qal	(2)	−.8	4,121	20.25	20.25	None		Measuring point, top of casing-flange connection.
169	SW¼SW¼ sec. 4	O. L. Gasch	69	8 in	Qal	(2)	+.3	4,124	16.95	15.10	Ir		Irrigates garden. Cased from 22 to 62 feet. Measuring point, copper washer in wood curb.
[4,6]170	NE¼SE¼ sec. 5	E. Woods	51	2 in	Qal	(2)	.0	4,125	17.15	16.05	None	50	Measuring point, copper washer in wood curb.
171	SW¼SE¼ sec. 6	Unknown	105	10 in	Qal						do		
[4,6]172	NW¼SE¼ sec. 9	Dan Jordan	42	1½ in	Qal	Top of casing	+2.5	4,122	20.70	19.95	do		
[4]173	SE¼NE¼ sec. 12	Unknown	40	8 in	Qal	Top of platform	.0	4,117	27.75	27.30	S		No casing.
174	NE¼NW¼ sec .13	do	33	6 by 6 in	Qal	Top of casing	+.2	4,116	Dry	33.00	None		
176	NE¼NW¼ sec. 18	do	13	5 by 5 in	Qal	do	+.3	4,119	10.45	9.20	do		
[4,6]178	NW¼NE¼ sec. 23	do	57	6 in	Qal	Top of platform	+.3	4,121.15	41.80	39.10	do	52	
[4,6]179	SE¼SW¼ sec. 23	Oscar West	46	6 in	Qal	Top of cover	.0	4,114.60	30.25	27.95	S	52	Do.
[6]181	SE¼SW¼ sec. 26	L. B. Hayes	16	6 by 6 ft	Qal	Top of girder	.0	4,107.30	13.30	5.95	S	49	
[4]182	NE¼SE¼ sec. 30	Geological Survey	15½	3 in	Qal	Top of casing	+.6	4,112	Dry	12.13	None		Cased 1.5 feet.
[4]183	do	Pacific Live Stock Co.	39½	2 in	Qal	do	+2.5	4,113.35	15.10	13.90	do		Land-surface altitude 4,111 feet at well 182 used as datum.
[6]184	SE¼NE¼ sec. 31	do	400	6 in	Th	Top of block	+.2	4,107	8.50	8.50	D	55	
185	do	do	73½	6 in	Qal	Top of casing	+1.6	4,109	13.15	8.60	None		
[6]186	do	do	12	6 by 6 ft	Qal	Top of platform	.0	4,107	11.35	4.30	S	48	No casing.
187	SE¼NW¼ sec. 35		13	2 by 6 in	Qal	Top of casing	+1.6	4,104	Dry	12.60	None		

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point			Observed extremes of ground-water stage, 1930 (feet below measuring point)		Use	Temperature (°F.)	Remarks
						Description	Above or below land surface (feet)	Altitude above sea level (feet)	Lowest	Highest			
	T. 24 S., R. 32½ E.												
[6] 188	NW¼SE¼ sec. 7	Fred Haines	41	10 in.	Qal	Top of pump base	+0.7	4,118	26.20	25.75	S		Cased 10 feet.
[6] 189	NW¼NW¼ sec. 10	Wm. J. Aldridge	40	6 to 4	Qal	Top of cover	+.2	4,121	26.00	25.45	D	54	No casing.
195	SW¼SW¼ sec. 21	Unknown	42	12 by 12 in.	Qal	Top of pump support.	+1.3	4,117.20	40.95	40.00	None		
[4] 197	SE¼SE¼ sec. 30	Ralph Catterson	130±	18 in.	Qal	Top of casing	+1.0	4,107.02	32.95	31.55	do.		Cased 80 feet. Imperfectly cased allowing water from deep and shallow valley fill to intermingle.
[6] 198	SW¼NW¼ sec. 32	Starr Buckland	180	2 in.	Qal						D	57	Cased 100+ feet.
199	NW¼SW¼ sec. 32	Oregon Short Line R. R. Co.		6 in.	Qal						D		
[4, 6] 200	NE¼NE¼ sec. 33	Unknown	35		Qal	do.	+.2	4,110.30	31.60	30.45	None		
	T. 24 S., R. 33 E.												
201	SE¼NE¼ sec. 7	—— Burke	66	10 in.		do.	−2.0	4,118	1.10	.55	do.		Reported 235 feet deep when drilled. Originally flowed.
[4] 203	Lot 3, sec. 30	C. M. Spencer	106	12 in.	Qal	Top of plank	+1.2	4,111	18.20	17.65	D		Cased 40 feet.
204	do.	do.	16	6 in.	Qal	Top of wood curb	+.7	4,111	Dry	16.50	None		Well went dry during the winter of 1931.
[6] 206	NE¼SW¼ sec. 34	Unknown	21	6 by 6 ft.	Qal	Top of casing	−.5	4,119	19.70	18.85	do.	54	
	T. 24 S., R. 34 E.												
207	NW¼NE¼ sec. 30	do.	16		Qal	Top of platform	.0	4,155	11.90	11.40	S		
208	SE¼SE¼ sec. 31	do.	200+		Ts(?)	Top of coupling	+1.2	4,159	19.62	19.62	None		

	T. 25 S., R. 28 E.												
209	SE¼SW¼ sec. 34	Unknown	11	6 ft	Qal	Top of cover	.0	4,128	9.65	9.65	S		Cased 11 feet.
210	NE¼NE¼ sec. 35	J. U. Côté	12	8 ft	Qal	do	.0	4,128	10.60	10.60	Ir	48	Irrigates garden. No casing.
	T. 25 S., R. 30 E.												
212	SE¼SE¼ sec. 24	Central Oregon Oil & Gas Co.	3,750±		Th in part.						None		Oil prospect.
213	NE¼SW¼ sec. 35	—— Wilson	28	6 by 20 ft	Qal	([2])	−2.0	4,130	19.8	19.8	do		Oct. 16, 1930, well badly caved. Formerly used for irrigation. Measuring point, top of mud sill of pit frame.
	T. 25 S., R. 31 E.												
[4] [6] 216	SE¼SW¼ sec. 9	E. N. Nelson	105	6 in	Th(?)	Top of casing	+1.1	4,124	[14] 15.40	12.45	S	51	
217	NW¼SW¼ sec. 15	Neva Geer		4 in		do	+.3	4,112	14.00	13.20	None		
[4] 218	SE¼SE¼ sec. 16	School district 14	40±	2 in	Qal(?)	Lower valve seat	+2.2	4,114	16.40	15.70	do		Aug. 5, 1931, well found bridged at 16.5 feet.
[4] 219	SE¼SE¼ sec. 28	Unknown	31	2 in	Qal(?)	do	+1.7	4,113	18.30	17.55	do		
220	NE¼SE¼ sec. 30	Frank Klitzke	60	4 in	Qal(?)	Top of casing	+1.0	4,186	54.50	54.40	do		
221	SE¼SE¼ sec. 30	E. Koenemann	107		Qal or Th.						S		
[6] 222	NE¼SE¼ sec. 33	Unknown	22	12 by 12 in.	Qal	do	+.8	4,111.55	20.05	20.00	None	56	No casing.
	T. 25 S., R. 32 E.												
[4] [6] 223	Lot 1 sec. 2	Pacific Live Stock Co.	43	6 in	Qal	do	+0.2	4,103.35	14.60	11.48	S		
[4] [6] 224	do	do	13	8 by 8 ft	Qal	Top of curb	+2.8	4,105.10	Dry	13.00	None		
225	Lot 2 sec. 2	do	150	1½ in	Qal	Lower valve seat	+3.0	4,107	9.90	9.90	S		
226	Lot 3 sec. 2	do	106½	8 in	Qal	Top of casing	+1.0	4,104.25	22.50	12.55	None		
227	SE¼NE¼ sec. 10	do	47	6 in	Qal	do	+.1	4,098	13.15	13.15	S		
228	NE¼NW¼ sec. 12	do	45	6 in	Qal	do	.0	4,098	14.00	14.00	S		
229	SW¼NW¼ sec. 13	do	48½	18 in	Qal	Top of cover	+2.0	4,100	15.55	15.55	S		
230	SW¼NE¼ sec. 15	do	48	18 in	Qal	do	+2.0	4,098	12.05	12.05	S		
231	NW¼SE¼ sec. 16	do	49		Qal	Top of timber	.0	4,097	12.25	12.25	S		
232	SE¼NE¼ sec. 17	do		10 in	Qal	Top of pipe clamp	−.6	4,095	9.45	9.25	S		
233	Lot 2 sec. 18	Oregon Oil Co	1,000+								None		Oil prospect; well abandoned and casing pulled.
234	do	Pacific Live Stock Co.	43	10 in	Qal	Top of pump support.	+1.8	4,099	11.40	11.55	S		
[4] 235	NW¼NE¼ sec. 25	Ruh Brothers	53	2 in	Qal	Top of casing	+1.8	4,098.80	17.80	14.65	None		Cased 27 feet.
[4] 236	NE¼NW¼ sec. 25	School district 17	15	1½ in	Qal	Lower valve seat	+1.7	4,097.85	Dry	13.90	do		
[4] 237	SE¼SW¼ sec. 28	Unknown	18	2 in	Qal	Top of casing	+1.4	4,103	16.45	15.85	do		
[4] 238	Lot 3 sec. 35	J. E. Graves	21	4 in	Qal	Top of board	+.5	4,096.30	14.50	13.80	S	52	
	T. 25 S., R. 32½ E.												
239	NE¼SE¼ sec. 1	Unknown	22	6 in	Qal	Top of casing	+.5	4,097	14.60	14.00	None		
240	NW¼SE¼ sec. 1	Will Howard	200±	2 in	Qal						S	52	
[4] 241	SE¼SW¼ sec. 1	C. M. Spencer	23	4 by 4 ft	Qal	Top of platform	+.2	4,103.10	23.45	20.55	None		No casing.
[4] [6] 242	do	do	86	1½ in	Qal	Lower valve seat	+2.7	4,102.45	15.00	13.75	D		Reported 190 feet deep when drilled.

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Altitude above sea level (feet)	Observed extremes of ground-water stage, 1930 (feet below measuring point): Lowest	Observed extremes of ground-water stage, 1930 (feet below measuring point): Highest	Use	Temperature (°F.)	Remarks
	T. 25 S., R. 32½ E.												
243	NW¼SE¼ sec. 2	L. E. Seely	253	2 in	Qal(?)						D		Cased 180 feet.
[4] 244	SE¼SW¼ sec. 4	Unknown	51	8 in	Qal	Top of casing	+0.2	4,098.65	15.55	12.00	S		
[4] 245	do	do	15	6 by 6 ft	Qal	Top of curb	+.4	4,098.65	Dry	11.20	None		
[4] 246	Lot 3 sec. 5	Fred Timm	67	4 in	Qal	do	+.4	4,105.65	23.20	20.15	D		Originally drilled 185 feet deep. No casing.
[4, 6] 247	do	do	22	8 in	Qal	Top of pump support.	+2.1	4,107.40	Dry	19.80	D	52	No casing.
248	Lot 3 sec. 6	Scott Catterson	18	4 ft	Qal	Top of cover	+2.0	4,106.60	18.98	18.00	D		Do.
[4, 6] 249	NE¼SW¼ sec. 8	Unknown	14	4 in	Qal	Top of casing	+3.5	4,102.00	16.85	7.55	None	52	
[4, 6] 250	NW¼NW¼ sec. 11	do	22	4 by 4 ft	Qal	Top of girder	.0	4,096.00	20.10	18.25	do		Do.
252	SW¼SE¼ sec. 15	J. A. Oard	14	7 ft	Qal	do	+.4	4,095	[9] 13.7	12.85	do		
[4] 253	SW¼SW¼ sec. 17	Unknown	13½	4 by 6 ft	Qal	do	+1.0	4,097.70	Dry	12.80	S		
254	SE¼NW¼ sec. 19	Oregon Oil Co	56	10 in	Qal	Top of timber	.0	4,096	15.75	14.60	None		Oil prospect, drilled 600 feet deep then abandoned. Casing pulled.
[6] 255	Lot 5 sec. 19	Charles Spurlock	23½	6 in	Qal	Top of casing	+.9	4,098.5	18.75	18.75	D	49	
256	Lot 1 sec. 20	J. O. Ausmus	19½	3 in	Qal	do	+2.3	4,098.30	Dry	18.15	D		Cased 18 feet.
[6] 257	do	do	47	4 in	Qal	Top of curb	+1.0	4,096.75	16.60	15.70	S	52	
[6] 258	Lot 7 sec. 22	Ralph Catterson	18	6 by 8 ft	Qal	Top of platform	+.9	4,097.70	18.65	[8] 10.95	None		
[6] 259	do	do	50	1½ in	Qal						S		
260	Lot 4 sec. 24	Unknown	12	1½ in	Qal	Lower valve seat	+2.2	4,097	14.30	13.70	None		
261	([15])	do	48	6 in	Qal	Top of 1-inch board	+.2	4,096	14.90	14.60	S		No casing.
262	([15])	B. C. Ausmus	56	6 in	Qal	Top of curb	.0	4,093	15.00	14.30	D		
263	([15])	Unknown	30	6 in	Qal	do	+.2	4,095	14.05	13.05	S		
264	Lot 6 sec. 30	do	13	1½ in	Qal	Lower valve seat	+1.8	4,097.25	13.65	13.65	None		
[6] 265	([16])	B. C. Ausmus	20	4 in	Qal	Top of casing	+.5	4,094.5	12.60	12.60	D		Do.

	T. 25 S., R. 33 E.												
266	Lot 4 sec. 5	Unknown	39	6 in	Qal	do	.0	4,113	19.85	19.50	D		
[4,6] 267	SE¼SW¼ sec. 6	do	21	5 by 5 ft	Qal	Top of girder	.0	4,101.85	18.07	13.55	D		Do.
[4] 268	SE¼SW¼ sec. 7	do	120	6 in	Th or Qal.	Top of platform	+.9	4,102.95	10.45	9.50	D		
270	NE¼SE¼ sec. 12	do	54	6 in	Qal	Top of casing	+1.3	4,118	17.60	17.60	D		
[6] 272	NW¼NW¼ sec. 23	do	28½	2 in	Qal	do	+2.0	4,110	26.15	26.85	D		
273	(15)	Hill Bros	75	6 in	Qal	Land surface	.0	4,093			S	52	Do.
274	NE¼NE¼ sec. 34	Geological Survey	14	3 in	Qal	Top of casing	.0	4,099	13.65	12.10	D		Do.
	T. 25 S., R. 34 E.												
275	NE¼SW¼ sec. 7	Oregon Short Line R. R. Co.	415	10 in	Ts(?)			4,134			R		
	T. 26 S., R. 28 E.												
276	NE¼SW¼ sec. 3	Unknown	9	8 by 8 ft	Qal	Top of girder	+1.3	4,131	8.25	8.25	None		
277	NW¼SW¼ sec. 12	William Hanley Co.	100+	3 in	Th(?)	Top of casing	+1.1	4,119	6.95	6.95	S		
[6] 278	NW¼NW¼ sec. 14	do	33	6 in	Qal	do	+.6	4,119	6.25	4.75	S	54	
	T. 26 S., R. 29 E.												
282	NE¼SE¼ sec. 18	do	14	6 by 6 ft	Qal	Top of cover	+1.8	4,120	10.25	10.25	S		
[6] 283	NW¼SE¼ sec. 27	Unknown	130	5½ in	Th	Top of casing	+2.0	4,105	12.35	11.60	None	52	
284	SW¼SW¼ sec. 27	do	34	2 in	Qal	do	.0	4,107			S	54	Flows slight amount. Flowing when visited.
	T. 26 S., R. 30 E. "North of Malheur Lake"												
286	Lot 4, sec. 28	Geological Survey	7½	3 in	Qal	do	+.5	4,086.05	4.83	4.83	None	55½	Cased 2.5 feet.
287	NE¼. sec. 29 (?)	Unknown	40	2 in	Qal	do	+2.2	4,102	11.90	11.60	do		
288	Lot 1, sec. 34	Geological Survey	6	3 in	Qal	do	+.2	4,085.05	4.57	4.37	do	60	Do.
	T. 26 S., R. 31 E. "North of Malheur Lake" and T. 26 S., R. 30 E. "South of Malheur Lake"												
289	SE¼NW¼ sec. 1	J. S. Wilson	10	2 in	Qal	Top of pump support.	+.8	4,095.20	8.92	8.92	D		No casing.
291	NW¼SW¼ sec. 1	do	11	3 in	Qal	Land surface	.0	4,096.5	10.40	10.40	None		Do.
290	NE¼SW¼ sec. 1	do	71½	4 in	Qal	Top of casing	.0	4,100.10	13.93	12.90	do		Reported drilled 400 feet deep.
[4,6] 292	SE¼SE¼ sec. 5	Geological Survey	14	3½ in	Qal	do	+.4	4,095.48	13.10	11.90	do		Cased 2.5 feet.
[4,6] 293	NE¼NE¼ sec. 15	do	14	3 in	Qal	do	+.5	4,096.41	13.50	13.08	do		Do.
[4,6] 294	SE¼SE¼ sec. 15	do	17	3 in	Qal	do	+.5	4,100.75	16.80	16.61	do		Do.
[6] 295	SW¼NE¼ sec. 26	W. M. McKenzie	24	2 in	Qal	Lower valve seat	+1.3	4,099.30	13.80	13.80	do	52	
[4] 296	SE¼SE¼ sec. 26	Unknown	21	4 in	Qb (?)	do	+1.0	4,111.90	21.40	20.85	do		
297	Lot 1, sec. 28	L. L. Griffen	14	4 in	Qal	Top of cover	.0	4,091.60	6.80	5.50	do		No casing.
[6] 298	Lot 2, sec. 32	Geological Survey	13	3 in	Qal	Top of casing	+5.	4,094.05	12.00	11.97	do	52	Cased 1.5 feet.
[6] 299	NW¼SW¼ sec. 35	Mrs. R. L. Thornton.	25	2 in	Qal	Lower valve seat	+2.0	4,096.05	10.00	9.95	S	52½	
[6] 300	do	do	53	1½ in	Qal	Top of casing	.0	4,095.35	5.60	5.30	D	54	Do.

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point: Description	Measuring point: Above or below land surface (feet)	Measuring point: Altitude above sea level (feet)	Observed extremes of ground-water stage, 1930 (feet below measuring point): Lowest	Observed extremes of ground-water stage, 1930 (feet below measuring point): Highest	Use	Temperature (°F.)	Remarks
	T. 26 S., R. 32 E. "North of Malheur Lake" and T. 26 S., R. 31 E. "South of Malheur Lake"												
301	Lot 8, sec. 5	Pacific Live Stock Co.	1,430	6 in	Ts						S	106	Flowing when visited. Flow estimated 30 gallons a minute.
302	Lot 4, sec. 7	Unknown	18	4 by 6 ft	Qal	Top of curb	+0.3	4,095.60	11.50	10.60	None		
[6] 303	(15)	J. E. Graves	18		Qal	Top of casing	+1.5	4,094.35	12.00	10.30	S	51	Do.
[6] 304	(15)	do	60		Qal	(2)	+.2	4,095.00	12.15	5.80	S	50	No casing. Measuring point, copper washer on 1- by 4-inch platform.
[6] 305	(15)	Lynn Vickers	18	6 by 6 ft	Qal	Top of cover	.0	4,094.85	13.55	[8] 6.60	D	51	
306	(15)	—— Hoffman	54	1½ in	Qal	Lower valve seat	+3.5	4,097.25	11.95	11.95	S		
[6] 307	NE¼NE¼ sec. 18	W. Scott Haley	46	2 in	Qal	Lower valve seat	+2.0	4,099.55	14.65	13.90	D	51	Cased 40 feet.
[6] 308	do	do	21	4 in	Qal	Top of casing	+1.2	4,096.05	13.35	13.10	S	52	
309	(15)	Unknown	18½	6 by 6 ft	Qal	Lower valve seat	+2.6	4,097.80	16.00	7.47	D		
[6] 310	(15)	W. A. Campbell	18	6 in	Qal	Top of platform	+.5	4,095	14.10	[8] 3.35	D	50	No casing.
311	(15)	Unknown	15	4 by 6 ft	Qal	Top of 4- by 4-inch wood sill.	.0	4,092.5	10.35	10.35	S		
312	Lot 3, sec. 25	C. H. Marshall	59	1½ in	Qal	Lower valve seat	+2.4	4,097.5	9.20	9.20	D	51	
313	Lot 7, sec. 33	Pete Caldwell	14	10 in	Qal	(2)	+1.6	4,100	10.00	10.00	Ir		Irrigates garden. No casing. Measuring point, top of tee on pump discharge pipe.
314	Lot 1, sec. 33	do	14	10 in	Qal	Top of board	.0	4,098.4	9.40	5.35	None		No casing.

[6] 315	Lot 6, sec. 34	W. J. Dunn	25½	4 in.	Qal	Top of casing	+1.7	4,100	9.45	4.45	D		
[6] 316	Lot 4 (?) sec. 35	Alva Springer	16	5 by 5 ft.	Qal	Top of cover	+.5	4,099.65	7.05	5.03	D		Do.
318	Lot 12, sec. 36	J. Kado	11	4 by 4 ft.	Qal	Top of curb	+2.3	4,096	Dry	12.65	D		
	T. 26 S., R. 32 E. "South of Malheur Lake"												
319	([15])	C. B. Ausmus	12	6 in.	Qal	Top of pump base	.0	4,089.55	9.10	Flooded.	S		No casing.
320	([15])	Unknown	14½	8 in.	Qal	Top of pipe union	.0	4,094.25	9.84	9.84	S	48	Do.
321	([15])	do	45	8 in.	Qal	Bottom of cover	.0	4,093.95	9.57	9.57	S		Do.
[6] 322	([15])	Unknown	35	4 in.	Qal	Top of casing	−1.8	4,091.25	.17	.05	S	56	
323	Lot 1, sec. 14	do	31	6 in.	Qal	do	0.0	4,095	.67	.67	None		
324	Lot 2, sec. 14	Frank Lueder	33	2 in.	Qal	Top of pump support.	.0	4,095.5	2.60	2.10	S		Cased 38 feet. Flows slight amount at times.
[6] 325	([15])	W. J. Dunn	46	6 in.	Qal	Top of pump support.	+.8	4,095	7.00	1.00	S	51	Do.
326	Lot 3, sec. 23	Frank Lueder	12	1¼ in.	Qal	Land surface	.0	4,101	6.±	6.±	S	51	
327	Lot 2, sec. 28	Mrs. Frank Dunn	80	3 in.	Qbv						S	52	Flowing when visited. Flow estimated 20 gallons a minute.
329	Lot 1, sec. 31	T. T. Dunn	67	4 in.	Qbv	Top of pump platform.	+1.5	4,112	19.40	16.30	S		
330	Lot 2, sec. 32	do	100	2 in.	Qbv	Top of casing	.0	4,098	.15	.15	None		Originally flowed small amount.
331	Lot 6, sec. 33	Mrs. Frank Dunn	83½	6 in.	Qbv	do	+.5	4,099	4.35	4.15	do		
[6] 332	NW¼SE¼ sec. 34	Hahn & Backus	215	8 in.	Qbv						Ir.	54	Flowing when visited. Flow estimated 120 gallons a minute.
333	do	do		8 in.	Qbv						Ir.	53½	Flowing when visited. Flow estimated 50 gallons a minute.
334	do	do	135	8 in.	Qbv						Ir.		Flowing when visited. Flow estimated 90 gallons a minute.
	T. 26 S., R. 33 E.												
[6] 335	([15])	Hill Bros.	70	6 in.	Qal	Land surface	.0	4,093	7.90	7.90	S	52	No casing.
[6] 336	([15])	W. J. Dunn	20	10 by 20 ft.	Qal	Top of platform	.0	4,093.35	9.03	7.25	S	50	
337		A. Haasterich	204	2 in.	Th (?)	Top of casing	—7.0	4,097.65	.85	.50	None		
338		Unknown	157	4 in.	Th (?)	do	.0	4,109.50	13.40	13.05	S		
[6] 339	Lot 3 sec. 17	R. J. Haines	15	6 in.	Qal	Top of pump support.	+2.0	4,102.25	8.71	8.50	S	52	Do.
[6] 340	Lot 13 sec. 22	Geological Survey	11	3 in.	Qal	Top of casing	.0	4,096.85	9.45	8.60	None	50	Do.
[6] 342	SE¼SW¼ sec. 26	Unknown	35	8 in.	Qal	Top of cover	+.2	4,103.40	12.30	11.95	S	54	Do.
[6] 343	NE¼NE¼ sec. 27	Geological Survey	16	3 in.	Qal	Top of casing	+.3	4,100.05	13.85	13.35	None	51	Cased 2.5 feet.

See footnotes at end of table.

Hydrologic data for representative wells in the Harney Basin, Oreg.—Continued

[Use of water—D, Domestic; Ind, industrial; Ir, irrigation; P, public service; R, railroad; S, stock]

No. on pl. 2	Location	Owner	Depth (feet)	Diameter	Geologic horizon of water-bearing bed [1]	Measuring point			Observed extremes of ground-water stage, 1930 (feet below measuring point)		Use	Temperature (°F.)	Remarks
						Description	Above or below land surface (feet)	Altitude above sea level (feet)	Lowest	Highest			
	T. 27 S., R. 29 E.												
344	SW¼SW¼ sec. 3	A. W. Hulburt	48	2 in	Qal	Land surface	.0	4,101			Ir	53	Irrigates lawn. Flowing when visited. Flows about 10 gallons a minute. Cased 48 feet.
345	Lot 4 sec. 5	Lewis M. Hughet	47	2 in	Qal	Top of casing	+2.0	4,117			D	68	Flowing when visited. Flows 2 gallons a minute. Cased 20 feet.
346	SW¼NW¼ sec. 5	do	8½	1½ in	Qal	Lower valve seat	+3.4	4,133	10.25	10.25	None		Cased 8 feet.
348	SW¼SE¼ sec. 5	Mrs. I. N. Hughet	63	6 in	Qal	Land surface	.0	4,115			Ir	64	Flowing when visited. Flows about 100 gallons a minute. No casing.
350	NE¼NW¼ sec. 9	Mrs. M. I. Hughet	43	2 in	Qal	do	.0	4,108			D	60	Cased 40 feet. Flowing when visited. Static water level 6± feet above land surface.
352	NE¼NW¼ sec. 10	P. G. Smith	40	1¼ in	Qal	do	.0	4,098			D	52	Flowing when visited. Flows ¼ gallon a minute.
353	NE¼NW¼ sec. 15	Edith Sizemore	103	2 in	Td (?)	Land surface	.0	4,120			D	64½	Flowing when visited. Flows about ½ gallon a minute. Static water level 2± feet above land surface.
356	SE¼SE¼ sec. 15	Unknown	18	6 ft	Qal	Top of cover	.0	4,120	15.75	15.75	None		No casing.
	T. 27 S., R. 30 E.												
362	Lot 2 sec. 1	W. L. Newton	54	5 ft	Qal	Top of platform	.0	4,030	39.90	39.90	D		No casing.
363	NW¼SW¼ sec. 2	State of Oregon	43½	6 in	Qal	Top of casing	+.5	4,132.50	42.15	41.60	None		

364	SW¼SW¼ sec. 3	Unknown	55	6 in.	Qal	do	+.8	4,130.20	45.00	42.75	do		
367	Lot 2 sec. 4	Geological Survey	17	3 in.	Qal	do	+.5	4,098.75	17.65	16.90	do		Cased 1.5 feet.
[6] 368	Lot 4 sec. 4	W. J. Dunn	315	1¼ in.	Td	do	+2.0	4,094.40			S	65½	Flowing when visited. Flow estimated 35 gallons a minute.
[6] 369	Lot 7 sec. 8	Geological Survey	13	3 in.	Qal	do	+.5	4,093.55	11.81	11.45	None	54	Cased 1.5 feet.
371	(15)	do	6	3 in.	Qal	do	+.5	4,085.70	5.60	4.85	do	54	Do.
	T. 27 S., R. 31 E.												
373	SW¼NW¼ sec. 3	Sodhouse ranch	21		Qal	(2)	.0	4,100	7.30	7.05	S		Measuring point, top of 2- by 4-inch timber over casing.
[6] 374	Lot 1 sec. 5	Unknown	18	1½ in.	Qal	Lower valve seat	+1.8	4,104	14.05	6.80	None	51	
	T. 27 S., R. 32 E.												
375	SE¼NW¼ sec. 4	T. T. Dunn	70	6 in.	Qbv	Land surface	.0	4,095			S	52	Flowing when visited. Flows about 40 gallons a minute. Cased 45 feet.
376	Lot 6 sec. 4	do	130	6 in.	Qbv	do	.0	4,095			S	52	Flowing when visited. Flows about 50 gallons a minute.
377	SE¼NE¼ sec. 5	do	100+	4 in.	Qbv	do	.0	4,096			S	54	Flowing when visited. Flows about 3 gallons a minute.

1 Qal, valley fill; Qb, late basalt (Qbh, near Hines; Qbv, near Voltage); Th, Harney formation; Td, Danforth formation; Ts, Steens basalt.
2 See remarks.
3 Creek or river channel flowing close by.
4 For periodic measurements of depth to water see pp. 152–180.
5 Windmill operating slowly in well during measurement.
6 For chemical analysis of water see pp. 114–118.
7 Reported by owner.
8 Water standing in creek or river channel close by.
9 Well dry at depth indicated.
10 Water flowing in ditch close by.
11 Water level drawn down by adjacent irrigation well.
12 Pump operating in well during measurement.
13 Water level depressed by steady pumping.
14 Windmill at observation well stopped just before measurement.
15 Unsurveyed land within inner meander line of Malheur and Harney Lakes.

Measurements of depth to water in observation wells, 1928–32

No. 5. Frank Whiting. Stock well, drilled 18 inches in diameter and 288 feet deep. Water from Danforth formation. Measuring point, top of casing, 1.0 foot above land surface; altitude 4,154 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 8	9.95	Feb. 7	13.15	Nov. 9	11.20	June 6	3.35
Sept. 6	10.90	Mar. 7	13.05	Dec. 4	11.10	July 1	4.90
Oct. 3	11.35	Apr. 4	6.05			Aug. 1	6.45
Oct. 18	11.45	May 9	4.90	1932			
Nov. 1	11.50	May 19	5.65				
Dec. 6	11.50	June 9	6.15	Jan. 4	12.35		
		July 6	7.10	Feb. 2	11.80		
1931		Aug. 4	9.30	Mar. 3	12.40		
		Sept. 2	10.60	Apr. 1	5.30		
Jan. 3	11.55	Oct. 1	11.15	May 9	2.60		

No. 8. Alex Rogers. Domestic well, dug 5½ feet in diameter and 11 feet deep. Water from shallow valley fill. Measuring point, top of well platform, 0.5 foot above land surface; altitude 4,147 feet (interpolated)

1930		1931		1932		1932	
Sept. 1	9.05	July 7	8.90	Jan. 4	10.25	July 1	6.10
Oct. 6	9.40	Aug. 4	9.25	Feb. 2	10.20	Aug. 1	7.40
		Sept. 2	9.50	Mar. 3	10.15		
1931		Oct. 1	10.20	Apr. 1	4.75		
		Nov. 9	9.95	May 9	3.50		
May 19	8.45	Dec. 4	9.85	June 6	4.25		
June 9	8.60						

No. 10. William Krzeska. Unused well, dug 6 feet in diameter and 14 feet deep. Water from shallow valley fill. Measuring point, top of 2- by 12-inch plank of platform, at land surface; altitude 4,144.5 feet

1930		1931		1931		1932	
Sept. 1	10.75	Apr. 4	10.90	Dec. 4	11.75	June 6	11.20
Oct. 6	10.85	May 9	11.00			July 1	10.90
Oct. 18	10.90	May 19	11.30	1932		Aug. 1	11.55
Nov. 1	10.85	June 9	11.30				
		July 7	11.30	Jan. 4	11.15		
1931		Aug. 4	11.40	Feb. 2	11.15		
		Sept. 2	11.45	Apr. 1	10.90		
Feb. 7	10.90	Oct. 1	11.50	May 9	11.30		
Mar. 7	10.70	Nov. 9	11.55	May 31	11.20		

No. 11. Frank Triska. Domestic well, drilled 6 inches in diameter and 44 feet deep. Water from deep valley fill. Companion to well 12, which is about 150 feet to the south and which taps the shallow valley fill. Measuring point, top of casing, 0.6 foot above land surface; altitude 4,133 feet (interpolated)

1930		1931		1931		1932	
Oct. 6	9.85	Mar. 7	10.15	Nov. 9	10.75	May 9	4.45
Oct. 18	9.90	Apr. 4	10.15	Dec. 4	10.75	June 6	5.25
Nov. 1	9.90	May 9	10.05			July 1	6.65
Dec. 6	9.70	May 19	9.80	1932		Aug. 1	8.10
		June 9	10.05				
1931		July 7	10.20	Jan. 4	10.85		
		Aug. 4	10.45	Feb. 2	11.30		
Jan. 3	9.70	Sept. 2	10.70	Apr. 1	[1]5.70		
Feb. 7	10.00	Oct. 1	10.70				

[1] Adjacent land flooded.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 12. Frank Triska. Unused well, drilled 8 inches in diameter and 16 feet deep. Water from shallow valley fill. Measuring point, top of casing, 2.0 feet above land surface; altitude 4,134 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1931	
Oct. 6	11.15	Jan. 3	11.35	Apr. 4	11.15	May 9	[1]
Oct. 18	11.15	Feb. 7	11.15				
Nov. 1	11.15	Mar. 7	11.15				
Dec. 6	11.25						

No. 14. I. L. Poujade. Unused well, dug 5 feet in diameter and 14 feet deep; water from shallow valley fill. Measuring point, top of 2- by 14-inch plank, at land surface; altitude 4,143 feet (interpolated)

1930		1931		1931		1932	
Sept. 6	11.40	Mar. 7	12.00	Nov. 9	12.40	May 9	9.35
Oct. 18	11.40	Apr. 4	11.50	Dec. 4	12.30	June 6	9.30
Nov. 1	11.50	May 9	11.45			July 1	10.20
Dec. 6	11.40	May 20	11.55	1932		Aug. 1	11.00
		June 9	11.90				
1931		July 7	[2] 13.40	Jan. 4	12.70		
		Aug. 4	12.45	Feb. 2	13.40		
Jan. 3	11.55	Sept. 2	12.65	Mar. 3	12.35		
Feb. 7	11.85	Oct. 1	12.60	Apr. 1	10.60		

No. 30. Davidson. Stock well, drilled; initial depth reported 400 feet; measured depth, 63 feet in 1930. Water from deep valley fill; underlying Danforth formation (?) not water-bearing. Companion to well no. 31, which is about 125 feet to the west and taps the shallow valley fill. Measuring point, top of casing, 8.40 feet below land surface; altitude, 4,135.28 feet

1930		1931		1931		1931	
Aug. 23	5.6	June 1	5.72	Aug. 3	7.50	Oct. 14	5.08
		June 8	6.06	Aug. 10	6.91	Oct. 19	5.00
1931		June 22	6.32	Aug. 17	[3] 6.93		
		July 6	6.91	Aug. 24	6.35	1932	
May 12	4.70	July 20	7.24	Sept. 7	5.64		
May 18	4.95	July 27	[3] 7.54	Sept. 14	5.32	May 12	2.90

No. 31. Davidson. Unused well, dug 5 feet in diameter and 22 feet deep. Water from shallow valley fill. Measuring point, top of casing, at land surface; altitude, 4,144.28 feet

1930		1931		1931		1931	
Aug. 9	13.30	June 8	13.55	Aug. 3	13.79	Oct. 19	14.05
		June 15	13.58	Aug. 10	13.82	Oct. 26	14.03
1931		June 22	13.60	Aug. 17	13.82		
		June 29	13.62	Aug. 24	13.88	1932	
May 12	13.40	July 6	13.65	Aug. 31	13.90		
May 18	13.42	July 13	13.69	Sept. 7	13.95	May 12	13.50
May 25	13.48	July 20	13.71	Sept. 14	13.97		
June 1	13.52	July 27	13.75	Oct. 14	14.03		

[1] Casing removed and well filled up.
[2] Pump or windmill stopped a short time before measurement.
[3] Windmill operating during measurement.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 33. Owner unknown. Unused well, dug 4 by 6 feet across and 13 feet deep Water from shallow valley fill. Measuring point, top of 2- by 12-inch well curb, 1.5 feet above land surface; altitude, 4,145 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 8	10.80	Feb. 7	11.15	Oct. 1	11.65	Apr. 1	11.20
Sept. 6	10.85	Mar. 7	11.05	Nov. 9	11.70	May 9	10.20
Oct. 4	11.00	Apr. 5	11.15	Dec. 4	11.65	June 6	10.00
Oct. 18	10.95	May 9	11.15			July 1	10.15
Nov. 1	11.00	May 19	11.15	1932		Aug. 1	10.75
Dec. 6	11.10	June 9	11.30				
1931		July 6	11.40	Jan. 4	11.70		
		Aug. 4	11.55	Feb. 2	11.60		
Jan. 3	11.35	Sept. 6	11.55				

No. 37. L. M. Hamilton. Unused well, bored 18 inches in diameter and 98 feet deep. Water from deep valley fill. Measuring point, top of casing, 1.0 foot above land surface; altitude, 4.153 feet (interpolated)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1930		1931		1932	
Aug 8	11.75	Dec. 6	12.45	June 9	12.77	Jan. 4	13.43
Aug. 11	[1] 11.82			July 6	12.95	Apr. 1	10.70
Aug. 17	11.84	1931		Aug. 4	13.15	May 9	8.95
Aug. 23	11.90			Sept. 2	13.24	May 31	8.46
Sept. 6	12.06	Feb. 7	12.60	Oct. 2	13.30	June 6	8.45
Sept. 13	12.11	Mar. 7	12.40	Nov. 9	13.27	July 1	9.19
Sept. 29	[2] 12.16	Apr. 4	12.68	Dec. 4	13.20	Aug. 1	10.43
Oct. 18	12.25	May 9	12.60				
Nov 1	12.36	May 19	12.62				

No. 40. William Hanley Co. Domestic well bored 3 feet in diameter and 42 feet deep. Water from shallow valley fill. Measuring point, in top of plank well cover, copper nail with washer, 2.0 feet above land surface; altitude, 4,162 feet (interpolated)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1931		1932		1932	
Aug. 12	14.20	June 9	13.60	Jan. 4	16.90	Aug. 1	11.95
Sept. 5	14.70	July 6	13.95	Mar. 3	16.70		
Oct. 4	15.10	Aug. 4	15.35	Apr. 1	12.65		
		Sept. 2	16.00	May 9	8.65		
1931		Oct. 1	16.35	June 6	9.50		
		Dec. 4	16.70	July 1	10.25		
May 19	13.60						

No. 43. Hansen. Unused well, drilled 4 inches in diameter and 14 feet deep. Water from shallow valley fill. Measuring point, top of casing, 2.3 feet above land surface; altitude, 4,157 feet (interpolated)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1931		1931		1932	
Aug. 12	11.10	Feb. 7	12.60	Nov. 9	12.60	June 6	9.40
Sept. 5	11.75	Mar. 7	12.45	Dec. 4	13.05	July 1	9.70
Oct. 4	12.15	Apr. 4	10.95			Aug. 1	10.80
Oct. 18	12.20	May 9	9.65	1932			
Nov. 1	12.25	May 19	9.55				
Dec. 6	11.65	June 9	9.85	Jan. 4	13.10		
		July 6	10.35	Feb. 2	13.00		
1931		Aug. 4	10.60	Mar. 3	12.70		
		Sept. 2	12.45	Apr. 1	11.70		
Jan. 3	12.30	Oct. 1	12.95	May 9	10.10		

[1] Water-stage recorder installed. [2] Water-stage recorder removed.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 49. Burns Airport. Domestic well, bored 4½ inches in diameter 25 feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.3 foot above land surface; altitude 4,150.19 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 8	10.85	Apr. 20	10.88	Aug. 24	11.60	Mar. 4	12.05
Sept. 6	11.15	Apr. 29	10.84	Aug. 31	11.71	Mar. 19	12.12
Oct. 3	11.40	May 9	10.10	Sept. 7	11.82	Mar. 26	10.32
Oct. 18	11.50	May 18	10.12	Sept. 14	11.91	Apr. 2	10.19
Nov. 1	11.25	May 25	10.14	Sept. 21	12.01	Apr. 9	7.82
Dec. 7	11.80	June 1	10.23	Sept. 28	12.09	Apr. 16	7.32
		June 8	10.36	Oct. 5	12.15	Apr. 23	6187
1931		June 15	10.49	Oct. 14	12.20	Apr. 30	6.40
		June 22	10.57	Oct. 19	12.19	May 7	[1] 5.78
Jan. 3	11.85	June 29	10.66	Oct. 26	12.20	May 14	[1] 5.59
Feb. 8	12.20	July 6	10.77	Nov. 10	12.30	May 23	[1] 5.47
Mar. 8	12.15	July 13	10.88	Dec. 6	12.80	June 7	5.06
Mar. 16	12.20	July 20	10.98			June 24	5.94
Mar. 25	12 14	July 27	11.11	1932		July 6	7.15
Mar. 31	12.05	Aug. 3	11.25			July 19	8.04
Apr. 5	11.77	Aug. 10	11.37	Jan. 6	13.55	Aug. 1	8.75
Apr. 11	11.23	Aug. 17	11.46	Feb. 3	12.38		

No. 50. George Whiting. Stock well, dug 12 feet deep. Water from shallow valley fill. Companion to well 51, which is about 100 feet to the southwest and which taps the deep valley fill; distributary channel of the Silvies River about 25 feet to the north. Measuring point, top of 2-inch plank in well platform, 0.2 foot above land surface; altitude 4,144.59 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Sept. 13	9.50	May 25	9.43	Oct. 5	10.17	Apr. 16	[3] 2.86
Oct. 4	9.50	June 1	9.50	Oct. 19	10.12	Apr. 23	[3] 2.37
Oct. 18	9.50	June 8	9.66	Oct. 26	10.10	Apr. 30	[3] 1.72
Nov. 1	9.50	July 6	10.01	Nov. 10	10.68	May 7	[3] 2.40
Dec. 7	[2] 9.55	July 13	10.05			May 14	[3] 2.89
		Aug. 3	10.31	1932		May 23	[3] 2.98
1931		Aug. 10	10.23			June 7	[3] 3.35
		Aug. 24	10.20	Mar. 4	10.30	June 24	5.17
Jan. 3	9.60	Aug. 31	10.27	Mar. 19	10.15	July 6	6.12
Feb. 8	9.15	Sept. 7	10.27	Mar. 26	8.94	July 19	5.73
Mar. 8	9.15	Sept. 21	10.21	Apr. 2	8.52		
May 18	9.37	Sept. 28	10.16	Apr. 9	[3] 2.62		

No. 53. Obil Shattuck. Unused well, drilled 6 inches in diameter and 848 feet deep in 1893, redrilled 325 feet deep in 1930. Water from deep valley fill and Harney (?) formation. Companion to well 54. Measuring point, top of 6-inch casing, 1.9 feet above land surface; altitude 4,141.15 feet (in common with well 54)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1931	
Aug. 12	10.80	June 8	[4] 21.86	Aug. 10	[4] 22.36	Oct. 14	15.72
Aug. 23	[4] 19.10	June 15	[4] 21.52	Aug. 17	23.86	Oct. 19	15.37
		June 22	[4] 22.37	Aug. 24	20.64	Oct. 26	15.49
1931		June 29	[4] 24.14	Aug. 31	19.28		
		July 6	[4] 23.65	Sept. 7	17.90	1932	
May 12	17.40	July 13	[4] 24.81	Sept. 14	17.01		
May 18	[4] 18.24	July 20	[4] 25.18	Sept. 21	18.04	Mar. 4	12.90
May 25	[4] 19.41	July 27	[4] 25.72	Sept. 28	17.41	May 12	11.64
June 1	[4] 20.87	Aug. 3	25.35	Oct. 5	16.59		

[1] Adjacent land flooded.
[2] Windmill operating during measurement.
[3] Water flowing in adjacent channel.
[4] Pumping from adjacent irrigation well in deep valley fill.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 54. Obil Shattuck. Unused well, dug 6 feet square and 28 feet deep. Water from shallow valley fill. Companion to well 53, whose casing it surrounds. Measuring point, top of 6-inch casing, 1.9 feet above land surface: altitude 4,141.15 feet (in common with well 53)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1931	
Aug. 12	14.15	June 8	14.65	Aug. 10	14.83	Oct. 19	14.90
Aug. 23	14.21	June 15	14.66	Aug. 17	14.81	Oct. 26	14.87
		June 22	14.69	Aug. 24	14.86		
1931		June 29	14.72	Aug. 31	14.86	1932	
		July 6	14.75	Sept. 7	14.85		
May 12	14.55	July 13	14.76	Sept. 21	14.88	Mar. 4	14.77
May 18	14.60	July 20	14.79	Sept. 28	14.88	May 12	14.58
May 25	14.60	July 27	14.81	Oct. 5	14.90		
June 1	14.62	Aug. 3	14.83	Oct. 14	14.88		

No. 55. Owner unknown. Stock well, drilled 16 feet deep. Water from shallow valley fill. Measuring point, top of pump-base flange, 2.3 feet above land surface; altitude 4,141 feet (interpolated)

Date	Depth to water	Date	Depth to water	Date	Depth to water	Date	Depth to water
1930		1931		1931		1932	
Sept. 13	16.65	Mar. 31	16.95	July 13	16.92	Apr. 16	17.03
Oct. 4	17.15	Apr. 4	16.82	July 20	16.94	Apr. 23	17.00
Oct. 18	17.20	Apr. 11	16.88	July 27	16.96	Apr. 30	17.04
Nov. 1	16.60	Apr. 20	16.88	Aug. 3	16.99	May 7	17.10
Dec. 7	16.70	Apr. 29	16.85	Aug. 10	17.01	May 14	16.90
		May 18	16.80	Aug. 17	17.03	May 23	16.89
1931		May 25	16.80	Aug. 24	17.04	June 6	17.10
		June 1	16.82	Aug. 31	17.25	June 24	16.87
Jan. 3	16.70	June 8	16.83			July 6	17.01
Feb. 7	16.95	June 15	16.86	1932		July 19	16.94
Mar. 8	16.90	June 22	16.87			Aug. 1	16.98
Mar. 16	16.90	June 29	16.88	Mar. 19	17.10		
Mar. 25	16.90	July 6	16.91	Mar. 26	17.20		

No. 56. J. S. Cook. Irrigation well, bored 18 inches in diameter and 105 feet deep. Water from deep valley fill. Measuring point, top of pump base, at land surface; altitude 4,142.80 feet

Date	Depth to water	Date	Depth to water	Date	Depth to water	Date	Depth to water
1931		1931		1931		1931	
May 11	[1] 12.00	June 15	20.25	July 20	16.57	Aug. 31	17.95
May 14	17.80	June 22	16.71	July 25	[2] 69.65	Sept. 7	19.22
May 16	20.35	June 29	21.15	July 27	[2] 68.90	Sept. 21	17.83
May 18	16.10	July 6	18.30	Aug. 10	18.38	Sept. 28	15.47
June 1	15.60	July 11	16.85	Aug. 17	16.80		
June 11	[2] 77.90	July 13	16.70	Aug. 24	16.12		

No. 57. Observation well, bored by Geological Survey, 4 inches in diameter and 12½ feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.7 foot above land surface: altitude 4,140.70 feet

Date	Depth to water	Date	Depth to water	Date	Depth to water	Date	Depth to water
1930		1931		1931		1932	
Oct. 4	10.84	May 9	11.13	Aug. 31	11.06	Mar. 19	11.13
Oct. 18	10.70	May 18	11.02	Sept. 7	11.12	Mar. 26	[3] 11.15
Nov. 1	10.89	May 25	11.06	Sept. 14	11.16	Apr. 2	[3] 10.97
Dec. 7	10.77	June 1	10.40	Sept. 21	11.11	Apr. 9	[3] 10.92
		June 8	10.57	Sept. 28	11.16	Apr. 16	[3] 10.83
1931		June 15	10.40	Oct. 5	11.22	Apr. 23	[3] 10.81
		June 22	10.59	Oct. 24	11.23	Apr. 30	[3] 10.77
Jan. 3	10.89	June 29	10.70	Oct. 19	11.26	May 7	[3] 10.71
Mar. 8	11.05	July 6	10.69	Oct. 26	11.27	May 14	[3] 10.58
Mar. 16	11.08	July 13	10.81	Nov. 9	10.55	May 23	[3] 9.92
Mar. 25	11.10	July 20	10.93	Dec. 6	11.35	June 6	[3] 10.02
Mar. 31	11.09	July 27	11.02			June 24	10.00
Apr. 5	11.11	Aug. 3	11.02	1932		July 6	10.56
Apr. 11	11.10	Aug. 10	10.60			July 19	(4)
Apr. 20	11.10	Aug. 17	10.79	Jan. 5	11.50		
Apr. 29	11.06	Aug. 24	10.97	Mar. 4	11.35		

[1] Measurement by owner.
[2] Pump operating in well during measurement.
[3] Water flowing in adjacent channel.
[4] Caved in.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 58. Observation well, bored by Geological Survey, 4 inches in diameter and 12 feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.4 foot above land surface; altitude 4,142.83 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 4	12.00	Apr. 29	12.10	Aug. 10	12.75	Apr. 2	[2] 10.70
Oct. 18	12.08	May 9	[1] 11.7+	Aug. 17	12.75	Apr. 9	[2] 10.54
Nov. 1	12.02	May 18	(1)	Aug. 31	12.78	Apr. 16	[2] 10.10
Dec. 7	11.65	May 25	(1)	Sept. 21	12.69	Apr. 23	[2] 9.52
		June 1	(1)	Oct. 14	12.78	Apr. 30	[2] 9.14
1931		June 8	(1)	Nov. 9	12.35	May 7	[2] 8.83
		June 15	12.58			May 14	[2] 8.87
Jan. 3	12.03	June 22	12.59	1932		May 23	[2] 9.11
Feb. 7	12.15	June 29	12.60			June 6	[2] 9.32
Mar. 16	12.35	July 6	12.65	Jan. 5	12.30	June 24	10.01
Mar. 25	12.35	July 13	12.70	Feb. 3	13.00	July 6	10.33
Apr. 5	12.50	July 20	[1] 12.7+	Mar. 4	12.86	July 19	10.53
Apr. 11	12.40	July 27	12.65	Mar. 19	12.76	Aug. 1	10.78
Apr. 20	12.10	Aug. 3	12.84	Mar. 26	[2] 12.47		

No 59. Observation well, bored by Geological Survey, 4 inches in diameter and 12½ feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.5 foot above land surface; altitude 4,142.85 feet

1930		1931		1931		1932	
Oct. 4	11.91	Apr. 20	12.35	Aug. 10	12.68	Apr. 2	[2] 7.25
Oct. 18	12.44	Apr. 29	12.31	Aug. 17	12.69	Apr. 9	[2] 7.15
Nov. 1	11.98	May 9	12.39	Aug. 31	12.73	Apr. 16	[2] 6.08
Dec. 7	12.00	May 18	12.37	Sept. 21	12.74	Apr. 23	[2] 7.00
		May 25	12.42	Oct. 14	12.66	Apr. 30	[2] 4.97
1931		June 1	12.43	Nov. 9	12.77	May 7	[2] 5.01
		June 8	12.46	Dec. 6	12.55	May 14	[2] 6.25
Jan. 3	11.99	June 15	12.48			May 23	[2] 6.86
Feb. 7	11.55	June 22	12.49	1932		June 6	[2] 7.50
Mar. 8	12.35	June 29	12.52			June 24	9.22
Mar. 16	12.32	July 6	12.53	Jan. 5	12.34	July 6	9.79
Mar. 25	12.36	July 13	12.57	Feb. 3	13.00	July 19	10.13
Mar. 31	12.33	July 20	12.59	Mar. 4	12.32	Aug. 1	10.41
Apr. 5	12.35	July 27	12.64	Mar. 19	12.40		
Apr. 11	12.32	Aug. 3	12.68	Mar. 26	[2] 9.84		

No. 60. Observation well, bored by Geological Survey, 4 inches in diameter and 12 feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.7 foot above land surface; altitude 4,141.96 feet

1930		1931		1931		1932	
Oct. 4	11.00	May 18	11.40	Aug. 17	11.79	Apr. 2	[2] 4.15
Oct. 18	10.99	May 25	11.55	Aug. 31	11.82	Apr. 9	[2] 4.26
		June 1	(1)	Sept. 21	11.86	Apr. 16	[2] 3.62
1931		June 8	11.5±	Oct. 14	11.82	Apr. 23	[2] 3.72
		June 15	11.55	Dec. 6	11.45	Apr. 30	[2] 3.57
Feb. 7	11.30	June 22	11.52			May 7	[2] 3.65
Mar. 8	11.45	June 29	11.57	1932		May 14	[2] 4.27
Mar. 16	11.68	July 6	11.57			May 23	[2] 5.01
Mar. 25	11.63	July 13	11.59	Jan. 5	12.05	June 6	[2] 5.90
Mar. 31	11.62	July 20	11.58	Feb. 3	11.80	June 24	8.15
Apr. 5	11.62	July 27	11.64	Mar. 4	11.57	July 6	8.71
Apr. 11	11.55	Aug. 3	11.76	Mar. 19	11.62	July 19	9.12
May 9	11.25	Aug. 10	11.79	Mar. 26	[2] 6.82	Aug. 1	9.39

[1] Well dry. [2] Water flowing in adjacent channel.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 61. Owner unknown. Stock well, bored 6 inches in diameter and 28 feet deep. Water from shallow valley fill. Measuring point, top of casing, 1.0 foot above land surface; altitude 4,144.50 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 9	12.80	Apr. 20	13.47	Aug. 10	13.77	Mar. 19	13.67
Sept. 13	12.90	Apr. 29	13.45	Aug. 17	13.80	Mar. 26	[1] 13.85
Oct. 4	13.10	May 9	13.46	Aug. 24	13.80	Apr. 2	[1] 13.50
Oct. 18	13.05	May 15	13.45	Sept. 21	13.94	Apr. 9	[1] 12.59
Nov. 1	13.10	May 18	13.45	Sept. 28	13.92	Apr. 16	[1] 12.08
Dec. 7	13.20	May 25	13.45	Oct. 14	13.95	Apr. 23	[1] 12.40
		June 1	13.47	Oct. 19	13.94	Apr. 30	[1] 12.41
1931		June 8	13.50	Oct. 26	13.91	May 7	[1] 12.16
		June 15	13.52	Nov. 10	13.90	May 14	[1] 12.15
Jan. 3	13.25	June 22	13.51	Dec. 6	13.97	May 23	[1] 11.85
Feb. 7	13.40	June 29	13.57			June 7	[1] 11.64
Mar. 8	13.45	July 6	13.62	1932		June 24	11.72
Mar. 25	13.45	July 13	13.65			July 6	11.70
Mar. 31	13.42	July 20	13.67	Jan. 6	14.01	July 19	11.84
Apr. 5	13.48	July 27	13.71	Feb. 3	14.00	Aug. 1	11.89
Apr. 11	13.45	Aug. 3	13.75	Mar. 4	13.73		

No. 62. William McLaren. Domestic well, bored 18 inches in diameter and 16 feet deep. Water from shallow valley fill. Companion to well 63, which is about 300 feet to the southwest; also to well 64, which is about 300 feet to the west and which taps the deep valley fill. Measuring point, top of casing, about 0.2 foot above land surface; altitude, 4,141.90 feet

1930		1931		1931		1932	
Oct. 22	9.20	Apr. 20	9.09	Sept. 28	9.54	Apr. 2	[1] 5.27
Nov. 1	9.20	Apr. 29	9.14	Oct. 5	9.58	Apr. 9	[1] 3.08
Dec. 7	9.25	May 9	8.83	Oct. 14	9.62	Apr. 16	[1] 1.70
		May 13	8.90	Oct. 19	9.65	Apr. 23	[1] 2.63
1931		June 1	8.90	Oct. 26	9.65	Apr. 30	[1] 2.28
		June 8	[2] 9.14	Nov. 10	9.71	May 7	[1,2] 4.22
Jan. 3	9.25	July 13	8.11			May 14	[1] 2.26
Feb. 8	9.25	July 20	8.45	1932		May 23	[1] 2.95
Mar. 8	9.15	Aug. 3	8.12			June 7	4.25
Mar. 16	9.15	Aug. 10	8.41	Jan. 6	9.77	June 24	4.55
Mar. 25	9.16	Aug. 24	9.07	Feb. 3	9.81	July 19	6.81
Mar. 31	9.18	Sept. 7	9.24	Mar. 4	9.44	Aug. 1	8.04
Apr. 5	9.17	Sept. 14	9.25	Mar. 19	9.36		
Apr. 11	9.15	Sept. 21	9.38	Mar. 26	8.78		

No. 64. William McLaren. Irrigation well, bored 18 inches in diameter and 87 feet deep. Water from deep valley fill. Measuring point, bottom of ½-inch drilled hole in side of casing, 0.1 foot above land surface; altitude, 4,141.92 feet

1930		1931		1931		1932	
Aug. 9	8.25	Mar. 31	8.62	Sept. 14	9.28	Mar. 19	8.74
Aug. 12	8.55	Apr. 5	8.62	Sept. 21	9.29	Mar. 26	8.82
Sept. 6	8.70	Apr. 11	8.47	Sept. 28	9.25	Apr. 2	[1] 4.40
Oct. 4	8.85	Apr. 20	8.39	Oct. 5	9.24	Apr. 9	[1] 3.54
Oct. 18	8.70	Apr. 29	8.37	Oct. 14	9.19	Apr. 16	[1] 2.86
Nov. 1	8.90	May 9	8.87	Oct. 19	9.20	Apr. 23	[1] 3.45
Dec. 7	8.95	May 18	8.65	Oct. 26	9.19	Apr. 30	[1] 2.14
		May 25	9.45	Nov. 10	9.17	May 7	[1] 1.90
1931		June 1	11.71	Dec. 6	9.14	May 14	[1] 2.09
		June 15	11.73			May 23	[1] 2.53
Jan. 3	9.00	Aug. 10	11.48	1932		June 7	2.50
Feb. 8	9.00	Aug. 17	9.33			July 6	5.47
Mar. 8	9.00	Aug. 24	9.25	Jan. 6	9.19	July 19	6.54
Mar. 16	8.48	Aug. 31	9.20	Feb. 3	9.27		
Mar. 25	8.64	Sept. 7	9.72	Mar. 4	8.93		

[1] Water flowing in adjacent channel.
[2] Windmill operating during measurement.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 65. Pacific Live Stock Co. Irrigation well, drilled 12 inches in diameter and 300 feet deep; water from Harney (?) formation. Measuring point, top of pump base, at land surface; altitude 4,145.58 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 12	[1] 9.6	June 29	9.62	Sept. 14	10.19	Jan. 6	10.71
Aug. 27	[2] 9.3	July 6	9.53	Sept. 21	10.21	May 10	[4] 5.19
Oct. 22	[3] 12.00	July 13	9.54	Sept. 28	10.21	June 24	5.41
		July 20	9.57	Oct. 5	10.21	July 7	6.17
1931		July 27	9.68	Oct. 14	10.25	Aug. 3	7.39
		Aug. 3	9.80	Oct. 19	10.26		
May 13	9.75	Aug. 10	9.91	Oct. 26	10.26		
May 18	9.00	Aug. 17	9.91	Nov. 10	10.29		
June 1	11.44	Aug. 24	9.97	Dec. 5	10.27		
June 15	13.36	Aug. 31	10.00				
June 22	10.19	Sept. 7	10.09				

No. 66. Observation well, bored by Geological Survey, 3 inches in diameter and 10 feet deep. Water from shallow valley fill. Measuring point, top of casing, 0.6 foot above land surface; altitude 4,147.75 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1932		1932		1932	
Oct. 22	10.73	Mar. 4	9.50	Apr. 16	[5] 0.60	June 24	[5] 1.59
Oct. 26	9.86	Mar. 19	9.20	Apr. 23	[5] .65	July 6	4.08
Nov. 10	9.15	Mar. 26	4.06	Apr. 30	[5] .57	July 19	5.78
Dec. 6	10.10	Apr. 9	[5] .82	May 14	[5] 2.25	Aug. 1	6.66

No. 67. Observation well, bored by Geological Survey, 4 inches in diameter and 11 feet deep. Water from shallow valley fill. Measuring points, (1) through October 19, 1931, top of casing, 0.8 foot above land surface; altitude 4,147.19 feet; (2) beginning October 26, 1931, top of casing (reset); altitude 4,147.26 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 3	7.79	Apr. 29	2.81	Aug. 24	7.20	Mar. 4	7.18
Oct. 18	7.86	May 9	2.23	Aug. 31	7.39	Mar. 19	7.09
Nov. 1	7.85	May 18	3.04	Sept. 7	7.57	Mar. 26	[5] 1.27
Dec. 7	8.10	May 25	3.07	Sept. 14	7.75	Apr. 9	[5] .19
		June 1	3.76	Sept. 21	7.89	Apr. 16	[5] .06
1931		June 8	4.50	Sept. 28	7.89	Apr. 23	[5] .11
		June 15	4.93	Oct. 5	8.12	Apr. 30	[5] .04
Jan. 3	8.13	June 22	5.16	Oct. 14	8.15	May 14	[5] 1.87
Feb. 8	8.22	June 29	5.40	Oct. 19	8.24	June 24	[5] .62
Mar. 8	8.10	July 6	5.63	Oct. 26	[6] 8.27	July 6	2.59
Mar. 16	8.09	July 13	5.82	Nov. 10	8.35	July 19	3.80
Mar. 25	7.54	July 20	6.05	Dec. 6	8.33	Aug. 1	4.95
Mar. 31	4.17	July 27	6.30				
Apr. 5	.72	Aug. 3	6.54	1932			
Apr. 11	2.85	Aug. 10	6.80				
Apr. 20	2.83	Aug. 17	6.97	Jan. 6	8.40		

[1] Well being drilled, 37 feet deep when measurement was made.
[2] Well being drilled, 53 feet deep when measurement was made.
[3] Drilling complete; well 300 feet deep.
[4] Water flowing in adjacent channel.
[5] Adjacent land flooded.
[6] New measuring point.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 68. Observation well, bored by Geological Survey, 4 inches in diameter and 1[illegible] feet deep. Water from shallow valley fill. Measuring points (1) through October 5, 1931, top of casing, 0.8 foot above land surface; altitude 4,148.31 feet; (2) beginning October 14, 1931, top of casing (reset); altitude 4,147.42 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 3	8.68	May 9	2.25	Aug. 31	8.00	Mar. 26	[2] 1.13
Oct. 18	8.50	May 18	2.65	Sept. 7	8.19	Apr. 2	[2] .12
Nov. 1	8.50	May 25	2.61	Sept. 14	8.37	Apr. 9	[2] .14
Dec. 7	8.47	June 1	3.20	Sept. 21	8.49	Apr. 16	[2] .08
		June 8	3.83	Sept. 28	8.57	Apr. 23	[2] .10
1931		June 15	4.23	Oct. 5	8.62	Apr. 30	[2] .01
Jan. 3	8.51	June 22	4.36	Oct. 14	[1] 7.72	May 7	[2] .05
Feb. 8	8.47	June 29	4.64	Oct. 19	7.78	May 14	[2] 1.29
Mar. 8	8.10	July 6	4.94	Oct. 26	7.78	May 23	[2] .25
Mar. 16	8.10	July 13	5.59	Nov. 10	7.69	June 24	[2] .69
Mar. 25	4.69	July 20	6.01			July 6	1.90
Mar. 31	3.45	July 27	6.24	1932		July 19	3.03
Apr. 5	1.87	Aug. 3	6.87	Jan. 6	7.42	Aug. 1	4.09
Apr. 11	2.29	Aug. 10	7.28	Feb. 3	7.33		
Apr. 20	2.30	Aug. 17	7.58	Mar. 4	6.42		
Apr. 29	2.28	Aug. 24	7.84	Mar. 19	6.08		

No. 69. Observation well, bored by Geological Survey, 4 inches in diameter and 12 feet deep. Water from shallow valley fill. Measuring points (1) through Oct. 19, 1931, top of casing, 1.0 foot above land surface; altitude 4,150.44 feet: (2) beginning Oct. 26, 1931, top of casing (reset); altitude 4,150.49 feet

1930		1931		1931		1932	
Oct. 3	10.85	May 9	3.70	Aug. 31	10.47	Mar. 19	6.32
Oct. 18	9.71	May 18	3.87	Sept. 7	10.60	Mar. 26	[2] 2.30
Nov. 1	9.71	May 25	3.74	Sept. 14	10.80	Apr. 2	[2] .88
Dec. 7	10.55	June 1	4.31	Sept. 21	10.94	Apr. 9	[2] 1.19
		June 8	4.66	Sept. 28	10.95	Apr. 16	[2] 1.02
1931		June 15	4.82	Oct. 5	11.00	Apr. 23	[2] 1.17
Jan. 3	10.62	June 22	4.86	Oct. 14	11.05	Apr. 30	[2] 1.11
Feb. 8	10.28	June 29	5.24	Oct. 19	11.01	May 7	[2] 1.25
Mar. 8	9.99	July 6	5.68	Oct. 26	[1] 10.91	May 14	[2] 3.16
Mar. 16	7.82	July 13	7.48	Nov. 10	10.41	May 23	[2] 2.39
Mar. 25	4.15	July 20	8.03	Dec. 6	9.67	June 6	[2] 2.62
Mar. 31	3.54	July 27	8.50			June 24	[2] 3.23
Apr. 5	2.50	Aug. 3	9.23	1932		July 6	3.99
Apr. 11	2.85	Aug. 10	9.67	Jan. 6	9.18	July 19	5.81
Apr. 20	3.12	Aug. 17	10.01	Feb. 3	9.30	Aug. 1	7.06
Apr. 29	3.09	Aug. 24	10.32	Mar. 4	8.06		

No. 70. Observation well, bored by Geological Survey. 4 inches in diameter and 14 feet deep. Water from shallow valley fill. Measuring points, (1) through October 19, 1931, top of casing, 0.5 foot above land surface; altitude 4,150.89 feet; (2) beginning October 26, 1931, top of casing (reset); altitude 4,151.05 feet

1930		1931		1931		1932	
Oct. 3	11.25	Apr. 29	3.12	Sept. 7	11.38	Mar. 19	3.42
Oct. 18	11.22	May 9	3.55	Sept. 14	11.52	Mar. 26	[2] 1.69
Nov. 1	11.20	May 18	4.16	Sept. 21	11.92	Apr. 2	[2] .83
Dec. 7	11.25	May 25	3.95	Sept. 28	[3]	Apr. 9	[2] .99
		June 1	4.60	Oct. 5	[3]	Apr. 16	[2] .81
1931		June 8	4.87	Oct. 14	[3]	Apr. 23	[2] 1.05
		June 15	4.97	Oct. 19	[3]	Apr. 30	[2] 1.04
Jan. 3	11.28	June 22	4.99	Oct. 26	[1] 11.42	May 7	[2] 1.17
Feb. 8	10.55	June 29	5.35	Nov. 10	10.00	May 14	[2] 3.61
Mar. 8	9.40	July 6	5.74	Dec. 6	9.05	May 23	[2] 2.61
Mar. 16	4.87	July 13	7.99			June 6	[2] 2.78
Mar. 25	3.22	Aug. 3	9.94	1932		June 24	[2] 3.45
Mar. 31	3.04	Aug. 10	10.50			July 7	4.18
Apr. 5	2.16	Aug. 17	11.00	Jan. 6	8.37	July 19	6.04
Apr. 11	2.70	Aug. 24	[3]	Feb. 3	9.10	Aug. 1	7.39
Apr. 20	3.13	Aug. 31	11.46	Mar. 4	7.17		

[1] New measuring point. [2] Adjacent land flooded. [3] Well dry.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 72. C. H. Voegtly. Domestic well, dug 6 feet square and 13 feet deep. Water from shallow valley fill. Measuring point, top of well cover, 0.7 foot above land surface; altitude 4,152 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 22	10.30	May 18	9.65	Sept. 7	10.25	Mar. 26	9.65
Nov. 1	10.30	May 25	9.40	Sept. 14	10.55	Apr. 2	9.50
Dec. 7	10.35	June 1	9.66	Sept. 21	10.65	Apr. 9	9.45
		June 8	9.45	Sept. 28	10.70	Apr. 16	9.30
1931		June 15	9.80	Oct. 14	10.80	Apr. 23	9.15
		June 22	9.90	Oct. 19	10.80	Apr. 30	9.10
Jan. 3	10.40	June 29	9.90	Oct. 26	10.75	May 7	9.10
Feb. 8	10.10	July 6	9.65	Nov. 11	10.80	May 14	8.95
Mar. 8	10.05	July 13	9.80	Dec. 6	10.75	May 23	8.90
Mar. 16	10.05	July 20	9.95			June 6	8.90
Mar. 25	10.00	July 27	9.70	1932		June 24	9.15
Mar. 31	9.95	Aug. 3	10.10			July 6	9.25
Apr. 5	9.95	Aug. 10	10.30	Jan. 6	10.65	July 19	9.50
Apr. 20	9.85	Aug. 17	10.30	Feb. 3	10.55	Aug. 1	9.85
Apr. 29	9.80	Aug. 24	10.15	Mar. 4	9.70		
May 9	9.65	Aug. 31	10.35	Mar. 19	9.70		

No. 76. Charles Culp. Unused well, bored 24 inches in diameter and 63½ feet deep. Water from deep valley fill. Companion to well 77, which is about 15 feet to the south and which taps the shallow valley fill; West Fork of the Silvies River 50 feet to the east. Measuring point, top of casing, 0.8 foot above land surface; altitude 4,147.79 feet

1930		1931		1931		1932	
Aug. 14	11.15	Feb. 28	11.25	Oct. 5	11.89	Mar. 31	5.06
Sept. 1	11.67	Mar. 12	10.97	Oct. 27	12.08	Apr. 8	4.27
Sept. 24	11.93	Mar. 25	5.32	Nov. 23	12.13	Apr. 17	3.90
Sept. 29	[1] 11.91	Apr. 2	4.50	Dec. 3	12.10	Apr. 24	3.65
Oct. 3	11.94	Apr. 4	4.20	Dec. 15	12.05	Apr. 30	3.50
Oct. 12	11.96	Apr. 11	3.99	Dec. 26	11.99	May 8	3.61
Oct. 20	11.97	Apr. 20	4.03			May 15	4.91
Oct. 31	11.98	Apr. 30	4.50	1932		May 29	4.37
Nov. 19	11.87	May 11	5.08			June 1	3.32
Dec. 3	11.82	May 23	5.67	Jan. 3	11.86	June 13	4.77
Dec. 17	11.77	June 8	6.70	Jan. 7	11.84	June 25	4.84
		June 29	7.71	Jan. 19	11.61	July 8	5.97
1931		July 6	7.96	Jan. 31	11.52	July 19	6.91
		July 20	8.91	Feb. 14	11.06	July 31	7.39
Jan. 8	11.75	July 27	9.57	Feb. 23	10.74	Aug. 14	7.83
Jan. 29	11.53	Aug. 10	10.20	Feb. 29	10.48	Aug. 30	[2] 8.37
Feb. 3	11.49	Aug. 19	10.52	Mar. 15	8.84		
Feb. 12	11.45	Aug. 24	10.72	Mar. 22	6.01		

No. 77. Charles Culp. Observation well, bored for Geological Survey, 18 inches in diameter and 15 feet deep. Water from shallow valley fill. Measuring point, top of casing, 1 foot above land surface; altitude 4,147.67 feet

1930		1931		1931		1932	
Sept. 27	11.46	Mar. 25	3.35	Nov. 23	11.81	Apr. 17	2.17
Oct. 3	[1] 11.40	Apr. 2	2.77	Dec. 3	11.81	Apr. 21	2.20
Oct. 12	11.46	Apr. 4	2.50	Dec. 15	11.77	Apr. 24	2.23
Oct. 19	11.47	Apr. 11	2.73	Dec. 26	11.71	Apr. 30	2.17
Oct. 23	11.47	Apr. 20	2.95			May 8	2.12
Oct. 31	11.47	Apr. 30	3.56	1932		May 15	3.75
Nov. 19	11.37	May 11	4.33			May 29	3.09
Dec. 4	11.35	May 23	4.88	Jan. 3	11.64	June 13	3.52
Dec. 17	11.37	June 8	5.85	Jan. 7	11.36	June 25	3.56
		June 29	6.63	Jan. 18	10.64	July 8	4.98
1931		July 6	6.51	Jan. 31	10.70	July 19	5.73
		July 20	7.76	Feb. 14	8.80	July 31	6.14
Jan. 8	11.28	July 27	8.28	Feb. 23	7.75	Aug. 14	6.56
Jan. 29	10.20	Aug. 10	9.26	Feb. 29	7.69	Aug. 30	[2] 6.80
Feb. 3	10.00	Aug. 19	9.74	Mar. 15	6.26		
Feb. 12	10.02	Oct. 22	11.66	Mar. 22	2.68		
Feb. 28	9.34	Oct. 27	11.70	Mar. 31	2.50		
Mar. 12	8.22	Nov. 13	11.80	Apr. 8	2.25		

[1] Water-stage recorder installed.

[2] Water-stage recorder removed.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 82. William Hanley Co. Stock well, drilled 4 inches in diameter and 55½ feet deep. Water from deep valley fill. Measuring point, top of casing, 0.5 foot above land surface; altitude 4,136.44 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1931	
Aug. 16	10.60	June 15	[1] 10.42	Aug. 3	[1] 11.51	Sept. 21	11.64
		June 22	[1] 10.61	Aug. 10	[1] 11.69	Sept. 28	11.57
1931		June 29	[1] 10.80	Aug. 17	[1] 11.75	Oct. 5	11.51
May 18	[1] 9.63	July 6	[1] 10.95	Aug. 24	11.80	Oct. 14	11.43
May 27	[1] 9.87	June 13	[1] 11.10	Aug. 31	11.74	Oct. 19	11.39
June 1	[1] 9.99	June 20	[1] 11.21	Sept. 7	11.70	Oct. 26	11.30
June 8	[1] 10.18	July 27	[1] 11.33	Sept. 14	11.68		

No. 85. Charles Culp. Stock well, drilled 8 inches in diameter and 45 feet deep. Water from deep valley fill. Companion to well 86, which is about 20 feet to the south and which taps the shallow valley fill. Measuring point, top of casing, 1.7 feet above land surface; altitude 4,139.2 feet (datum is land surface at well 86, altitude 4,137 feet interpolated)

1930		1931		1931		1932	
Aug. 13	9.90	Feb. 8	9.05	Oct 2	10.35	June 6	2.80
Sept. 2	10.00	Mar. 8	9.90	Nov. 10	10.40	July 7	6.55
Oct. 3	10.20	Apr. 5	9.20	Dec. 5	10.35	Aug. 3	7.90
Oct. 19	10.25	May 11	7.85				
Nov. 2	10.25	May 22	8.05	1932			
Dec. 6	10.20	June 10	8.60	Jan. 6	10.30		
		July 8	9.15	Feb. 4	10.10		
1931		Aug. 5	9.70	Mar. 7	9.95		
Jan. 4	10.20	Sept. 2	10.15	May 10	[2] 2.65		

No. 86. Charles Culp. Unused well, dug 4 feet square and 9 feet deep. Water from shallow valley fill Measuring point, in top of 2- by 12-inch well curb, copper nail with washer, 0.5 foot below land surface· altitude 4,137 feet (interpolated)

1930		1931		1931		1932	
Aug. 13	7.80	Feb. 8	8.80	Oct. 2	8.40	June 6	1.00
Sept. 2	8.10	Mar. 8	8.50	Dec. 5	8.70	July 7	5.10
Oct. 3	8.40	Apr. 5	8.40			Aug. 3	6.55
Oct. 19	8.10	May 11	6.40	1932			
Nov. 2	8.80	May 22	6.20	Jan. 6	([3])		
Dec. 6	8.65	June 10	6.75	Feb. 4	8.40		
		July 8	7.10	Mar. 7	7.80		
1931		Aug. 5	7.90	Apr. 3	([2])		
Jan. 4	([3])	Sept. 2	8.20	May 10	[2] .10		

No. 90. O. D. Hotchkiss. Unused well, driven 1¼ inches in diameter and 10 feet deep Water from shallow valley fill. Measuring point, lower valve seat of pump, 2.2 feet above land surface; altitude 4,134 feet (interpolated)

1928		1929		1929		1930	
Oct. 6	8.4	Apr. 10	[4] 4.1	Dec. 10	[4] 9.3	Aug. 15	9.70
Dec. 6	[4] 8.7	May 6	[4] 3.1			Oct. 3	10.20
		July 6	[4] 6.3	1930		Oct. 19	10.55
1929		Aug. 10	[4] 8.3	Mar. 18	[4] 5.3	Dec. 6	8.75
Jan. 8	[4] 8.5	Sept. 10	[4] 9.2	May 25	[4] 6.9		
Feb. 8	[4] 8.5	Oct. 10	[4] 9.6	June 25	[4] 8.4		
Mar. 9	[4] 8.5	Nov. 10	[4] 9.6	July 28	[4] 9.3		

[1] Pumping from adjacent irrigation well in deep valley fill.
[2] Adjacent land flooded.
[3] Well dry.
[4] Measurement by owner.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 92. Owner unknown. Unused well, dug 5 feet in diameter and 19½ feet deep. Water from shallow valley fill. Measuring point, top of 4- by 6-inch girder of pump platform, at land surface; altitude 4,138 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 9	14.45	Mar. 7	14.20	Nov. 9	15.35	May 9	12.45
Sept. 6	14.65	Apr. 4	14.10	Dec. 4	15.35	May 31	12.50
Oct. 6	14.60	May 9	14.05			June 6	12.55
Oct. 18	14.65	May 19	14.10	1932		July 1	13.20
Nov. 1	14.60	June 9	14.45			Aug. 1	14.30
		July 7	14.95	Jan. 4	15.30		
1931		Aug. 4	15.40	Feb. 2	14.90		
		Sept. 2	15.50	Mar. 3	15.05		
Feb. 7	14.30	Oct. 1	15.60	Apr. 1	13.10		

No. 93. Harney Branch Experiment Station. Observation well, bored 11½ feet deep. Water from shallow valley fill. Companion to well 94, which is about 20 feet to the southwest and which taps the deep valley fill. Measuring points, (1) through Sept. 2, 1930, at land surface; altitude 4,135.2 feet; (2) beginning Oct. 3, 1930, top of casing, 0.4 foot above land surface; altitude 4,135.6 feet

1929	(1)	1930	(1)	1931	(1)	1932	(1)
Feb. 1	8.2	Feb. 5	8.7	Feb. 5	9.6	Feb. 2	8.9
Mar. 1	8.4	Mar. 1	8.1	Mar. 2	9.7	Mar. 5	8.9
Apr. 1	8.1	Apr. 1	8.3	Mar. 27	9.7	Apr. 2	8.7
May 1	8.3	May 2	8.5	May 2	9.1	May 2	7.9
June 1	7.0	July 2	8.1	May 12	8.9	June 3	6.6
July 2	6.5	Aug. 7	8.0	June 1	8.2	June 30	7.0
Aug. 1	6.8	Aug. 20	8.6	July 3	7.7	Aug. 1	7.5
Sept. 2	8.0	Sept. 2	8.8	Aug. 7	7.5		
Oct. 2	8.2	Oct. 3	[2] 9.1	Sept. 2	7.7		
Nov. 7	8.2	Nov. 3	9.2	Oct. 5	8.0		
Dec. 11	8.4	Dec. 1	9.3	Nov. 12	8.4		
				Dec. 5	8.7		
1930		1931					
Jan. 1	8.6	Jan. 5	9.5				

[1] Measurements by owner. [2] New measuring point.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 94. Harney Branch Experiment Station. Irrigation well, bored 18 inches in diameter and 87 feet deep. Water from deep valley fill. Measuring points, (1) through Mar. 27, 1931, top of casing, 0.2 foot above land surface; altitude 4134.88 feet; (2) beginning Apr. 27, 1931, center of pneumatic depth gage, 1.4 feet above land surface; altitude 4,136.64 feet

Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]
1928		
Oct. 5	6.90	
Dec. 1	6.55	
1929		
Jan. 1	6.20	
Feb. 1	6.20	
Mar. 1	6.20	
Apr. 1	6.10	
May 1	6.00	
Sept. 2	9.5	
Oct. 2	9.1	
Nov. 7	7.6	
Dec. 11	7.2	
1930		
Jan. 1	7.0	
Feb. 5	6.9	
Mar. 1	6.9	
Apr. 1	6.7	
May 2	6.7	
May 29	18.35	
May 31	14.50	
June 4		50.65
June 5	22.15	
June 7	23.75	
June 9		50.00
June 10	23.00	
June 11	25.00	50.50
June 12	26.50	
June 13	28.85	
June 14	27.60	
June 17		49.00
June 18	26.50	
June 19	27.35	
June 20	28.35	52.50
June 21	28.35	53.25
June 23	21.50	
June 24	28.50	
June 26	18.90	
June 27	20.65	
June 28	28.60	58.25
June 30	21.65	
July 1	27.25	
July 3	29.00	
July 5	22.50	
July 7	21.00	
July 8	26.75	
July 9	28.60	
July 10	[2] 28.90	
July 14	16.00	48.00
July 15	21.85	36.60
July 16	23.15	
July 17	23.65	37.50
July 18	23.00	
July 21	19.00	46.85
July 22	21.60	
July 23	23.50	
July 24	23.15	
July 25	23.10	
July 26	23.00	
July 28	19.50	
July 29	23.00	
July 30	23.15	
July 31	23.75	
Aug. 1	24.00	

Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]
1930		
Aug. 2	23.65	
Aug. 7	23.35	
Aug. 12	20.40	
Aug. 18	14.50	
Aug. 19	16.65	
Aug. 20	19.40	
Aug. 21	20.35	
Aug. 22	18.65	
Aug. 23	20.10	
Aug. 25	17.00	
Aug. 27	14.60	
Sept. 2	12.30	
Oct. 2	9.15	
Oct. 4	9.10	
Nov. 3	8.50	
Dec. 1	8.00	
1931		
Jan. 5	7.80	
Feb. 5	7.60	
Mar. 2	7.60	
Mar. 27	7.55	
Apr. 27		[3] 47.0
Apr. 28	[3] 11.0	59.0
Apr. 29	17.0	58.0
Apr. 30	20.0	60.0
May 1	21.0	59.5
May 2	22.0	60.5
May 4	18.0	60.0
May 5	21.0	60.0
May 6	22.0	59.5
May 7	23.0	60.5
May 8	24.0	60.5
May 9	27.0	61.0
May 12	17.5	
May 13	17.0	59.0
May 14	21.0	59.75
May 15	24.0	60.5
May 16	26.0	59.5
May 18	20.0	60.0
May 19	23.5	60.5
May 20	23.5	58.5
May 21	27.0	58.5
May 23	27.0	61.0
May 25	22.0	
May 26	28.0	59.5
May 27	29.5	59.0
May 28	31.0	55.0
May 29	31.0	55.5
May 30	31.0	55.0
June 1	24.0	54.0
June 2	30.0	56.0
June 3	32.0	57.0
June 4	32.5	56.0
June 5	32.0	
June 6	32.0	56.5
June 8	27.0	55.5
June 9	30.5	57.0
June 11	25.1	
June 12	21.0	50.5
June 15	21.5	54.0
June 16	25.0	
June 17	25.5	57.0
June 18	29.0	59.0
June 19	31.0	60.0
June 20	32.5	61.0

Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]
1931		
June 21	33.0	59.0
June 22	27.5	60.0
June 23		62.5
June 24		64.0
June 25		64.5
June 26		65.5
June 27		66.0
June 28		66.0
June 29		66.25
June 30		66.5
July 1		66.5
July 2		66.5
July 5	24.0	46.0
July 6		60.5
July 7		62.0
July 8		64.0
July 9		65.0
July 10		65.5
July 11		66.0
July 12		66.25
July 13		66.5
July 14		66.25
July 15		66.5
July 16		66.75
July 17		67.0
July 18		67.0
July 19		67.0
July 20		67.0
July 21		67.0
July 22		66.5
July 23		66.5
July 24		66.5
July 25		66.5
July 26		66.5
July 27		66.5
July 28		66.5
July 30	40.0	65.25
July 31	39.5	64.0
Aug. 1	37.0	62.0
Aug. 10		58.5
Aug. 11		60.0
Aug. 12		62.0
Aug. 14		64.5
Aug. 15		64.5
Aug. 24	18.0	
Aug. 27	17.0	51.0
Aug. 28	22.0	55.0
Aug. 29	25.0	52.0
Sept. 7	15.0	
Sept. 14	13.5	
Sept. 18	14.0	45.5
Sept. 19	18.0	51.0
Sept. 21	17.0	
Sept. 22	15.0	45.0
Sept. 23	18.0	
Sept. 24		55.0
Sept. 25	25.0	
Sept. 26	26.0	56.0
Sept. 28	20.0	
Oct. 5	14.0	
Oct. 11	15.0	30.0
Oct. 13	14.0	34.0
Oct. 14	12.5	
Oct. 17	12.0	31.0
Oct. 19	12.0	
Oct. 20	13.0	47.0
Oct. 21	17.0	49.0

[1] Measurements by owner. [2] Caved in. [3] New measuring point.

Measurements of depth to water in observation wells, 1928–32—Continued

Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]	Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]	Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]
1931			1932			1932		
Oct. 22	19.0	50.0	June 7	25.0	57.0	July 8	31.0	63.0
Oct. 26	14.0	----------	June 8	26.0	57.0	July 9	33.0	----------
Nov. 12	11.4	----------	June 9	26.0	58.0	July 11	26.0	58.0
Dec. 5	11.0	----------	June 10	27.0	59.0	July 12	27.0	61.0
			June 11	28.0	58.0	July 13	----------	63.0
1932			June 12	27.0	53.0	July 14	----------	65.0
			June 13	23.0	58.0	July 15	----------	66.5
Jan. 2	10.0	----------	June 14	25.0	58.0	July 16	34.0	64.0
Feb. 2	9.7	----------	June 15	26.0	59.0	July 18	26.0	61.0
Mar. 5	9.6	----------	June 16	27.0	59.0	July 19	25.0	----------
Apr. 2	9.3	----------	June 17	27.0	59.0	July 20	59.0	62.0
May 2	8.5	----------	June 18	27.0	59.0	July 21	----------	64.0
May 11	9.0	----------	June 20	26.0	56.0	July 22	----------	65.0
May 14	----------	59.0	June 21	25.0	57.0	July 23	----------	66.0
May 16	19.0	55.0	June 22	25.0	59.0	July 24	----------	66.0
May 17	25.0	55.0	June 23	27.0	60.0	July 25	34.0	66.0
May 23	13.0	47.0	June 24	28.0	60.0	July 26	34.0	62.0
May 24	17.0	----------	June 25	28.0	61.0	July 27	----------	65.5
May 25	----------	55.0	June 26	----------	62.5	July 28	----------	66.0
May 26	----------	58.0	June 27	27.0	----------	July 29	----------	67.0
May 27	----------	61.0	June 28	----------	63.0	July 30	36.0	64.0
May 28	29.0	----------	June 29	32.0	62.0	Aug. 1	29.0	62.0
May 29	----------	61.0	June 30	----------	63.0	Aug. 2	31.0	62.5
May 30	----------	62.0	July 1	----------	65.0	Aug. 3	----------	65.0
May 31	----------	63.0	July 2	----------	65.0	Aug. 4	----------	66.0
June 1	----------	63.5	July 3	----------	65.0	Aug. 5	----------	66.5
June 2	----------	65.0	July 4	30.0	62.2	Aug. 18	17.0	54.0
June 3	32.0	61.0	July 5	31.0	62.0	Aug. 19	21.0	55.0
June 4	30.0	61.0	July 6	32.0	63.0	Aug. 23	17.0	52.0
June 6	23.0	57.0	July 7	31.0	62.0			

No. 95. Harney Branch Experiment Station. Irrigation well, drilled 8 inches in diameter; initial depth reported 218 feet, measured depth 160 feet in 1920. Water from Harney formation (?). Companion to well 96, which is about 300 feet to the southeast and which taps the shallow valley fill. Measuring points, (1) through Mar. 27, 1931, top of casing, 10 feet below land surface; altitude 4,126.75 feet; (2) beginning Apr. 28, 1931, center of pneumatic depth gage, 0.7 foot above land surface; altitude 4,137.40 feet

1929			1929			1929		
May 27	[2]3.0	16.0	June 27	12.6	30.2+	July 29	10.2	27.7
May 28	1.2	15.0	June 28	13.3	30.8	July 30	12.5	27.0
May 29	2.8	15.5	June 29	13.8	31.3+	July 31	12.8	28.3
May 31	1.4	15.7	July 1	9.8	29.5	Aug. 1	13.0	30.2
June 1	----------	16.5	July 2	12.5	30.0	Aug. 2	13.8	32.1
June 3	2.6	----------	July 3	13.2	29.8	Aug. 3	14.1	----------
June 4	4.4	21.7	July 4	13.6	30.2	Aug. 5	10.0	29.0
June 5	5.8	----------	July 5	14.0	30.7	Aug. 7	8.8	----------
June 6	7.9	26.0	July 8	8.0	27.5	Aug. 9	8.0	----------
June 7	8.8	26.0	July 9	11.9	29.0	Sept. 2	9.9	----------
June 8	9.7	26.0	July 10	12.3	28.1	Oct. 2	[2]1.0	----------
June 10	5.7	24.0	July 11	12.8	29.8	Nov. 7	[2]1.6	----------
June 11	8.1	27.3	July 12	12.5	28.0	Dec. 11	[2]2.2	----------
June 12	10.1	27.+	July 13	13.4	29.0			
June 13	10.6	27.+	July 15	9.7	28.8	1930		
June 14	11.2	26.5	July 16	12.4	30.9			
June 15	10.9	----------	July 17	13.6	30.0	Jan. 1	[2]2.4	----------
June 17	6.2	27.+	July 18	13.9	----------	Feb. 5	[2]2.6	----------
June 19	5.8	----------	July 20	8.2	27.2	Mar. 1	[2]2.7	----------
June 20	5.9	26.7	July 22	7.7	27.9	Apr. 1	[2]2.8	----------
June 21	9.6	29.0	July 23	11.4	30.0	May 2	[2]2.9	----------
June 22	11.0	29.4	July 24	12.8	29.8	May 27	6.0	24.9
June 24	7.7	29.2	July 25	13.3	28.9	May 28	7.0	24.9
June 25	10.8	28.4	July 26	13.8	29.3	May 29	8.0	25.5
June 26	11.7	29.0	July 27	13.6	29.0	May 30	8.3	25.5

[1] Measurements by owner. [2] Above measuring point.

Measurements of depth to water in observation wells, 1928–32—Continued

Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]	Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]	Date	Static level (feet below measuring point) [1]	Pumping level (feet below measuring point) [1]
1930			1930			1931		
May 31	5.0	25.9	Oct. 3	[2] 0.75	----------	June 29	23.5	43.2
June 2	4.5	25.7	Nov. 3	[2] 1.85	----------	June 30	25.4	43.2
June 3	7.5	25.7	Dec. 1	[2] 2.15	----------	July 1	23.6	43.7
June 4	8.7	28.4				July 2	26.0	44.0
June 5	9.7	28.4	1931			July 3	27.4	44.5
June 6	10.3	29.1				July 6	21.5	41.0
June 7	10.7	28.6	Jan. 5	[2] 2.65	----------	July 7	24.6	39.0
June 9	7.3	27.9	Feb. 5	[2] 2.85	----------	July 8	24.7	44.0
June 10	10.4	27.9	Mar. 2	[2] 2.85	----------	July 9	26.2	44.4
June 11	11.2	28.4	Mar. 27	[2] 3.05	----------	July 10	27.5	45.2
June 12	11.8	28.9	Apr. 28	[3] 8.5	[3] 35.0	July 11	27.6	45.2
June 13	12.4	29.4	Apr. 29	12.0	37.5	July 13	23.6	43.6
June 14	12.9	29.2	Apr. 30	15.5	39.2	July 14	26.5	43.5
June 16	8.0	27.9	May 1	16.8	39.2	July 15	27.0	44.0
June 17	11.0	29.0	May 2	17.5	40.0	July 16	27.6	43.5
June 18	12.1	28.9	May 4	15.0	37.5	July 17	28.0	43.5
June 19	12.7	29.1	May 5	16.3	40.0	July 18	25.7	42.7
June 20	13.6	29.1	May 6	17.8	41.0	July 20	22.8	42.4
June 21	13.4	29.1	May 7	20.0	41.3	July 21	25.6	43.0
June 23	9.6	29.1	May 8	21.0	42.0	July 22	26.8	43.0
June 24	12.4	29.5	May 9	22.5	42.5	July 23	27.6	43.5
June 25	13.2	30.0	May 12	16.1	----	July 24	27.8	43.0
June 26	11.3	----------	May 13	15.0	38.6	July 25	28.0	45.5
June 27	11.4	----------	May 14	18.5	39.0	July 27	23.0	41.4
June 28	13.5	31.9	May 15	20.7	40.2	July 28	23.4	45.4
June 30	10.1	----------	May 16	21.6	40.6	July 29	27.4	45.0
July 1	10.3	31.4	May 18	18.0	40.6	July 30	28.2	43.8
July 2	13.1	31.4	May 19	21.5	42.0	July 31	27.8	44.5
July 3	13.9	31.4	May 20	22.6	43.0	Aug. 1	28.0	43.0
July 5	10.4	31.7	May 21	23.0	43.0	Aug. 2	24.0	----
July 7	9.8	31.9	May 22	23.8	43.0	Aug. 3	24.0	42.5
July 8	13.3	31.9	May 23	24.6	43.3	Aug. 4	22.3	42.5
July 9	14.3	32.7	May 25	20.2	42.0	Aug. 7	19.5	41.0
July 10	15.0	33.8	May 26	23.0	43.0	Aug. 8	22.7	42.0
July 11	15.3	34.0	May 27	24.3	43.0	Aug. 13	18.0	39.5
July 12	15.6	34.5	May 28	25.6	43.0	Aug. 14	21.3	41.5
July 14	11.6	31.3	May 29	25.3	44.0	Aug. 15	23.3	43.5
July 15	14.0	----------	May 30	26.0	44.0	Aug. 17	21.4	42.4
July 16	14.7	33.8	June 1	22.0	41.5	Aug. 24	17.0	--------
July 17	15.7	34.0	June 2	24.0	43.5	Aug. 29	15.1	33.8
July 18	16.3	33.5	June 3	25.2	45.5	Sept. 7	14.0	----------
July 19	14.5	33.4	June 4	26.0	44.6	Sept. 14	13.0	----------
July 21	11.7	33.3	June 5	26.6	44.0	Sept. 17	12.4	31.0
July 22	15.0	----------	June 6	--------	45.0	Sept. 18	13.5	35.5
July 23	12.3	32.9	June 8	21.8	41.2	Sept. 19	15.4	36.0
July 24	15.0	34.8	June 9	23.0	44.0	Sept. 21	15.5	----------
July 25	15.9	35.4	June 10	25.0	42.0	Sept. 28	13.5	----------
July 26	17.0	36.4	June 11	26.0	45.0	Oct. 5	12.5	----------
July 28	12.5	35.1	June 12	26.8	44.5	Oct. 14	12.0	----------
July 29	15.3	35.6	June 13	27.0	45.5	Oct. 19	12.4	32.5
July 30	16.3	36.1	June 15	22.7	41.7	Oct. 26	11.5	----------
July 31	16.8	35.9	June 16	23.8	42.6	Nov. 12	11.2	----------
Aug. 1	----------	35.5	June 17	25.4	41.8	Dec. 5	10.0	----------
Aug. 2	17.3	35.9	June 18	26.0	42.0			
Aug. 4	12.9	35.1	June 19	26.6	44.6	1932		
Aug. 5	15.9	34.9	June 20	27.2	46.0			
Aug. 6	16.8	35.5	June 22	23.5	44.0	Jan 2	9.5	----------
Aug. 7	17.4	32.9	June 23	26.5	44.0	Feb. 2	8.9	----------
Aug. 8	16.7	----------	June 24	27.2	45.0	Mar. 5	8.8	----------
Aug 11	9.7	32.0	June 25	27.6	45.5	Apr. 2	8.3	----------
Aug. 12	13.6	32.2	June 26	27.8	45.5	May 2	7.8	----------
Sept. 2	14.05	----------	June 27	27.9	43.7	May 12	7.6	----------

[1] Measurements by owner. [2] Above measuring point. [3] New measuring point.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 96. Harney Branch Experiment Station. Unused well, bored 11 feet deep. Water from shallow valley fill. Measuring point, land surface; altitude 4,136 feet (interpolated)

Date	Depth to water (feet below measuring point)[1]	Date	Depth to water (feet below measuring point)[1]	Date	Depth to water (feet below measuring point)[1]	Date	Depth to water (feet below measuring point)[1]
1929		1930		1930		1931	
Feb. 1	9.0	Feb. 5	9.5	Aug. 20	9.5	Aug. 7	9.6
Mar. 2	8.6	Mar. 1	9.3	Sept. 2	9.6	Dec. 5	10.2
Apr. 1	8.6	Apr. 1	9.4	Oct. 3	9.6		
May 1	8.6	May 2	9.4	Dec. 1	9.9	1932	
June 1	8.4	May 31	9.6				
July 2	8.2	June 2	9.6	1931		Jan. 2	10.2
Aug. 1	8.6	June 3	9.6			Feb. 2	10.3
Sept. 2	9.1	June 9	9.5	Jan. 5	10.0	Mar. 5	10.4
Oct. 2	9.1	June 16	9.5	Feb. 5	9.9	May 2	9.8
Nov. 7	9.3	June 23	9.4	Mar. 2	10.0	June 3	9.3
Dec. 11	9.3	July 1	9.3	Mar. 27	9.9	June 30	8.9
		July 10	9.4	May 2	9.9	Aug. 1	9.0
1930		July 18	9.4	May 12	10.0		
		July 29	9.4	June 1	9.7		
Jan. 1	9.4	Aug. 7	9.4	July 3	9.6		

No. 97. Owner unknown. Unused well, driven 1½ inches in diameter and 45 feet deep. Water from deep valley fill. Measuring point, top of casing, 1.5 feet above land surface; altitude 4,134.95 feet

1930		1931		1931		1931	
Aug. 9	14.35	June 15	[2] 14.60	Aug. 17	17.12	Oct. 19	12.26
		June 22	[2] 14.85	Aug. 24	16.22	Oct. 26	12.24
1931		June 29	[2] 15.94	Aug. 31	15.22		
		July 6	[2] 16.60	Sept. 7	14.63	1932	
May 12	11.65	July 13	[2] 16.89	Sept. 14	13.62		
May 18	[2] 12.10	July 20	[2] 17.70	Sept. 21	13.11	May 12	[3] 8.68
May 25	[2] 12.80	July 27	[2] 18.22	Sept. 28	13.56		
June 1	[2] 13.72	Aug. 3	18.39	Oct. 5	13.37		
June 8	[2] 14.53	Aug. 10	[2] 17.05	Oct. 14	12.57		

No. 99. Owner unknown. Unused well, drilled 6 inches in diameter and 33 feet deep. Water from deep valley fill (?). Measuring point, top of 8- by 8-inch wood curb, 1.5 feet above land surface; altitude 4,133 feet (interpolated)

1930		1931		1931		1931	
Sept. 1	11.30	May 15	11.25	Aug. 10	11.85	Dec. 4	12.00
Oct. 6	11.40	May 18	11.30	Aug. 17	11.88		
Oct. 18	11.45	May 25	11.26	Aug. 24	11.98	1932	
Nov. 1	11.50	June 1	11.30	Aug. 31	12.02		
Dec. 6	11.40	June 8	11.33	Sept. 7	12.05	Jan. 4	11.98
		June 15	11.37	Sept. 14	12.09	April 1	11.65
1931		June 22	11.38	Sept. 21	12.14	May 9	11.40
		June 29	11.45	Sept. 28	12.15	May 31	11.24
Jan. 3	11.55	July 6	11.53	Oct. 5	12.18	June 6	11.24
Feb. 7	11.20	July 13	11.57	Oct. 14	12.18	July 1	11.29
Mar. 7	11.30	July 20	11.65	Oct. 19	12.19	Aug. 1	11.54
Apr. 4	11.25	July 27	11.71	Oct. 26	12.15		
May 9	11.45	Aug. 3	11.77	Nov. 9	12.12		

[1] Measurements by owner.
[2] Pumping from adjacent irrigation well in deep valley fill.
[3] Water flowing in adjacent channel.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 100. Owner unknown. Unused well, dug 4 by 6 feet across and 18½ feet deep. Water from shallow valley fill. Measuring point, top of 2- by 4-inch girder spanning well, at land surface; altitude 4,128 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 8	9.85	Feb. 7	10.0	Sept. 2	10.7	Apr. 1	10.5
Oct. 18	9.9	Mar. 7	[1] 13.0	Oct. 1	10.6	May 9	10.1
Nov. 1	9.9	Apr. 4	10.15	Nov. 9	10.65	June 6	9.8
Dec. 6	9.9	May 9	10.1	Dec. 4	10.60	July 1	9.9
		May 19	10.15			Aug. 1	10.0
1931		June 9	10.2	1932			
		July 7	10.35				
Jan. 3	10.05	Aug. 4	10.4	Jan. 4	11.0		

No. 101. Dr. Horton. Unused well, drilled 6 inches in diameter; initial depth reported 800 feet. Water from bedrock, formation unknown. Measuring point, top of casing, 0.5 foot above land surface; altitude 4,132 feet (interpolated)

Date	Depth to water	Date	Depth to water	Date	Depth to water	Date	Depth to water
1930		1931		1931		1931	
Aug. 14	5.55	June 15	5.75	Aug. 10	5.91	Oct. 5	5.96
		June 22	5.67	Aug. 17	5.83	Oct. 14	5.97
1931		June 29	5.80	Aug. 24	6.00	Oct. 19	5.88
May 15	5.72	July 6	5.80	Aug. 31	5.91		
May 18	5.91	July 13	5.76	Sept. 7	5.84		
May 25	5.52	July 20	5.75	Sept. 14	5.76	1932	
June 1	5.68	July 27	5.81	Sept. 21	5.96	May 13	5.84
June 8	5.58	Aug. 3	5.77	Sept. 28	5.84		

No. 103. B. L. Allen. Unused well, drilled 8 inches in diameter and 53 feet deep. Water from deep valley fill. Measuring point, top of casing, at land surface; altitude 4,135.70 feet

Date	Depth to water	Date	Depth to water	Date	Depth to water	Date	Depth to water
1930		1931		1931		1932	
Aug. 14	17.50	June 15	[2] 17.62	Aug. 10	[2] 20.64	Oct. 5	16.68
		June 22	[2] 17.94	Aug. 17	20.60	Oct. 14	15.99
1931		June 29	[2] 18.56	Aug. 24	20.25	Oct. 19	15.66
May 15	[2] 14.43	July 6	[2] 19.12	Aug. 31	19.31	Oct. 26	15.40
May 18	[2] 14.82	July 13	[2] 19.54	Sept. 7	18.50		
May 25	[2] 15.51	July 20	[2] 20.19	Sept. 14	17.67	1932	
June 1	[2] 16.30	July 27	[2] 20.77	Sept. 21	17.06	May 13	11.35
June 8	[2] 17.11	Aug. 3	21.11	Sept. 28	16.91		

No. 104. B. L. Allen. Domestic well, drilled 8 inches in diameter and 52 feet deep. Water from deep valley fill. Measuring point, top of casing, 1.0 foot above land surface; altitude 4,134 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1931		1931	
May 15	12.75	July 20	[1] 17.25	Aug. 3	[1] 18.26
June 8	14.84				

[1] Windmill operating during measurement.
[2] Pumping from adjacent irrigation well in deep valley fill.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 105. Fred Denstedt. Unused well, drilled 3 inches in diameter; initial depth reported 565 feet. Water from bedrock, formation unknown. Companion to well 106, which is about 50 feet to the west-northwest and which taps the shallow valley fill; also to well 107, which is 40 feet to the north-northwest and which taps the deep valley fill. Measuring point, in top of pit curb, copper nail with washer, 0.5 foot above land surface; altitude 4,137.89 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 23	21.61	June 29	[1] 23.36	Sept. 7	14.81	Jan. 5	10.20
		July 6	[1] 21.83	Sept. 14	13.87	Apr. 2	9.43
1931		July 13	[1] 23.68	Sept. 21	15.89	May 12	9.34
May 14	[1] 16.68	July 20	[1] 23.24	Sept. 28	13.80	June 6	[1] 18.55
May 18	[1] 18.12	July 27	[1] 24.27	Oct. 5	13.29	July 6	(2)
May 25	[1] 20.26	Aug. 3	[1] 23.37	Oct. 14	12.59		
June 1	[1] 21.60	Aug. 10	21.79	Oct. 19	12.27		
June 8	[1] 22.33	Aug. 17	[1] 21.56	Oct. 26	12.29		
June 15	[1] 22.55	Aug. 24	17.95	Nov. 9	11.49		
June 22	[1] 23.06	Aug. 31	16.20	Dec. 6	10.50		

No. 107. Fred Denstedt. Unused well, drilled 6 inches in diameter and 60 feet deep. Water from deep valley fill. Measuring point, in top of pit curb, copper nail with washer, 0.5 foot above land surface; altitude, 4,138.85 feet

1930		1931		1931		1932	
Aug. 23	[3] 17.62	June 29	[3] 21.45	Sept. 7	18.31	Jan. 5	13.32
		July 6	[3] 21.52	Sept. 14	17.34	Feb. 3	13.07
1931		July 13	[3] 22.24	Sept. 21	17.01	Mar. 4	13.00
May 14	[3] 15.80	July 20	[3] 23.06	Sept. 28	18.03	Apr. 2	8.72
May 18	[3] 16.41	July 27	[3] 23.50	Oct. 5	17.01	May 12	10.95
May 25	[3] 17.38	Aug. 3	[3] 23.40	Oct. 14	15.79	June 6	16.25
June 1	[3] 18.54	Aug. 10	[3] 21.34	Oct. 19	15.38	July 6	19.57
June 8	[3] 19.33	Aug. 17	22.35	Oct. 26	15.65	Aug. 1	21.16
June 15	[3] 18.89	Aug. 24	20.43	Nov. 9	14.50		
June 22	[3] 19.81	Aug. 31	19.09	Dec. 6	13.75		

No. 108. R. W. Cozad. Domestic well, drilled 6 inches in diameter and 39 feet deep. Water from deep valley fill. Measuring point, top of casing, 0.3 foot above land surface; altitude, 4,132.98 feet

1931		1931		1931		1931	
May 13	[3] 17.90	June 29	[3] 16.20	Aug. 17	[3] 21.17	Oct. 14	13.71
May 18	[3] 16.75	July 6	[3] 18.24	Aug. 24	17.60	Oct. 19	13.56
May 25	14.80	July 11	[3] 19.85	Aug. 31	16.34	Oct. 26	13.33
Do	[3] 16.19	July 13	[3] 18.82	Sept. 7	15.54		
June 1	[3] 17.15	July 20	[3] 20.06	Sept. 14	15.01	1932	
June 8	[3] 19.15	July 27	[3] 19.17	Sept. 21	14.62	May 11	9.72
June 15	[3] 19.48	Aug. 3	[3] 19.46	Sept. 28	14.25		
June 22	[3] 18.31	Aug. 10	[3] 19.84	Oct. 5	14.00		

No. 110. R. W. Cozad. Stock well, dug 15½ feet deep. Water from shallow valley fill. Companion to well 111, which is about 100 feet to the north and which taps the deep valley fill; also to well 112, which is 300 feet to the northeast and which taps the deep valley fill. Measuring point, top of plank well cover, 0.5 foot above land surface; altitude, 4,132.60 feet

1930		1931		1931		1932	
Aug. 14	10.40	Jan. 3	10.55	Nov. 9	10.90	Mar. 4	10.45
Oct. 18	10.40	Mar. 7	10.60	Dec. 5	11.50	Apr. 2	10.45
Nov. 1	10.45	Apr. 4	10.55			May 11	10.85
Dec. 6	10.45	May 9	10.65	1932		July 6	11.40
		May 23	10.70	Jan. 5	10.59	Aug. 1	11.05
		Oct. 1	10.60	Feb. 3	10.60		

No. 111. R. W. Cozad. Domestic well, driven 2 inches in diameter and 44 feet deep. Water from deep valley fill. Measuring point, lower valve seat of pump, 4.0 feet above land surface; altitude, 4,135.27 feet

1931		1931		1931		1931	
May 13	[3] 29.40	June 22	[3] 27.79	Aug. 3	[3] 29.32	Sept. 21	17.96
May 18	[3] 27.00	June 29	[3] 25.17	Aug. 10	[3] 29.65	Sept. 28	17.52
May 25	18.10	July 6	[3] 28.55	Aug. 17	[3] 31.70	Oct. 5	17.37
Do	[3] 26.66	July 11	[3] 30.40	Aug. 24	21.10	Oct. 14	16.94
June 1	[3] 27.15	July 13	[3] 28.87	Aug. 31	19.75	Oct. 19	16.22
June 8	[3] 29.42	July 20	[3] 30.30	Sept. 7	18.67	Oct. 23	16.66
June 15	[3] 28.79	July 27	[3] 24.93	Sept. 14	17.98		

[1] Pumping from adjacent irrigation well in bedrock.
[2] Caved in.
[3] Pumping from adjacent irrigation well in deep valley fill.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 112. R. W. Cozad. Irrigation well, bored 24 inches in diameter and 72 feet deep. Water from deep valley fill. Measuring point, top of pump base, 0.4 foot below land surface; altitude 4,132.75 feet

Date	Hour	Depth to water (feet below measuring point)
1930		
Aug. 14		18.10
Aug. 17		16.35
Aug. 18		16.05
Sept. 13		13.55
Oct. 18		12.35
Nov. 1		12.10
Dec. 6		12.15
1931		
Jan. 3		12.15
Feb 7		11.15
Mar. 7		11.10
Apr. 4		11.05
May 9		[1] 36.7
May 13		[1] 55.±
May 15		[2] 19.40
May 16		[2] 19.60
May 18		[2] 16.80
May 19		[2] 18.8
May 20		[2] 19.0
May 23	4:30 p. m.	15.75
May 24	6:10 p. m.	[2] 15.70
May 25	5:20 a. m.	15.09
May 25	3:22 p. m.	[1] 45.55
May 26	5:10 a. m.	[2] 17.50
May 27	5:10 a. m.	[2] 18.65
May 28	5:10 a. m.	[2] 18.60
May 29	5:05 a. m.	[2] 18.90
May 30	5:10 a. m.	[2] 19.30
June 1	5:10 a. m.	[2] 17.20
June 2	5:00 a. m.	[2] 19.00
June 3	5:00 a. m.	[2] 19.25
June 4	5:05 a. m.	[2] 20.00
June 5	5:05 a. m.	[2] 20.10
June 6	5:00 a. m.	[2] 20.60
June 7	8:50 a. m.	[2] 20.10
June 8	5:00 a. m.	[2] 20.45
Do	4:30 p. m.	[1] 55.90
June 9	5:05 a. m.	[2] 20.80
June 10	5:10 a. m.	[2] 20.90
June 11	5:05 a. m.	[2] 21.30
June 12	5:05 a. m.	[2] 21.45
June 13	5:10 a. m.	[2] 21.50
June 14	9:30 a. m.	[2] 20.80
June 15	5:15 a. m.	[2] 20.75
June 16	12:00 m.	[2] 19.50
June 17	5:10 a. m.	[2] 19.60
June 18	5:20 a. m.	[2] 20.20
June 19	5:10 a. m.	[2] 20.40
June 20	5:00 a. m	[2] 20.65
June 22	5:10 a. m.	[2] 18.80
June 24	6:50 a. m.	[2] 18.25
June 29	7:00 a. m.	16.30
June 30	5:15 a. m.	[2] 18.50
July 1	7:00 a. m.	[2] 19.00
July 2	5:10 a. m.	[2] 19.60
July 3	5:10 a. m.	[2] 20.10
July 4	5:10 a. m.	[2] 20.50
July 6	5:15 a. m.	[2] 18.50
July 7	5:15 a. m.	[2] 20.00
1931		
July 8	5:10 a. m.	[2] 21.00
July 9	12:10 p. m.	[2] 19.20
July 10	5:20 a. m.	[2] 20.10
July 11	5:10 a. m.	[2] 21.10
Do	11:30 a. m.	[1] 54.80
July 13	5:10 a. m.	[2] 19.00
July 14	5:10 a. m.	[2] 20.85
July 15	5:15 a. m.	[2] 19.90
July 16	5:20 a. m.	[2] 18.90
July 17	5:10 a. m.	[2] 20.80
July 18	5:10 a. m.	[2] 21.40
July 19	7:45 a. m.	[2] 21.00
July 20	5:40 a. m.	[2] 21.10
Do	5:30 p. m.	[1] 55.50
July 21	5:15 a. m.	[2] 21.90
July 22	5:20 a. m.	[2] 21.90
July 23	5:15 a. m.	[2] 22.00
July 24	5:10 a. m.	[2] 22.15
July 25	5:10 a. m.	[2] 22.40
July 27	11:00 a. m.	[2] 19.80
July 28	5:15 a. m.	[2] 21.00
July 29	5:10 a. m.	[2] 21.75
July 30	5:10 a. m.	[2] 22.00
July 31	5:10 a. m.	[2] 22.30
Aug. 1	5:10 a. m.	[2] 22.40
Aug. 3	5:15 a. m.	[2] 19.65
Aug. 4	5:10 a. m.	[2] 21.60
Aug. 5	5:10 a. m.	[2] 22.00
Aug. 6	5:30 a. m.	[2] 21.60
Aug. 7	5:15 a. m.	[2] 22.00
Aug. 8	5:10 a. m.	[2] 22.35
Aug. 10	5:25 a. m.	[2] 19.85
Aug. 11	5:10 a. m.	[2] 21.65
Aug. 12	5:15 a. m.	[2] 22.20
Aug. 13	5:10 a. m.	[2] 22.60
Aug. 14	5:20 a. m.	[2] 22.20
Aug. 15	5:25 a. m.	[2] 22.65
Aug. 16	6:00 a. m.	[2] 22.85
Aug. 17	5:30 a. m.	[2] 22.20
Aug. 18	5:20 a. m.	[2] 22.85
Aug. 19	4:30 p. m.	[2] 20.7
Aug. 24		18.08
Aug. 31		16.73
Sept. 7		15.87
Sept. 14		15.29
Sept. 21		14.89
Sept. 28		14.48
Oct. 5		14.24
Oct. 14		13.91
Oct. 19		13.71
Oct. 26		13.49
Nov. 9		12.95
Dec. 5		11.90
1932		
Jan. 5		12.05
Feb. 3		12.20
Mar. 4		11.45
Apr. 2		11.25
May 11		9.90

[1] Pump operating in well during measurement. [2] Measurement by owner.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 114. D. N. Varien. Domestic well, driven 2 inches in diameter and 47 feet deep. Water from deep valley fill. Companion to well no. 115, which is about 80 feet to the east and which taps the shallow valley fill. Measuring point, top of tee in casing, 8.5 feet below land surface; altitude 4,124.39 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1931		1931		1931	
May 16	[1] 7.37	June 29	[1] 9.10	Aug. 17	[1] 10.87	Oct. 5	8.15
May 18	[1] 7.55	July 6	[1] 9.37	Aug. 24	10.58	Oct. 14	7.82
May 25	[1] 7.75	July 13	[1] 9.65	Aug. 31	9.99	Oct. 19	7.67
June 1	[1] 8.14	July 20	[1] 9.91	Sept. 7	9.47	Oct. 26	7.44
June 8	[1] 8.67	July 27	[1] 10.34	Sept. 14	8.96		
June 15	[1] 9.25	Aug. 3	[1] 10.50	Sept. 21	8.61		
June 22	[1] 9.40	Aug. 10	[1] 10.70	Sept. 28	8.37		

No. 121. Duhaime Bros. Unused well, bored 24 inches in diameter and 135 feet deep. Water from deep valley fill. Measuring point, top of casing, at land surface; altitude 4,129 feet (interpolated)

1928		1931		1931		1931	
Oct. 5	15.65	May 14	19.25	June 22	[2] 18.61	Aug. 10	[2] 19.27
		May 18	19.70	June 29	[2] 18.94	Aug. 17	[2] 19.27
1930		May 25	19.26	July 6	[2] 18.95		
Aug. 6	21.40	June 1	19.28	July 20	[2] 18.88	1932	
Oct. 4	19.80	June 8	19.08	July 27	[2] 18.96	May 13	[2] [3] 15.80
		June 15	[2] 18.63	Aug. 3	[2] 18.98		

No. 122. Owner unknown. Unused well, bored 8 inches in diameter and 12½ feet deep. Water from shallow valley fill. Measuring point, top of bucket in top of well, 0.2 foot above land surface; altitude 4,128 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1930		1931	
Sept. 13	11.8	Oct. 19	11.3	Mar. 8	11.45
Oct. 4	11.5	Nov. 2	11.3	Apr. 5	([4])

[1] Pumping from adjacent irrigation well in deep valley fill.
[2] Water from shallow valley fill leaking through casing into well.
[3] Water flowing in adjacent channel.
[4] Well dry.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 124. Owner unknown. Stock well, dug 6 feet square and 15 feet deep. Water from shallow valley fill. Measuring point, top of 4- by 12-inch plank in well cover, 1.2 feet above land surface; altitude 4,134 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 6	11.2	Jan. 3	11.2	July 7	[1] 14.1	Apr. 1	[2] 9.7
Oct. 18	11.05	Mar. 7	11.35	Sept. 2	[1] 13.15	May 9	[2] 6.8
Nov. 1	11.1	Apr. 4	11.57	Oct. 1	12.4	June 6	4.95
Dec. 6	11.1	May 9	11.7	Nov. 9	12.4	July 1	5.25
		May 20	[1] 14.1	Dec. 4	12.35	Aug. 1	7.2

No. 129. Henry Anderson. Domestic well, dug 18 feet deep. Water from shallow valley fill. Companion to well 128, which is about 100 feet to the southeast and which taps the deep valley fill; "slough" about 150 feet to the east. Measuring point, lower valve seat of pump, 0.7 foot above land surface; altitude 4,120 feet (interpolated)

1930		1931		1931		1932	
Oct. 4	16.7	Jan. 3	17.05	June 9	19.95	Jan. 5	17.85
Oct. 18	16.6	Feb. 7	17.05	July 7	17.05	Feb. 3	17.9
Nov. 1	16.8	Mar. 7	17.05	Aug. 5	17.25	Mar. 4	17.75
Dec. 6	16.8	Apr. 4	17.25	Oct. 1	17.5	Apr. 2	17.15
		May 9	16.85	Nov. 9	17.35	May 13	17.35
		May 20	17.4	Dec. 5	18.0	June 6	17.2

No. 134. Owner unknown. Stock well, dug 8 feet square and 11½ feet deep. Water from shallow valley fill. Measuring point, top of 2- by 6-inch plank in well cover, at land surface; altitude 4,134 feet (interpolated)

1930		1931		1931		1932	
Oct. 6	7.45	Jan. 3	7.85	June 9	7.7	Jan. 4	8.55
Oct. 18	7.45	Feb. 7	7.75	July 7	[1] 9.95	Apr. 1	4.25
Nov. 1	7.5	Mar. 7	7.55	Aug. 5	[1] 9.45	May 9	5.0
Dec. 6	7.55	Apr. 4	7.55	Oct. 1	[1] 11.4	June 6	5.45
		May 9	7.6	Nov. 9	8.25	July 6	5.35
		May 20	7.6	Dec. 4	8.2	Aug. 1	7.8

No. 138. State of Oregon. Stock well, dug 8 feet in diameter and 18½ feet deep. Water from shallow valley fill. Measuring point, top of 2- by 12-inch plank in well cover, 0.2 foot above land surface; altitude 4,130 feet (interpolated)

1930		1931		1931		1932	
Oct. 6	14.7	Jan. 3	12.4	July 7	[1] 18.15	Jan. 4	12.25
Oct. 18	12.15	Feb. 7	12.9	Aug. 4	[1] 18.15	Mar. 3	12.45
Nov. 1	12.25	Mar. 7	12.05	Sept. 2	13.7	Apr. 1	[1] 13.75
Dec. 6	12.15	Apr. 4	11.7	Oct. 1	14.05	May 9	12.25
		May 9	13.15	Nov. 9	12.85	June 6	11.9
		May 20	13.0	Dec. 4	12.8	July 6	12.05

No. 159. Owner unknown. Domestic well, drilled 2 inches in diameter and 44½ feet deep. Water from deep valley fill. Companion to well 160, which is about 150 feet to the south-southwest and which taps the shallow valley fill. Measuring point, top of casing, 1.6 feet above land surface; altitude 4,129.85 feet (datum is land surface at well 160, altitude 4,128 feet interpolated)

1930		1931		1931		1932	
Aug. 15	5.6	Feb. 8	6.15	Dec. 5	6.95	July 7	4.8
Sept. 4	5.8	Apr. 5	6.0			Aug. 3	4.8
Oct. 3	6.05	May 11	6.2	1932			
Oct. 19	6.1	May 22	5.9				
Nov. 2	6.2	June 10	6.0	Jan. 6	6.85		
Dec. 6	6.15	July 8	6.2	Feb. 4	6.8		
		Aug. 5	6.45	Mar. 7	6.80		
1931		Sept. 2	6.7	Apr. 3	6.25		
		Oct. 2	6.85	May 10	[2] 4.6		
Jan. 4	5.7	Nov. 10	6.8	June 7	3.8		

[1] Windmill operating during measurement. [2] Adjacent land flooded.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 160. Owner unknown. Unused well, bored 3 inches in diameter and 10 feet deep. Water from shallow valley fill. Measuring points, (1) through February 8, 1931, top of 1- by 6-inch board, 2.3 feet above land surface; altitude, 4,130.3 feet (interpolated); (2) beginning March 8, 1931, top of 2- by 6-inch plank, at land surface; altitude, 4,128 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 15	10.9	Feb. 8	11.2	Oct. 2	(2)	Apr. 3	8.7
Sept. 4	11.15	Mar. 8	[1] 8.9	Nov. 10	9.7	May 10	(3)
Oct. 3	11.25	Apr. 5	9.35	Dec. 5	(2)		
Oct. 19	11.5	May 11	9.1				
Nov. 2	11.65	May 22	9.1	1932			
		June 10	9.2				
1931		July 8	9.45	Jan. 6	(2)		
		Aug. 5	9.8	Feb. 4	(2)		
Jan. 4	11.2	Sept. 2	10.0	Mar. 7	(2)		

No. 164. Owner unknown. Stock well, dug 6 feet square and 11 feet deep. Water from shallow valley fill. Measuring point, in top of log girder, copper nail with washer, 0.3 foot above land surface; altitude, 4,126 feet (interpolated)

1930		1931		1931		1932	
Sept. 4	9.2	Mar. 8	9.7	Nov. 10	9.80	May 10	[4] 1.55
Oct. 3	9.35	Apr. 5	9.85	Dec. 6	9.75	June 7	[4] 1.60
Oct. 19	9.45	May 11	9.7			July 7	4.6
Nov. 2	9.75	May 22	9.6	1932		Aug. 3	6.7
Dec. 6	9.7	June 10	9.5				
		July 8	9.65	Jan. 6	9.9		
1931		Aug. 5	9.7	Feb. 4	9.95		
		Sept. 4	9.75	Mar. 7	9.7		
Feb. 8	9.75	Oct. 2	10.05	Apr. 3	[4] 3.4		

No. 165. Larsen ranch. Stock well, drilled 2 inches in diameter and 53 feet deep. Water from deep valley fill. Companion to well 166. Measuring point, top of casing, 2.5 feet above land surface; altitude, 4,126.5 feet (1.5 feet above measuring point of well 166)

1930		1931		1931		1932	
Sept. 2	10.25	Feb. 8	11.1	Nov. 11	11.55	May 10	10.5
Oct. 3	10.4	Mar. 8	11.05	Dec. 6	12.3	June 7	9.85
Oct. 19	10.5	Apr. 5	11.1			July 1	9.7
Nov. 2	10.6	May 22	10.85	1932		Aug. 3	9.7
Dec. 7	11.0	June 10	11.0				
		July 8	11.0	Jan. 6	12.4		
1931		Aug. 5	11.15	Feb. 4	12.5		
		Sept. 4	11.35	Mar. 7	11.45		
Jan. 4	10.5	Oct. 2	11.45	Apr. 3	11.05		

No. 166. Larsen ranch. Unused well, dug 3 by 5 feet across and 11 feet deep. Water from shallow valley fill. Companion to well 165, whose casing it surrounds. Measuring point, top of 2- by 12-inch curb, 1.0 foot above land surface; altitude, 4,125 feet (interpolated)

1930		1931		1931		1932	
Sept. 2	9.55	Mar. 8	10.0	Oct. 2	(2)	Apr. 3	6.35
Oct. 3	9.9	Apr. 5	9.45	Nov. 11	(2)	May 10	3.25
Oct. 19	9.6	May 11	8.95	Dec. 6	(2)	June 7	5.25
Nov. 2	9.6	May 22	9.35			July 7	7.1
Dec. 7	(2)	June 9	(2)	1932			
		June 11	9.75				
1931		July 8	9.9	Jan. 6	(2)		
		Aug. 5	(2)	Feb. 4	(2)		
Feb. 8	9.9	Sept. 4	(2)	Mar. 7	(2)		

[1] New measuring point. [2] Well dry. [3] Caved in. [4] Adjacent land flooded.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 170. E. Woods. Unused well, driven 2 inches in diameter and 51 feet deep. Water from deep valley fill. Measuring point, in top of pit curb, copper nail with washer, at land surface; altitude 4,125 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1931	
May 15	16.05	Oct. 2	16.7
June 10	16.8	1932	
July 8	16.4	May 11	17.15
Aug. 5	17.1		
Sept. 4	17.0		

No. 172. Dan Jordan. Unused well, driven 1½ inches in diameter and 42 feet deep Water from deep valley fill. Measuring point, top of casing, 2.5 feet above land surface; altitude 4,122 feet (interpolated)

1930		1931	
Sept. 13	19.95	Nov. 11	20.6
		Dec. 6	20.7
1931		1932	
May 15	20.05	May 11	20.3
June 10	20.15	June 7	20.2
July 8	20.25	July 7	20.2
Aug. 5	20.35	Aug. 3	20.25
Sept. 4	20.5		
Oct. 2	20.6		

No. 173. Owner unknown. Stock well, bored 8 inches in diameter and 40 feet deep. Water from shallow valley fill. Measuring point, top of 1- by 12-inch board in platform, at land surface; altitude 4,117 feet (interpolated)

1931		1932	
May 21	29.05	May 13	27.3
June 9	27.6		

No. 178. Owner unknown. Unused well, drilled 6 inches in diameter and 57 feet deep. Water from shallow valley fill. Measuring point, top of plank platform, 0.3 foot above land surface; altitude 4,121.15 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Sept. 4	40.65	Feb. 8	39.35	Aug. 11	40.88	Mar. 9	39.65
Oct. 13	40.15	Mar. 8	39.20	Sept. 4	41.80	Apr. 3	39.53
Oct. 19	40.05	Apr. 5	39.15	Oct. 2	41.50	May 11	39.56
Nov. 2	39.90	May 11	39.10	Nov. 11	40.40	May 31	39.45
Dec. 7	39.60	May 16	39.10	Dec. 6	40.55	June 7	39.64
		June 10	39.15			July 7	39.64
1931		July 7	39.50	1932		Aug. 3	40.37
Jan. 4	39.40	Aug. 4	40.55	Jan. 6	39.90		

No. 179. Oscar West. Stock well, upper part dug 4½ feet in diameter, lower part bored 6 inches in diameter, 46 feet deep. Water from shallow valley fill. Measuring point, top of plank cover, at land surface; altitude 4,114.60 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1932	
Aug. 11	30.20	May 11	28.34
Sept. 4	30.00	May 31	27.95

Measurements of depth to water in observation wells, 1928–32—Continued

No. 182. Observation well, drilled by Geological Survey, 3 inches in diameter and 15½ feet deep. Water from shallow valley fill. Companion to well 183, which is about 6 feet to the west and which taps the deep valley fill. Measuring point, top of casing, 0.6 foot above land surface; altitude 4,112 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1931		1932		1932	
June 11	13.7	Sept. 4	14.3	Jan. 6	14.3	May 10	13.65
July 8	13.8	Oct. 2	14.4	Mar. 7	14.05	June 7	13.45
Aug. 5	14.05			Apr 3	12.15	July 7	13.9

No. 183. Pacific Live Stock Co. Unused well, drilled 2 inches in diameter and 39½ feet deep. Water from deep valley fill. Measuring point, top of casing, 2.5 feet above land surface; altitude 4,113.35 feet (1.35 feet above measuring point of well No. 182)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1931		1932		1932	
Oct. 14	14.4	July 8	14.75	Jan. 6	15.3	June 7	13.9
		Aug. 5	14.95	Feb. 4	15.25	July 7	14.25
1931		Sept. 4	15.1	Mar. 7	15.1	Aug. 3	14.8
May 22	14.5	Oct. 2	15.25	Apr. 3	15.0		
June 10	14.65	Nov. 11	15.25	May 10	14.1		

No. 197. Ralph Catterson. Unused well, bored 18 inches in diameter and about 130 feet deep. Water from deep valley fill. Measuring point, top of casing, 1.0 foot above land surface; altitude 4,107.02 feet

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1930		1931		1932	
Aug. 16	31.86	Oct. 18	32.05	May 16	31.56	Jan. 6	32.01
Aug. 18	[1] 31.77	Nov. 1	32.60	June 9	31.55	Feb. 4	31.70
Aug. 19	31.85	Dec. 7	32.26	July 7	31.88	Mar. 9	31.70
Aug. 22	31.77			Aug. 5	32.54	Apr. 3	31.61
Aug. 26	32.03	1931		Aug. 11	32.77		
Sept. 4	32.14	Jan. 4	32.00	Sept. 4	33.11		
Sept. 13	32.10	Feb. 8	31.95	Oct. 1	32.95		
Sept. 22	32.10	Apr. 5	31.85	Nov. 11	32.40		
Oct. 2	[2] 32.16	May 11	31.75	Dec. 6	32.49		

No. 200. Owner unknown. Unused well, bored 7 inches in diameter and 35 feet deep. Water from shallow valley fill. Measuring point, top of wood casing, 0.2 foot above land surface; altitude 4,110.30 feet

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1931		1931		1932	
Oct. 10	30.45	Jan. 3	30.50	June 9	30.80	Jan. 5	31.60
Oct. 18	30.45	Feb. 7	30.60	July 7	30.80	May 11	31.30
Nov. 1	30.50	Mar. 7	30.60	Aug. 4	30.90	May 31	31.20
Dec. 6	30.45	Apr. 4	30.80	Oct. 1	31.10	June 6	31.20
		May 9	30.60			July 6	31.26
		May 21	30.60			Aug. 1	31.34

No. 203. C. M. Spencer. Domestic well, drilled 12 inches in diameter, measured depth 106 feet in 1931. Water from deep valley fill. Companion to well no. 204, which is about 500 feet to the south and which taps the shallow valley fill. Measuring point, top of 2-inch plank on casing, 1.2 feet above land surface; altitude 4,111 feet (interpolated)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1930		1931		1931		1932	
Oct.	17.75	May 21	17.65	Aug. 4	17.90	May 11	17.90
		June 9	17.65	Sept. 2	18.00		
		July 7	17.70	Oct. 1	18.20		

No. 216. E. N. Nelson. Stock well, drilled 6 inches in diameter and 105 feet deep. Water from Harney formation (?). Measuring point, top of casing 1.1 feet above land surface; altitude 4,124 feet (interpolated)

Date	Depth	Date	Depth	Date	Depth	Date	Depth
1931		1931		1932		1932	
May 26	14.8	Nov. 11	15.0	Jan. 6	12.8	May 10	14.4
July 8	15.4	Dec. 6	14.95	Feb. 4	14.3	June 7	14.55
Sept. 4	15.3			Mar. 7	14.6	July 7	12.45
Oct. 2	15.2			Apr. 3	14.45	Aug. 3	15.05

[1] Water-stage recorder installed. [2] Water-stage recorder removed.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 218. School district no. 14. Unused well, driven 2 inches in diameter and about 40 feet deep. Water from valley fill (?). Measuring point, lower valve seat of pump, 2.2 feet above land surface; altitude 4,114 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1928		1930		1931		1931	
Oct. 6	15.7	Oct. 19	16.25	Jan. 4	16.15	May 26	16.05
		Nov. 2	16.25	Feb. 8	16.1	June 10	16.25
1930		Dec. 7	16.25	Mar. 8	16.0	July 8	16.4
Sept. 2	16.3			Apr. 5	16.1	Aug. 5	[1] 16.5+
Oct. 15	16.3			May 11	16.0		

No. 219. Owner unknown. Unused well, driven 2 inches in diameter and 31 feet deep. Water from valley fill (?). Measuring point, lower valve seat of pump, 1.7 feet above land surface; altitude 4,113 feet (interpolated)

1930		1931		1931		1932	
Sept. 11	17.8	Feb. 8	17.6	Sept. 4	18.0	Mar. 9	17.70
Oct. 15	17.7	Mar. 8	17.6	Oct. 2	17.95	Apr. 3	17.75
Oct. 19	17.65	Apr. 4	17.55	Nov. 11	17.85	May 10	17.80
Nov. 2	17.7	May 11	17.6	Dec. 6	17.80	June 7	17.80
Dec. 7	17.6	May 26	17.7			July 7	18.10
		June 10	17.85	1932		Aug. 3	18.30
1931		July 8	17.9	Jan. 6	17.55		
Jan. 4	17.6	Aug. 5	17.95	Feb. 4	17.75		

No. 223. Pacific Live Stock Co. Stock well, drilled 6 inches in diameter and 43 feet deep. Water from deep valley fill. Companion to well no. 224, which is about 150 feet to the south and which taps the shallow valley fill. Measuring point, top of casing, 0.2 foot above land surface; altitude 4,103.35 feet

1930		1931		1932		1932	
Oct. 9	11.90	July 7	13.00	Jan. 5	14.60	May 31	11.70
		Aug. 4	13.45	Feb. 3	14.55	June 6	11.60
1931		Sept. 2	13.95	Mar. 4	14.35	July 6	11.50
May 16	12.75	Oct. 1	14.25	Apr. 2	14.25	Aug. 1	11.55
June 9	12.85	Nov. 9	14.20	May 11	12.30		

No. 224. Pacific Live Stock Co. Unused well, dug 8 feet square and 13 feet deep. Water from shallow valley fill. Measuring point, top of 2- by 12-inch wood curb, 2.8 feet above land surface; altitude 4,105.10 feet

1930		1931		1932		1932	
Oct. 9	13.80	Aug. 4	15.15	Jan. 5	([1])	June 6	14.20
		Sept. 2	([1])	Feb. 3	([1])	July 6	13.00
1931		Oct. 1	([1])	Mar. 4	([1])	Aug. 1	15.60
May 16	14.50	Nov. 9	([1])	Apr. 2	([1])		
June 9	14.80	Dec. 5	([1])	May 11	15.90		
July 7	14.85			May 31	14.40		

No. 225. Ruh Brothers. Unused well, drilled 2 inches in diameter and 53 feet deep. Water from deep valley fill. West Fork of the Silvies River about 100 feet to the west. Measuring point, top of casing, 1.8 feet above land surface; altitude 4,098.80 feet

1931		1931		1932		1932	
July 10	16.45	Nov. 11	17.15	Jan. 6	17.25	May 10	[2] 15.95
Aug. 5	16.65	Dec. 6	17.20	Feb. 4	16.90	June 7	[2] 14.65
Sept. 4	17.05			Mar. 9	17.80	July 7	17.05
Oct. 2	17.05			Apr. 3	17.25	Aug. 3	15.80

No. 236. School district 17. Unused well, driven 1½ inches in diameter and 15 feet deep. Water from shallow valley fill. Measuring point, lower valve seat of pump, 1.7 feet above land surface; altitude 4,097.85 feet

1930		1931		1931		1932	
Oct. 11	14.75	Apr. 5	15.00	Nov. 11	([1])	May 10	[2] 16.10
Oct. 19	14.80	May 11	15.25	Dec. 6	([1])	May 19	[2] 15.50
Nov. 2	14.85	May 22	15.30			June 7	[2] 14.55
Dec. 7	15.05	June 10	15.40	1932		July 7	13.90
		July 8	15.60	Jan. 6	([1])	Aug. 3	([1])
1931		Aug. 5	15.85	Feb. 4	([1])		
Feb. 8	15.25	Sept. 4	16.00	Mar. 9	([1])		
Mar. 8	15.25	Oct. 2	[1] 16.1+	Apr. 3	([1])		

[1] Well dry. [2] Water flowing in adjacent channel.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 237. Owner unknown. Unused well, driven 2 inches in diameter and 18 feet deep. Water from shallow valley fill. Measuring point, top of casing, 1.4 feet above land surface; altitude 4,103 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 11	15.85	Mar. 8	15.85	Sept. 4	16.3	Feb. 4	16.15
Oct. 19	15.85	Apr. 5	15.85	Oct. 2	16.4	Mar. 9	16.1
Nov. 2	15.9	May 11	15.85	Nov 11	16.4	Apr. 3	16.3
Dec. 7	15.9	May 22	15.85	Dec. 6	16.0	May 10	16.25
		June 10	15.9			June 7	16.2
1931		July 8	16.0	1932		July 7	16.1
Feb. 8	15.85	Aug. 5	16.15	Jan. 6	16.35	Aug. 3	16.45

No. 241. C. M. Spencer. Unused well, upper part dug 4 feet square, lower part bored 10 inches in diameter, 23 feet deep. Water from shallow valley fill. Companion to well 242, which is about 125 feet to the northwest and which taps the deep valley fill. Measuring point, top of 2- by 12-inch plank platform, 0.2 foot above land surface; altitude 4,103.10 feet

1930		1931		1931		1932	
Oct. 10	21.00	Mar. 7	21.00	Oct. 1	22.40	Apr. 1	22.10
Oct. 18	21.00	Apr. 4	20.50	Nov. 9	22.65	May 11	21.65
Nov. 1	21.00	May 9	21.10	Dec. 5	22.15	May 31	21.65
Dec. 6	21.05	May 20	21.10			June 6	21.65
		June 9	21.25	1932		July 6	22.05
1931		July 7	21.50	Jan. 5	22.00	Aug. 1	22.55
Jan. 3	21.20	Aug. 4	21.90	Feb. 3	23.45		
Feb. 7	20.55	Sept. 2	22.25	Mar. 4	21.95		

No. 242. C. M. Spencer. Domestic well, drilled 1½ inches in diameter, initial depth reported 190 feet measured depth 86 feet in 1930. Water from deep valley fill. Measuring point, lower valve seat of pump 2.7 feet above land surface; altitude 4,102.45 feet

1930		1931		1931		1932	
Oct. 22	13.75	July 7	14.10	Dec. 5	14.60	Mar. 4	14.55
		Aug. 4	15.00			Apr. 1	14.35
1931		Sept. 2	14.65	1932			
May 21	14.00	Oct. 1	14.75	Jan. 5	14.70		
June 9	14.05	Nov. 9	14.50	Feb. 3	14.60		

No. 244. Owner unknown. Stock well, drilled 8 inches in diameter and 51 feet deep. Water from deep valley fill. Companion to well 245, which is about 25 feet to the west and which taps the shallow valley fill. Measuring point, top of casing, 0.2 foot above land surface; altitude 4,098.65 feet

1931		1931		1932		1932	
June 3	14.30	Oct. 1	15.20	Jan. 5	15.45	May 31	[1] 12.25
June 9	14.30	Nov. 9	13.35	Feb. 3	15.50	June 6	12.00
July 7	14.45	Dec. 5	15.45	Mar. 4	15.55	July 6	12.45
Aug. 4	14.70			Apr. 1	15.50	Aug. 1	13.10
Sept. 2	14.95			May 11	13.20		

No. 245. Owner unknown. Unused well, dug 6 feet square and 15 feet deep. Water from shallow valley fill. Measuring point, top of 4- by 6-inch curb, about 0.4 foot above land surface; altitude 4,098.65 feet

1930		1931		1932		1932	
Oct. 10	11.20	Aug. 4	12.50	Jan. 5	(2)	June 6	12.30
		Sept. 2	12.90	Feb. 3	(2)	July 6	12.95
1931		Oct. 1	12.90	Mar. 4	(2)	Aug. 1	14.75
May 21	12.30	Nov. 9	13.15	Apr. 1	13.40		
June 9	12.30	Dec. 5	13.15	May 11	13.05		
July 7	12.40			May 31	[1] 12.45		

[1] Adjacent land flooded. [2] Well dry.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 246. Fred Timm. Domestic well, drilled 4 inches in diameter, initial depth reported 185 feet deep, measured depths 162 feet on May 16, 1931, 66½ feet on June 3, 1931. Water from deep valley fill. Companion to well 247, which is about 20 feet to the northwest and which taps the shallow valley fill. Measuring point, top of vertical wood curb, 0.4 foot above land surface; altitude 4,105.65 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1931		1932		1932	
May 16	20.15	Sept. 2	22.05	Jan. 5	22.50	Apr. 1	22.65
June 3	21.20	Oct. 1	22.15	Feb. 3	23.20	May 11	21.05
July 7	21.40	Nov 9	22.80	Mar. 4	22.65	May 31	21.60
Aug. 4	21.70						

No. 247. Fred Timm. Domestic well, bored 8 inches in diameter and 22 feet deep Water from shallow valley fill. Measuring point, top of box pump support, 2.1 feet above land surface; altitude 4,107.40 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1928		1929		1930		1931	
Oct. 5	19.80	Dec. 2	[1] 20.6	Oct. 19	21.30	Dec. 5	22.80
Dec. 2	[1] 19.80			Nov. 2	21.35		
		1930				1932	
1929		Jan. 2	[1] 20.6	1931		Jan. 5	23.25
Jan. 3	[1] 19.80	Feb. 2	[1] 20.6	Feb. 8	21.45	Feb. 3	23.25
Feb. 3	[1] 19.80	Mar. 2	[1] 20.70	Mar. 8	21.60	Mar. 4	(2)
Mar. 3	[1] 19.90	Apr. 1	[1] 20.70	Apr. 5	21.75	Apr. 1	(2)
Mar. 31	[1] 19.80	May 3	[1] 20.70	May 16	21.65	May 11	22.75
Apr. 30	[1] 19.80	June 4	[1] 20.80	June 3	22.05	May 31	[3] 21.60
July 3	[1] 20.00	July 1	[1] 29.90	July 7	22.25	June 6	22.60
Aug. 1	[1] 20.20	Aug. 1	[1] 21.00	Aug. 4	22.50	July 6	22.75
Sept. 1	[1] 20.30	Sept. 1	[1] 21.10	Sept. 2	22.60	Aug. 1	23.00
Oct. 1	[1] 20.4	Oct. 6	[1] 21.20	Oct. 1	23.10		
Nov. 1	[1] 20.5	Oct. 9	21.15	Nov. 9	23.00		

No. 249. Owner unknown. Unused well, drilled 4 inches in diameter and 14 feet deep. Water from shallow valley fill. Measuring point, top of casing, 3.5 feet above land surface; altitude 4,102.00 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1932		1932	
Oct. 9	15.35	Aug. 5	16.15	Jan. 6	16.80	June 7	[3] 7.60
		Sept. 4	16.40	Feb. 4	16.65	July 7	8.85
1931		Oct. 2	16.55	Mar. 9	16.60	Aug. 3	11.05
May 16	15.80	Nov. 11	16.75	Apr. 3	16.80		
June 10	15.85	Dec. 6	16.85	May 10	[3] 11.00		
July 8	16.00			May 31	[3] 7.55		

No. 250. Owner unknown. Unused well, dug 4 feet square and 22 feet deep. Water from shallow valley fill. Measuring point, top of 4- by 4-inch girder at land surface; altitude 4,096.00 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1932		1932	
Oct. 10	18.25	Aug. 4	18.90	Jan. 5	19.65	June 6	19.25
		Sept. 2	19.15	Feb. 3	19.40	July 6	19.55
1931		Oct. 1	19.30	Mar. 4	19.10	Aug. 1	19.50
May 21	18.60	Nov. 9	19.35	Apr. 1	19.25		
June 9	18.65	Dec. 5	20.10	May 11	19.35		
July 7	18.80			May 31	19.40		

No. 253. Owner unknown. Stock well, dug 4 by 6 feet across and 13½ feet deep. Water from shallow valley fill. Measuring point, top of 2- by 4-inch girder, 1 foot above land surface; altitude 4,097.70 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Aug. 28	[4] 13.30	May 22	12.95	Aug. 5	(2)	May 10	15.65
Oct. 6	12.80	July 8	15.15	Sept. 4	(2)		

[1] Measurement by owner.
[2] Well dry.
[3] Adjacent land flooded.
[4] Windmill operating during measurement.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 267. Owner unknown. Unused well, dug 5 feet square and 21 feet deep. Water from shallow valley fill; on bank of Malheur Slough. Measuring point, top of 2- by 6-inch girder, at land surface; altitude 4,101.85 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1932		1932	
Oct. 10	17.30	Aug. 4	18.55	Jan. 4	18.05	June 6	13.65
		Sept. 2	18.85	Mar. 3	17.50	July 6	14.60
1931		Oct. 1	19.05	Apr. 1	12.55	Aug. 1	14.60
May 20	17.80	Nov. 9	19.30	May 11	[1] 12.50		
June 9	17.95	Dec. 4	19.35	May 31	13.55		
July 7	18.20						

No. 268. Owner unknown. Unused well, drilled 6 inches in diameter, measured depth 120 feet in 1930. Water from Harney formation or valley fill. Measuring point, top of well platform, 0.9 foot above land surface; altitude 4,102.95 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 10	9.50	Mar. 7	9.80	Sept. 2	10.15	Feb 3	10.00
Oct. 18	9.55	Apr. 4	9.80	Oct. 1	10.25	Mar. 3	10.00
Nov. 1	9.65	May 9	9.85	Nov. 9	10.15	Apr. 1	9.95
Dec. 6	9.65	May 21	9.80	Dec. 4	10.10	May 11	10.00
		June 9	9.90			June 6	10.10
1931		July 7	9.95	1932		July 6	10.35
Jan. 3	9.70	Aug. 4	10.05	Jan. 4	10.05	Aug. 1	10.45

No. 272. Owner unknown. Unused well, driven 2 inches in diameter and 28½ feet deep. Water from shallow valley fill. Measuring point, top of casing, 2.0 feet above land surface; altitude 4,110 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Oct. 10	26.2	Mar. 7	25.55	Oct. 1	26.8	Apr. 1	25.55
Oct. 18	26.1	Apr. 4	25.45	Nov. 9	26.35	May 11	25.6
Nov. 1	26.05	May 9	25.35	Dec. 4	26.3	June 6	25.55
Dec. 6	26.05	May 21	25.3			July 6	26.2
		June 5	25.5	1932		Aug. 1	26.85
1931		July 7	25.95	Jan. 4	26.25		
Jan. 3	26.15	Aug. 4	26.55	Feb. 3	25.45		
Feb. 7	25.65	Sept. 2	26.8	Mar. 3	25.6		

No. 292. Observation well, bored by Geological Survey, 3½ inches in diameter and 14 feet deep. Water from valley fill. Measuring point, top of casing, 0.4 foot above land surface; altitude 4,095.48 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1932	
Aug. 14	12.75	May 10	11.95
Sept. 4	12.95	June 7	11.90
Oct. 2	12.90	July 7	12.35
		Aug. 3	13.10

No. 293. Observation well, bored by Geological Survey, 3 inches in diameter and 14 feet deep. Water from valley fill. Measuring point, top of casing, 0.5 foot above land surface; altitude 4,096.41 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1932	
June 16	13.08	Jan. 6	13.46
June 24	13.12	Feb. 4	13.35
July 8	13.20	Mar. 9	13.37
Aug. 5	13.40	Apr. 3	13.20
Sept. 4	13.60	May 10	13.40
Oct. 2	13.60		
Dec. 6	13.45		

[1] Water flowing in adjacent channel.

Measurements of depth to water in observation wells, 1928–32—Continued

No. 294. Observation well, bored by Geological Survey, 3 inches in diameter and 17 feet deep. Water from valley fill. Measuring point, top of casing, 0.5 foot above land surface; altitude 4,100.75 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1931		1932	
Aug. 12	16.61	May 26	16.80
Sept. 4	16.71		
Oct. 2	16.79		

No. 296. Owner unknown. Unused well, drilled 4 inches in diameter and 21 feet deep. Water from late basalt (?). Measuring point, top of casing, 1.0 foot above land surface; altitude 4,111.90 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Sept. 14	20.85	Mar. 8	20.85	Oct. 2	21.15	Apr. 3	21.00
Oct. 19	20.85	Apr. 5	20.90	Nov. 11	21.25	May 10	21.15
Nov. 2	20.85	May 11	20.80	Dec. 6	21.70	June 7	21.05
Dec. 7	20.85	May 26	20.80			July 7	21.15
		June 10	21.30	1932		Aug. 3	21.25
1931		July 8	20.90	Jan. 6	21.40		
Jan. 4	20.85	Aug. 5	20.95	Feb. 4	21.05		
Feb. 8	20.85	Sept. 4	21.05	Mar. 9	21.10		

No. 316. Alva Springer. Domestic well, dug 5 feet square and 16 feet deep. Water from shallow valley fill. Measuring point, top of 2-inch plank well cover, 0.5 foot above land surface; altitude 4,099.65 feet

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Sept. 12	6.65	Mar. 8	6.75	Oct. 2	6.95	Apr. 3	6.15
Oct. 19	6.65	Apr. 5	6.65	Nov. 11	6.90	May 10	6.30
Nov. 2	6.70	May 11	[1] 9.75	Dec. 6	7.00	June 7	5.05
Dec. 7	6.70	May 26	6.30			July 7	5.55
		June 10	[1] 6.45	1932		Aug. 3	6.45
1931		July 8	[1] 6.85	Jan. 6	7.05		
Jan. 4	6.80	Aug. 5	[1] 7.95	Feb. 4	7.05		
Feb. 8	6.80	Sept. 4	6.90	Mar. 9	6.65		

No. 374. Owner unknown. Unused well, driven 1½ inches in diameter and 18 feet deep. Water from valley fill. Measuring point, lower valve seat of pump, 1.8 feet above land surface; altitude 4,104 feet (interpolated)

Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)	Date	Depth to water (feet below measuring point)
1930		1931		1931		1932	
Sept. 15	9.25	Mar. 8	8.85	Oct. 2	13.10	Apr. 3	8.35
Oct. 19	8.10	Apr. 5	8.65	Nov. 11	11.50	May 10	[2] 7.40
Nov. 2	6.80	May 11	9.35	Dec. 6	13.60	June 7	[2] 8.80
Dec. 7	7.75	May 26	9.65			July 7	10.20
		June 10	10.05	1932		Aug. 3	11.40
1931		July 8	10.90	Jan. 6	13.55		
Jan. 4	7.40	Aug. 5	11.90	Feb. 4	13.60		
Feb. 8	9.45	Sept. 4	12.65	Mar. 9	14.05		

[1] Pump stopped a short time before measurement. [2] Adjacent land flooded.

Hydrologic data for springs in the Harney Basin

[Use of water: B, bath; Ind., industrial; Ir., irrigation; S, stock]

No. on pl. 2	Location	Owner	Name	Altitude above sea level (feet)	Type of spring	Geologic horizon of water-bearing bed [1]	Discharge: Gallons a minute	Discharge: Date of measurement	Use of water	Temperature (° F.)	Remarks
	T. 22 S., R. 31 E.										
3	NW¼SW¼ sec. 27	Frank Whiting	Uncle Tom Spring	4,165	Seepage	Qal	[2] 75 [2] 125	Sept. 6, 1930 May 27, 1931	S, Ir		Irrigates meadow; noticeable annual fluctuation.
	T. 22 S., R. 32 E.										
9	SW¼NE¼ sec. 26	—— Houser		4,165	do	Qal	[2] 20 [2] 65	Sept. 1, 1930 May 28, 1931	S		Reported not to have gone dry in 45 years.
	T. 22 S., R. 32½ E.										
[3] 13	NE¼SW¼ sec. 14	Danforth & Co.				Qal (overlying Td).	[4] 225 [2] 225	Sept. 6, 1930 May 28, 1931	S, Ir	72	Aids in irrigation of 60-acre meadow.
	T. 22 S., R. 33 E.										
15	SE¼NE¼ sec. 20	Archie McGowan			do	Qal	2 2	Sept. 8, 1930 May 28, 1931	S	52	
	T. 23 S., R. 30 E.										
20	NW¼NE¼ sec. 22				do	Qal	[2] 10 [2] 5	Oct. 21, 1930 May 29, 1931	S	50	
[3] 27	NE¼NE¼ sec. 35	Edward Hines Western Pine Co.	Mill Pond Spring	4,135	Joint	Qbh	[2] 500 [2] 500	Sept. 4, 1930 May 29, 1931	Ind	73–80	Supplies sawmill log pond.
28	SE¼SE¼ sec. 35	Mrs. Goodman		4,138	do	Qbh	[2] 300 [2] 300	Sept. 3, 1930 May 29, 1931	S., Ir		Aids in irrigation of meadow.
29	NW¼SW¼ sec. 36	Western Compensation Co.		4,138	do	Qbh	[2] 300 [2] 300	Sept. 3, 1930 May 29, 1931	S, Ir	78	Do.
	T. 23 S., R. 34 E.										
141	Lot 2, sec. 6				Tubular	Older siliceous extrusives.	[2] 10 [2] 10	Sept. 8, 1930 May 28, 1931	S	62	
142	NE¼SW¼ sec. 7			4,154	Seepage	Qal	[2] 5 [2] 5	Sept. 8, 1930 May 28, 1931	S	54	

See footnotes at end of table.

Hydrologic data for springs in the Harney Basin—Continued

No. on pl. 2	Location	Owner	Name	Altitude above sea level (feet)	Type of spring	Geologic horizon of water-bearing bed [1]	Discharge: Gallons a minute	Discharge: Date of measurement	Use of water	Temperature (° F.)	Remarks
	T. 24 S., R. 30 E.										
148	SW¼NW¼ sec. 9	T. J. Jenkins		4,146	Joint	Td (?)	[4] 330 [4] 250	Sept. 3, 1930 May 29, 1931	S., Ir.	54	Irrigates 40-acre meadow.
149	NW¼SW¼ sec. 10	Vermont Loan & Trust Co.			do	Td (?)	[2] 75 [2] 5	Sept. 3, 1930 May 29, 1931	S	64	
[3] 150	SE¼SW¼ sec. 11	Oregon & Western Colonization Co.	Roadland Spring	4,135	do	Td	[4] 495 [4] 370	Sept. 3, 1930 May 29, 1931	S., Ir.	72	Irrigates meadow.
151	NE¼NW¼ sec. 15				do	Qal (?)	[2] 1	Aug. 12, 1931	S	56	
153	NW¼NW¼ sec. 24	Mrs. Doug Baker		4,128	Seepage	Th (?)	[2] 50 [2] 50	Sept. 4, 1930 May 29, 1931	S	62–70	Group of 5 orifices.
	T. 24 S., R. 33 E.										
[3] 205	NW¼SE¼ sec. 34	Ralph Catterson	Crane Hot Spring	4,125		Qal (overlying Th (?).	[5 6] 180 [5] 180	Oct. 10, 1930 June 3, 1931	B	122–126	Water pumped to natatorium.
	T. 25 S., R. 30 E.										
211	SE¼SW¼ sec. 22		Weaver Spring		do	Th	[2 6] 20 [2] 10	Oct. 16, 1930 June 2, 1931	S	53	
	T. 26 S., R. 28 E.										
279	SE¼SE¼ sec. 26	William Hanley Co.	OO Cold Spring	4,120		Th	[2 6] 450±	July 22, 1931	S., Ir.	58	
280	NE¼SE¼ sec. 34	do	OO Spring	4,120	Fissure or joint.	Td	[4 6] 5,350	May 30, 1932	S	74	
281	NE¼NW¼ sec. 36	do	OO Barnyard Spring.	4,120	Fissure	Td	[4 6] 1,750	July 21, 1931	S	72	
	T. 26 S., R. 29 E.										
[3] 285	Lot 4, sec. 31	do	Basque (East OO) Spring.	4,120	do	Td	[4 6] 1,200 [4] 900	July 22, 1931 May 30, 1932	S., Ir.	68–74	
	T. 26 S., R. 31 E. "South of Malheur Lake"										
[3] 317	Lot 6, sec. 35	Alva Springer	Sodhouse Spring	4,093	Gravity	Qbv	[4 6] 5,200 [4] 4,100	Sept. 9, 1930 Aug. 22, 1931	S., Ir.	54	
	T. 26 S., R. 32 E. "South of Malheur Lake"										
328	Lot 11 sec. 31	T. T. Dunn	Indian Spring	4,093	Seepage	Qbv	[2] 5±	Sept. 10, 1930	S	58	

	T. 27 S., R. 29 E.										
347	SW¼NW¼ sec. 5	Lewis M. Hughet	Johnson Spring	4,115	Fissure	Td	[2] 850	July 24, 1931	S, Ir	68–72	
349	NE¼NE¼ sec. 8		Hughet Spring	4,105	do	Td	[4,6] 5,850 [4] 5,400	do May 30, 1932	S, Ir	68	Irrigates 500-acre meadow.
351	SE¼SE¼ sec. 9	Edith Sizemore	Sizemore Upper Spring.	4,120	do	Td	[4,6] 1,160	July 28, 1931	S, Ir	67	
354	NW¼NW¼ sec. 15	do	Sizemore Lower Spring.	4,120	do	Td	[4,6] 410	July 28, 1931	S, Ir	66	
355	NE¼SE¼ sec. 15	A. W. Hulburt	Sizemore Upper Spring.	4,105	Seepage	Qal	[2] 25±	July 28, 1931	S		
	T. 27 S., R. 29½ E.										
357	[7]	Edith Sizemore	Sizemore Lower Spring.	4,082	Concealed fissure.	Qal (overlying Td?).			None	68–70	Group of springs.
358	[7]			4,082	do	do			do	104	Group of springs within area of ¼ square mile.
359	[7]			4,082	do	do			do	92	Group of springs.
360	[7]			4,085	do	do	[2] 20	Aug. 21, 1931	do	108	
[3] 361	NE¼SE¼ sec. 36				do	Td	[5,6] 150 [5] 150	Sept. 11, 1930 June 2, 1931	S	140–154	Red algae on water.
	T. 27 S., R. 30 E.										
365	Lot 11 sec. 4	W. J. Dunn		4,096	do	Qal (overlying Td).	[2] 25	June 4, 1931	S	70	
366	SE¼NW¼ sec. 4	do		4,095	do	do	[2] 10	do	S		
369	[7]			4,098	do	do	[2] 5	June 17, 1931	S	66	
372	Lot 5 sec. 8		Lynch Spring	4,095	do	do	[2] 25	June 4, 1931	S	65½	
	T. 28 S., R. 29 E.										
378	SW¼NE¼ sec. 20		Buzzard Spring	4,450±		Td		Sept. , 1932	S		
	T. 31 S., R. 32 E.										
379	NW¼NE¼ sec. 13	Eastern Oregon Livestock Co.	Hog House Spring		Fissure	Ts	[2] 900	Aug. 27, 1932	Ir	78–80	
	T. 31 S., R. 32½ E.										
380	NW¼SE¼ sec. 21	do	Knox Spring			Ts	[2,6] 450	July , 1932	Ir		
	T. 32 S., R. 32 E.										
381	SW¼NE¼ sec. 12	do			Fissure	Ts	[2,6] 500	Aug. 27, 1932	Ir	88–89	
	T. 32 S., R. 32½ E.										
382	NE¼SW¼ (?) sec. 5	do				Qal (overlying Ts).	[2,6] 100	do	S	83	

[1] Qal, valley fill and alluvium; Qb, late basalt (Qbh, near Hines; Qbv, near Voltage); Th, Harney formation; Td, Danforth formation; Ts, Steens basalt.
[2] Estimated.
[3] For chemical analysis of water see pp. 114–118.
[4] Current-meter measurement.
[5] Float measurement.
[6] For additional record of discharge see pp. 184–185.
[7] Unsurveyed land within inner meander line of Harney Lake.

Records of discharge from major springs in the Harney Basin, 1902–32

No on pl. 2	Location	Name	Discharge [1]		
			Date of measurement	Cubic feet a second	Gallons a minute
	T. 22 S., R. 32½ E.				
13	NE¼SW¼ sec. 14		Sept. 6, 1930	0.50	225
			May 8, 1931	.50	[2] 225
	T. 24 S., R. 30 E.				
148	SW¼NW¼ sec. 9		Sept. 3, 1930	.73	330
			May 29, 1931	.56	250
150	SE¼SW¼ sec. 11	Roadland Spring	Sept. 3, 1930	1.08	485
			May 29, 1931	.82	370
	T. 24 S., R. 33 E.				
205	NW¼SE¼ sec. 34	Crane Hot Spring	—— 1903	.25	110
			Aug. 13, 1907	.40	180
			Oct. 10, 1930	.40	[2] 180
			June 3, 1931	.40	[2] 180
	T. 25 S., R. 30 E.				
211	SE¼SW¼ sec. 22	Weaver Spring	Aug. 18, 1907		20
			Oct. 16, 1930		[2] 20
			June 10, 1931		[2] 10
	T. 26 S., R. 28 E.				
273	SE¼SE¼ sec. 26	OO Cold Spring	July 29, 1907	[2] 0.6–0.8	[2] 270–360
			July 22, 1931	[2] 1±	[2] 450±
280	NE¼SE¼ sec. 34	OO Spring	July 30, 1907	12.5	5,600
			Aug. 23, 1913	20.9	9,400
			Apr. 13, 1916	15.8	7,100
			May 14, 1916	15.7	7,100
			Oct. 28, 1916	16.4	7,400
			Apr. 18, 1917	14.1	6,300
			May 22, 1917	16.0	7,200
			Oct. 1, 1917	14.1	6,300
			Apr. 26, 1918	13.9	6,300
			June 10, 1918	8.4	3,800
			Mar. 23, 1919	15.2	6,800
			Sept. 5, 1919	15.0	6,700
			Apr. 24, 1921	15.2	6,800
			May 30, 1932	11.89	5,350
281	NE¼NW¼ sec. 36	OO Barnyard Spring	Apr. 12, 1916	6.6	3,000
			May 15, 1916	5.8	2,600
			Oct. 28, 1916	7.9	3,600
			Apr. 19, 1917	6.0	2,700
			May 22, 1917	5.7	2,600
			Oct. 1, 1917	5.1	2,300
			Apr. 26, 1918	6.0	2,700
			June 10, 1918	3.0	1,350
			Mar. 23, 1919	6.0	2,700
			Sept. 5, 1919	9.2	4,100
			July 21, 1931	3.85	1,750
	T. 26 S., R. 29 E.				
285	Lot 4 Sec 31	Basque (East OO) Spring	July 29, 1907	4.0	1,800
			Apr. 12, 1916	2.1	950
			May 15, 1916	2.7	1,200
			Oct. 28, 1916	1.8	800
			Apr. 19, 1917	2.3	1,100
			Oct. 2, 1917	2.2	1,000
			July 22, 1931	2.70	1,200
			May 30, 1932	1.97	900
	T 26 S., R. 31 E.				
317	Lot 6 sec. 35	Sodhouse Spring	Aug. 20, 1907	4–5	1,800-2,250
			Sept. 9, 1930	11.60	5,200
			Aug. 22, 1931	9.13	4,100

[1] Records of discharge in 1902 from Russell, I. C., Preliminary report on artesian basins in southwestern Idaho and southeastern Oregon: U. S. Geol. Survey Water-Supply Paper 78, p. 39, 1903 (presumably discharge estimated); in 1903 from Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Water-Supply Paper 252, p. 241, 1905 (presumably discharge estimated); in 1907 from Waring, G. A., Geology and water resources of the Harney Basin, Oreg.: U. S. Geol. Survey Water-Supply Paper 231, pp. 39, 40, 1909; in 1911 to 1921 from U. S. Geol. Survey Water-Supply Paper 310, p. 196, 1913; 440, p. 326, 1919; 460, p. 271, 1921; 480, p. 266, 1922; 510, p. 341, 1923; and 530, p. 190, 1926; in 1930 and 1931 from measurements by T. W. Robinson.

[2] Estimated.

Records of discharge from major springs in the Harney Basin, 1902–32—Continued

No. on pl. 2	Location	Name	Discharge		
			Date of measurement	Cubic feet a second	Gallons a minute
	T. 27 S., R. 29 E.				
347	SW¼NW¼ sec. 5	Johnson Spring	July 29, 1907	2.0	900
			Apr. 12, 1916	1.5	680
			Oct. 28, 1916	1.3	580
			May 22, 1917	1.7	760
			Oct. 2, 1917	2.0	900
			July 24, 1931	1.9	850
349	NE¼NE¼ sec. 8	Hughet Spring	Apr. 12, 1916	[4] 13.6	[4] 6,100
			Apr. 24, 1916	[4] 9.2	[4] 4,100
			Oct. 28, 1916	14.5	6,500
			Apr. 19, 1917	13.3	6,000
			May 22, 1917	12.0	5,400
			Oct. 2, 1917	12.8	5,800
			July 24, 1931	13.0	5,850
			May 30, 1932	11.94	5,400
351	SE¼SE¼ sec. 9	Sizemore Upper Spring	Apr. 12, 1916	1.5	680
			May 14, 1916	2.1	950
			Oct. 28, 1916	1.2	540
			May 22, 1917	2.8	1,250
			Oct. 2, 1917	[5] 3.5	[5] 1,580
			July 28, 1931	2.58	1,160
354	NW¼NW¼ sec. 15	Sizemore Lower Spring	Apr. 12, 1916	1.4	630
			May 14, 1916	1.6	720
			Oct. 28, 1916	1.3	590
			May 22, 1917	1.6	720
			Oct. 2, 1917	[5] 3.5	[5] 1,580
			July 28, 1931	.92	410
	T. 27 S., R. 29½ E.				
361	NE¼SE¼ sec. 36		—— 1902	.8	360
			Aug. 19, 1907	.4	180
			Sept. 11, 1930	[3] .35	[3] 150
			June 2, 1931	[3] .35	[3] 150
	T. 31 S., R. 32 E.				
379	NW¼NE¼ sec. 13	Hog House Spring	Nov. 1, 1907	4	1,800
			Aug. 27, 1932	[2] 2	[2] 900
	T. 31 S., R. 32½ E.				
380	NW¼SE¼ sec. 21	Knox Spring	Apr. 11, 1911	1.5	680
			July —, 1932	[2] 1	[2] 450
	T. 32 S., R. 32 E.				
381	SW¼NE¼ sec. 12		Aug. 28, 1907	0.4–0.6	180–270
			June 9, 1916	1.4	630
			Aug. 27, 1932	[2] 1.1	[2] 500
	T. 32 S., R. 32½ E.				
382	NE¼SW¼ (?) sec. 5		Aug. 27, 1907		20
			Aug. 27, 1932	.2	[2] 100

[2] Estimated.
[3] Float measurement.
[4] Measured 1 mile below head of spring.
[5] Combined flow of springs Nos 351 and 354.

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