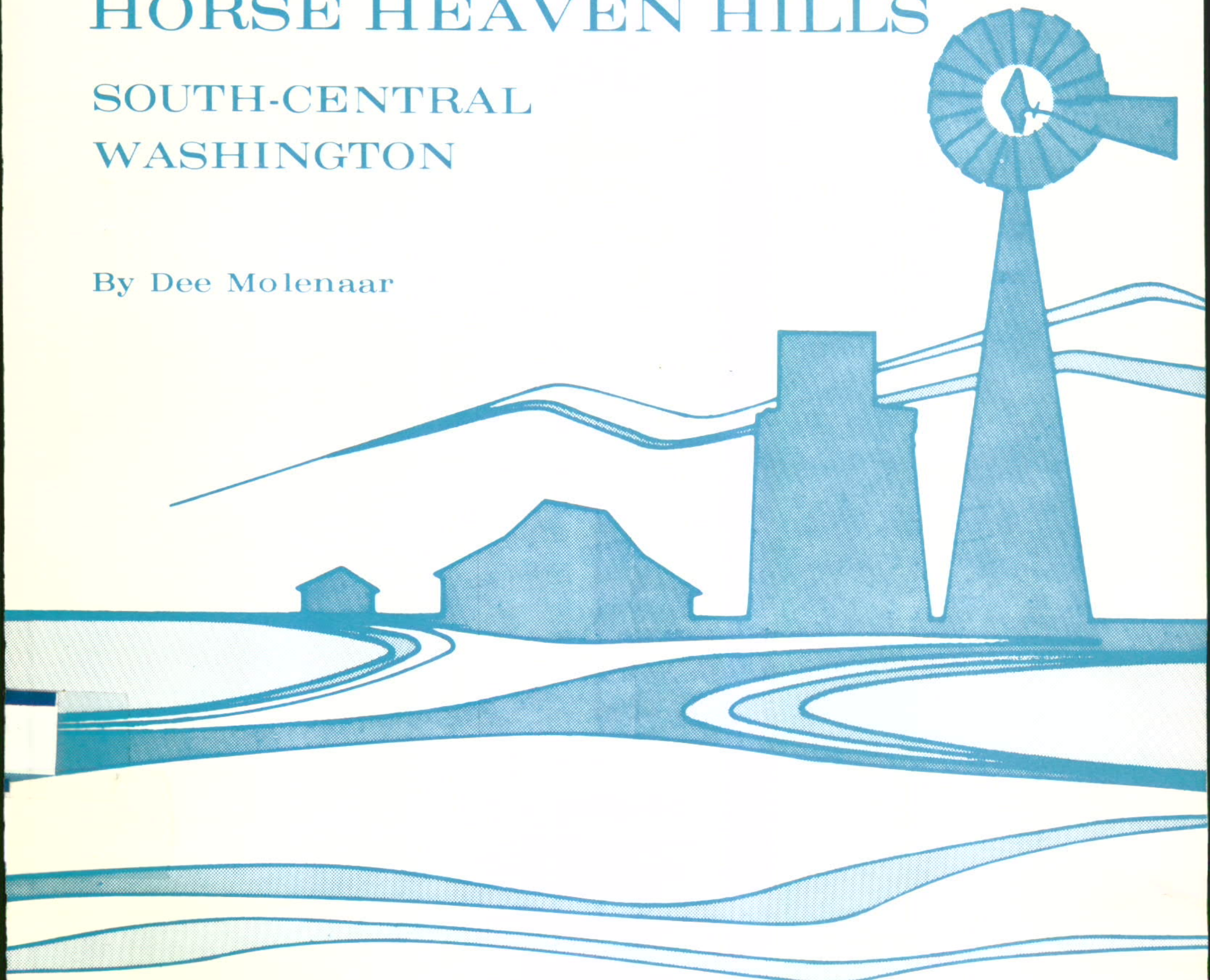
WATER IN THE HORSE HEAVEN HILLS

SOUTH-CENTRAL WASHINGTON

By Dee Molenaar



STATE OF WASHINGTON
John D. Spellman, Governor

DEPARTMENT OF ECOLOGY
Donald W. Moos, Director

WATER-SUPPLY BULLETIN 51

Prepared cooperatively by the U.S. Geological Survey

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UNITED STATES GEOLOGICAL SURVEY

1982

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METRIC CONVERSION TABLE

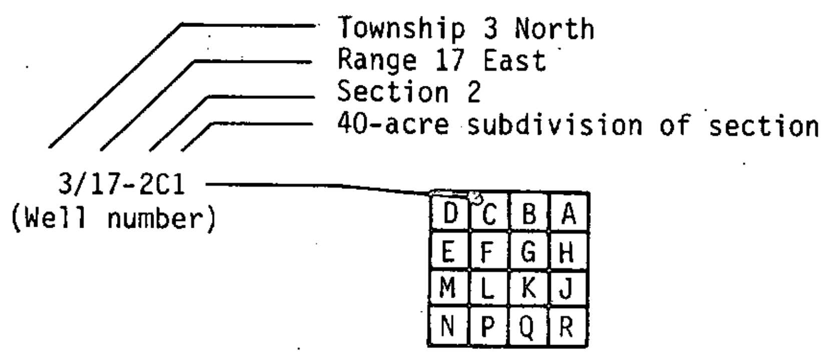
Multiply	By	To obtain
inch	25.4	millimeter (mm)
	2.54	centimeter (cm)
	.0254	meter (m)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (Km^2)
acre	4047.	square meter (m^2)
acre-foot (acre-ft)	1233.	cubic meter (m^3)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	.06309	liter per second (L/s)
gallon per minute per foot (gal/min)/ft	.2070	liter per second per meter (L/s)/m
foot per second (ft/s)	.3048	meter per second (m/s)
foot squared per day (ft^2/d)	.0929	meter squared per day (m^2/d)
degree Fahrenheit (°F)	0.5556, after subtracting 32	degree Celsius (°C)

WELL- AND LOCATION-NUMBERING SYSTEM

Wells inventoried during this study (table 16, at end of report) have been assigned numbers identifying them by location within a section, township, and range. Locations of other features in the study area are similarly described.

For example, in the symbol 3/17-2C1, the part preceding the hyphen indicates successively the township and range (T. 3 N., R. 17 E.) north and east of the Willamette base line and meridian. Because the study area lies entirely north and east of the base line and meridian, the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec. 2), and the letter "C" gives the 40-acre subdivision of the section, as shown in the figure below. The numeral "1" indicates that this well is the first one inventoried within the subdivision.

WELL-NUMBERING SYSTEM



WATER IN THE HORSE HEAVEN HILLS, SOUTH-CENTRAL WASHINGTON

By Dee Molenaar

ABSTRACT

The study area of 1,460 square miles has a temperate to semiarid climate, with mean annual precipitation ranging from about 25 inches in the higher western part to less than 10 inches in the lower eastern part. Until about 1970, the sparsely populated area (less than one person per square mile) had been characterized by dryland wheat farming and cattle and sheep grazing and production. In the 1970's, however, irrigation from the Columbia River resulted in a conversion to irrigated agriculture of about 64,000 acres (by 1977) of former dryland-farming and sagebrush land. Nearly concurrent development of irrigation from wells tapping large-yield artesian aquifers in the Columbia River Basalt Group has resulted in an additional 2,760 acres of agricultural land in the central part of the area.

Sparse streamflow data show that, except for the lower spring-fed reach of Alder Creek, all streams are ephemeral. Discharges range from no flow to high flash-flood runoff, with a maximum daily discharge of 4,800 cubic feet per second in the lower reach of Rock Creek, recorded on December 22, 1965, during the 1963-68 period of record. The monthly suspended-sediment discharge at this site in December 1965 was 280,000 tons.

Data from 294 wells in the area, including drillers' logs (104 wells), geophysical analysis (25 wells), and water-level observations (13 wells) disclose that wells range in depth from a few feet to 1,100 feet, well yields range from a few gallons per minute to artesian flows as great as 4,000 gallons per minute and specific capacities as great as 1,200 gallons per minute per foot. Water-quality analyses of water from selected wells show hardness ranging from 17 to 218 milligrams per liter and specific conductance ranging from 145 to 640 micromhos per centimeter.

INTRODUCTION

The Horse Heaven Hills study area covers about 1,460 mi^2 in Klickitat, Benton, and Yakima Counties in south-central Washington (fig. 1). The plateau-like area was originally called "Horse Heaven," a name derived from its being a sanctuary for bands of wild horses which were eventually driven from the natural pastureland by the development of farms (Phillips, 1971, p. 64).

The region has a temperate to arid climate, with mean annual precipitation ranging from about 25 inches in the higher western parts to less than 10 inches in the lower eastern part. Historically, the area has long been characterized by dryland wheat farming and cattle production on the upland interior, with only minor amounts of irrigation of fruit and some grain crops on lands near the Columbia River. The lack of perennial streams in much of the area and the excessive depth to adequate ground-water supplies except near the Columbia River have precluded irrigation in the higher areas distant from the river.

Only since about 1970 has there been a significant increase in irrigation, mostly by large withdrawals of water from the Columbia River, virtually all in Benton County in the eastern half of the area. Also, exploration for ground water at greater depths in some areas has resulted in the tapping of artesian zones that now provide large quantities of water for irrigation. The region has nearly 640,000 acres (1,000 mi^2) of irrigable land, about 10 percent of the potentially irrigable land of the State and more than the acreage now irrigated in the Columbia Basin Irrigation Project to the north.

The Columbia River is the only reliable source of surface water for the area, and increasing quantities of water are being pumped from the pools behind John Day and McNary Dams. Diversion of water to satisfy the estimated water needs of the entire area, however, would comprise less than 2 percent of the average annual flow of the Columbia River at The Dalles. The area has a growing season of 170 to more than 200 days, and the frost hazard is low enough that fruit could become a major crop in the future. Intensive field crops such as potatoes and sugar beets also are projected for the area, as is supplementally irrigated wheat.

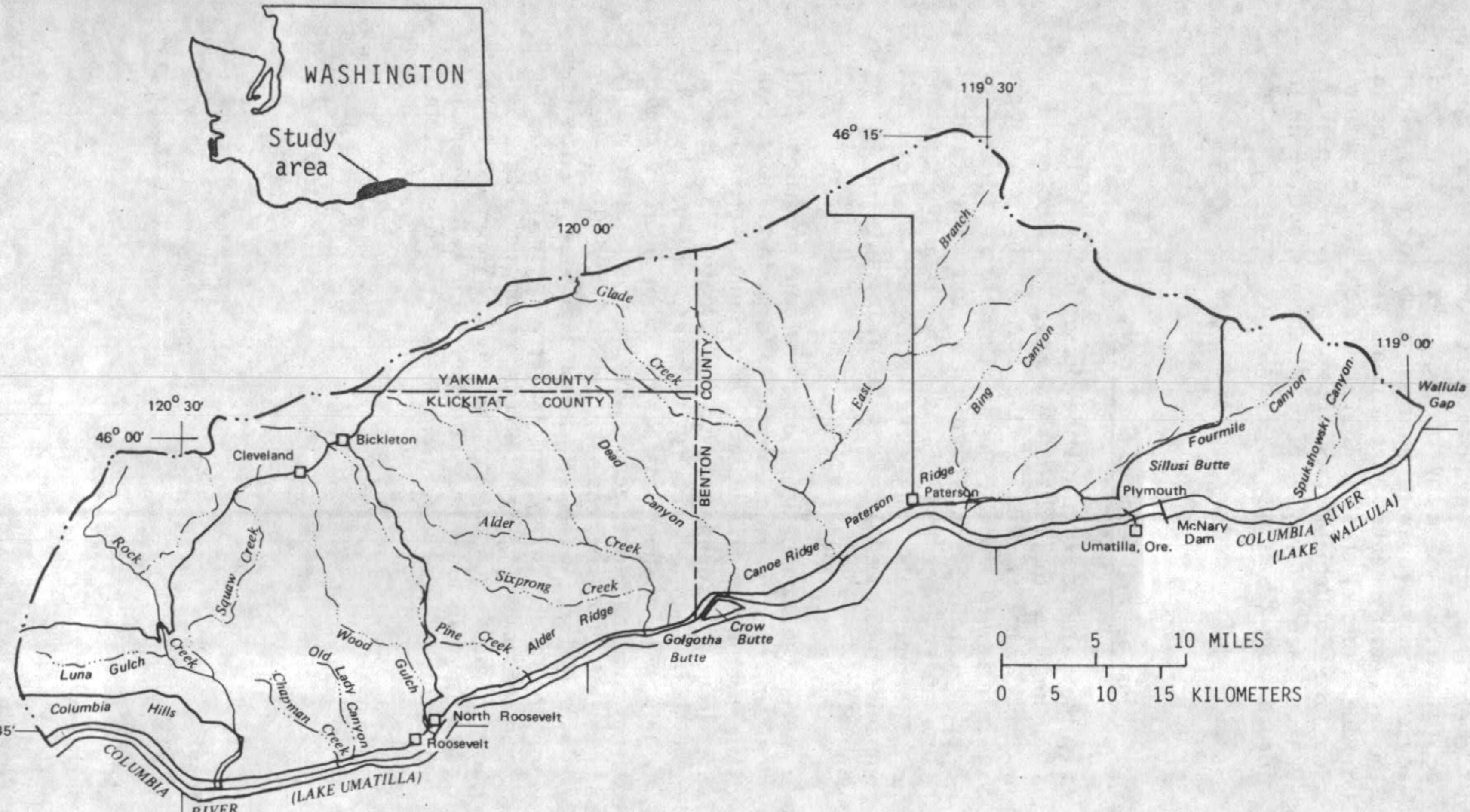


FIGURE 1.--Location of study area.

The Horse Heaven Hills is developed chiefly for agriculture, and only a few small communities have been established in the area--all but Bickleton and Cleveland are situated along the Columbia River. Farm homes are widely scattered and many of the older ones have been abandoned. Many owners now operate their farms by commuting from towns outside the area--many being in the Yakima Valley to the north, in Mabton, Sunnyside, Prosser, and the Tri-Cities area. The few small communities along the Columbia River--Roosevelt, North Roosevelt, Paterson, and Plymouth--consist largely of mobile homes, with residents employed in railroad work or on the large irrigation projects farther inland.

Purpose and Scope of the Study

This report on the water resources of the Horse Heaven Hills is one in a series that summarizes the existing hydrologic data collected in major water-resource inventory areas of the State. The reports are prepared in cooperation with the Washington Department of Ecology (DOE), for use by Federal, State, County, and municipal agencies involved in the use and management of the State's valuable land and water resources. The report also may serve as a guide to individuals and private companies interested in the local availability of surface water and ground water.

The study included the compilation and general interpretation of all available hydrologic information on the area. The surface-water data include records of streamflow and water quality and information on diversion of water from the Columbia River for irrigation in the area. The ground-water data include records of wells, drillers' logs of materials penetrated, water-yielding characteristics of aquifers tapped (as determined from pumping tests), geophysical logs, and water-quality analyses. Because of the increasing interest in ground-water occurrence and availability in the central part of the area, some interpretations of the geohydrology of the area were made. The interpretations were based on drillers' records, geophysical logs, field observations, and previous studies in the area. Water-use data, particularly for irrigation, include those obtained from well owners and various town and county officials and from interpretation of satellite photos of irrigated areas.

Previous Investigations

There have been no previous geohydrologic studies of the entire Horse Heaven Hills area as defined for this study and report. However, a number of investigations have included parts of the area, and some broader regional hydrogeologic and geologic studies include the study area. These include the State geologic map by Huntting and others (1961), soils surveys of Yakima County (U.S. Department of Agriculture, 1958) and Benton County (Kocher and Strahorn, 1919), and generalizations of ground-water occurrence in the Columbia River Basalt Group in eastern Washington and Oregon (Newcomb, 1958, 1965). Thesis research by Laval (1956) included studies of the stratigraphy and geologic structure in eastern Klickitat County in the western part of the area, as did later work by Schmincke (1967) and Newcomb (1970, 1971). A report by Muckleston and Highsmith (1978) discusses the large corporately operated center-pivot irrigation systems in the area and their potential impact on both the hydroelectric power resources and the socioeconomic fabric of the region.

Several previous ground-water investigations have been made in the study area. Reconnaissance studies in eastern Klickitat County were made by Waring (1913) and Piper (1932). A study of the water resources of Klickitat County was made recently by J.C. Brown (1979), and an analysis of stratigraphic controls on ground-water occurrence and the potentiometric surface in the central part of the area was made by J. C. Brown (1978). A study of the ground-water resources of the Bickleton area was made by Strait (1978). A study of wells on the Prior Ranch properties in the eastern part of the study area was made by R. E. Brown (1973), and a geophysical study of selected wells in the area was conducted by Crosby, Anderson, and Kiesler (1972) of Washington State University. A test-observation well drilled in the East Fork Glade Creek valley is described in a report by Pearson (1973).

Previous investigations entirely within the present study area include a reconnaissance of the area's irrigation potential (CH_2M Hill, 1976) and studies of (1) the irrigation-development potential of the soils, by the Soil Conservation Service (U.S. Department of Agriculture, 1977); (2) the hazards of salinity on irrigation-development potential (McNeal and Starr, 1974), and (3) the feasibility of the proposed Paterson Ridge Pumped-Storage Reservoir. This latter study included an evaluation of various canal-distribution systems designed to develop the irrigation potential of large parts of the plateau. These reservoir studies resulted in a geologic map by Newcomb (1971), a topographic map by the U.S. Geological Survey (1970), and a federal-land-classification report by Young (1967).

Acknowledgments

The author wishes to acknowledge the assistance of a number of individuals and agencies who provided much of the information and data forming the basis for this report.

Dorothy Prior provided use of a consultant's report (R. E. Brown, 1973) on wells on the Prior Ranch. Wilbert G. Gerlitz, Benton County Extension Agent, provided information on 1977 pumpage from the Columbia River for irrigation of large areas in Benton County (Gerlitz, 1977). William R. Smith, Howard Powell, and William Myers of the Washington Department of Ecology (Central Region office in Union Gap, Wash.) provided drillers' logs of many new wells drilled in the area, and personnel of the Department of Civil and Environmental Engineering, Washington State University, provided additional geophysical logs of wells as they became available. Jeffrey C. Brown, of that department and author of a report on the water resources of Klickitat County (J. C. Brown, 1979), provided additional information during several telephone conversations. Steve R. Strait, also of Washington State University, provided data on wells and water levels in the Bickleton area. The data were eventually published (Strait, 1978).

In addition, the author expresses thanks to the many well owners who provided data and allowed access to their property for water-level measurements.

DESCRIPTION OF THE AREA

Location and Extent

As defined for the purpose of this report, the study area includes the southern slope of the Horse Heaven Hills in south-central Washington (fig. 1). The area covers about 1,460 mi^2, of which about 690 mi^2 is in eastern Klickitat County, 670 mi^2 is in southern Benton County, and 100 mi^2 is in southeastern Yakima County. The area extends about 80 miles east and west and, generally, 20 miles between the crest of the Horse Heaven Hills on the north and the Columbia River on the south. The western boundary of the study area is defined as the divide between the Rock Creek drainage (within the study area) and the Klickitat River basin to the west. On the east the study area extends to Wallula Gap on the Columbia River.

Topography and Drainage

The Horse Heaven Hills is a broad upland within the Columbia Plateau Province. Except for an abrupt descent to the Columbia River from the Columbia Hills in the western 15 miles of the area, the "Horseheaven Plateau" (Fenneman, 1931, p. 226) area has a gentle southward slope to the Columbia River at Lake Umatilla (normal pool altitude about 265 ft above sea level, as defined by the National Geodetic Vertical Datum of 1929), which is formed behind John Day Dam (downstream from the study area).

The crest of the Horse Heaven Hills ranges in altitude from about 4,600 ft in the western part of the area to 2,000 ft in the eastern part, near Wallula Gap. North of the crest, the hills descend to the Yakima River valley.

The plateau has local variations in its gentle southward slope to the Columbia River (pl. 1). These include small synclinal basins, several low anticlinal ridges near and parallel to the river, and more sharply rising areas in the western part of the study area. The lower ridges along the Columbia River include, from west to east, Alder Ridge, Golgotha Butte, Canoe Ridge, Paterson Ridge, and Sillusi Butte. Local areas of poor drainage occur upslope (north) of these ridges.

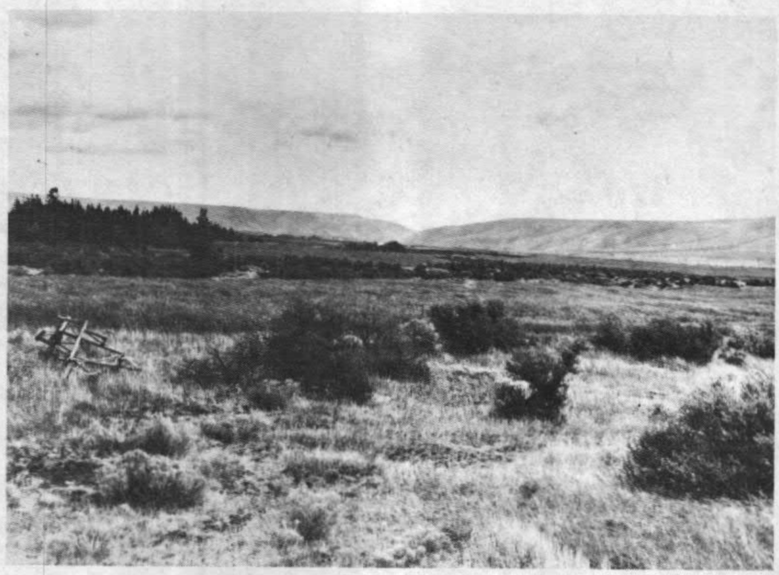
In its western part the plateau rises more abruptly above the Columbia River--greater than 2,500 ft in the Columbia Hills in the extreme western part of the area--and a large intensive, dendritic-patterned network of canyons is cut into the plateau. These occur primarily in the basins of Alder Creek, lower Pine Creek, Wood Gulch, Old Lady Canyon, Chapman Creek, and Rock Creek.

The Rock Creek basin is the most rugged in the study area. Its general aspect is one of a broad undulating surface cut by several deeply incised valleys (plate 1). In its lower reaches Rock Creek occupies a valley cut as much as 1,800 feet below the level of the adjacent plateau.

The lower, eastern part of the study area is much flatter, and the streams occupy shallow valleys, some with bottoms only 25 to 50 ft below the general level of the plateau. The Glade Creek basin covers 428 mi^2 in the central part of the study area and is by far the largest of the topographic subareas. The basin is divided, with East Branch Glade Creek draining the larger part of the subarea. The main stem bends sharply westward in its headward reach and follows a small synclinal valley near and parallel to the crest of Horse Heaven Hills. Besides the more dominant drainages and streams noted above, several smaller streams, mostly in the lower eastern part of the study area, drain to the Columbia River (fig. 1).

The variety of scenery, due to topographic, climatic, and agricultural influences in various parts of the study area, is shown in the photographs in figures 2 through 9.

A. Wind-powered pump on stock-supply well at 4/17-2P. View is north-westerly toward Simcoe Mountain.



B. View southeasterly across upper Rock Creek basin from 4/17-2P. Lower Rock Creek flows through deep valley cut into background hills.

FIGURE 2.--Upper Rock Creek basin.

FIGURE 3.--View northerly from Oak Flat across upper Rock Creek basin.

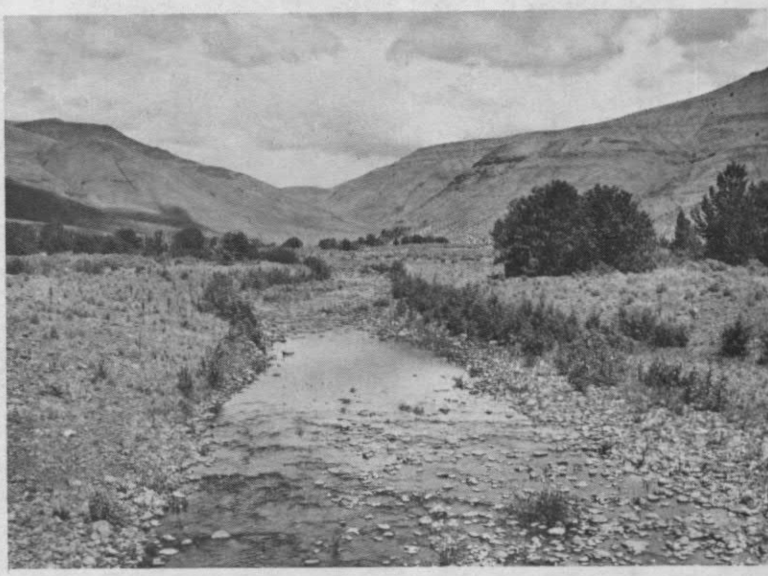


FIGURE 4.--View upstream in lower Rock Creek basin, at 3/19-16B. Streamflow here was estimated to be about 4 ft^3/s at time of photography, May 24, 1977.

FIGURE 5.--Plateau-like upper slope of study area, looking eastward.

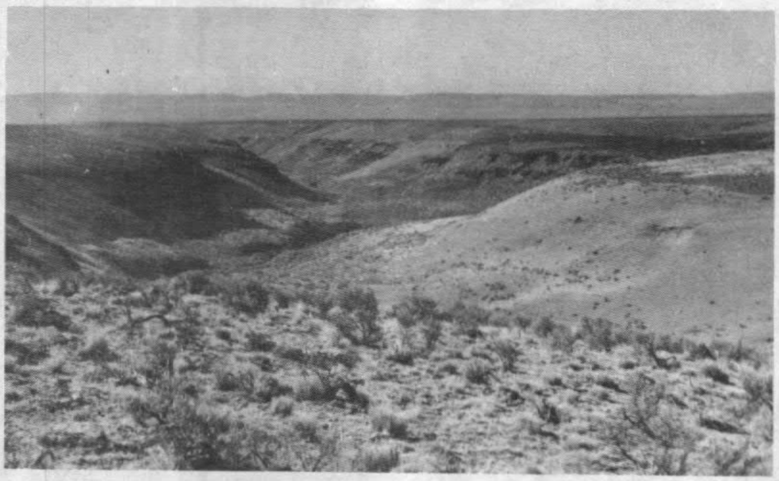


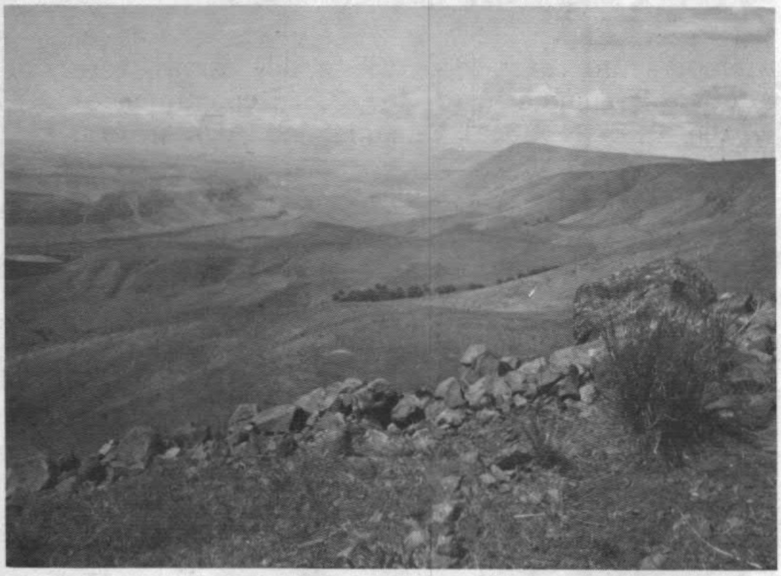
FIGURE 6.--View south down Spring Canyon, from 5/22-3N.

FIGURE 7.--View southwesterly toward Plymouth and Columbia River from 5/28-4C below Sillusi Butte.

A. View east to Wallula Gap and abandoned farmstead, from 6/30-12N.

B. View southeasterly into Wallula Gap, from 6/30-12N.

FIGURE 8.--Near Wallula Gap.



A. View westerly down Columbia River (Lake Umatilla) toward John Day Dam, with Columbia Hills on the right. From 4/18-35N.

B. View easterly up Columbia River (Lake Umatilla), from 3/21-3B.

FIGURE 9.--The Columbia River.

Climate

Precipitation and temperature data for the study area were obtained from annual and monthly summaries of the U.S. Department of Commerce (1955-73) and the U.S. National Oceanic and Atmospheric Administration (1974-77).

The study area has a temperate to arid climate, with cold winters and warm summers. According to the precipitation map (fig. 10), the mean annual precipitation during 1930-57 ranged from nearly 25 inches in the higher western part near Satus Pass (altitude 2,610 ft) to less than 10 inches or less at McNary Dam (altitude 360 ft; pl. 1) in the lower eastern part. At the weather station at Bickleton (altitude 360 ft), with the most complete long-term record in the area, the average annual precipitation was 14.0 inches during the 1955-77 water years.[1]

Precipitation varies widely among water years, as shown for the Bickleton station in figure 11 and as given in table 1. Precipitation ranged from 25.09 inches in 1971 to 6.82 inches in 1977--the water year of the greatest recorded drought in the State's history. The drought was particularly severe during October-February, when precipitation at Bickleton totaled 1.59 inches; the normal for that period is 9.40 inches.

Mean monthly precipitation at Bickleton during the 1955-77 water years ranged from 2.48 inches in December to 0.26 inches in July (fig. 12). However, as shown for comparison in the figure, the conditions were erratic during the 1977 drought water year. During most of that year precipitation was below normal, but during May, August, and September it was 1.73, 1.38 and 0.69 inches, respectively—well above the means of 0.80, 0.35, and 0.48 inches for those months during 1955-77.

Mean annual temperature at Bickleton is about 47°F, and mean monthly temperatures range from 27.5° F in January to 67.4°F in July (fig. 13). Relative to temperatures at Bickleton, those at Satus Pass are a few degrees (°F) cooler and those at McNary Dam are a few degrees warmer.

[1] A water year covers the period of October 1 of one year through September 30 the following year. For example, the 1977 water year encompasses the period October 1, 1976-September 30, 1977.

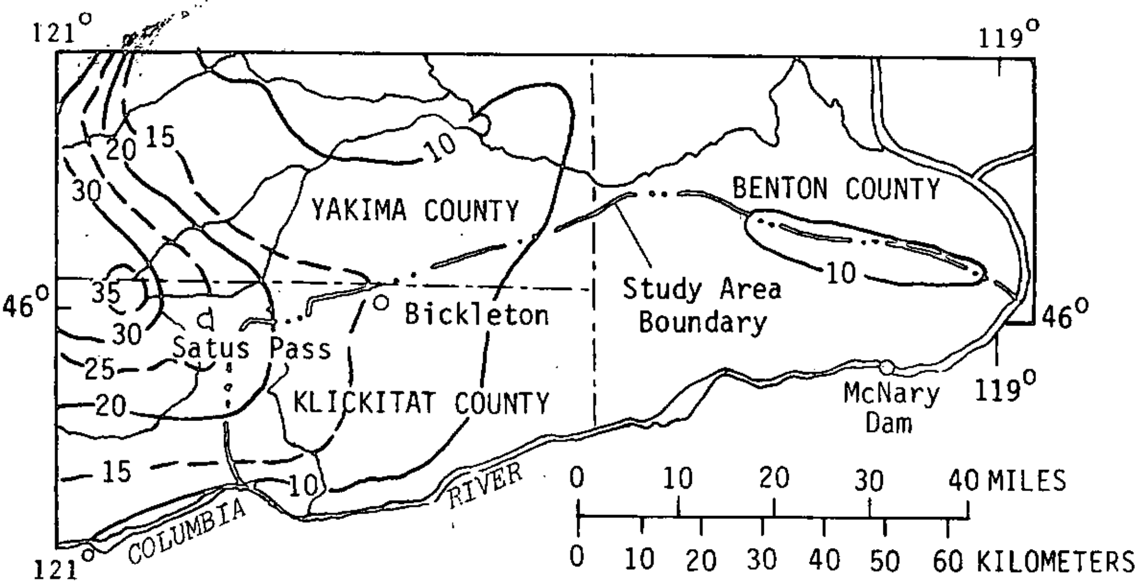


FIGURE 10.--Mean annual precipitiaon in study area and vicinity during the period 1930-57, and location of selected weather stations. Numbered lines connect points of equal precipitation in inches. Adapted from map by U.S. Weather Bureau (1965).

TABLE 1.--Monthly, average monthly, annual, and average annual precipitation at Bickleton during 1955-77 water years

[From U.S. Department of Commerce, 1929-70, and U.S. National Oceanic and Atmospheric Administration, 1970-77.]

Water year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	Annual average
1955	0.65	1.20	1.07	1.00	0.68	0.95	1.48	0.89	0.38	1.06	0.00	0.53	9.89
56	1.03	.465	4.48	4.04	1.53	.87	.01	1.50	1.16	.02	.46	.26	20.01
57	1.18	.30	1.27	.72	1.99	3.70	.75	1.41	.52	.22	.09	1.27	13.42
58	1.89	.61	2.10	3.45	3.39	.77	1.36	.92	.38	.11	T	.08	15.06
59	.23	3.10	.96	2.87	.85	1.35	.24	.35	.30	.00	.00	1.54	11.79
1960	.96	.64	.97	.77	2.55	2.31	1.24	.61	.23	.28	.10	.06	10.72
61	.67	4.61	1.48	2.53	4.87	2.59	.89	1.49	.75	.25	.17	.05	20.35
62	.54	1.46	2.72	.47	1.79	1.46	1.34	1.66	.38	.00	.22	.69	12.73
63	2.01	2.54	1.36	.80	1.74	1.61	2.11	1.13	.53	.35	.05	.15	14.38
64	.50	2.50	1.76	2.35	.03	.72	.27	T	1.09	.10	.10	.39	9.81
1965	.63	2.64	8.82	1.38	.60	.28	.85	.30	.87	.12	.57	.57	17.63
66	.26	2.56	1.15	2.94	.60	1.78	.09	T	.10	1.93	T	.64	12.05
67	1.03	3.42	2.90	2.41	.45	.94	1.58	.42	.78	.00	T	.01	13.94
68	1.58	1.26	.92	2.35	3.17	.40	.03	.46	.18	T	2.14	.31	12.80
69	1.24	2.42	2.07	2.71	1.21	.28	.71	1.21	.99	.00	.00	.51	13.35
1970	.24	.28	3.85	6.02	1.31	.80	.36	.19	.25	.03	.00	.09	13.42
71	.89	3.96	4.19	4.95	1.54	3.24	.92	1.27	1.83	.00	.22	2.08	25.09
72	.96	1.61	2.33	3.14	1.67	1.22	.60	1.44	1.29	.11	.28	.34	14.99
73	.12	1.33	2.33	1.96	.39	.31	.24	.14	.05	.00	T	.60	7.47
74	1.81	4.91	3.94	5.50	1.23	1.84	1.60	.31	.27	.70	.00	.00	22.11
1975	.20	1.07	2.11	3.28	2.14	1.04	.46	.54	.27	.39	1.15	.00	12.65
76	1.65	1.94	2.50	1.18	1.49	.94	.62	.41	.17	.15	1.14	.14	12.33
77	.33	.10	.26	.16	.74	.83	T	1.73	.39	.21	1.38	.69	6.89
Averages	.90	2.14	2.42	2.48	1.56	1.31	.77	.80	.57	.26	.35	.48	14.04

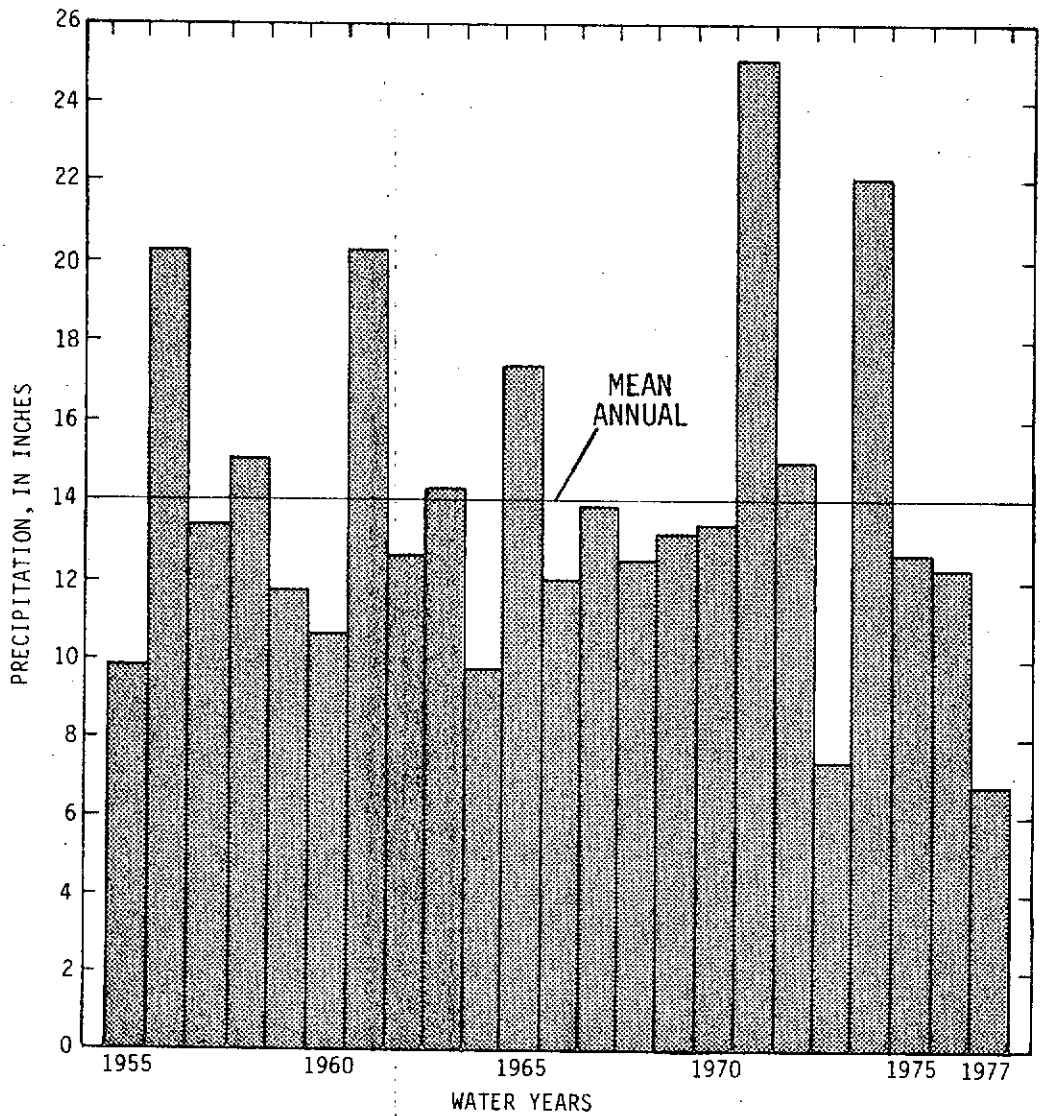


FIGURE 11.--Annual precipitation at Bickleton, 1955-77 water years.

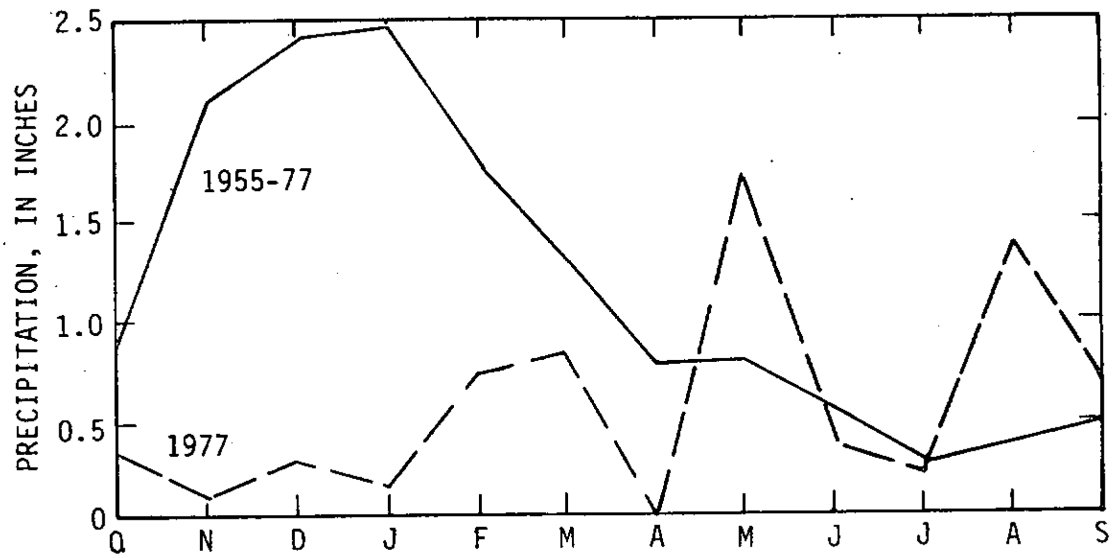


FIGURE 12.--Comparison of mean monthly precipitation at Bickleton during 1955-77 water years and monthly precipitation during 1977 drought water year. Data from U.S. Department of Commerce (1954-73) and (U.S.) National Oceanic and Atmospheric Administration (1974-77).

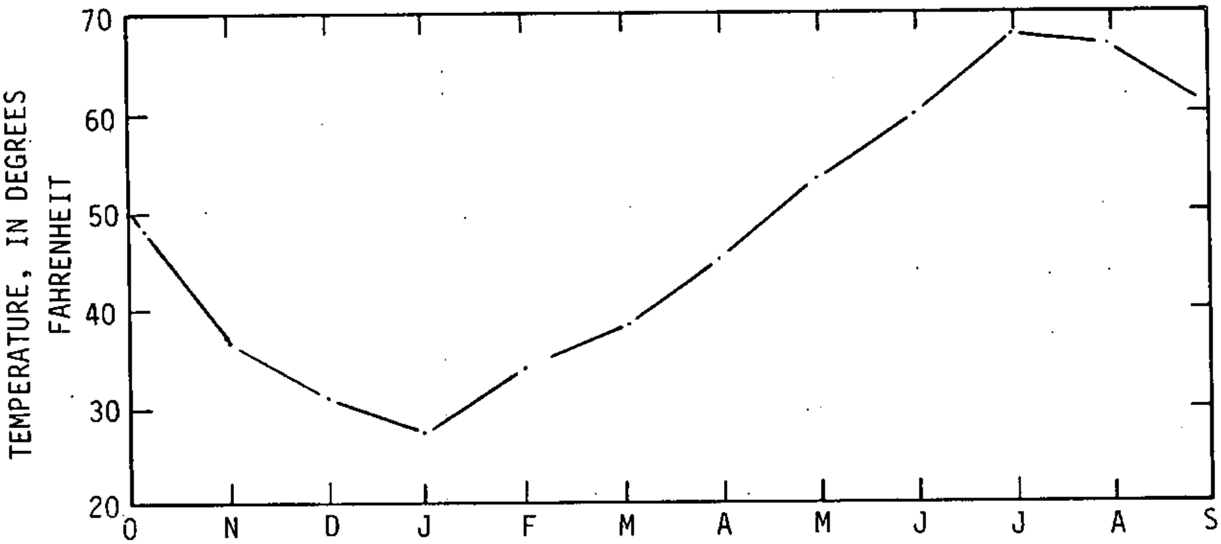


FIGURE 13.--Mean monthly temperatures at Bickleton, 1930-76. Data from (U.S.) National Oceanic and Atmospheric Administration (1977).

Geologic Setting and Soils

The rocks underlying the Horse Heaven Hills—exposed or beneath a thin soil mantle--are basalt and some sedimentary interbeds of the Columbia River Basalt Group of Miocene Age (Griggs, 1976). The basalt occurs in flow layers ranging in thickness from a few feet to more than 100 ft, and their cumulative thickness beneath the study area is probably 5,000 ft or greater, as determined by drillers' logs of wells in areas adjacent to the study area. Overlying the basalt, particularly in the eastern half of the area, are unconsolidated fine-grained materials of lacustrine (lake) and loessal (wind-carried) derivation, mostly deposits of silt and sand. The higher lands are mantled by silt of variable depths (a few inches to 10 ft or more); the areas of intermediate altitude (up to 1,000 ft) have lacustrine sediments of layered silt and very fine sand (the Touchet Beds of Flint, 1938); and the areas nearer the river are underlain by alluvial sand and gravel.

The Horse Heaven Hills is part of a structural upwarp affecting the basalt and interbedded sediments of the Columbia River Basalt Group. The axis of the Horse Heaven anticline extends generally east and west across south-central Washington and northeastern Oregon. The north limb of the anticline descends steeply to the Yakima and Walla Walla valleys, whereas the south limb forms the relatively gentle, plateau-like slope descending to the Columbia River and Umatilla basin (fig. 1, pl. 1).

Several smaller east-west trending anticlinal ridges and synclinal valleys and minor faults occur in the area. These are described in greater detail in the discussion of ground-water resources (p. 50).

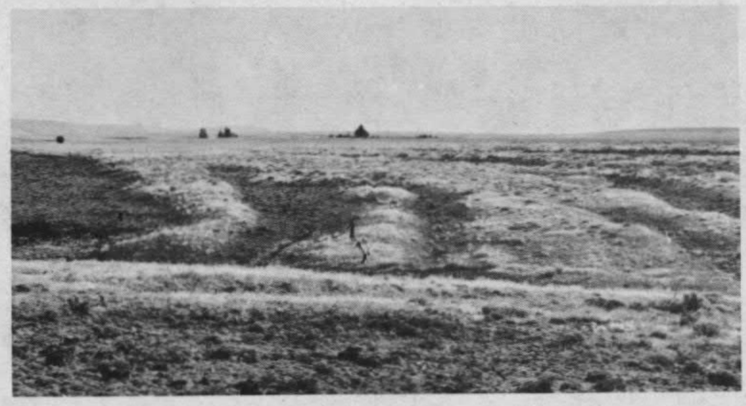
The soils underlying the Horse Heaven Hills vary in thickness and general composition throughout the area. The soils in the western part of the study area—from the upper Alder Creek basin westward—are thinner and more a product of the weathering of the basalt surface than of lacustrine and loessal deposition. In some places the soil is missing and basalt is exposed, as in the channel of Glade Creek (fig. 14).

In the area south and southwest of Bickleton are large areas of farmland characterized by "islands" of loessal soil 1 to 3 ft thick, which are separated by linear areas of exposed basalt (fig. 15). Such areas appear to have resulted from erosion by rapid and intense localized rainfall and (or) snowmelt runoff in recent geologic time.

According to McNeal and Starr (1974, p. 1), "As one proceeds upslope from the river, differences between soils occur. Organic matter in the surface soils increases, salts and carbonates are leached deeper, calcium carbonate hardpan (caliche) lies deeper, and clay contents and bulk densities of the subsoils increase slightly."

For additional information on the types and characteristics of soils of the study area, the reader is referred to maps and reports on the soils of Benton County (Kocher and Strahorn, 1919; U.S. Department of Agriculture, 1919) and Yakima County (U.S. Department of Agriculture, 1958); at this writing (1978), there are no published soils maps covering Klickitat County.

FIGURE 14.--Basalt bedrock exposed in channel in middle reach of Glade Creek, at 6/24-22H, and flow due mostly to upstream discharge of McKinley Spring.



A. View northeasterly from 6/20-15R east of Bickleton.

B. View southwesterly from 6/20-15R east of Bickleton.

C. View north from 5/20-18Q.

FIGURE 15.--Areas of patterned ground, with thin loessal silt mantle separated by exposed strips of basalt, probably resulting from erosion by rapid melting of snow.

Vegetation

The variety and density of vegetation in the Horse Heaven Hills are influenced by altitude and precipitation. Vegetation in the higher northwestern parts of the Rock Creek and Alder Creek basins includes pine forests, with valley bottoms supporting groves of oak, cottonwood, alder, and aspen (figs. 3 and 4). The remainder of the study area is open country covered naturally by sagebrush, cheat grass, tumbleweed, and smaller plants (fig. 7)--and even small species of cactus near Plymouth and McNary Dam.

Population

The study area is sparsely settled, having a 1977 population of about 1,135 people, a density of less than one person per square mile. The rural population was estimated on the basis of an average of three persons per occupied home, or 700 persons in 233 homes. Community populations were reported at local postoffices or estimated as follows: Bickleton, 95; Cleveland, 35; Paterson, 100; Plymouth, 125; Roosevelt, 40; and North Roosevelt, 40.

The upper Rock Creek basin has the greatest concentration of rural homes. However, even there many homes are abandoned and much of the land is operated by commuters living in Goldendale, a few miles west of the study area.

AGRICULTURE AND IRRIGATION

History of Development

Agricultural development in the Horse Heaven Hills started around the turn of the century. According to a report by Kocher and Strahorn (1919, p. 12), who conducted a soils study of this part of Benton County (eastern half of study area),

"About 1902 a considerable influx of settlers began, and during the next few years a large part of the Horse Heaven Plateau was taken up by homesteaders. During the next decade many thousand acres of bunch-grass land were plowed and seeded to wheat. The rapidity of development is indicated by the fact that in 1907, a year of low yields, nearly 500,000 bushels of wheat were shipped from Benton County.

"Owing to the low rainfall the fields must be summer fallowed every other year, so that a harvest is retrieved only once in two years. Even with this procedure crop failures have been common. In view of these trying conditions and of the difficulty of obtaining underground water, so that water for all stock and domestic purposes had to be hauled long distances, many settlers, after acquiring title to their homesteads, immediately abandoned them. About 1909 a pronounced exodus began, and by 1913 there were only a few houses occupied on the Horse Heaven Plateau. At the present time (1919), however, a considerable acreage is still in cultivation, as the farmers remaining work a number of homesteads. The continued success of all the better farmers has demonstrated that wheat can be profitably grown where proper attention is given to seed selection and to the details of cultivation."

Until the 1970's irrigation in the Horse Heaven Hills was limited to pumpage from wells at Sundale Orchards at the mouth of Chapman Creek in Klickitat County. However, in the early 1970's large-scale diversion of water from the Columbia River initiated irrigation--by center-pivot sprinkler systems—of large tracts inland from the river, all in Benton County to date (1978). A number of large pumping plants have been installed on the river, and water is now being pumped inland as far as 10 or 12 miles in some areas; in one area the pumping to more than 1,100 ft above river level (1,400 ft above sea level) is accomplished through a booster pumping station enroute.

In other areas extensive irrigation has resulted from development of wells tapping large-yield artesian aquifers. These wells are situated in the central part of the Horse Heaven Hills—in the Alder Creek, Dead Canyon, and western Glade Creek subbasins.

Past Irrigation Proposals

The Horse Heaven Hills has long been recognized as having the potential for agricultural development through irrigation. According to a report by Washington State University (1970, p. 1.4), the first proposal for irrigation in the area was made in 1904 by the Klickitat Development Company, which later became the Klickitat Irrigation and Power Company. The company conducted a reconnaissance study before being taken over by Klickitat County in 1916. The county initiated a study of the feasibility of irrigating about 134,000 acres in the study area by a 120-mile canal diverting water from the Klickitat River. The project was never formalized and the plans were abandoned in the 1930's. A recent report by the Washington Department of Ecology (1976) includes a summary of potential irrigation projects in the study area.

Consideration of irrigation from the Columbia River was initiated in 1921, when the Umatilla Rapids Power Site Association proposed a hydroelectric power development on the river which would have also included development of irrigation of 129,000 acres. In 1926 a Bureau of Reclamation feasibility study concluded that only 50,000 acres could be irrigated from the river under the proposed project, but in 1959 the bureau reappraised this to the initial 129,000 acres. However, further study was postponed because most potential water users would not consent to the 160-acre limitation placed on the amount of land an individual could have irrigated under the bureau's projects.

In the late 1960's a proposal was made to irrigate parts of the Horse Heaven Hills as part of the proposed Paterson Ridge Pumped-Storage Reservoir, a site described by Young (1967, p. 4) as offering "a unique opportunity for the development of one of the largest and most versatile pumped-storage plants in the world." The project was to involve pumping water from the Columbia River into an earth-dammed reservoir in the lower Glade Creek drainage, with water to be impounded up to an altitude of 500 ft in the area north of Paterson and Canoe Ridges. Besides serving as a heat sink for a potential nuclear powerplant, the reservoir would supply water to a proposed canal system that would allow irrigation of much of the eastern part of the study area. However, to date (1978) the pumped-storage reservoir project has not progressed beyond feasibility studies.

THE HYDROLOGIC CYCLE

The hydrologic cycle is the pattern of water movement as it circulates through the natural system. It includes precipitation from the atmosphere to the earth, surface runoff and streamflow to the sea or lakes, percolation to ground-water bodies and seepage back to the surface, and evaporation and transpiration back to the atmosphere. Figure 16 diagrammatically illustrates the hydrologic cycle.

Precipitation as rain or snow is the source of all freshwater. A part of the precipitation on the land surface runs off rapidly to streams and lakes, some soaks into the ground, and some is evaporated directly back to the atmosphere from the soil and from streams, lakes, and plant surfaces. A part of the water entering the soil is drawn up by plants and returns to the atmosphere by transpiration from leaves; the combination of evaporation and transpiration is called evapotranspiration. Some of the water that enters the ground continues to percolate downward to the zone of saturation to become ground water. In turn, most of the ground water returns to the surface by seepage to springs, lakes, streams, and the sea.

SURFACE-WATER RESOURCES

The surface-water resources available to the study area include the Columbia River along its southern margin and a few small streams. Only one of these small streams has continuous flow, and that only in its lowermost reach due to perennial discharge from a spring. The discussion of surface water includes a summary of the discharge characteristics of the Columbia River—now largely controlled by numerous upstream dams--and of Alder and Rock Creeks, the only streams within the study area for which daily discharges were recorded continuously for several years (1963-68). The only information on other streams is miscellaneous-discharge data. Figure 17 shows the locations of all streamflow data-collection sites in the study area, including continuous-record, miscellaneous-record, and crest-stage-data sites, and table 2 summarizes the types and periods of records at the sites.

Aside from the lower reach of Alder Creek, which had a continuous flow at its mouth during the 1963-68 data-collection period, all streams are intermittent and usually flow only during the months of greater precipitation. When flowing, these streams normally have relatively low daily discharges, but the discharges frequently increase for short periods immediately following intense rainfall or rapid melting of snow. Such short-term increases are characteristic of streams in arid and semiarid regions.

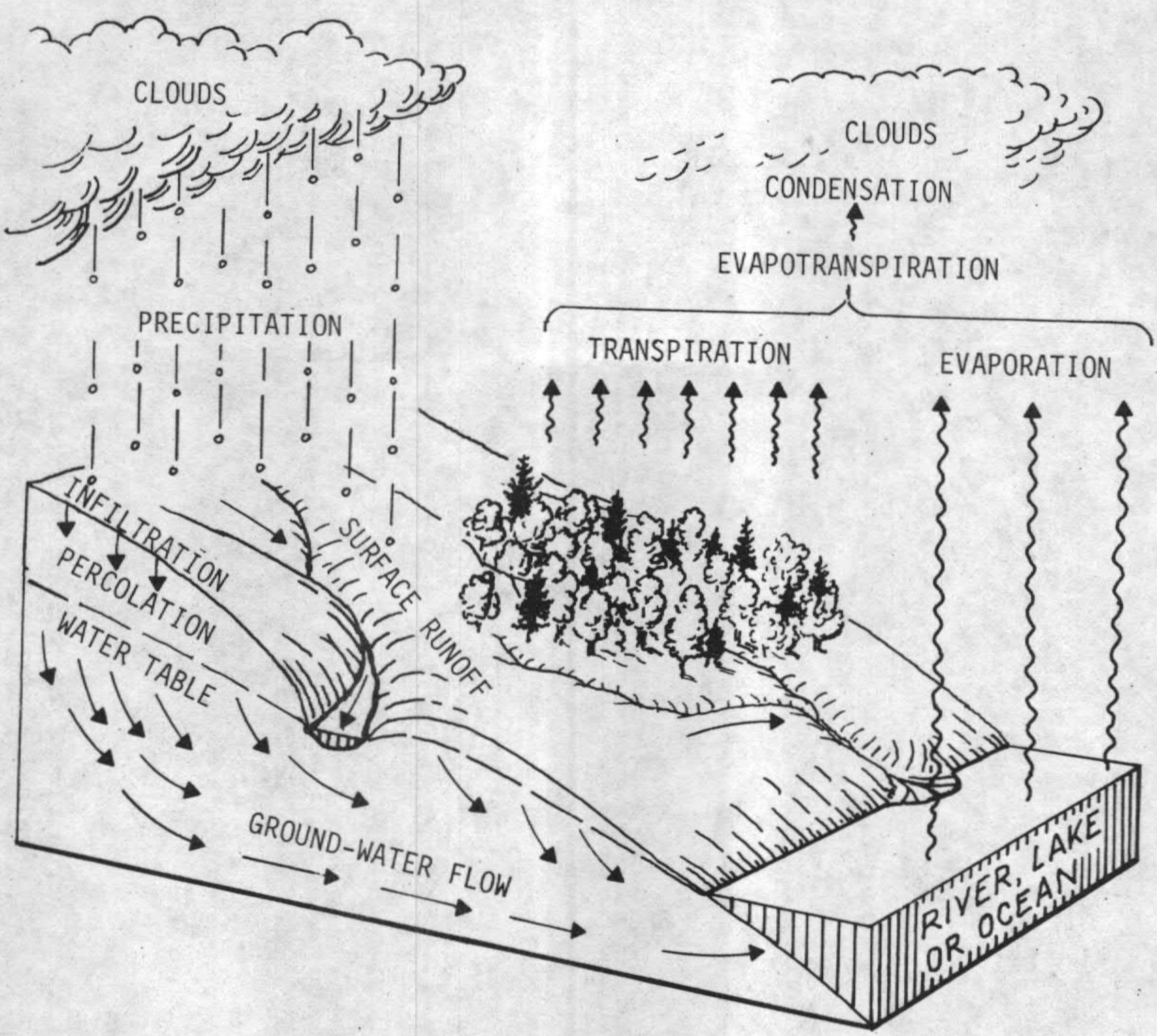


FIGURE 16.--The hydrologic cycle.

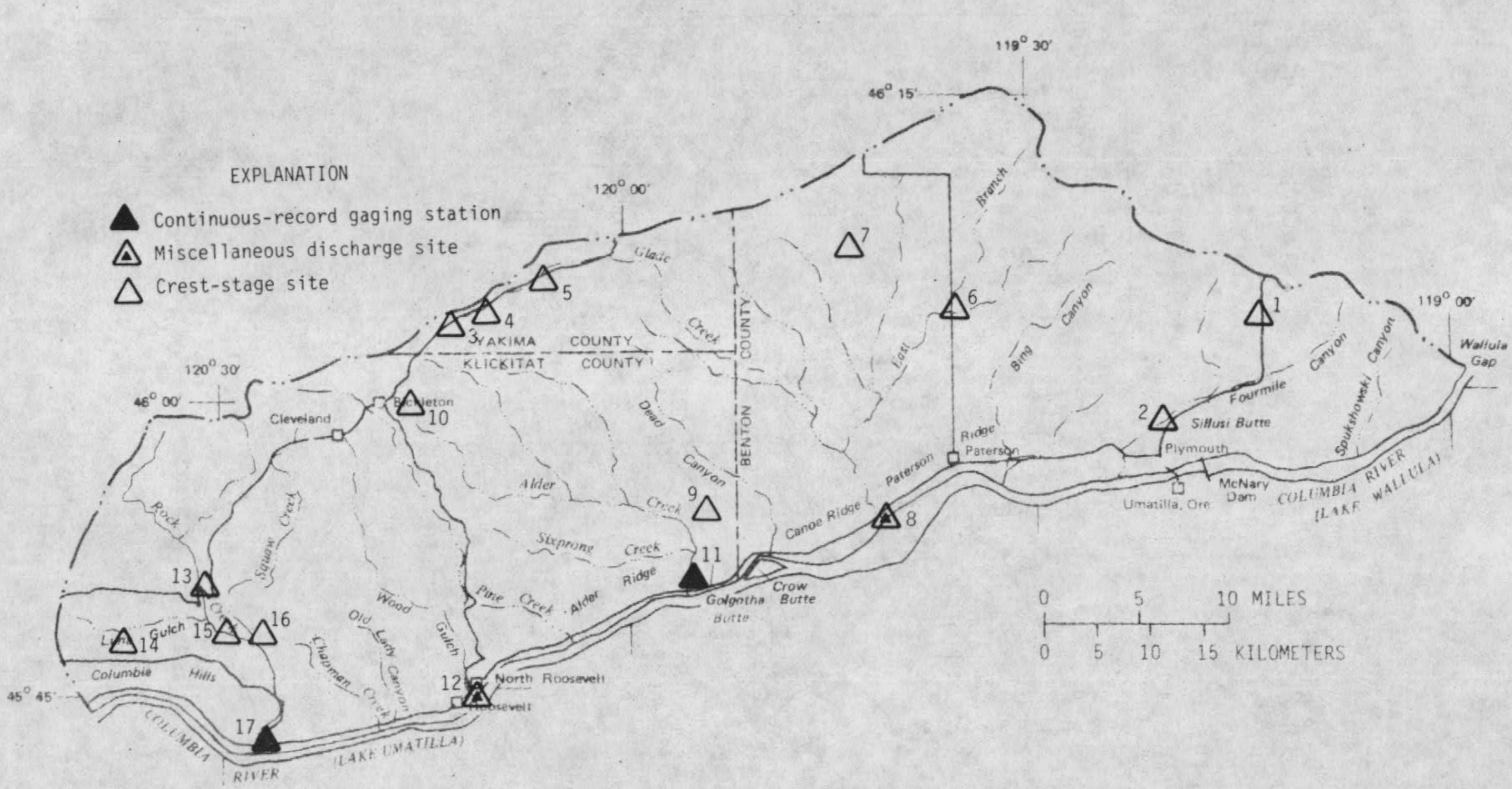


FIGURE 17.--Locations of streamflow data-collection sites in study area. See Table 2 for station names.

TABLE 2.--Types and periods of records at streamflow-measuring sites, 1911-77

[From U.S. Geological Survey, 1961 through 1977; and Washington Division of Water Resources, 1953, 1964.]

Site in fig. 17	Streamflow station and USGS number or location	Drainage area[a] (mi²)	Water years		
			Daily discharge	Miscellaneous discharge	Crest-stage discharge
1	Bofer Canyon tributary to Fourmile Canyon (14034040)	1.53	--	--	1965, 1967-77
2	Fourmile Canyon near Plymouth (14034100)	81.2	--	--	1962-70
3	Glade Creek tributary near Bickleton (14034250)	.5	--	--	1961-75
4	Glade Creek tributary (7/21-21K)	.36	--	--	1963
5	Glade Creek (7/22-7K1)	14.2	--	--	1963
6	East Branch Glade Creek near Prosser (14034270)	50.3	--	--	1962-77
7	East Branch Glade Creek tributary near Prosser (7/25-5)	.96	--	--	1965-75
8	Glade Creek near Paterson (5/25-28B)	428	--	1977	--
9	Dead Canyon Creek tributary near Alderdale (14034320)	.62	--	--	1955-74
10	Alder Creek near Bickleton (14034325)	8.35	--	--	1963-77
11	Alder Creek at Alderdale (14034350)	196	1963-68	1977	1963-68
12	Wood Gulch (3/21-9N)	60.0	--	1977	--
13	Rock Creek (4/18-11N)	67.6	--	1977	1953, 1955
14	Unnamed tributary to Luna Gulch (3/17-36P)	.46	--	--	1953
15	Rock Creek near Goldendale (14036500)	125	--	--	1911-13
16	Squaw Creek (4/19-29N)	76.6	--	--	1911-12
17	Rock Creek near Roosevelt (14036600)	213	1963-68	1977	1963-68

[a]From Williams (1964)

Alder Creek

The only gaging station on Alder Creek, which drains an area of 196 mi^2 (Williams, 1964), was operated during 1963-68 under the station name "Alder Creek at Alderdale." Crest-stage data were obtained during 1963-77 on the upper reach of Alder Creek about a mile east of Bickleton (fig. 17). Because of the intermittent character of the stream along most of its length, it is used mostly for livestock watering. As there is virtually no irrigation in the Alder Creek basin, there has been no contribution to the natural flow from irrigation runoff.

Mean annual precipitation over the basin varies between 10 and 15 inches and is estimated to average 11 inches. Most of the precipitation occurs in the northwestern part of the basin.

Although most of Alder Creek and its tributaries flow only during periods of heavy rainfall or rapid snowmelt, gaging-station data during 1963-68 indicate that at its mouth Alder Creek flowed continuously through the year. This flow results from seepage from Sally Spring (5/23-34K), about 3 miles upstream from the gaging station. The spring is situated near the axis of the Swale Creek-Glade Creek syncline and has a relatively constant discharge of about 0.8 ft^3/s (Brown, 1979).

Hydrographs of the maximum and minimum daily discharges of Alder and Rock Creeks during 1963-68 (fig. 18) show the great variations in the streamflows in this arid to semiarid region--where flashfloods result from short periods of intense rainfall or from the rapid melting of snow. Snowmelt runoff also has caused much sheet erosion of the silty soil mantle in some parts of the upper Alder Creek basin, as shown in the photographs of figure 15. As indicated in table 3, maximum daily and annual mean discharges vary greatly among water years. The streamflow records also indicate great variations in the monthy average discharges throughout the year. The larger discharges generally occur during December-March.

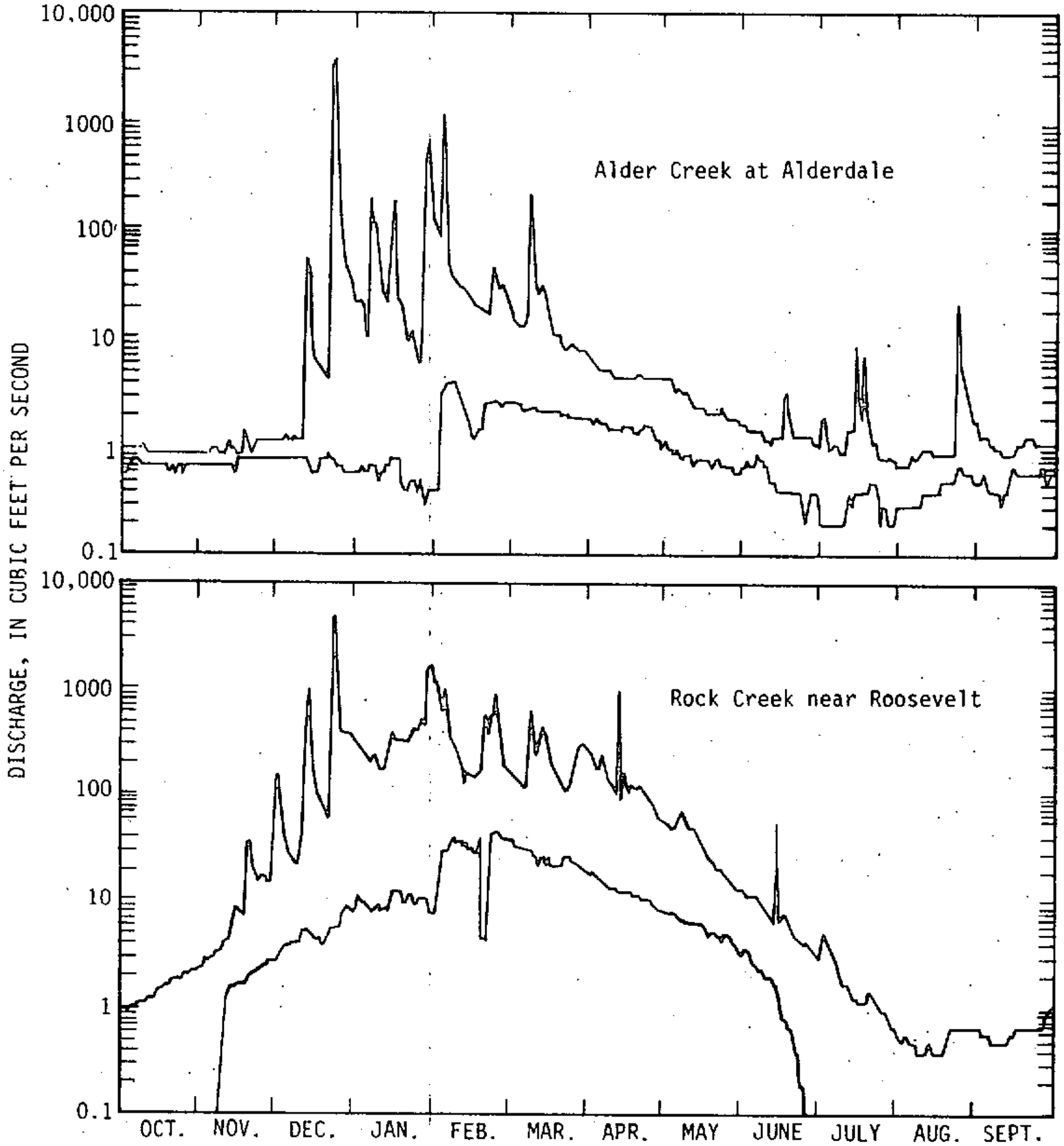


FIGURE 18.--Maximum and minimum daily discharges of Alder Creek at Alderdale and Rock Creek near Roosevelt, 1963-68. From Brown (1979).

TABLE 3.--Monthly and annual average discharges and maximum and minimum daily discharges, Alder Creek at Alderdale and Rock Creek near Roosevelt, 1963-68 water years

[Discharge data, in cubic feet per second and acre-feet per month, are from U.S. Geological Survey (1963-68).
Monthly and annual values converted in acre-feet are given in parentheses.]

Water year	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Alder Creek at Alderdale (14034350)							
1963	0.75 (46)	0.81 (48)	0.82 (51)	0.72 (44)	55.9 (3,100)	2.35 (144)	3.09 (184)
1964	.89 (55)	.93 (55)	.96 (59)	2.63 (162)	4.16 (239)	2.25 (139)	1.65 (98)
1965	.80 (48)	.80 (48)	274 (16,800)	61.2 (3,760)	30.4 (1,690)	8.21 (505)	4.69 (279)
1966	.92 (56)	.96 (57)	1.07 (66)	31.0 (1,910)	10.8 (598)	24.4 (1,500)	3.66 (218)
1967	.85 (52)	.93 (56)	6.00 (369)	6.95 (427)	5.33 (296)	2.62 (161)	2.07 (123)
1968	.73 (45)	.93 (45)	.83 (51)	7.12 (438)	15.9 (915)	3.12 (192)	1.66 (99)
Average monthly	.82 (50.5)	.75 (51.5)	47.3 (2,900)	18.3 (1,120)	20.4 (1,330)	7.16 (440)	2.80 (167)
Rock Creek near Roosevelt (14036600)							
1963	0.91 (56)	6.21 (370)	46.7 (2,870)	14.4 (886)	135 (7,490)	37.8 (2,330)	122 (7,270)
1964	.0 (0)	2.06 (123)	9.46 (582)	83.8 (5,160)	72.0 (4,140)	59.3 (3,650)	59.9 (3,560)
1965	.0 (0)	1.75 (104)	475 (29,200)	489 (30,100)	254 (14,100)	82.6 (5,080)	30.2 (1,800)
1966	1.45 (89)	4.35 (259)	6.24 (384)	99.9 (6,140)	61.6 (3,420)	214 (13,200)	92.1 (5,480)
1967	.30 (18)	10.1 (602)	102 (6,260)	130 (8,010)	80.6 (4,470)	31.6 (1,940)	26.6 (1,580)
1968	.032 (2.0)	1.56 (93)	8.23 (506)	42.2 (2,600)	231 (13,300)	47.0 (2,890)	13.6 (810)
Average monthly	.45 (27.5)	4.34 (259)	108 (6,630)	143 (8,820)	139 (7,820)	78.7 (4,850)	57.4 (3,420)

[a]Average of the two rounded values totaled from monthly and annual columns.

May	June	July	Aug	Sept	Annual	Maximum daily and date	Momentary maximum and date	Minimum daily and date
2.14 (132)	1.06 (63)	1.09 (67)	0.83 (51)	0.80 (48)	5.50 (3,980)	1,250 (2/3)	5,560 (2/3)	0.2 (7/25)
1.08 (66)	.74 (44)	.58 (36)	.60 (37)	.80 (48)	1.43 (1,040)	26 (1/26)	68 (1/26)	.3 (7/13)
2.60 (160)	1.49 (89)	.81 (50)	1.95 (120)	1.08 (64)	32.6 (23,600)	4,000 (12/22)	17,600 (12/22)	.4 (8/9)
.87 (54)	.82 (49)	1.29 (79)	.81 (50)	.79 (47)	6.47 (4,680)	197 (1/6)	670 (1/6)	.4 (7/9-12)
1.33 (82)	.84 (50)	.56 (34)	.51 (32)	.67 (40)	2.38 (1,720)	59 (12/13)	154 (1/28)	.3 (8/4-5)
.91 (56)	.53 (32)	.32 (19)	.48 (30)	.61 (36)	2.70 (1,960)	180 (1/15)	513 (2/3)	.2 (6/26, 7/2-11, 28-30)
1.49 (91.7)	.91 (56.5)	.78 (47.5)	.86 (53.3	.79 (47.2)	8.51 (6,260)[a]	Extremes during 1963-68: 4,000	 17,600	 0.2
38.4 (2,360)	6.15 (366)	0.55 (34)	0 (0)	0 (0)	33.2 (24,000)	1,000 (2/3)	3,940 (2/3)	0
11.5 (707)	3.58 (213)	.28 (17)	0 (0)	0 (0)	25.0 (18,200)	539 (1/25)	912 (1/25)	0
16.1 (992)	6.24 (371)	1.56 (96)	.55 (34)	.66 (39)	113.0 (81,900)	4,800 (12/22)	14,200 (12/22)	0
13.4 (825)	3.61 (215)	1.71 (105)	.03 (2)	0 (0)	41.6 (30,100)	656 (3/9)	962 (3/9)	0
16.4 (1,010)	3.83 (228)	.12 (7.5)	0 (0)	0 (0)	33.3 (24,100)	1,150 (1/28)	1,570 (1/29)	0
6.21 (382)	1.55 (92)	.026 (1.6)	0 (0)	0 (0)	28.4 (20,800)	908 (2/23)	1,760 (2/23)	0
17.0 (1,050)	4.16 (248)	.71 (43.5)	.09 (6)	.10 (6.5)	45.8 (33,200)	Extremes during 1963-68: 4,800	 14,200	 0

The annual 7-day low flows of the lower 5-mile reach of Alder Creek--in effect, of Sally Spring--during the 1963-68 water years of record all occurred in July. They are as follows:

Water year		Discharge (ft^3/s)	Date
1963		0.40	(7/25-31)
1964		.514	(7/8-14)
1965		.557	(7/7-13)
1966		.571	(7/8-14)
1967		.40	(7/7-16)
1968		.20	(7/2-11)
	Average	.39	

The 7-day low flows that statistically will be repeated at selected recurrence intervals are as follows:

2 years	0.458 ft^3/s	20 years	0.192 ft^3/s
5 years	.318 ft^3/s	50 years	.140 ft^3/s
10 years	.246 ft^3/s	100 years	.110 ft^3/s

Rock Creek

A daily-discharge and crest-stage gaging station on Rock Creek near Roosevelt, above which the drainage area is 213 mi^2 (Williams, 1964), was operated in the basin during 1963-68, and crest-stage gages at three other sites (fig. 17) were operated at various times (table 2). During the period of record, seepage of ground water sustained the flow of Rock Creek through July in most years; in 1965 the streamflow was sustained into August. Because Rock Creek flows only intermittently, no major diversions or withdrawals are made above the daily-discharge gaging station near its mouth.

Mean annual precipitation over the basin varies between 15 and 25 inches and is estimated to average about 18 inches, with most occurring in the northern and western parts of the basin. Although the Rock Creek basin is only slightly larger than the Alder Creek basin, the average discharge from the former was more than five times that of the latter (table 3) during the same period of record (1963-68).

Glade Creek

Glade Creek drains a basin covering 428 mi^2, the largest in the study area and about the size of the combined drainages of Alder and Rock Creeks. However, no continuously recorded streamflow data are available from the basin and the only information is that obtained at six crest-stage gages in the basin (fig. 17, table 2) and at a miscellaneous discharge site at the creek's mouth near Paterson (tables 4 and 5).

Average annual precipitation over the Glade Creek basin ranges from about 14 inches in the northwestern part to less than 8 inches in the southern part near Paterson; it probably averages about 9 inches over the entire basin. As most of the precipitation occurs during the November-April period, there is little or no water in most reaches of the stream during the summer months. However, McKinley Spring (at 6/24-7A on plate 1) provides a small seepage of water which flows for a short distance in the middle reach of the stream (fig. 14).

In the uppermost reach of Glade Creek, at the head of the east-west trending synclinal valley near the crest of the Horse Heaven Hills, several springs provide domestic and stock supplies. These help to maintain some flow in this reach of the creek during the summer.

TABLE 4.--Miscellaneous discharges recorded at selected sites, 1911-77

Site no. in fig. 17	Streamflow station and USGS number or location	Drainage area[1] (mi^2)	Discharge (ft^3/s)	Date	Data source[2]
3	Glade Creek tributary near Bickleton (14034250)	0.5	[a]26 [a]0	2-10-61 1962	USGS 1961 USGS 1962
4	Glade Creek tributary (7/21-21K)	.36	[a]16.5	2-3-63	USGS 1963
5	Glade Creek (7/22-7K)	14.2	[a]965	2-3-63	Do.
7	East Branch Glade Creek tributary near Prosser (7/25-5)	.96	18.1	2-12-69	USGS 1976 v. 2
8	Glade Creek near Paterson	428	4.80 6.63 5.01	2-14-77 6-3-77 8-12-77	USGS 1977 v.2 Do.
9	Dead Canyon Creek tributary near Alderdale (14034320)	.62	[a]0 [a]2.1	1961 1962	USGS 1961 USGS 1962
10	Alder Creek near Bickleton (14034325)	8.35	1.03 10.0 3.84 .25 .05 0	3-7-73 1-23-74 4-3-75 2-14-77 6-3-77 8-12-77	USGS 1976 v. 2 Do. USGS 1977 v. 2 Do. Do.
11	Alder Creek at Alderdale (14034350)	196	.65 .40 3.35	2-14-77 6-3-77 8-12-77	Do. Do. Do.
12	Wood Gulch (3/21-9N)	60	.10 0 0	2-14-77 7-6-77 8-12-77	Do. Do. Do.
13	Rock Creek (4/18-11N)	67.6	[a]2,580 [a]2,870 2.29 1.38 .18	1-9-53 12-2-55 2-14-77 6-3-77 8-12-77	WDWR 1964 Do. USGS 1977 v. 2 Do. Do.
14	Unnamed tributary to Luna Gulch (3/17-36P)	.46	123	1-19-53	WDWR 1964
15	Rock Creek near Goldendale (14036500)	125	[a]1,103 [a]1,850	2-16-12 2-16-13	WDWR 1955 Do.
16	Squaw Creek (4/19-29N)	76.6	[a]1.11 [a]49.3 [a]6.64	12-28-11 2-19-12 4-1-12	WDWR 1964 Do. Do.
17	Rock Creek near Roosevelt (14036600)	213	6.48 3.15 0	2-14-77 6-3-77 8-12-77	USGS 1977 Do. Do.

[a] Annual maximum instantaneous discharge calculated from field observation of high-water marks.

[1] From Williams (1964).

[2] Data source: USGS, U.S. Geological Survey; WDWR, Washington Division of Water Resources.

TABLE 5.--Annual maximum instantaneous discharges at selected sites, 1963-76 water years

Site in fig. 17	Stream station and number (or location)	Drainage area (mi²)	Cubic feet per second Water year and date if known 1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	Bofer Canyon tributary to Fourmile Canyon (14034040)	1.53	--	--	—	47 (1/28)	0	0	76 (2/11)	16 (1/23)	0	0	0	0	0	0
2	Fourmile Canyon near Plymouth (14034100)	81.2	0	0	559 (1/28)	0	0	0	200 (2/11)	16 (1/23)	(Discontinued)					
3	Glade Creek tributary near Bickleton (14034250)	.5	43 (2/3)	8.1 (6/-)	6.6 (1/29)	<2	0	<.1	14 (1/16)	9 (1/23)	17 (1/16)	15 (2/28)	4.0 (1/13)	5.3 (1/15)	11 (3/1)	(Discontinued)
6	East Branch Glade Creek near Prosser (14034270)	50.3	0	0	478 (1/29)	0	0	0	500 (2/12)	73 (1/23)	0	.1 (1/21)	.1 (1/13)	.1 (1/16)	.1 (1/26)	0
7	East Branch Glade Creek tributary near Prosser (7/25-5)	.96	0	0	300 (1/29)	0	0	0	30 (2/12)	0	0	0	0	.4 (1/16)	0	(Discontinued)
9	Dead Canyon Creek tributary near Alderdale (14034320)	.62	0	0	17 (12/22)	0	0	0	9.2 (2/11)	0	0	0	0	12 (1/16)		(Discontinued)
10	Alder Creek near Bickleton (14034325)	8.35	880 (2/3)	58 (1/25)	973 (12/22)	149 (3/9)	110 (1/28)	137 (1/15)	251 (1/6)	164 (1/23)	234 (1/16)	293 (1/20)	240 (1/13)	992 (1/16)	165 (3/1)	115 (12/26)
11	Alder Creek at Alderdale (14034350)	196	5,560 (2/3)	68 (1/26)	17,600 (12/22)	670 (1/6)	154 (6/28)	513 (2/3)	((Discontinued as crest-stage gage)							
17	Rock Creek near Roosevelt (14036600)	213	3,940 (2/3)	912 (1/25)	14,200 (12/22)	962 (3/9)	1,570 (6/29)	1,760 (2/23)	(Discontinued as crest-stage gage)							

Two miscellaneous discharge measurements made near the mouth of Glade Creek, when compared to discharges of Alder and Rock Creeks on the same date, indicate an inconsistent relationship between the basins relative to drainage area and discharge. These data are given below:

	Discharge					
	Glade Creek (428 mi²)		Alder Creek (196 mi²)		Rock Creek (222 mi²)	
Date	(ft³/s)	(ft³/s/mi²)	(ft³/s)	(ft³/s/mi²)	(ft³/s)	(ft³/s/mi²)
2/14/77	4.80	0.011	0.65	0.003	6.48	0.029
6/3/77	6.63	.015	.40	.002	3.15	.014

Water-Quality Data

Few data are available on the quality of surface water in the study area. Aside from daily water temperatures recorded during the 1963-66 water years (not included in report), suspended-sediment data were the only data collected from Alder and Rock Creeks during those years (table 13).

Columbia River

The Columbia River, flowing along the southern margin of the study area, is the only perennial source of surface-water supply for the area. Daily, monthly, and annual discharge data obtained from the Columbia River at McNary Dam, near Umatilla, Oreg., (station 14019200) and discharge and water-quality data from the Columbia River at The Dalles, Oreg., (station 14057000) have been recorded for the 1951-77 water years. These are given in other publications by the U.S. Geological Survey (1964, 1965-78) and are not repeated here.

The flow of the Columbia River has become increasingly controlled over the years since the first dam (Rock Island Dam) was completed in 1933; today 11 dams are situated on the river within Washington State; 8 are upstream from the study area. All have been constructed for hydroelectric power generation, but they also play a big part in flood control during the late spring, when snowmelt runoff from the vast Columbia River basin reaches its peak.

The discharge of the river is so large relative to the amount of water presently (1978) diverted from the river for irrigation in the Horse Heaven Hills that, for the purpose of this study, only summary data are given below for the Columbia River at McNary Dam during the 1951-77 water years.

Type of discharge	Discharge (ft^3/s)
Mean annual	185,300
Maximum annual mean	233,100 (1972)
Minimum annual mean	119,600 (1977)
Maximum monthly mean	623,900 (June 1956)
Minimum monthly mean	75,220 (December 1953)
Maximum instantaneous	818,000 (June 2, 1956)
Minimum daily	39,500 (July 10, 1977)

GROUND-WATER RESOURCES

Occurrence Within Stratigraphic Units

Ground water in the study area occurs principally in the Columbia River Basalt Group (Griggs, 1976) of Miocene age, a thick sequence of basalt lava flows with some interbeds of sedimentary materials, that extends beneath the Columbia Plateau in south-central and eastern Washington, Oregon, and southern Idaho. The thickness of the basalt in the study area probably is greater than 5,000 ft, with individual flows ranging in thickness from a few feet to more than 100 ft. Interbedded with the basalt in its upper parts is the Ellensburg Formation, also of Miocene age, which consists of silt, sand, gravel, and clay and consolidated materials (siltstone, sandstone, and conglomerate). These were laid down between basalt extrusions, particularly in marginal areas of the Columbia Plateau, where streams from adjacent mountains transported and deposited their sediment loads. Photographs of outcrops of some of these units are shown in figure 19.

Basalt is a dense rock characterized by columnar jointing and by fracture and rubble zones at the tops and bottoms of most flows. Ground water generally moves within these zones and in the sedimentary interbeds. On the basis of available data it appears that some of the aquifers[1] are not continuous throughout the area, and wells may penetrate several basalt layers before intercepting one or more aquifers capable of providing adequate water supplies.

Individual basalt units differ locally in their transmissivity[2], with changes occurring in part because of thinning or thickening of the water-bearing unit. For purpose of the discussion of the various units of the Columbia River Basalt Group underlying the study area, table 6 summarizes the relationship of named units.

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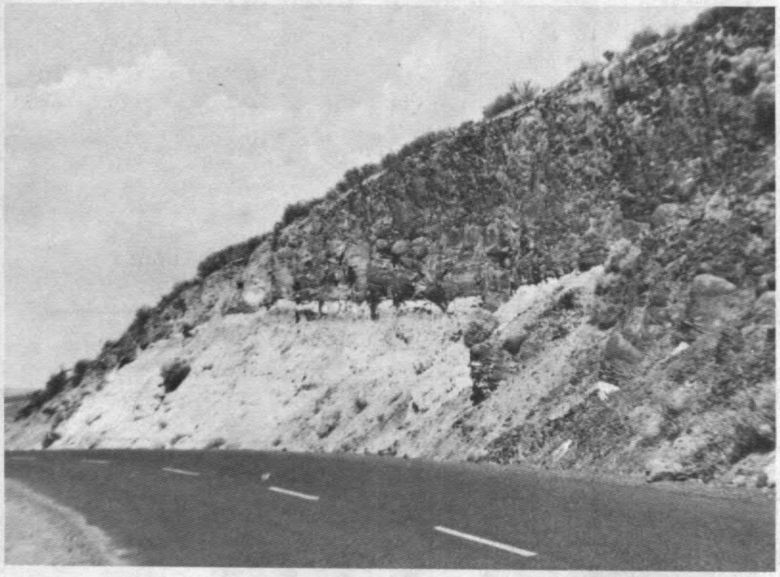
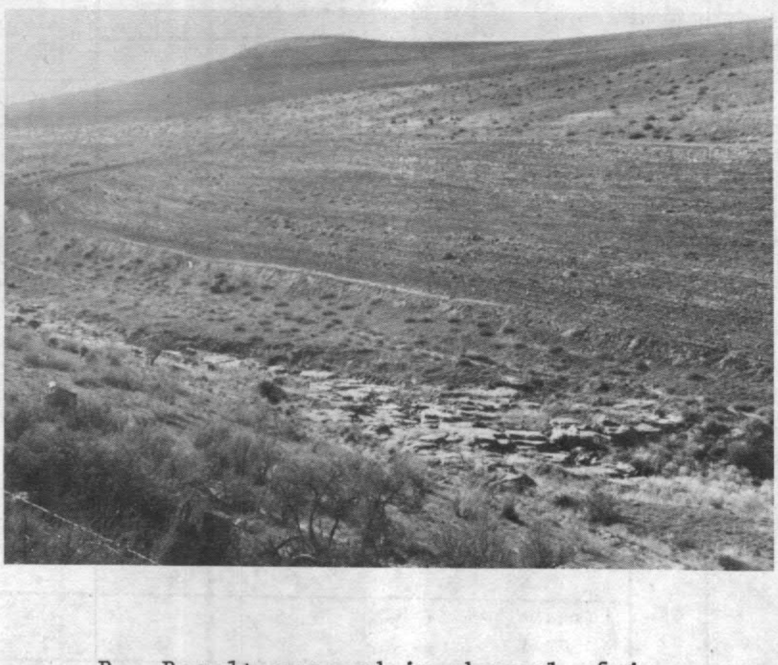
[1]Water-saturated earth or rock materials capable of yielding significant quantities of water to wells or springs.

[2]The rate at which water would move through a unit width of the aquifer under a unit hydraulic gradient.



A. Road cut at 7/22-4R in upper Glade Creek valley, showing basalt flow overlying sedimentary interbed, in Columbia River Basalt Group.



B. Basalt exposed in channel of intermittent stream, overlain by eolian silt. At 7/22-11B.

FIGURE 19.--Rock types exposed in study area.

TABLE 6.--Stratigraphic relationship of rock formations in the Columbia River Basalt Group

Formally accepted nomenclaure of Swanson and others (1979)				Sedimentary interbeds named informally by Crosby, Anderson, and Kiesler (1972) and Brown (1979)
Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Lower Monumental Member	
			Ice Harbor Member	
			Buford Member	
			Elephant Mountain Member	
				Rattlesnake Ridge interbed
			Pomona Member	
				Selah interbed
			Esquatzel Member	
			Weissenfels Ridge Member	
			Asotin Member	
			Wilbur Creek Member	
			Umatilla Member	
				Mabton interbed
		Wanapum Basalt	Priest Rapids Member	
			Roza Member	
			Frenchman Springs Member	
			Eckler Mountain Member	
		Grand Ronde Basalt		
		Picture Gorge Basalt		
		Imnaha Basalt		

Geophysical Logging of Wells

Geophysical logging of selected wells has been done in recent years to determine the depth, water-bearing properties, and extent of strata underlying the Horse Heaven Hills and to correlate these with strata found elsewhere beneath the Columbia Plateau. This work included logging of neutron neutron and neutron gamma radiation, caliper recording of borehole diameter, and measurements of water-temperature changes with depth, fluid resistivity, and vertical-flow velocity. The logging was done by both the U.S. Geological Survey and by the Washington State University Hydraulic Laboratory (Crosby, Anderson, and Kiesler, 1972). Additional geophysical logs of wells were obtained from the Washington State University College of Engineering. The locations and numbers of the 25 wells logged are shown in figure 20.

When combined with information in drillers' logs, the geophysical logs are useful in defining the depths of water-yielding zones. Table 7 presents a summary of the interpretations of the logged wells.

Ground-Water Recharge and Movement

Ground water beneath the study area probably is recharged by local precipitation, sparse though it is over most of the area. This recharge occurs mostly during the winter and spring, when the rainfall is sufficient to saturate the soil mantle and percolate to the water table. During the warm summer months there is little ground-water recharge, because any precipitation generally evaporates or is transpired by plants. The extent of ground-water inflow from outside the area is unknown.

Some ground-water recharge probably occurs locally in southern Benton County, by percolation of irrigation water pumped from the Columbia River. The amount of this water reaching the water table is not measurable, but most of the irrigation water probably is taken up in the crop roots and lost by evapotranspiration.

As determined from water-level data included in well records (table 16), ground water moves beneath the study area southward and southeasterly toward the Columbia River, which represents the lowest level of the potentiometric surface[1]. However, it should be noted that because most wells in the study area penetrate more than one aquifer, the water levels in these wells do not represent a single potentiometric surface, but rather a combination of two or more. The occurrence of springs issuing from the sides of the valleys at various altitudes in the rock Creek basin corroberates the existence of several saturated zones beneath the area.

[1]Potentiometric surface of an aquifer is an imaginary surface that represents the level to which water rises in wells.

TABLE 7.--Summary of geohydrologic conditions at selected wells, as interpreted from geophysical logs

Well number	Altitude (ft)	Depth (ft)	Static Water Level (ft)	Interpretation of geophysical logs		
				Date (mo/yr)	Porosity and moisture increases (ft)	Temperature increases (°C and ft)
4/17-17R1	1820	320	43	12/77	10-30, 40-70, 210-250, 280-320	---
4/17-20R1	2010	334	102	12/77	40-65, 115-140, 160-180, 250, 270, 290-325	From 150 to bottom
5/20-27B1	2490	927	752	1/72	65-100, 255-300, 760-904	19.3° at 755, increasing to 23° at 904
5/22-27A2	1105	1061	27	9/76	270-350, 370-460	21.2° at top, 28.1° at bottom
5/23- 3A2	716	555	124	9/76	70, 225-300	14.5° at 124 (SWL) increase to 14.65° at 240-270, abrupt increase to 14.8-14.9° at 275-285
5/23-13R1	575	1081	142	3/78	110-230, 340-520, 670-800, 885-950, 1000-1010, 1050-1070	17.5° at 140, increase to 25° at 250, stable toward bottom where 28.8°
5/23-29D1	870	871	Flow	8/77	390-520, 725-825	80-180
5/26- 5D1	630	1002	265	--	100-110, 265(SWL)-370, 510-640, 700-750, 820-850, 940-990	26.5° at SWL, then increase to 24.3° at 370, slow increase to 26.5° at bottom
6/20-13H1	2862	306	31	6/75	140-170	11° at 60, to 12.6° at bottom
6/21-28D1	2670	310	276	8/76	--	Erratic to SWL (276) then increase
6/21-31F2	2740	300	260	12/75	80-100, 260, 290-300	14.8° at 265 (SWL), increase to 15.8° at 300
6/21-35P1	2360	300	75	9/76	50, 180-200	12.4° at 100, steady increase to 14° at 290
6/23-15H1	1050	950	Flow	2/71	60-140, 270-360, 500-560, 660-680, 860-900	Slight decrease to 640, then rapid increase, then stable to bottom
6/23-16R1	1090	950	41	7/76	20-80, 230-260, 440-480	13.5° at 41 ft, to 16.7° at 115 ft
6/23-22J1	982	1040	293	2/78	90-120, 290-360, 550-630, 700-720, 900-920	18.0° at SWL, to 22.3° at 450, 23.1° at bottom
6/24-22H1	550	661	142	2/72	0-30, 290-360, 490-610	16.8° to 180, 17.4° to 350, 19.3° to 485, 20° to 661
6/30-12Q1	1180	974	855	3/73	840-842 and at bottom	20° at SWL, steady increase to 21° at 974
6/30-19N1	990	736	695	--	Erratic to bottom	Steady increase from 16° at top to 19.9° at 585
7/22-23B1	2120	1000	320	--	60-150, 350-1000	--
7/23-36R1	950	805	Flow	10/77	15-40, 210-220, 410-470 580-620, 785-800+	19° at 110, steady increase to 19.6° at 500, decrease to 18.2° at 580, increase to 19.8° at 600, steady to 750, increase to 20.5° at 800
7/24- 8D1	1450	1092	868	1/78	40- 80, 230-260, 410-460, 610, 740-760, 870, 990-1020, 1070-1080	24.2° at 865-1092
7/25-36F1	753	867	390	4/78	0-70, 220-250, 385-400 450-520, 620-650, 740-770, 800-810, 850-867	18.4° to 385, increase to 18.7° at 450, to 19.3° at bottom
7/25-36N1	730	860	373	9/72	50-70, 80-90, 480-540, 590-620	8/1/72: 16.7° at 372, 18.3° at 735, 19.3° at 842, 22.5° at 860. 9/27/72: 15° at 372-457, 16.5° at 460, 16.7° at 740
7/26- 5B1	1130	1061	403	4/69	300-375, 550-650, small increases 720-760, 840-930	Stable 19.2°-19.3°
7/27-29Q1	1150	575	170	1/73	40-80, 220-575	10.4° at 170 to 11.5° at 350, to 14.5° at 440

-/ Source of data: A, U.S. Geological Survey; B, Crosby, Anderson, and Kiesler (written commun., 1972); C, Washington State University Department of Civil and Environmental Engineering (miscellaneous logs submitted when available, 1978); D, Jeffrey C. Brown (written commun., 1978).

Interpretation of geophysical logs		Source of data ^/	Other information (SWL = static water level)	Water-bearing intervals according to drillers' logs (ft); NA, log not available
Hole-diameter increases (ft)	Zone of combined factors to left (ft)			
50-70, 240-250, 285-310	50-70, 240-250, 280-310	C		NA
at 65, 130, 250, 285-290, 310	130-140, 270-290	C		NA
---	760-904	B		NA
---	---	A,B,D	SWL 42 ft when 273 ft deep, 62 ft when 364 ft, 55 ft when 673 ft, 150 ft when 684 ft, 30 ft when 753 ft, 27 ft when 1061 ft	349-568, 673-767, 806-930
---	240-285	B	Well filled back to 555 ft from drilled depth of 575 ft	70-80
900-930, 1010-1020	900-930, 1010	C	Casing to 830 ft	NA
230-260, 530-560	---	C	Artesian flow 2100 gal/min in June 1977	Not indicated in log
365-380, 405-415, 945-960	365-370, 945-960	B		108-121, 279-360, 599-610, 949-974
140-170	140-170	B		NA
295-300, at 310	---	B		NA
---	---	B		NA
---	---	B		NA
130-140, 345-355, 660-680, 850-900	130-140, 345-355, 660-680, 860-900	B	Artesian flow 2200 gal/min in Feb. 1971. Head increase when deepened below 405 ft	377-405; water level rose as well deepended below 405 ft
----	---	B		
500-510, 550-600, 710-725	550-600, 710-720	C	Log states well 1069 ft; filled back to 1040 ft	
140, 210-213, 362-384, 492-498, 650-661	492-498	B		NA
168-196, 420-430, 660-680, 885-920	---	A		NA
176-196	---	B	Log shows 585-ft depth, 475 ft SWL	Not indicated in log
---	---	B	SWL 350 ft when well 460 ft deep and 750 ft when 1000 ft deep	Do.
70-75, 475-480, 580-620, 745-760, 800-870	580-620, at 800	C	Artesian flow 1755 gal/min in October 1977	Do.
40-80, 230-250, 410-460	40-80, 230-250, 410-460	C	Well deepened from 800+ ft to 868 ft in 1977	NA
223-242, 750-770, 800-815, 855-865	223-242, 750-770, 800-810, 855-865	C	Cascading water at about 230 ft	NA
485-512, 736-750, 820-840	485-512, 740-840, 842-860	A, B	DOE test-observation well. SWL 166.5 ft when 547 ft, 372.5 ft when deepened to 740 ft	70-85, 814-860
378-382, 678-680, 772-782, 930-938, 1050	---	B	SWL 403 ft when 780 ft deep, 607 ft when deepened to 1061 ft	609-681
83-92, 150-162, 180-195, 320-325	320-325	A		NA

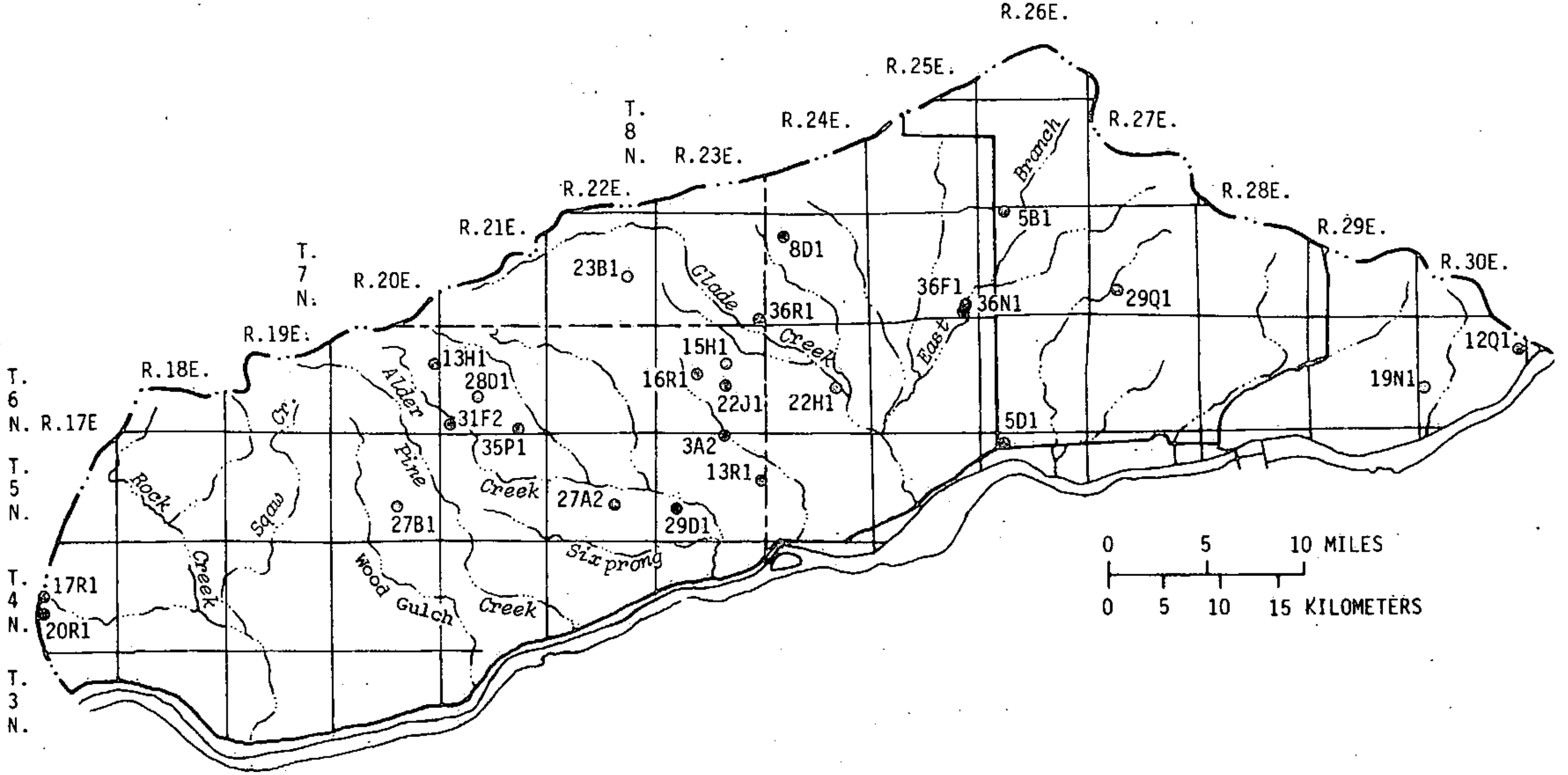


FIGURE 20.--Wells from which geophysical-logging data were obtained. Township and range numbers omitted from well numbers for brevity. (See p. ix for well-numbering system.)

Structural Controls

The folding of the basalt into anticlines (upward folds) and synclines (downward folds) and faults (fractures in rocks resulting in vertical or horizontal displacement) may or may not disrupt the lateral continuity of the aquifers. Because an understanding of these structures is important to the evaluation of ground-water occurrence and movement in the area, a discussion of the recognized structures is given below.

East-West Trending Structures

As shown in figure 21, two major and several minor east-west anticlinal and synclinal structures exist in the study area. On the north the axis of the Horse Heaven anticline coincides with the crest of the Horse Heaven Hills to and beyond Wallula Gap. The anticline is broad and asymmetrical, with the steeper flank extending to the Yakima River valley on the north and the southern, more gently sloping, flank forming the plateau-like surface of much of the study area. The structure is highest in the west and it gradually descends eastward to a few miles west of Bickleton where it dies out. Two similar, but shorter, structures occur south of and roughly parallel to the western part of the Horse Heaven anticline (fig. 21). The axis of the westernmost of these two structures is separated from the main anticline by a synclinal valley north of Bickleton, which contains the upper reach of Pine Creek. The easterly of the small anticlines is separated from the main anticline by a small syncline that forms a valley containing the easterly flowing upper reach of Glade Creek. The crest of the Horse Heaven anticline may possibly mark the divide between ground water flowing north to the Yakima River valley and that flowing south and southeasterly beneath the study area.

In the southwestern part of the study area in Klickitat County, the Columbia Hills anticline is the major structure. The crest of the Columbia Hills (pl. 1) rises to an altitude of more than 2,500 feet, high above the Columbia River (Lake Umatilla altitude 240 feet), and forms the southern boundary of the Rock Creek basin. The anticline continues eastward and gradually descends in elevation and continues as the Alder Ridge anticline (Newcomb, 1971). Eastward the anticline forms Paterson Ridge, beyond which it is no longer obvious from topographic features. Sillusi Butte, northeast of Plymouth, may represent a topographic extension of the structure.

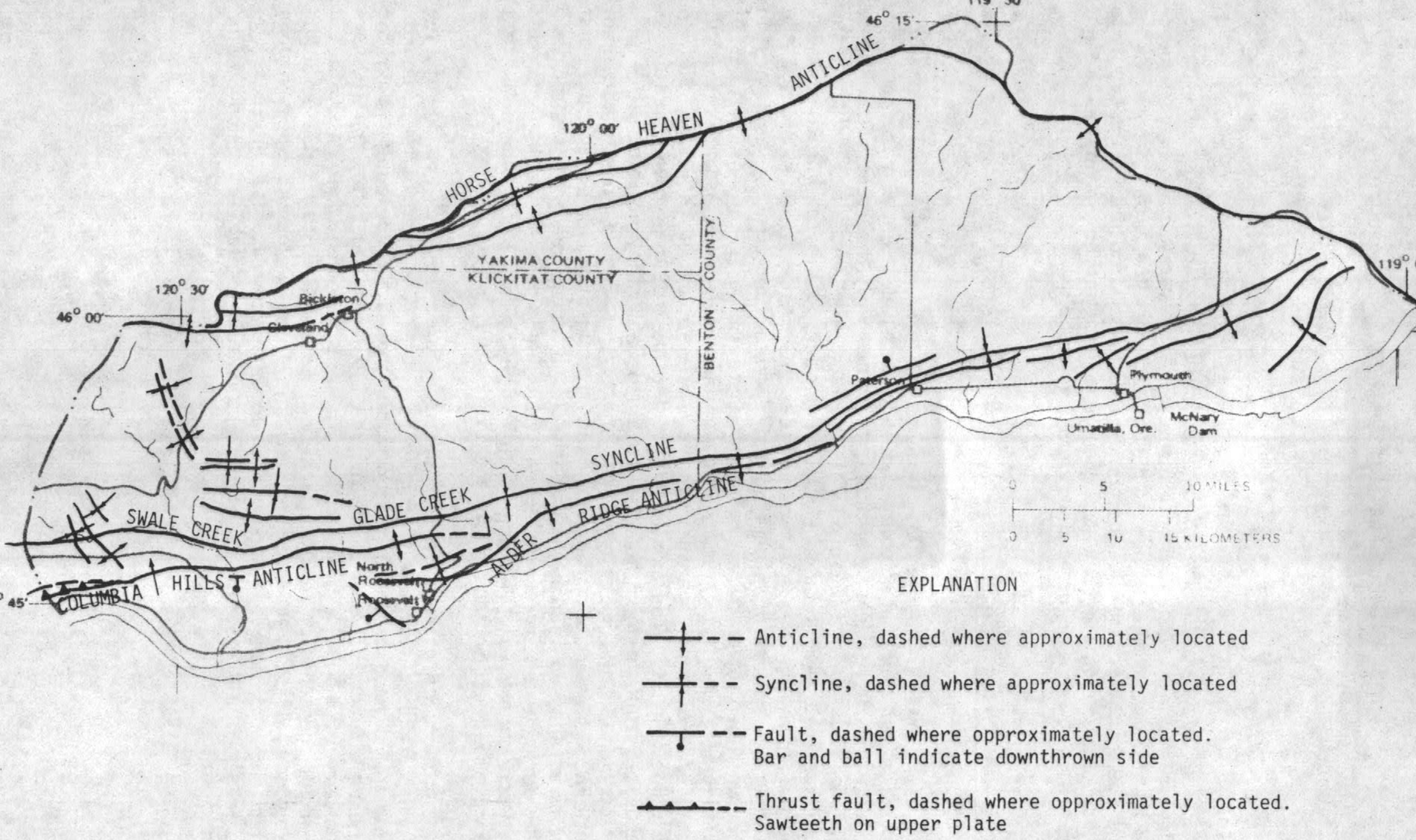


FIGURE 21.--Geologic structures in the study area. From Newcomb (1970).

Smaller east-west structures are found in the southern part of the study area. These include, according to the map by Newcomb (1971), the Swale Creek-Glade Creek syncline north of and parallel to the Columbia Hills and Alder Ridge anticlines and a small anticline and syncline represented by small low hills and valleys near the Columbia River, on the south side of Golgotha Butte.

Newcomb (1970) mapped several short faults in the study area (fig. 21). Although these may affect ground-water movement where they occur, well data in these areas are too sparse to permit interpretation of the local influence of these faults.

North-South Trending Structures

Several north-south trending structures in the western part of the study area were mapped by Newcomb (1971; fig. 21). They appear to be parallel to those farther west in the Goldendale area as mapped by Sheppard (1967) and are indicated by several topographic prominences (pl. 1), including Luna Butte (4/17-24), Tumwater Butte (5/18-15), and Harrison Ridge (5/18-35 to 4/18-13).

North-south structures are not apparent from surface features farther east in the study area.

Stratigraphic Controls

In addition to the possible structural controls, ground-water movement may also be controlled by hydrologic changes in the basalt or sedimentary interbeds. This may be true particularly in the eastern part of Klickitat County, where changes in potentiometric head in short distances cannot be explained by any structural feature apparent at land surface. The change in head is noted in deep wells situated along both sides of a northeasterly trending zone that evidently crosses the Klickitat County-Benton County line. Several wells northwest of this zone penetrate strata in which ground water is confined under high artesian pressure, with the potentiometric head above land surface at several wells. On the other hand, wells drilled to similar depths southeast of the zone obtain water with a potentiometric head 200 to more than 400 ft lower than that to the northwest.

According to Crosby, Anderson, and Kiesler (1972, p. III-18 and III-19) of Washington State University, who interpreted geophysical logs of selected wells in the central Horse Heaven Hills area, the artesian conditions are associated with one or two zones of higher transmissivity 600 ft or more below the surface. They believe these zones occur in a broad syncline superimposed on the south flank of the Horse Heaven Hills. They contend that the land-surface gradient in the area exceeds that of the potentiometric surface, thereby resulting in flowing discharges of wells tapping these deeper, more transmissive zones confined beneath zones of lesser transmissivity.

Brown (1978, p.11) also of Washington State University, believes that stratigraphy plays a significant role in controlling ground-water movement in the study area. He contends that pumping tests and geophysical logs of wells indicate that production obtained from aquifers within the Saddle Mountains Basalt is limited mostly to only domestic quantities, and that in much of this area the high-production aquifers occur beneath the uppermost flow of the Wanapum Basalt (uppermost Priest Rapids Member). Brown concludes that wells drilled into these productive aquifers in this area will undergo substantial changes in hydrostatic head upon complete penetration of the upper Priest Rapids member and that below a surface altitude of 1,500 ft the change will be toward increased head.

Seasonal and Long-Term Water-Level Fluctuations

In his study of Klickitat County, Brown (1979) made monthly water-level measurements of selected wells during 1975 and 1976, to determine the extent of seasonal fluctuations. The data are included in table 14, and hydrographs of the fluctuations in five wells are shown in figure 22. The hydrographs show that annual fluctuations vary among the wells, and that in three of the wells there was a general decline between summer 1975 and summer 1976, indicating that annual ground-water recharge did not balance ground-water discharge. On the other hand, the water level in 555-ft well 5/23-3A2 exhibited an unusual rise of about 24 ft between May and September 1976. The reason for this apparent anomaly is unknown.

Longer term, twice-yearly measurements were made by the U.S. Geological Survey of 44-ft well 6/20-22D1 (in Bickleton), which represents unconfined (water-table) conditions that most readily respond to seasonal variation in precipitation. During the period 1968-78 the measurements indicated that some decline had occurred, particularly between 1968 and 1973. Since 1973, however, the measurements indicate no significant further decline.

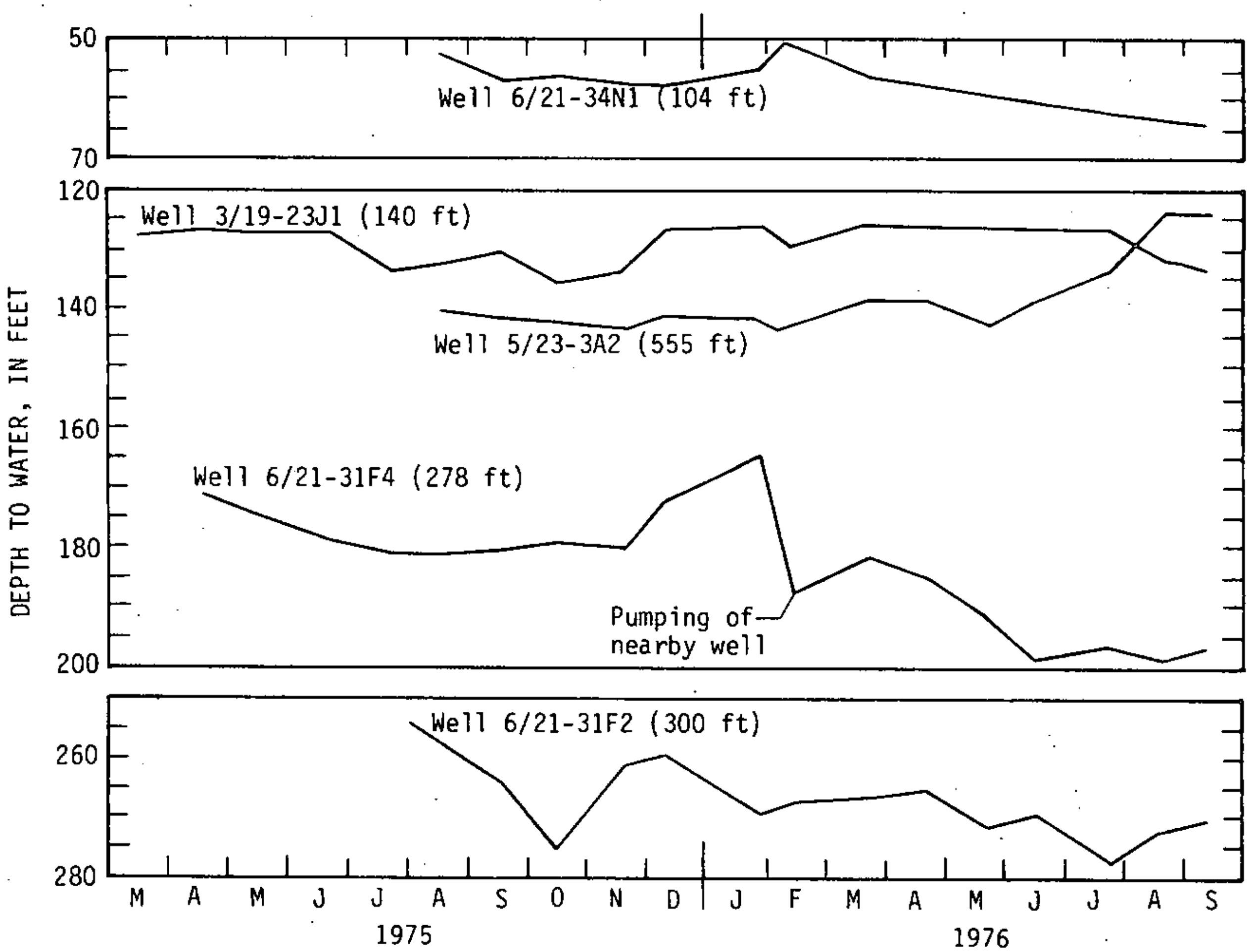


FIGURE 22.--Water-level fluctuations in selected wells during period of spring 1976-summer 1977. Well depths are given in parentheses.

Water-level measurements have been made since late 1972 in observation test-well 7/25-36N1, to record the seasonal and long-term changes in water levels representing three separate water-bearing zones in the 860-ft well (table 15). A zone 105-185 ft below land surface has significant seasonal and annual fluctuations, but two deeper zones (720 to 755 ft and 770 to 860 ft), with similar water levels, have little long-term changes.

Ground-Water Development

Well Data

The locations of all 294 wells in the study area from which some data were obtained are shown in plate 1. In most cases, the well data (table 16) were obtained from the files of the U.S. Geological Survey and Washington Department of Ecology, but data from additional wells were obtained during field visits to the area. Nearly all wells were visited to determine their accurate locations and land-surface altitudes from topographic maps; during the field visits only a few static water-level measurements were made. The well data include (1) records of wells, (2) drillers' logs, (3) chemical analyses of ground-water samples, and (4) water-level measurements. Some of the well data were obtained from other reports on the area (Crosby, Anderson and Kiesler, 1972; Brown, 1979; Strait, 1978).

Drillers' logs (table 17) provided general information on geohydrologic conditions at the well sites.

Areal Development

As is apparent from the areal distribution of wells shown in plate 1, the intensity of development varies considerably, with some areas—the upper western Rock Creek basin, the Goodnoe Hills bench in the Columbia Hills, and the Bickleton area—being more developed, while most of the area to the east is characterized by widely dispersed wells—mostly low-yield domestic and stock wells.

All domestic water supplies in the Horse Heaven Hills are obtained from wells or springs. Nearly all the springs are in Klickitat County, as indicated in figure 23 and plate 1; some of these provide both domestic and stock-water supplies. In most of the remaining study area individual domestic wells are the primary source of water; however, in some of the higher parts of the eastern half of the area, where the aquifers are too deep for development of domestic wells, many residents haul water by tank trucks from two county-owned public-supply wells.

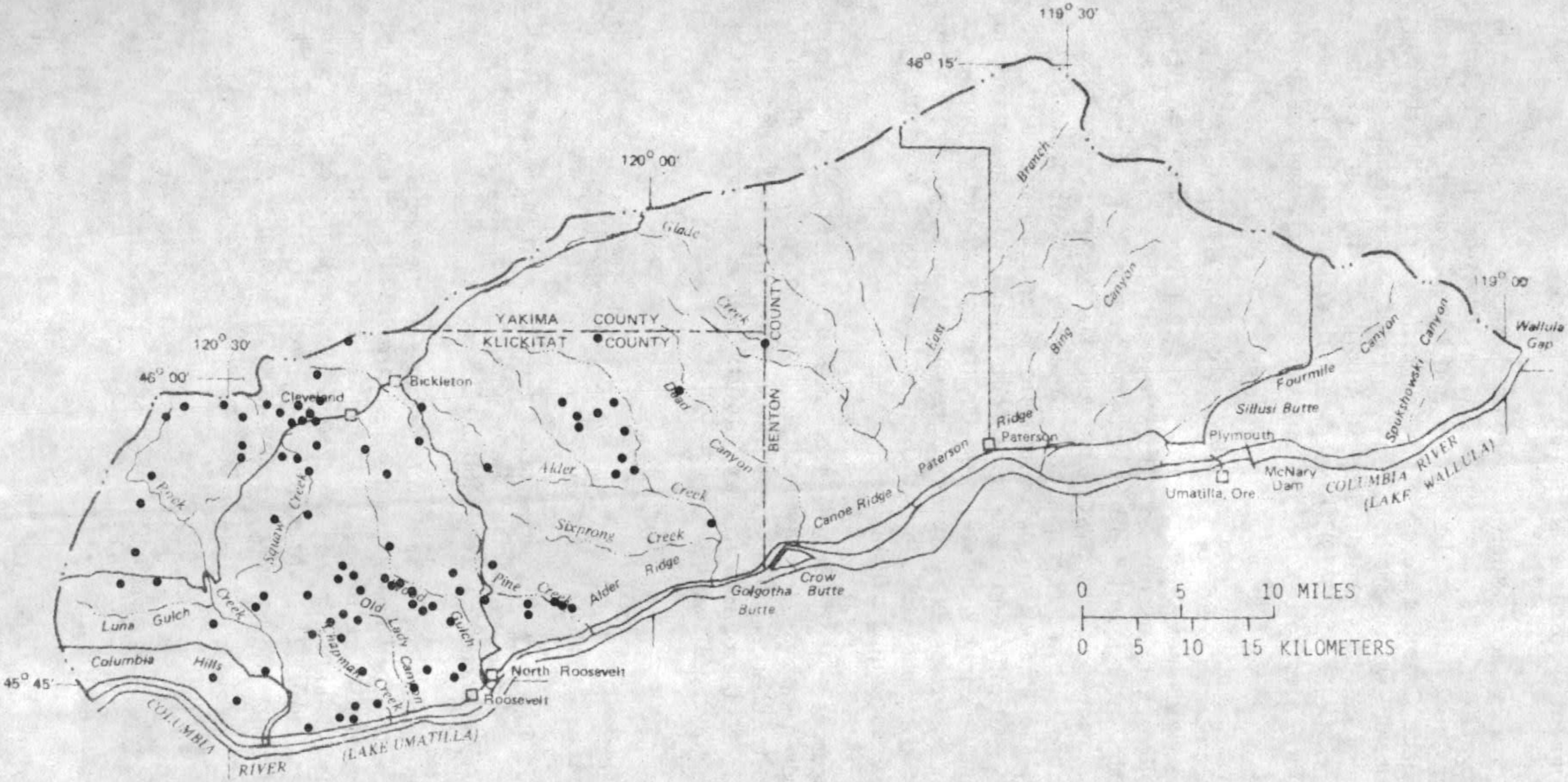


FIGURE 23.--Generalized locations of springs in the study area, as shown on U.S. Geological Survey topographic quadrangles.

Several industrial wells are in the area. These include wells at railroad maintenance stations along the Columbia River and at irrigation-equipment shops situated inland.

Irrigation wells are widely distributed (fig. 24), but all the high-yield irrigation wells are in an area crossing the Klickitat County-Benton County line in the central and lower Alder Creek, Dead Canyon, and Glade Creek areas. Most have been drilled within the past 5 years and obtain water from a highly productive artesian aquifer underlying the area. The photographs in figure 25 show one of these capped artesian wells (5/23-29D1) soon after drilling, with a deep channel cut into the soil zone by an artesian discharge of about 2,500 gal/min.

The reported pump yields of wells (table 16) are shown in figure 26. However, these yields may be considerably less than the potential yields of the wells. For example, unused domestic well 3/19-18B1, 195 ft deep and with a static water level of 110 ft, was pumped at 28 gal/min for 24 hours without noticeable drawdown; the well doubtlessly could produce considerably more with a larger pump. In a similar situation, irrigation well 5/23-3A2, 555 ft deep and with a static water level of 125 ft, was pumped at 95 gal/min and had a 14-foot drawdown, indicating a potential yield of nearly 2000 gal/min. On the other hand, some wells are fitted with pumps of excessive capacity and tend to go "dry" when pumped. Most domestic wells are drilled and developed to depths to produce only domestic quantities.

For the purpose of discussing the areal development of ground water, the study area has been divided into five subareas. As shown in figure 27, most subarea boundaries follow topographic divides. The general conditions of ground-water availability and development in the subareas are summarized as follows.

Rock Creek Subarea

As outlined in figure 27, the Rock Creek area includes the Rock Creek, Chapman Creek, and Old Lady Canyon drainages, and the Columbia Hills area bordering the Columbia River.

Most wells in the Rock Creek subarea are in the upper, relatively flat western part. They are generally less than 300 ft deep and used mostly for domestic supplies; a few are used for stock water, and several are abandoned. Yields are generally adequate for domestic needs (15-20 gal/min). The water levels in wells in this part of the subarea are generally less than 50 ft below land surface.

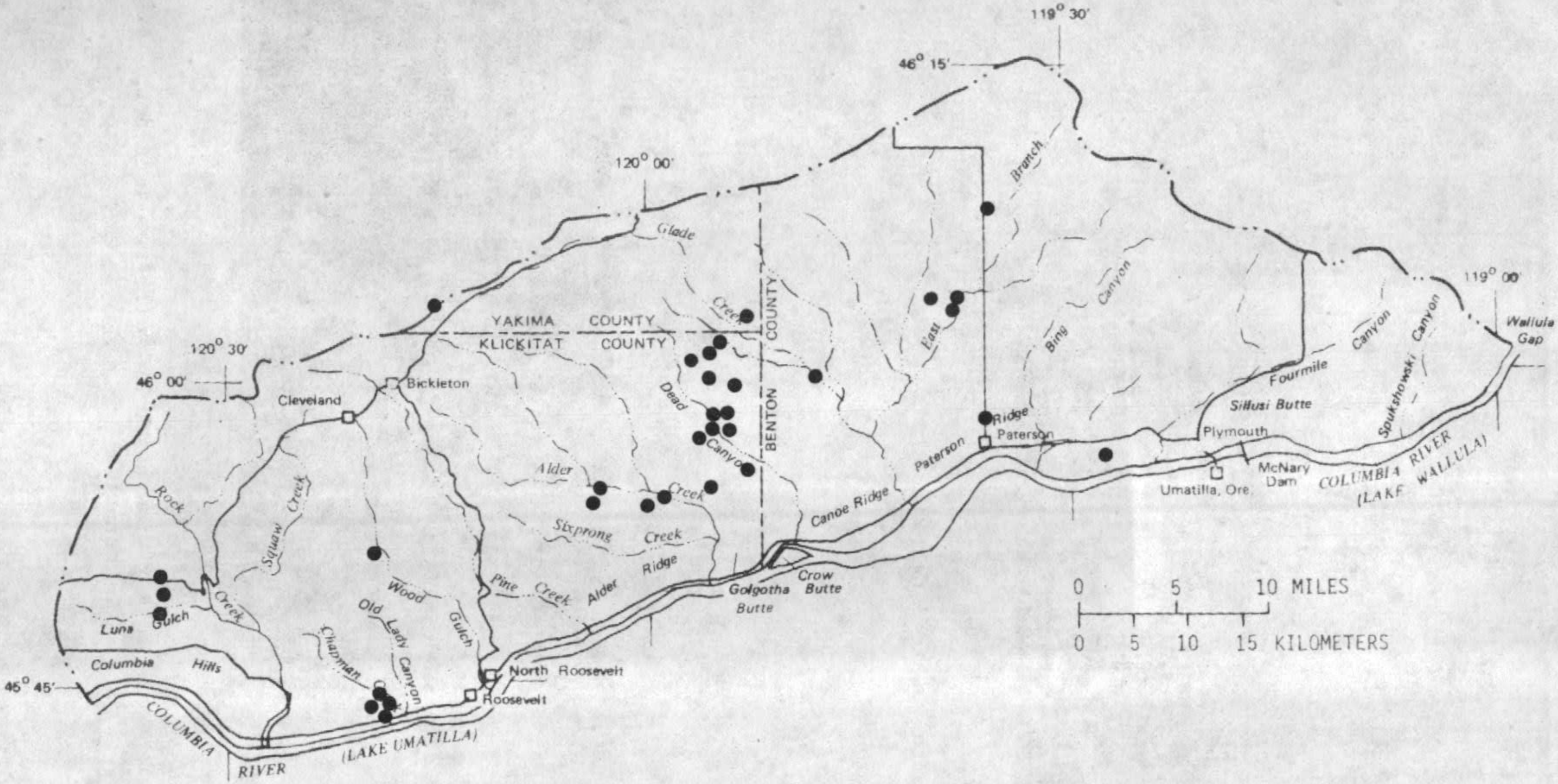
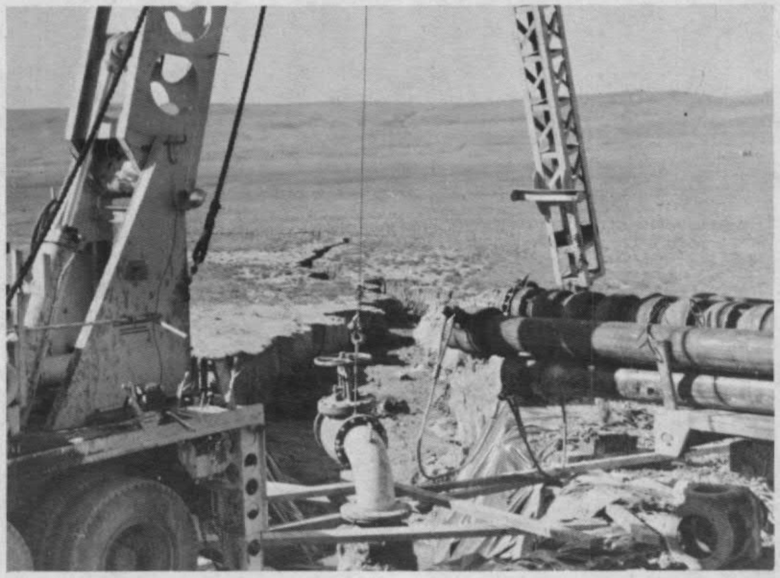


FIGURE 24.--Distribution of known irrigation wells.



A. View south toward Alder Ridge.

B. View north to well from 4-ft deep channel.

FIGURE 25.--Well 5/23-29D1 after drilling in 1977, showing channel cut 4 feet into softer loess over harder silt by artesian discharge of about 2,500 gal/min.

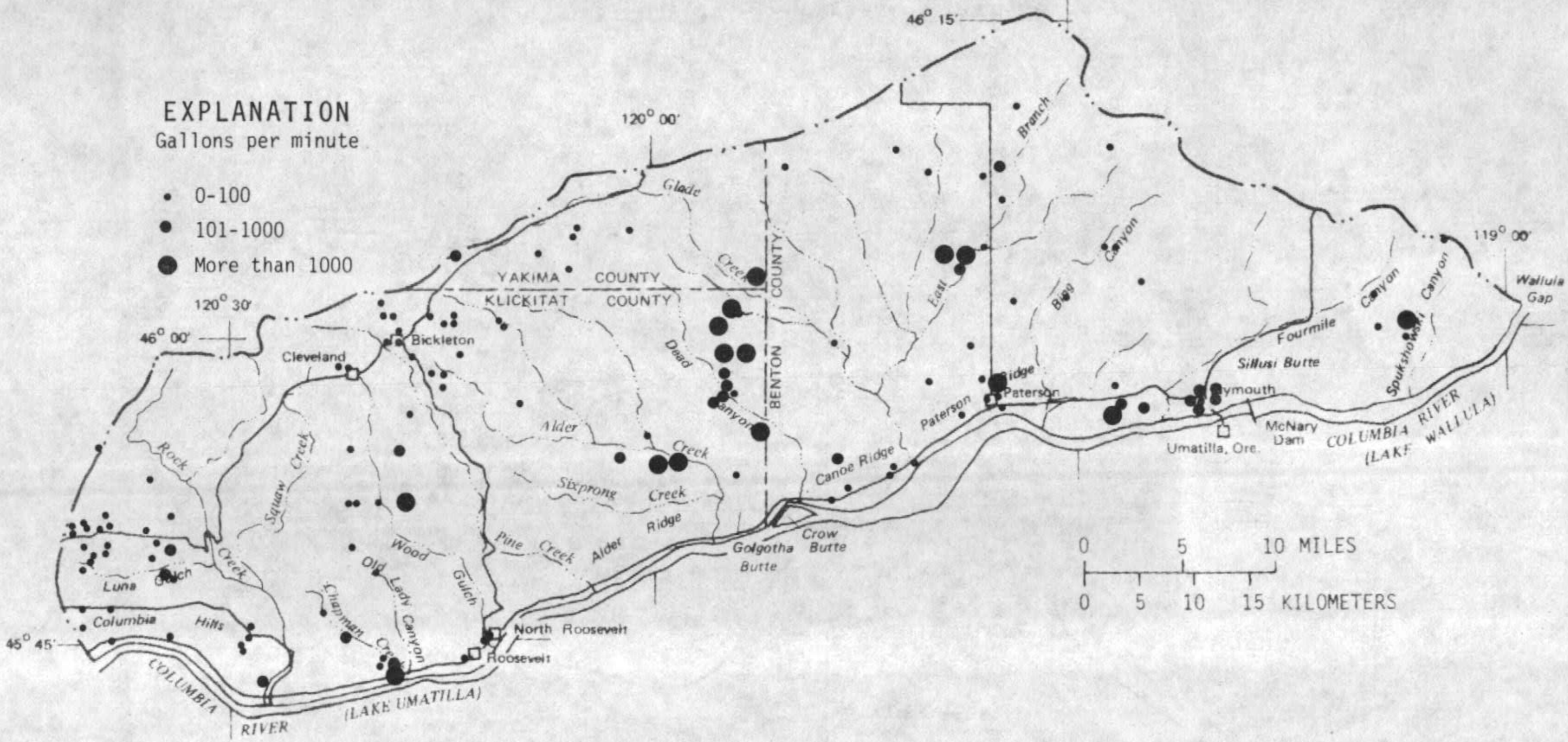


FIGURE 26.--Ranges of pump yields reported for wells in study area.

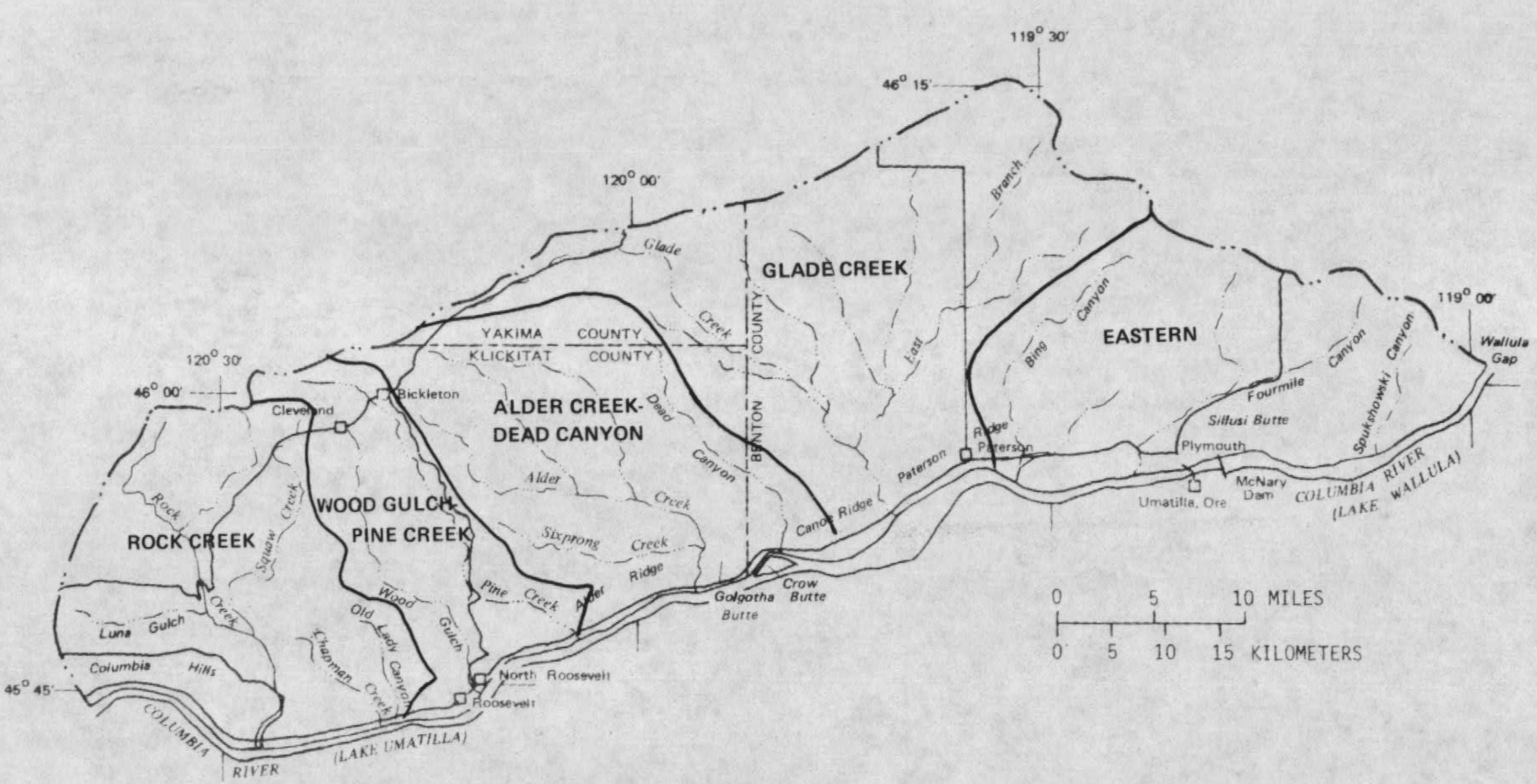


FIGURE 27.--Subareas of study area.

Several domestic wells are located on the small bench at Goodnoe Hills (pl. 1), on the south slope of the Columbia Hills. Nearly all the wells are less than 300 ft deep and have water levels less than 150 ft deep; yields are adequate for domestic needs. Four wells are used for irrigation at the Sundale Orchards near the mouth of Chapman Creek.

The Rock Creek basin has many springs (pl. 1, fig. 23), generally near the heads of the basin's many tributary valleys. Few of the springs are in developed areas and apparently none are used for domestic supply; some probably are used for stock water.

The Chapman Creek and Old Lady Canyon drainages have many springs situated in valley bottoms and sides and on upper slopes, indicating numerous water-bearing layers in the basalt. An examination of U.S. Geological Survey topographic quadrangles (7½-minute scale) shows these springs at 14 different altitudes, from 480 to 2,380 ft. Springs in valley bottoms provide domestic supplies for several homes.

Wood Gulch - Pine Creek Subarea

As indicated in well logs (table 17), the upper parts of the Wood Gulch and Pine Creek basins are underlain by several water-yielding units in the upper part of the basalt sequence, with the water levels in most wells being less than 100 ft below land surface. Well yields range from domestic quantities (5-20 gal/min) to about 1,000 gal/min, a quantity obtained from irrigation well 4/20-3L1.

Most of the wells in the subarea are less than 200 ft deep and are used for domestic supplies, including several wells in the communities of Bickleton and Cleveland on the upland. Although many wells there tap different water-yielding zones, most of the water levels are at about the same altitude and may define a potentiometric surface that represents a composite of several relatively shallow water-bearing zones.

The communities of Roosevelt and North Roosevelt have several domestic and public-supply wells. The wells range in depth from 223 to 260 ft and have water levels at or near river level.

Alder Creek-Dead Canyon Subarea

The subarea includes the basins of Alder Creek and Dead Canyon and small areas along the Columbia River--Alder Ridge, Golgotha Butte, and Crow Butte.

Until the recent drilling of deep irrigation wells in the central Dead Canyon basin, wells were drilled mainly for domestic and stock supplies. Most of these wells are 150 to 200 ft deep, with production coming from the top of the Pomona Member of the Saddle Mountains Basalt (table 6); in some areas, domestic wells drilled to the 500-to 600-ft depths also obtain adequate water, from the underlying informally named Selah or Mabton interbeds. In the southern part of the Alder Creek basin, most ground water is obtained from relatively shallow wells, with some obtained from springs in canyon areas.

The only recorded well along the Columbia River is a public-supply well at a park on Crow Butte (now an island). The 432-ft well obtains water from gravel and basalt aquifers and has a water level near river level.

Drilling to greater depth (700-1,000 ft) has proven the existence of large-yielding artesian zones, and several flowing artesian wells are now being used for irrigation of large tracts. At the time of drilling, some of these wells had flows greater than 2,000 gal/min; one well (6/23-24N1) had a reported flow of 4,000 gal/min. According to Brown (1978, p.13), analyses of drillers' and geophysical logs of several of the deep wells indicate that the greatest potentiometric heads and artesian flows are recorded for wells drilled to a depth below the uppermost Priest Rapids Member of the Wanapum Basalt.

Glade Creek Subarea

The Glade Creek drainage basin occupies much of the eastern (Benton County) part of the Horse Heaven Hills. The wells in the subarea are generally deeper than in the other subareas; of 52 wells recorded in the basin, 16 are deeper than 600 ft, 12 are deeper than 800 ft, and 3 are deeper than 1,000 ft. Eleven of the wells are used for irrigation--these represent nearly one-third of the irrigation wells in the entire study area.

The zone separating the areas with deep wells of significant differences in potentiometric head, discussed earlier (p.50), crosses the western part of the basin. Five deep irrigation wells, (6/23-11Q2, 6/23-15H1, 6/23-22J1, 6/23-24N1, and 7/23-36R1), obtain water under flowing artesian conditions at depths of 892, 950, 1,069, 965, and 806 ft, respectively, on the northwest side of the zone, whereas similarly deep but nonflowing wells are situated southeast of the zone. For example, well 6/23-36B1 (1,469 ft deep), 2.3 miles southeast of flowing well 6/23-22J1 (1,069 ft deep), has a potentiometric head about 350 ft lower in altitude.

The water level becomes lower eastward from well 5/23-3A3 through wells 6/24-22H1 and 7/25-36N1. The levels in deep wells continue to become lower all the way to Wallula Gap.

In the area east of the zone of significant water-level differences, flow of water from shallow zones to deeper zones has occurred in some wells. For example, according to Crosby, Anderson, and Kiesler (1972, p. 2), well 7/26-5B1 was 780 ft deep in 1969, the static water level was 403 ft, and the well produced about 162 gal/min with a 97-ft drawdown in 8 hours. When the well was deepened to 1,061 ft, the water was heard cascading down the well bore and the water level stabilized at 607 ft. Another example is that of observation test well 7/25-36N1. When the well was 547 ft deep the water level was 166.5 ft below land surface, but when the well was deepened to 740 ft, the water level dropped to 372.5 ft below the surface; subsequent deepening of the well to 860 ft resulted in no further significant change in the water level.

According to Brown (1978, p. 12), well 7/25-35M1 (35D1 in this report) also had a substantial downhole loss of water during drilling, as did well 7/22-23B1. When the latter well was drilled to a depth of 1,000 ft, the water level was about 750 ft below the surface, but when the driller set a plug at the 450-ft depth the water level rose to 350 ft below the surface.

The valley in the upper, west-to-east reach of Glade Creek near the crest of the Horse Heaven Hills has several springs and relatively shallow wells (less than 50 ft to about 100 ft deep), indicating the proximity of the local water table to the surface in this area. All wells are used for domestic supplies except irrigation well 7/21-30G1.

In the upper, northeastern part of the Glade Creek basin (upper East Fork Glade Creek basin) ground water is 300-400 ft below the surface and in many places is beyond depths economically feasible for more than domestic supplies. Many residents in this area obtain domestic supplies by hauling water by tank trucks from two county wells (8/26-16C1 and C2) located off County Well Road.

In the areas of Canoe and Paterson Ridges, which flank the mouth of Glade Creek near the Columbia River, several domestic and public-supply wells obtain adequate water from aquifers in hydraulic continuity with the river.

Eastern Area

Ground-water development in the eastern area, which includes the Bing Canyon, Fourmile Canyon, Spukshowski Canyon, and Wallula Gap drainages (fig. 27), is limited mostly to a few widely scattered domestic and stock wells, with well depths mostly in the 300-to 800-ft range. The water level in these wells is only about 50-100 ft above the level of the Columbia River at Lake Umatilla and nearly level with the river at Lake Wallula. Wells in the higher parts of the area must therefore penetrate deeply to reach water. Locally, however, aquifers at higher altitudes have evidently been tapped by some wells (7/27-29Q1, 6/29-8M1).

A study of several domestic and stock wells on the Prior Ranch and vicinity was made by Randall E. Brown, ground-water consultant. According to his stratigraphic interpretations and conclusions (R. E. Brown, 1973, p. 1-2), the principal aquifer is the Pomona Member of the Saddle Mountains Basalt. Its yield, though only about 10 gal/min in numerous wells drilled into it, appears to be consistent and reliable. The base of the aquifer lies at a maximum depth of about 250 ft. Deeper basalt flows produce little water, and in fact the deepening of shallow wells results in loss of water to the deeper zones and considerably greater pumping lift.

In the Plymouth area near the Columbia River, many wells tap relatively shallow aquifers in basalt and sand and gravel near river level to obtain domestic supplies; 80-ft well 5/27-9P1 obtains 2,400 gal/min from a sand-and-gravel aquifer and irrigates several hundred acres.

Ground-Water Quality

Wells from which water-quality data were obtained are concentrated mostly in the western part of the study area. The data are limited to those provided in the well records on file in the Tacoma office of the U.S. Geological Survey and to some data on water temperatures and specific conductance obtained from selected wells in the Bickleton area by Strait (written commun., May 1978). Most of the data on file were obtained at the time of drilling, from water samples collected by the driller or well owner. No sanitary-quality analyses were made of ground water in the area.

The data provided from the above-noted sources are sparse. Relatively complete analyses were made of samples from only 2 wells (table 8); water from 8 wells was analyzed for silica, chloride, hardness, and specific conductance (table 9); water from 27 other wells was analyzed only for specific conductance (table 10); and water-temperature data were obtained from a total of 46 wells (data included in table 16 at end of report).

TABLE 8.--Chemical analyses of water from two wells

[All values in milligrams per liter unless noted otherwise]

Constituent or property	Well 5/23-3A1 (87 ft deep) May 5, 1961	(670 ft deep) April 30, 1962	Well 7/25-36N1 (735 ft deep) Aug. 4, 1972	(860 ft deep) Oct. 5, 1972
Silica (SiO_4)	55	57	61	52
Aluminum (Al)	--	--	.01	.03
Iron (Fe)	0	.02	.02	.03
Manganese (Mn)	--	--	.00	.01
Calcium (Ca)	46	12	4.5	5.6
Magnesium (Mg)	12	4.1	1.4	1.7
Sodium (Na)	29	55	92	81
Potassium (K)	4.3	11	14	14
Bicarbonate (HCO_3)	162	95	225	209
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	46	2.2	18	24
Chloride (Cl)	27	9.8	18	16
Fluoride (F)	.3	--	1.2	1.1
Nitrate (NO_3) as N	10	--	.02	.08
Orthophosphate (PO_4)	.13	.10	--	--
Dissolved solids	344	[a]255	321	299
Hardness as $CaCO_3$	165	47	17	21
Specific conductance (micromhos/cm at 25°C)	464	344	454	430
pH units	--	--	8.2	8.2
Temperature (°F)	--	74	71.3	71.2
Color (platinum-cobalt units)	--	--	5	0

[a]Calculated on basis of 74 percent of the specific-conductance value, as indicated for the values obtained when well 87-ft deep.

TABLE 9.--Partial chemical analyses of water from eight wells

[All values in milligrams per liter unless noted otherwise.]

Well no.	Well depth (ft)	Date	Silica (SiO_2)	Chloride (Cl)	Hardness as $CaCO_3$	Specific Conductance (micromhos at 25°C)	Temperature (°F)
3/17- 4B1	287	10/ 6/65	51	2.4	100	161	53.5
3/21-17F1	223	--	37	27.4	196	--	--
4/17-12M2	455	10/ 6/65	60	13	120	233	58
-15D2	103	do.	32	11	130	268	55.5
-22N1	41	10/--/65	52	4.9	71	145	55.5
4/18- 7L1	--	10/ 6/65	53	3.4	96	208	--
- 7R1	400	do.	47	3.9	77	178	58
-31Q1	59	10/23/65	60	45	218	516	55

TABLE 10.--Specific conductance of water from selected wells

Well no.	Well depth (ft)	Depth to water level (ft)	Date	Analyst[1]	Specific conductance (micromhos/cm at 25°C)
5/20- 4N1	180	86.2	6-25-75	WSU	193
8R1	200	21.0	--do--	WSU	156
9A1	145	.5	--do--	WSU	170
18L1	110	14.7	6-26-75	WSU	260
5/21- 3J1	207	100	7-05-68	USGS	300
4A1	84	24	8-01-75	WSU	500
18B2	121	116	--do--	WSU	325
28N1	238	53.2	--do--	WSU	310
29H1	116	36.0	11/24/75	WSU	325
6/20- 2A2	200	--	--	WSU	640
9J1	167	.6	6-22-75	WSU	177
13H1	306	34	6-24-75	WSU	360
13H2	375	40	8-21-69	USGS	425
17H1	125	--	--	WSU	300
22C2	147	4	6-21-75	WSU	430
26D1	180	15.6	6-23-75	WSU	420
32B1	62	48	6-22-75	WSU	290
35B1	227	23.4	6-21-75	WSU	600
6/21- 7L1	200	29.5	8-04-75	WSU	250
18R1	165	21.4	8-03-75	WSU	250
19Q1	865	700	8-15-75	WSU	315
28DL	310	280	8-31-75	WSU	520
31F1	278	177	--do--	WSU	460
31F1	300	260	--do--	WSU	560
35P1	300	77	8-06-75	WSU	405

[1]Analyst: USGS, U.S. Geological Survey
WSU, Washington State University (Strait, 1978)

Because ground water has a longer period of contact with rock materials than does surface water, it usually contains more dissolved minerals. Ground water at greater depths has usually more dissolved solids--and higher temperatures--than has water at lesser depths. The amount of dissolved solids in the ground water is indicated by the specific conductance of the water.

In 1962 the U.S. Public Health Service established standards for public drinking water in the United States. These have since been updated by the U.S. Environmental Protection Agency (1975, 1977), and the criteria relative to water-quality characteristics analyzed in the study area are presented in table 11. As can be noted in tables 8 and 9, none of the key elements tested in ground water in the study area exceeded the maximum allowable concentration for drinking water.

Most ground water in the Horse Heaven Hills can be considered generally acceptable for domestic, irrigation, and present industrial purposes. Some industrial processes are more sensitive to certain constituents, however, and future industrial users should evaluate the water on the basis of the particular water-quality requirements of their industrial processes.

Specific Conductance

The specific conductance of water is a measure of the ability of water to conduct an electrical current and is an indicator of the concentration of dissolved solids in the water. The dissolved-solids concentration, in milligrams per liter, is generally 55 to 75 percent of the specific-conductance value. On this basis, the dissolved-solids concentration of the water analyzed for specific conductance (range 145 to 640 micromhos/cm) ranged from about 80 to 480 mg/L (milligrams per liter), all below the maximum of 500 mg/L recommended for drinking water.

Silica

Silica concentrations in the 12 samples analyzed ranged from 32 to 61 mg/L. These rather high concentrations probably reflect the influence of the siliceous basalt; silicon is the most abundant element in these igneous rocks. The higher concentrations (57-61 mg/L) were generally found in the warmer water of deeper wells; the solubility of silica is also dependent on water temperature. Although silica may form objectionable scale in heat-exchange equipment, it is not physiologically significant to humans or livestock nor of any importance in judging the suitability of water for irrigation.

TABLE 11.--Quality criteria for drinking-water supplies, for constituents analyzed in study area

[Adapted from U.S. Environmental Protection Agency (1975 and 1977).]

Constituent	Criteria	
	Maximum contaminant level[1] (EPA, 1975)	Proposed secondary level[2] (EPA, 1977)
Iron	0	0.03 mg/L
Manganese	--	.05 mg/L
Sulfate	--	250. mg/L
Chloride	--	250. mg/L
Fluoride[3]	2.0 mg/L	--
Nitrate	10.0 mg/L	--
Total dissolved solids	--	500. mg/L
pH	--	<6.5 or <8.5
Color	--	15 platinum cobalt units
Fecal-coliform bacteria	0.0 counts per 100 mL of sample	0.00 counts per 100 mL of sample

[1]Level that may affect the health of the consumer.
[2]Level that affects esthetic quality of drinking water.
[3]The maximum contaminant level (MCL) for fluoride is dependent upon the annual average of the maximum daily air temperatures at the location of the water-supply system, from 1.4 mg/L (26.3° to 32°C) to 2.4 mg/L (≤12.0°C).

Iron

Only four samples were analyzed for iron concentration, and all were considerably less than the 0.30 mg/L maximum recommended for drinking water. Excessive iron is objectionable because it stains plumbing fixtures, laundry, and industrial products and imparts an unpleasant taste to water.

Sulfate

Sulfate concentrations in the four samples analyzed ranged from 2.2 to 46 mg/L, much less than the 250 mg/L maximum recommended for drinking water.

Chloride

Chloride concentrations in the 12 samples analyzed ranged from 2.4 to 45 mg/L, all below the 250 mg/L maximum recommended.

Nitrate

Nitrate (as N) concentrations in the three samples analyzed were 0.02, 0.08, and 10 mg/L, all within the limit of 10 mg/L recommended as maximum for drinking water. Excessive nitrate in water consumed by infants may cause methemoglobinemia.

Hardness

Hardness of water is classified as follows:

Hardness range (mg/L)	Classification
0-60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

"Hard water" requires excessive amounts of soap or detergents in homes and laundries, and chemical treatment for domestic use is desirable. Hardness of the 12 samples analyzed ranged from 17 to 218 mg/L and averaged 105 mg/L. Most of the samples were within the soft to moderately hard categories.

Sodium-Adsorption Ratio and Salinity Hazard

In evaluating the suitability of water for irrigation, the relative activity of sodium ions in exchange reactions with soil is expressed by the sodium-adsorption ratio (SAR). The SAR is determined by the formula

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

where the ionic concentrations are expressed in milliequivalents per liter (U.S. Salinity Laboratory Staff, 1954). The salinity hazard of water also is an important indicator of the water's suitability for irrigation. It refers to the deleterious effects on agricultural soils resulting from irrigating with water having excessive concentrations of soluble salts. Measurement of salinity hazard is generally based on its specific conductance. High-quality irrigation water typically has a low SAR and a low salinity hazard.

Determination of SAR was possible from data obtained from only three wells (5/23-3A1, 6/23-11Q2, and 7/25-36N1), as computed by the above formula. Along with salinity hazard determined from specific-conductance values for the water from the wells, the data indicate that well 5/23-3A1 had water of very low SAR (0.98), and of medium salinity hazard, well 6/23-11Q2 had water of very low SAR (1.70), and of medium salinity hazard, and well 7/25-36N1 had water of low SAR (7.7) and of medium salinity hazard.

A study of the potential hazards of salinity on irrigation development in the Horse Heaven Hills was made by McNeal and Starr (1974). They concluded that salinity is not sufficient to lead to extensive in-place development of salt problems, but that extensive salinity problems will develop in natural drainageways and in low-lying depressions.

Water Temperature

In general, ground-water temperatures increase with depth. In relatively shallow wells (less than 200 ft) temperatures reflect the mean annual air temperature, which over the study area averages about 51°F (10.5°C), whereas in deeper wells temperatures are increasingly affected by heat from the earth's interior. However, comparison of well-depth and water-temperature data obtained from 45 wells in the study area (table 16) shows a poor correlation between the two factors. Analysis of the data shows no distinct relationship between well depth and water temperature. The apparent anomalies probably are due either to (1) the well depth not representing the water-yielding zone, or (2) the water being a composite of water from zones of different depths. However, examination of well records and drillers' logs does not always provide explanations for some of the anomalies.

WATER USE

Information on water use in the study area came from several sources. The field canvass of wells and well records on file with the U.S. Geological Survey provided data on the number, locations, and use of most wells. County extension agents in the Goldendale and Prosser offices of the U.S. Soil Conservation Service provided data on crops and acreages irrigated by surface- and ground-water sources. In addition, a study of ERTS (Earth Resources Technical Satellite) photographs (fig. 28) showed the location and extent of irrigated areas. Together, these sources provided the following information.

Nearly all domestic water supplies come from ground-water sources. The estimate of the quantity used is based on a Statewide average of 100 gallons per day per person. For an estimated population of 1,135 people in the study area, this amounts to 113,500 gallons or 0.348 acre-ft per day, or 127 acre-ft/yr.

The quantity of water used for industrial supplies in the study area--all from wells--was probably insignificant in comparison to other uses. Only seven wells provide water for industrial use; six of these are at railroad-maintenance stations along the tracks, while the seventh is a shop-supply well at the headquarters of one of the large irrigators.

The quantity of water used for stock supplies--mostly from wells and springs--was not estimated and probably is insignificant compared to other uses.

Aside from water pumped from about 35 wells in scattered parts of Klickitat County, by far the greatest amount of water used for irrigation in the study area comes from the Columbia River; this is applied to land in Benton County (Quema, 1978, p.6-7). Irrigation has increased considerably in recent years, as may be noted in the two ERTS photographs of figure 28, showing land irrigated in 1972 and 1977. Each small dark circular feature on the photographs represents about 120 acres, irrigated by a large center-pivot sprinkler system. A study of the two photographs indicates that an equivalent of about 554 "circles," or 66,500 acres, was irrigated in the study area in 1977, more than five time the approximately 12,700 acres irrigated in 1972. In 1977, about 2,760 acres was irrigated from wells and about 63,700 acres was irrigated from the Columbia River.

Pumping plants serving the larger irrigators are situated at seven points along the river. One plant has a total pumping capacity of about 120,000 gal/min through a 72-inch main line. This diversion facility includes a booster pumping station that allows irrigation of land 12 miles inland, at an altitude of 1,400 ft--more than 1,100 ft above river level. Figures 29 and 30 show these large diversion and irrigation systems.

A summary prepared by Gerlitz (1977) for a conducted tour of irrigation development in the Benton County part of the Horse Heaven Hills includes a tabulation of the number of acres of each crop type irrigated in 1977 (table 12). The amount of water used for each crop in the area also is given in the table, based on the allotments quoted by Howard Powell of the DOE office in Union Gap, Wash. The total quantity of water used on the 64,000 acres was about 199,000 acre-ft, or 3.1 acre-ft per acre.

Based on the average of 3.1 acre-ft per acre it is calculated that a total of 206,000 acre-ft was used on approximately 66,500 acres irrigated in the entire study area in 1977. Although information differentiating between the types of crops irrigated by ground water and surface water is not available, the 63,700 acres irrigated from the Columbia River used about 197,470 acre-ft, and the 2,760 acres irrigated by wells used about 8,560 acre-ft.

In summary, the calculated 1977 water use for domestic and irrigation supplies is as follows:

Purpose	Acre-feet: Surface water (from Columbia River)	Acre-feet: Ground water	Acre-feet: Total
Domestic supply	(insignificant)	127	127
Irrigation supply	197,470	8,560	206,030
Totals	197,470	8,687	206,157
(rounded)	197,000	8,700	206,000

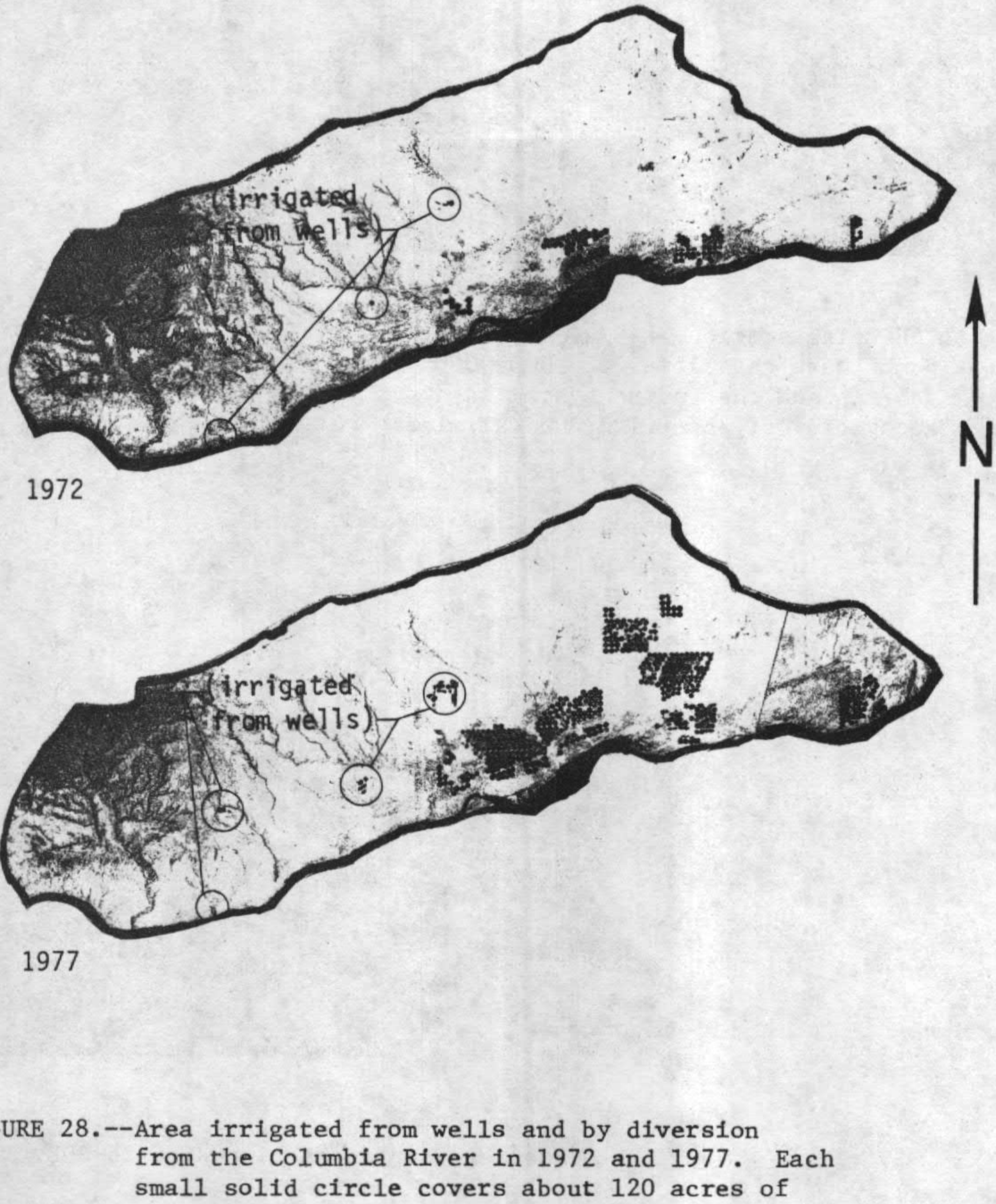
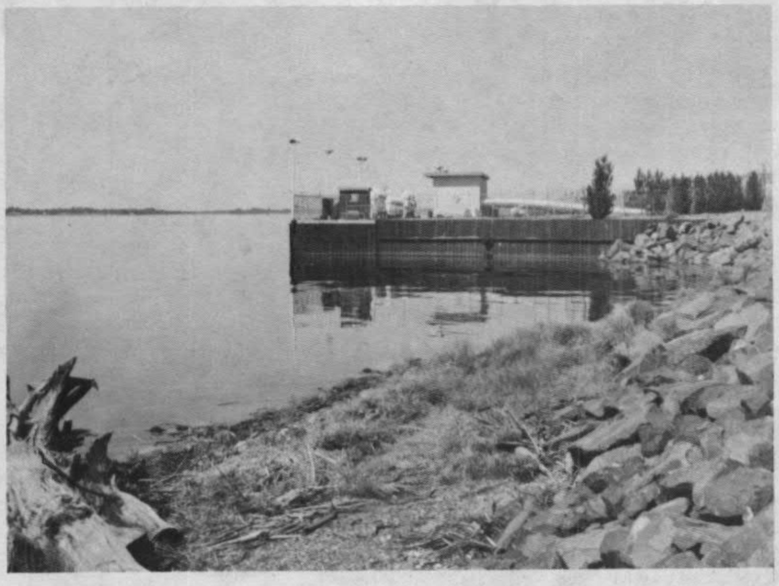
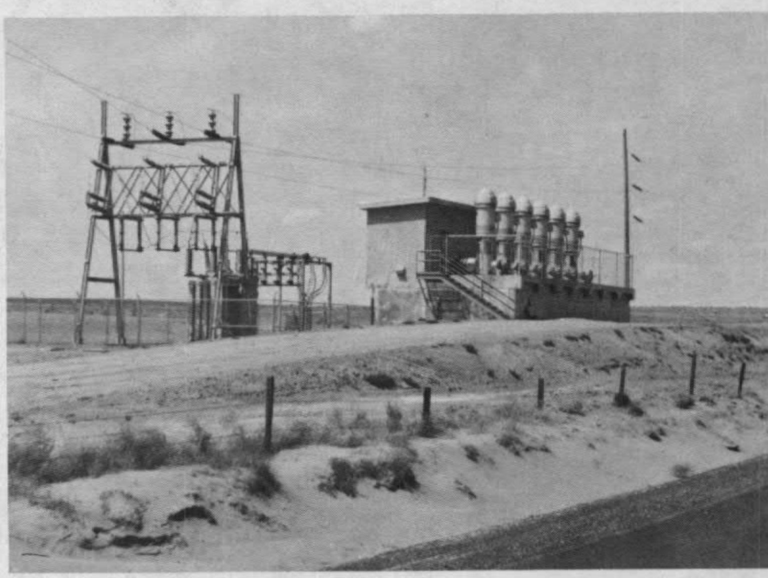


FIGURE 28.--Area irrigated from wells and by diversion from the Columbia River in 1972 and 1977. Each small solid circle covers about 120 acres of center-pivot sprinkler irrigation. Landsat photographs.



A. Pumping station at 5/27-15D. The pumps have capacities of 1500-9000 gal/min and the entire system has a capacity of about 120,000 gal/min.



B. Booster pumping station at 6/26-20D.

FIGURE 29.--Irrigation pumping plant on Columbia River and booster pumping station.

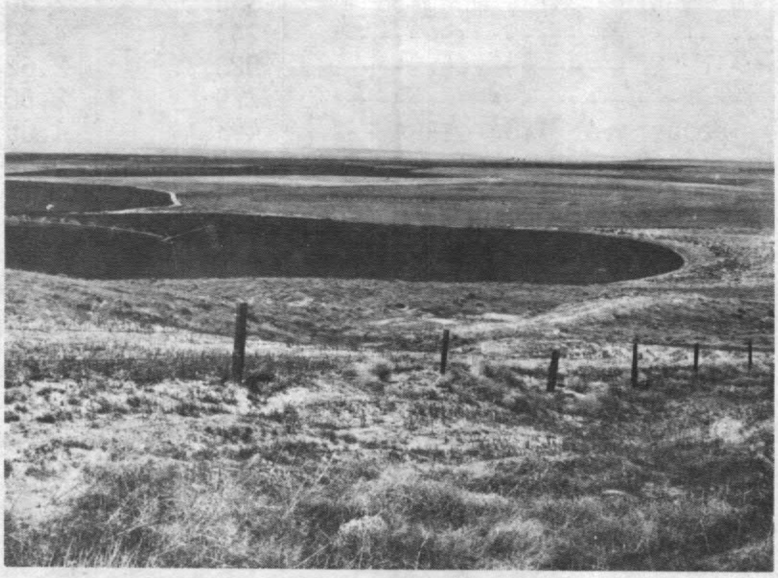


FIGURE 30.--Center-pivot irrigation of approximately 120-acre circular plots, by diversion from Columbia River.

TABLE 12.--Types of crops, acres irrigated, and quantity of water used for each crop in eastern Horse Heaven Hills in 1976

Crop	Acres[1]	Water used[2] (ac-ft/ac)	Water used[2] (ac-ft)
Potatoes	20,355	3.58	72,871
Wheat	16,928	1.43	24,207
Corn (grain 6,262, silage 3,336, sweet 313)	10,411	3.22	33,523
Sugar beets	5,741	4.28	24,571
Alfalfa (hay 3,566, seed 994)	4,560	5.24	23,894
Dry beans (pink, red, white 1,312, mung 38)	1,350	2.50	3,375
Pasture	1,241	4.28	5,311
Barley (feed 406, malt 522)	928	2.62	2,431
Soybeans	779	2.50	1,948
Mint (spearment 20, peppermint 423)	443	4.05	1,794
Sorghum (hay 250, grain 60)	320	5.57	1,782
Peas	299	2.14	640
Green beans	205	2.50	512
Grapes (wine)	157	3.58	562
Onions	127	4.25	540
Red clover	100	4.65	465
Asparagus	42	4.00	168
Oats	24	2.62	63
Christmas trees	3	--	--
Totals (rounded)	64,000	--	199,000

Average: $\frac{199{,}000 \text{ acre-ft}}{64{,}000 \text{ acres}} = 3.1$ acre-ft/acre

[1]Wilbert G. Gerlitz, Chairman, Benton County Extension Service (written commun., June 16, 1977).

[2]Calculated from allotments quoted by Washington Department of Ecology (Howard Powell, oral commun., 1977).

CONSIDERATIONS FOR FUTURE STUDIES

Large parts of the study area still are little known hydrologically because of the lack of development, but information from some areas of relatively recent ground-water development would be enhanced by more detailed data collection and interpretation. Of particular interest in this regard is the Dead Canyon and west-central Glade Creek areas. Although high-yield artesian wells are continuing to be drilled there, an appreciable stress on the aquifer system could occur if wells were overpumped or too closely spaced. A comprehensive determination of the depth, thickness, lateral extent, transmissivity, and storage characteristics of the deeper aquifers will benefit from collection of additional drillers' logs and geophysical logs for existing wells and from drilling of test wells where data are lacking. Extrapolation of geophysical information from logged wells to nonlogged wells can provide broader areal interpretations of geohydrologic conditions. Determinations of the nature of the zone in the central part of the study area, which separates areas of significant differences in potentiometric head, can be made easier from such areal interpretations.

A program of monitoring water levels in a network of observation wells on a monthly or bimonthly basis over 2-3 years would provide data necessary for evaluating seasonal fluctuations and yearly changes in the potentiometric surface. If obtained in the near future, such information would be useful in determining the storage capacity and characteristics of the aquifer before overdraft occurs. Relating changes in ground-water storage to precipitation would also more clearly define the amount of precipitation that becomes effective recharge to the area's aquifers.

Determinations of annual ground-water pumpage from all irrigation wells over a 2- to 3-year period also would provide useful information for a more comprehensive water-budget analysis. The pumpage data could be determined by the method used by Luzier and Burt (1974, p.25-26) for calculating pumpage from irrigation wells in east-central Washington. Pumpage is estimated from electrical-power consumption on the basis that pump-power input is related to water discharge.

Additional stream-discharge data--particularly from Glade Creek and the East Branch of Glade Creek—would provide a better basis for understanding the relationships between precipitation, stream discharge, and ground-water hydrology in the central part of the study area. Continuous-recording gages placed on Glade Creek above and below McKinley Springs (6/24-7A,B) would be useful for this purpose.

Records of annual diversions of water from the Columbia River for irrigation in the study area could be maintained over the years to evaluate the effects of such imported water on the underlying ground-water reservoir. Also, analysis of water samples from wells during a period of several years would help determine any changes in ground-water quality resulting from percolation of irrigation water that may contain significant amounts of pesticides and (or) fertilizing agents.

The increase in irrigation in large sections of the central and eastern parts of the study area, both from the Columbia River and from ground-water sources, may increase the development of homes and communities along the Columbia River. This would necessitate increased development of individual and public-supply wells in the area. To date (1978) there appear to be no problems with the availability or the chemical or sanitary quality of the water pumped from existing wells along the river. However, there is a possibility that the water quality will deteriorate at some future time because of the percolation of irrigation water from lands farther inland. Chemicals and fertilizers used in agriculture could conceivably affect the quality of water in the aquifer system underlying the area along the river. Therefore, collection of water samples from existing wells for comprehensive inorganic and organic chemical analyses would provide a basis for evaluating any future changes or deterioration of the ground-water quality.

Concern has been expressed over the impact of the large center-pivot irrigation systems in the lower eastern part of the study area—those diverting water from the Columbia River for large corporately owned farms. Although the amount of water pumped is a very small fraction of the average flow of the river, the principal concern is over the amount of hydroelectric power required by these irrigation systems and the effects on downstream power users. A report by Muckleson and Highsmith (1978) summarizes information on the irrigation systems and on the related concerns and potential problems.

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TABLE 13.--Summary of suspended-sediment and related water-discharge data, Alder and Rock Creeks, 1963-68 water years

[Data values interpreted from those of U.S. Geological Survey, 1963-68, and rounded to two and three significant figures.]

Water year	Suspended-sediment discharge (tons)/water discharge (acre-ft) OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	Annual sediment discharge (tons)	Annual water discharge (acre-ft)
Alder Creek at Alderdale (14034350):														
1963	0.1/45.8	0.3/48.0	0.1/50.6	0.2/44.0	46,100/3100	2.3/144	2.7/184	1.7/132	1.0/63.3	48.5/67.2	3.1/50.8	1.8/47.6	46,100	3980
1964	.7/54.5	.3/55.3	.3/58.9	3.2/162	1.9/239	1.1/139	.9/98.2	.2/66.4	.3/43.8	T/35.7	T/36.9	.1/47.6	9	1040
1965	.3/49.2	.3/47.6	262,000/16,800	9760/3760	14.9/1690	2.2/505	2.0/279	1.6/160	.2/88.7	.3/49.6	1230/120	1.0/64.5	273,000	23,600
1966	.4/56.3	.3/57.3	.2/66.1	7480/1910	80.4/598	1440/1500	.7/218	.6/53.6	.3/49.0	991/79.1	.5/50.0	.3/47.0	9900	4680
1967	.3/52.0	.2/55.5	89.1/369	194/427	2.0/296	2.9/161	.7/123	.4/81.9	.1/50.2	.1/34.3	T/31.5	.1/40.1	290	1720
1968	.1/45.0	.1/44.6	T/50.8	688/438	712/915	.5/192	.3/99.0	.2/55.7	.1/31.5	T/19.4	.1/29.6	.1/36.3	1400	1960
Mean	.3/50.5	.3/51.4	43,700/2900	3020/1120	7820/1140	242/440	1.2/167	.8/91.6	.3/54.4	157/47.6	206/53.1	.6/47.2	55,100	6160
	Maximum monthly sediment discharge: 262,000 tons, December 1965													
	Maximum monthly water discharge: 16,800 acre-ft, December 1965													
Rock Creek near Roosevelt (14036600):														
1963	0.2/55.7	4.3/370	24.2/2870	1.6/886	46,500/7490	19.4/2340	115/7270	15.1/2360	4.0/366	0.2/34.0	0/0	0/0	46,600	24,000
1964	0/0	0.8/123	6.6/582	1170/5160	35.3/4140	44.2/3650	33.6/3560	2.3/707	1.5/213	0.0/17.3	0/0	0/0	1300	18,000
1965	0/0	0.1/104	280,000/29,200	15,600/30,100	190/14,100	46.0/5080	7.0/1800	4.0/992	1.1/371	0.1/95.6	0.2/33.7	0.2/39.5	296,000	81,900
1966	0.6/88.9	1.2/259	2.0/384	684/6140	38.4/3420	1550/13,200	86.2/5480	4.8/825	1.8/215	1.0/105	T/1.98	0/0	2370	30,100
1967	0.1/18.4	3.1/602	973/6260	1390/8010	18.3/4470	6.0/1940	6.0/1580	4.3/1010	0.6/228	T/7.54	0/0	0/0	2400	24,100
1968	T/1.98	0.2/92.8	1.2/506	93.9/2600	3590/13,300	9.1/2890	1.2/810	1.0/382	0.3/92.4	T/1.59	0/0	0/0	3700	20,600
Mean	.2/27.5	.2/258	46,800/6630	3160/8820	8400/7820	279/4850	42/3420	5/1046	2/248	.2/43.5	0/5.95	0/6.6	58,700	33,200
	Maximum monthly sediment discharge: 280,000 tons, December 1965													
	Maximum monthly water discharges: 30,100 acre-ft, January, 1965													

TABLE 14.--Periodic water-level measurements in selected wells

[Data are from report on Klickitat County by Brown (1979), except for well 7/25-36N1, which are from report by Pearson (1973). Water levels are in feet below land surface.]

3/19-7G1. Bob Imrie. Altitude 1435 feet. Well depth 298 feet.

August	15, 1975	245.80	March	18, 1976	246.60
September	16	244.95	April	20	246.30
October	15	244.75	May	19	242.55
November	18	245.45	June	18	245.40
December	10	244.15	July	21	245.60
January	28, 1976	244.00	August	18	245.55
February	11	243.40	September	13	247.12

3/19-23J1. Ed Morris. Altitude 1018 feet. Well depth 140 feet.

March	14, 1975	127.20	January	28, 1976	126.48
April	15	126.86	February	11	129.60
May	9	127.00	March	18	125.90
June	20	126.91	April	20	126.20
July	22	133.60	May	19	126.60
August	16	132.20	June	18	126.70
September	16	130.35	July	21	126.70
October	15	135.55	August	18	131.83
November	18	133.89	September	13	133.35
December	11	126.55			

3/20-7E1. Horace White. Altitude 830 feet. Well depth 265 feet.

April	15, 1975	23.92	January	28, 1976	26.35
May	9	24.10	February	11	26.50
June	20	25.70	March	18	24.40
July	22	27.20	April	20	24.50
August	15	27.25	May	19	25.10
September	16	28.30	June	18	25.90
October	15	29.79	July	21	26.90
November	18	29.75	August	18	28.20
December	11	28.90	September	13	28.78

3/20-13R1. Dewey Beeks. Altitude 405 feet. Well depth 260 feet.

August	15, 1975	168.45	March	18, 1976	164.95
September	16	167.60	April	20	161.75
October	15	167.15	May	19	166.70
November	18	167.40	June	15	164.80
December	9	166.50	July	21	166.40
January	28, 1976	166.28	August	18	167.60
February	11	166.05	September	13	167.57

TABLE 14.--Periodic water-level measurements in selected wells (cont.)

5/23-3A2. R.J. Peterson. Altitude 716 feet. Well depth 555 feet.

August	15,	1975	140.55	March	19,	1976	143.50
September	16		141.95	April	21		143.30
October	15		142.45	May	19		147.90
November	18		143.30	June	15		138.60
December	11		141.15	July	23		128.30
January	28,	1976	141.90	August	19		123.84
February	3		143.80	September	13		123.70

6/20-22C1. Roy Van Nostern. Altitude 2990 feet. Well depth 147 feet.

March	12,	1975	1.80	January	28,	1976	2.09
April	16		2.00	February	13		2.15
May	9		2.90	March	19		1.85
June	20		3.88	April	21		2.35
July	21		4.80	May	19		2.00
August	15		5.08	June	15		2.00
September	16		5.55	July	23		5.40
October	15		6.50	August	18		5.38
November	18		5.68	September	13		6.24
December	11		4.05				

6/20-22D1. L. D. Whitemore. Altitude 3005 feet. Well depth 44 feet.

May	31,	1968	15.60	May	30,	1971	8.62
July	19		15.76	July	9		15.70
August	22		24.97	August	16		23.05
October	1		21.03	October	8		16.30
November	6		14.43	November	18		14.92
December	14		12.03	January	6,	1972	13.75
February	14,	1969	12.33	March	9		25.60
March	19		3.88	April	28		5.47
May	21		10.85	June	16		9.10
June	1		11.93	August	4		14.45
July	1		13.23	September	16		18.73
August	5		10.93	November	16		17.33
September	15		13.83	January	11,	1973	16.10
October	7		9.93	March	7		13.60
November	4		8.93	May	4		13.79
December	5		22.33	June	29		20.72
February	3,	1970	6.33	August	25		31.27
March	4		3.73	October	19		27.80
April	1		4.83	December	7		18.90
May	11		5.63	March	12,	1974	27.50
June	4		11.49	October	17		31.10
July	13		18.88	April	3,	1975	25.61
August	26		25.14	September	26		28.93
October	5		23.74	April	15,	1976	26.23
November	24		21.02	October	18		29.23
February	26,	1971	4.40	March	15,	1977	30.02
April	9		3.30	October	12		30.93

TABLE 14.--Periodic water-level measurements in selected wells (cont.)

6/20-30Q1. Roy Van Nostern. Altitude 3045 feet. Well depth 14 feet.

April	16,	1975	5.16	January	28,	1976	4.72
May	9		5.60	February	13		5.10
June	20		11.05	March	19		4.55
July	21		7.10	April	21		5.45
August	15		7.50	May	19		6.40
September	16		7.50	June	15		6.80
October	15		7.05	July	23		7.30
November	18		6.04	August	18		7.34
December	11		4.71	September	13		7.54

6/21-31F2. Howard Coleman. Altitude 2740 feet. Well depth 300 feet.

August	2,	1975	254.85	March	19,	1976	266.60
September	16		264.00	April	21		265.40
October	15		275.60	May	19		271.40
November	18		261.70	June	15		269.50
December	11		259.90	July	22		277.40
January	28,	1976	269.52	August	18		272.13
February	13		267.10	September	13		270.25

6/21-31F4. Howard Coleman. Altitude 2738 feet. Well depth 278 feet.

April	16,	1975	171.85	January	28,	1976	164.43
May	9		174.55	February	13		187.80*
June	20		179.23	March	19		181.80
July	21		181.29	April	21		185.00
August	15		181.45	May	19		191.70
September	16		180.95	June	15		198.05
October	15		179.80	July	23		196.60
November	18		180.40	August	18		198.50
December	11		172.42	September	13		196.60

6/21-34N1. Tom Gray. Altitude 2477 feet. Well depth 104 feet.

August	15,	1975	52.45	March	19,	1976	56.35
September	16		57.08	April	20		57.80
October	15		56.20	May	19		59.55
November	18		57.84	June	15		60.45
December	11		57.94	July	23		62.10
January	28,	1976	55.40	August	18		63.70
February	12		50.70	September	13		64.53

*Pumping, or pumping of nearby well, may have affected measurement.

TABLE 15.--Water-level measurements in three water-bearing zones in test well 7/25-36N1 during 1972-78

[Water-level data, measured in three piezometers, are in feet below land surface.]

Date		Depth of water-bearing interval (ft) 105-185	720-755	770-860
1972:	11/1	133.5	374.3	373.2
	12/14	125.8	373.7	373.4
1973:	2/7	119.8	365.4	371.8
	4/6	115.3	372.8	371.5
	6/1	111.5	372.5	371.3
	7/31	108.9	369.2	370.9
	9/21	107.0	371.7	370.9
	11/7	105.7	372.6	371.0
1974:	1/23	104.4	371.6	370.6
	3/12	103.4	371.1	370.2
	6/27	103.3	371.5	370.4
	8/23	102.5	371.6	369.9
	10/4	103.7	370.5	370.3
	11/25	103.8	371.0	370.2
1975:	1/30	104.0	371.7	370.5
	3/18	104.0	371.3	370.1
	6/27	105.1	368.9	369.8
	9/12	105.4	370.7	369.6
	11/4	105.5	370.6	369.8
1976:	1/7	105.5	370.8	369.8
	3/4	105.1	368.4	369.7
	6/23	101.4	368.1	369.4
	8/25	105.2	369.0	369.6
	10/20	119.1	370.6	369.9
	12/1	124.2	369.3	370.1
1977:	1/19	127.0	369.6	369.5
	3/24	129.8	369.4	368.6
	5/5	109.0	364.5	368.3
	4/5	130.7	369.0	--
	7/5	130.7	369.0	368.2
	9/16	131.8	369.5	368.4
	12/6	133.1	369.3	368.3
1978:	1/17	132.2	369.0	369.6
	3/14	132.9	369.25	368.75
	6/19	132.9	366.0	368.75
	7/27	132.6	370.8	369.75
	9/12	125.6	370.8	370.0
	12/8	127.0	370.2	369.5

TABLE 16.--Records of wells

Explanation:

Well no.: See figure on page for well-numbering system.

Alt.: Altitude of land surface above mean sea level, interpolated from topographic maps.

Aquifer depth interval: Depth, in feet, of top and bottom of water-bearing zone(s) if indicated, or of screened or perforated intervals.

Aquifer material: Type of rock or unconsolidated deposits, if indicated.

SWL, static water level: Measurement in feet and decimal fraction were made by Department of Ecology or U.S. Geological Survey; those in whole numbers were reported by owner, tenant, or driller; F, flowing.

Drawdown: Depth, in feet, water level is drawn down below static water level during pumping.

Yield: Pumping rate of well, in gallons per minute, reported by owner or driller; b indicates bailer test.

Specific capacity: Yield of well during pumping, in gallons per minute per foot of drawdown.

Use of water: D, domestic; Ind, industrial; I, irrigation; U, not used; PS, public supply, S, stock; T, test well.

Sequence of remarks:
C, Chemical Analysis in table 8;
Cp, partial analysis in table 9;
L, driller's log in table 17;
G, geophysical log available;
Obs., water-level observation well with data in table 14 and (or) hydrograph in fig. 23.
Temperature in degrees Fahrenheit.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/(ft)	Use	Remarks, other data
3/17- 1A1	Wm. Claussen	2,070	100	6	--	--	28.60	12/10/75	--	--	--	U	
2C1	Wm. Claussen	2,040	55	6	43-55	basalt, sediments	F	8/12/75	60b	30/1 hr	2	D	L; temp. 54°F.
2C2	do.	2,040	35	36	--	--	4.4	8/12/75	--	--	--	U	
3A1	Davenport	2,040	260	6	--	--	154.4	8/12/75	--	--	--	D	
4A1	Wm. Hoctor	1,990	88	4	--	--	35r	10/ 6/65	--	--	--	D	
4B1	do.	1,990	287	6,4	--	basalt	80 92.5	8/--/73 8/12/75	12	--	--	D	Deepened; from 88 ft in 1965; from 112 ft in 1969, and to 325 ft in 1973, backfilled to 287 ft; Cp, temp. 53.5°F, 8/12/75.
9B1	Wm. Hoctor	2,580	112	6	--	basalt, sediments	80	11/ 9/69	35	--	--	S	Temp. 52°F.
12P1	S.P. & S. RR.	400	325	12,10	194-196, 314-325	basalt	148	6/15/66	85	27	3.2	Ind	L; temp. 62°F.
3/18- 6D1	W. C. Yeley	2,100	120	8	--	--	7.5	Summer '75	--	--	--	D	
9N1	Leland Huot	440	116	8	--	basalt	14	5/ 9/69	40	--	--	D,I	Temp. 60°F.
3/19- 2A1	C.D. Kelley	1,100	30	6	--	--	11	11/16/72	45	--	--	D	L; Temp. 52°F.
2G1	do.	1,240	310	6	--	--	--	--	--	--	--	U	Dry well; L.
7G1	B. Imrie	1,435	298	6	--	--	245.6	7/21/76	--	--	--	U	
8F1	F. Wesley	1,350	300	6	--	--	260	8/ 6/75	9	--	--	D	
8N1	A. L. Wesley	1,240	223	6	219-220	basalt	160 205.7	6/24/70 8/6/75	7b	40/1 hr	.18	D	L; temp. 54°F.
11K1	M. E. Kelley	1,170	150	6	--	--	125r	--	--	--	--	D	Supplies four homes
13R1	J. Beeks	1,140	176	6	--	--	147.8	8/ 7/75	--	--	--	D	
14H1	L. Goddard	1,240	350	6	--	--	283.5	7/ 2/76	--	--	--	D	
18B1	R. A. Wesley	1,270	195	8	--	--	110	6/20/65	28	"0"/24 hrs	--	U	L.
18C1	B. Imrie	1,255	214.4	6	--	--	91	8/ 6/75	7	--	--	D,S	
3/19/18C2	B. Imrie	1,270	190r	--	--	--	150	8/ 6/75	--	--	--	D	
18L1	N. Dorff	1,242	115	48	--	--	110	8/ 6/75	3	--	--	D	
18Q1	B. Imrie	1,120	180	--	--	--	35.2	8/ 6/75	--	--	--	S	
20Q1	U.S. Corps of Engineers	280	285	10,8	87-128, 250-278	basalt	24.2	11/13/74	615 820	6/20 hrs 9/4 hrs	97 (average)	PS	L; temp. 63°F
23J1	J. Horrigan	1,018	140	6	--	--	126.7	7/21/76	--	--	--	D	

TABLE 16.--Records of wells - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/(ft)	Use	Remarks, other data
3/20- 7E1	H. White	780	265	10	103-115	basalt	28.3 29.95	9/16/75 6/28/77	250	125/1 hr	2	U	L.
10P1	Juris	667	100	--	--	--	3.5	8/ 7/75	--	--	--	U	
13R1	D. Beeks	405	260	6	--	--	167.6	9/13/76	--	--	--	U	
21L1	Sundale Orchards	320	386	6	71-98, 165-210, 342-386	basalt	66	7/17/75	60	--	--	I	L.
21P1	do.	310	215	8	--	basalt	87	8/24/52	100	--	--	I	
21Q1	do.	280	272	12	20-57, 225-227, 251-270	basalt	109	5/ 1/64	900	61/4 hrs	15	I	Irrigates 109 acres; L; temp. 58°F.
21Q2	do.	280	270	12	178-192	basalt	60	10/ 4/52	1500	30/5 hrs	50	I	L.
3/21- 9L1	U.S. Corps of Engineers	300	192	14,10, 8	170-182	basalt	101	4/12/66	92	7/4 hrs	13	PS	L, temp. 62°F
9N1	N. Roosevelt Water Assn.	300	81	8	55-65	basalt	55	10/20/61	100b	--	--	PS	L, temp. 60°F
9N2	do.	300	83	8	57-73	basalt	67	--	--	--	--	PS	L, temp. 60°F.
17F1	Roosevelt Water Assn.	350	223	6	200-223	basalt	--	--	--	--	--	PS	Cp, L.
18J1	N. Goree	375	250	6	224-250	basalt	140	11/ 7/72	60	--	--	D	L.
4/17- 2P1	Eleanor Dooley	2,180	308	6	at 82	basalt	57	9/29/69	2	25/1 hr	0.1	S	L.
9F1	K.L. O'Leary	2,410	355	6	320-340	basalt	215	11/15/74	25	100	.25	U	L, temp. 52°F.
9H1	L Osbornson	2,240	21	6	--	--	13.70	8/13/75	--	--	--	D	
9P1	K.L. O'Leary	2,240	554	6	532-554	baslat	170	10/25/73	85b	200/hr	.43	D	L, temp. 52°F.
10E1	K.Demings	2,270	775	6	760-768	basalt, claystone	--	--	15b	--	--	D	L, temp. 54°F.
10N1	J.Shuster (Fenton Bros.)	2,160	230	8	--	--	158.60	10/ 5/65	--	--	--	U	No water.
10N2	do.	2,160	700	6	--	--	425	--	--	--	--	D	
10P1	L. M. Moore	2,170	460	6	60-95	basalt, claystone	70	7/28/75	15b	--	--	D	L.
11M1	O. Boehler	2,120	176	6	155-160	basalt	25.12	5/23/77	20	18	1	D	
12L1	Boehler	1,965	176	6	--	--	29.20	8/12/75	--	--	--	D	
12M1	do.	2,000	220	6	--	--	60.46 44.2 46.0	10/ 6/65 8/12/75 5/23/77	2	--	--	U	
12M2	A.Schuster	1,980	445	8	--	--	188.10	10/ 6/65	35	--	--	D	Cp, temp. 58°F.
4/17-15D1	J.Schuster (Fenton Bros.)	2,140	69	8	--	--	57.08	10/ 5/65	--	--	--	S	
15D2	do.	2,150	103	8,6	--	--	75r	10/5/65	--	--	--	U	Cp, temp. 55.5°F
15M1	Schuster	2,000	220	--	--	--	60.46	10/ 6/65	2	--	--	U	
16B1	G. L. Trumbo	2,140	203r	6	--	--	53.35 57.93	8/12/75 5/23/77	--	--	--	D,S	
16H1	do.	2,140	50	6	--	--	9	8/12/75	--	--	--	U	Reportedly 270 ft deep. may have caved in.
17R1	C.Hoctor	1,820	320	--	--	--	43	12/16/77	--	--	--	D	G.
20R1	C.Schuster	2,010	334	--	--	--	102	12/16/17	--	--	--	D	G.
21J1	do.	2,000	250	6	--	--	35	8/29/76	--	--	--	U	
22A1	F. L. Sanders	1,985	265	6	235-261	basalt	60	9/ 5/75	60b	100	0.6	D	L, temp. 53°F.
22N1	Fenton Bros	1,990	41	6	--	--	25	10/--/65	30	2	15	D	Cp, L, temp. 55.5°F.

TABLE 16.--Records of wells - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/(ft)	Use	Remarks, other data
22N2	O. Myra	1,995	150	6	--	--	37.10	8/13/75	--	--	--	D	
22N3	J. Schuster	1,990	--	6	--	--	22.60	10/14/75	--	--	--	U	
22Q1	D. Myra	1,910	6	--	--	--	.50	10/14/75	--	--	--	U	
23C1	J. D. Dumm	1,960	175	6	--	basalt	20	9/10/75	4b	50	0.8	D	
23F1	do.	1,960	250	6	--	--	F	8/25/76	60b	150/1 hr	.40	D	L.
28H1	C. Schuster	1,940	508	6	72-260, 430-476, 490-508	basalt	0 65.90 70.1	6/27/73 10/14/75 5/23/77	60	50/1 hr	1.2	U	L.
28R1	Unknown	1,960	53	--	--	--	9.61	10/23/65	--	--	--	U	
4/18- 4N1	Holter Bros.	2,000	410	6	110-126, 359-374	basalt	280	3/18/77	2b	120/1 hr	.02	D	L.
4N2	do.	2,000	37	48	--	--	35.56	5/23/77	--	--	--	D	
7L1	C. Schuster	1,940	--	--	--	--	133.4	10/ 6/65	--	--	--	D	Cp.
7R1	do.	1,870	400	8	--	--	197.0	10/14/75	10	--	--	D	Cp, temp. 58°F.
8Q1	I. Anderson	1,830	21	48	--	basalt	7.08	5/23/77	--	--	--	D	
8R1	J. Johnson	1,840	120	6	--	basalt	94.0	9/ 8/75	--	--	--	U	Reportedly once 200 feet deep.
17B1	L. R. Smith	1,760	--	--	--	--	285	5/23/77	--	--	--	U	Open casing.
17D1	Holter Bros.	1,830	352	6	154-156, 345-352	basalt	147	7/ 6/77	30b	180/1 hr	0.17	U	
17G1	C. Schuster	1,640	150	10	--	--	126.90	10/14/75	--	--	--	I	
17K1	C. Schuster	1,720	200	10	111-178	basalt	75 100.3 126.5	6/ 8/70 10/14/75 5/23/77	600	--	--	I	L, Temp. 62°F.
18R1	Wm. Anderson	1,713	10	--	--	--	9.0	10/14/75	--	--	--	U	
28M1	W. Jones	1,690	45	6	--	--	40r	10/14/75	40	--	--	D	
29G1	R. R. Brack	1,660	277	10,8	at 83, 106-170	gravel basalt	98	9/22/68	500	--	--	I	L.
4/18-31Q1	O. Trumbo	2,130	59	6	--	--	37.88 21.64	10/23/65 5/24/77	--	--	--	D	Cp, temp. 55°F.
4/20- 3E1	Berk Bros.	2,100	35	48	--	alluvium	14.75	6/27/75	--	--	--	U	
3L1	H. Berk	2,225	274	12	171-177	sandstone	165 202.25	1940 6/27/75	1,070	8.5	126	I	L.
4/D1	Berk Bros.	2,270	335	6	319-335	basalt	93 85.75	-- 6/27/75	30 12	--	--	D	L.
6A1	B. Powers	2,270	200	6	--	clay	18.25	6/27/75	12	--	--	D	
6A2	A.L. Powers	2,280	130	6	--	--	25	3/15/71	5	0	--	U	
18Q1	B. Wilkins	2,440	253	6	--	--	130	10/ 3/69	10	--	--	D	L.
20Q1	B. Powers	2,220	175	6	110-147	basalt	30	11/14/75	15	90/1 hr	0.17	D	L.
4/21- 9K1	D. Whitmore	1,620	302	6	--	clay	--	--	--	--	--	S	
4/22- 3N1	Unknown	942	45	48	--	alluvium	21.00	4/ 5/75	--	--	--	U	
7J1	Goodnight	1,118	38	6	--	--	26.70	8/ 5/75	--	--	--	S	
12C1	C. McBride	1,000	547	10	--	--	(Dry)	--	--	--	--	U	
4/24- 3A1	S.P. & S. R.R.	305	398	16,12, 8	385-398	basalt	63	7/27/66	93	8/60 hrs	12	Ind	L, temp. 69°F.
6J1	State Park	300	432	8,4	50-415	gravel, basalt	38	--	--	--	--	PS	
5/17-23G1	Trans West Co.	2,560	370	6	50-63	basalt	47	10/ 6/70	20	--	--	T	L, temp 52°F.
24M1	do.	2,520	372	6	--	basalt	289	11/ 2/70	--	--	--	D	Temp. 52°F.
5/18-29N1	Unknown	2,255	300	6	--	--	--	--	5	--	--	D	
5/19-25K1	Rathspeth	2,415	20	72	--	--	2.30	8/ 8/75	--	--	--	U	

TABLE 16.--Records of wells - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/(ft)	Use	Remarks, other data
5/20- 1G1	K.J. Clark	2,710	105	6	--	--	.20	8/ 8/75	--	--	--	S	
4N1	J.H. Hooker	2,840	180	6	--	basalt	86.30	5/24/75	--	--	--	U	
8R1	F. Naught	2,752	200	6	--	--	20.92	8/24/75	--	--	--	D	
9A1	J. H. Hooker	2,780	145	6	80-96, 124-145	basalt sandstone	3 .40	5/24/71 5/24/75	60	--	--	S	L, temp. 56°F.
18L1	M.E. Slater	2,665	110	6	--	clay,sand	14.7	6/--/75	--	--	--	D	
19C1	A.L. Powers	2,585	93	6	--	--	12	3/15/71	5	"0"/ 48 hrs	--	D	
19G1	--	2,560	150	6	--	--	--	--	--	--	--	D	
22Q1	Berk Bros.	2,500	275	6	--	--	200r	--	--	--	--	U	
25K1	M.E. Slater	2,357	40	6	--	alluvium	12.75	6/27/75	--	--	--	U	
27B1	Berk Bros.	2,490	927	12	--	--	752	1/12/71	--	--	--	D	G.
28B1	do.	2,495	330	8	168-176, 242-263, 298-311	basalt	22	3/ 1/69	480	76/6 hrs	6.3	D	Drilled to 410 ft, backfilled; L.
28R1	Berk Bros.	2,400	410	10,8	311-321	basalt	83	10/23/69	--	--	--	U	L.
5/20-30N1	Rathspeth	2,410	150	6	--	sand	28	--	--	--	--	D	
30Q1	A.L. Powers	2,395	83	8	--	--	30	--	--	--	--	D	Went dry
5/21- 3J1	T. Gray	2,345	207	6	203-207	basalt	100	7/ 5/68	30b	100/5 hrs	.3	D,I	Supplies 4 homes; L. Temp. 54°F.
4A1	do.	2,480	84	6	--	--	24	8/ 4/75	--	--	--	S	
6F1	M. Larson	2,620	230	6	--	--	160	--	--	--	--	S	
8D1	Busch	2,560	160	6	--	--	10r	--	--	--	--	S	
18B1	H. Busch	2,545	160	6	--	--	--	--	--	--	--	S	
18B2	do.	2,530	121	6	--	--	116	8/ 4/75	--	--	--	D	
24J1	R. Ferguson	1,665	300	6	--	--	--	--	--	--	--	D	
28N1	L. Whitmore	2,020	238	6	--	basalt	53.20	8/ 4/75	--	--	--	D	
29H1	K.J. Clark	2,120	116	6	--	--	36 58.2	11/24/75 6/28/77	--	--	--	D	
5/22-13Q1	C. McBride	700	74	8	--	basalt	F	9/15/76	12F	--	--	D,S	
20N1	R. Ferguson	1,435	16	72	--	alluvium	5.90 7.4	8/ 6/75 6/28/77	--	--	--	S	
27A1	A.M. Matson	1,105	1,061	10,8, 6	349-568, 673-767, 806-930	sand	27.00	1/--/72	750	50	15	I	G.
27A2	do.	1,105	150	6	--	--	51.50	8/ 6/75	--	--	--	S	
27P1	J. Renta	1,100	787	12,8	554-568, 759-767, 770-787	basalt	58	7/ 6/76	--	--	--	I	L.
35D1	Unknown	1,018	22	72	--	alluvium	18.50	8/ 6/75	--	--	--	S	
5/23- 3A1	R.J. Petersen	716	81	6	80-81	sand	30 53 29.3	11/--/55 5/20/68 8/15/75	205 235	31 --	6.6 --	I	C, L.
3A2	do.	716	555	12,10, 8	27-79, 225-240, 278-321	--	125 123.70	11/--/56 9/13/76	95	14	6.8	I	L; G; temp. 61°F.
3A3	do.	716	1,100	--	--	--	226	10/15/75	--	--	--	I	
3L1	do.	825	150	8	--	--	125 180.00	11/--/56 6/15/77	--	--	--	U	L.
3L2	do.	825	313	12,10	--	basalt	190	1/20/76	400	14	29	I	L.

TABLE 16.--Records of wells - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/ft)	Use	Remarks, other data
5/23-11N1	M. Mercer	719	250	4	--	--	165.90	8/ 9/75	--	--	--	S	
13R1	T. Powers	575	1,081	16,12, 10, 9	--	basalt	144	2/15/78	2,990	14/8 hrs	150	I	G; specific capacity calculated form variable-yield pumping test.
5/23-27A1	A. Matson	760	1,040	10	--	--	27	1/--/72	--	--	--	I	
29D1	C. McBride	870	875	16	--	--	F (+136 ft)	6/28/77	2,100 (flow) 5,000 (pump)	--	--	I	G; L; temp 72°F; 59 psi shut-in pressure
30M1	do.	860	843	22,15	324-340, 791-793, 807-843	basalt	(+125 ft)	7/12/78	4,650 (pump) 2,500 (flow)	(to 179.5)	--	I	L; 54 psi shut-in pressure
31A1	do.	760	--	8	--	--	51.4	6/28/77	--	--	--	D	
35C1	M. Mercer	635	266	8	--	basalt	186.30	8/ 9/75	30	--	--	D,S	
5/24-28A1	Three Wells Farms	490	272	12,10	203-208, 218-228, 238-264	basalt	202.72	5/ 6/74	350	36/8 hrs	9.7	I	L.
35N1	Wyatt	290	52	8	--	gravel	27.20	11/30/68	40	--	--	D	
5/25- 1M1	Columbia Farms	538	--	--	--	--	60	6/--/74	--	--	--	S	
12G1	do.	485	330	6	--	--	100	6/--/74	75	--	--	D	
22M1	F. Milliman	400	336	6	326-330	basalt	170	1967	100b	--	--	D	
29B1	Sandpiper Land Co.	460	350	8,6	225-235	basalt	172	6/17/74	100	--	--	PS	L; temp. 68°F.
29N1	do.	325	245	6	--	--	72	2/ 6/75	38 27 11	110 65 20	.35 .42 .55	PS	L.
5/26- 5D1	T. Powers	630	1,002	16,12,10	108-121, 279-360, 599-610, 949-974	basalt	271	9/28/76	1,529	57/12 hrs	27	I	G; L; temp. 74°F.
5N1	Paterson Heights Water Dist.	437	354	10	--	--	97	9/ 2/64	100	175/6 hrs	0.57	PS	L.
7A1	D. Heier	420	320	6	at 320	basalt	60	1967	--	--	--	D	Restaurant supply.
7B1	Paterson School Dist.	440	347	8	124-128, 329-342	basalt	107	8/21/67	60	90/8 hrs	.67	PS	L.
8G1	S.P. & S. R.R.	300	143	6	125-130	basalt	25	1947	11	100	.11	D	L.
5/27- 4C1	Prior Land Co.	410	320	10	294-298	basalt	90	2/12/65	60	120/4 hrs	.29	D	L.
8D1	J. Christy	370	137	8	100-137	sand, gravel	100r	--	--	--	--	D	L.
9A1	Prior Land Co.	395	276	10	--	basalt	140	7/--/57	240	--	--	S	L.
9P1	J. Christy	300	80	20	35-80	sand, gravel	35	9/17/73	2,400	2/1.5 hrs	1,200	I	L.
11M1	El Paso Natural Gas Co.	300	372	8	--	--	37.00	5/23/56	120	122/12 hrs	1	Ind.	L.
5/28- 5D1	Coffin Sheep Co.	500	455	8	418-424, 424-428	basalt sand	235	11/11/63	--	--	--	S	L.
6R1	Burlington Northern RR	325	556	10,8	505-525	basalt	18.50	2/26/51	500	14/4.3 hrs	36	Ind.	L.
7A1	B.R. Craig	290	81	6	--	--	21	6/ 9/75	60b	40/2 hrs	1.5	D	L.
5/28- 7A2	Crawford	290	--	6	--	--	25.61	5/25/77	--	--	--	D	
7B1	B.M. Boyle	280	26	72	10-26	gravel	10	6/15/46	250	2	125	D	L.
7F1	Beeler	300	192	8	50-54, 54-73, 79-87, 175-192	sand gravel basalt basalt	48	8/14/47	500 (permit)	--	--	D	L.
8D1	S.P. & S. R.R.	280	95	12,10	59-72	sand, gravel	38	10/22/16	150	1.5/4 hrs	100	Ind	L.

TABLE 16.--Records of wells - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/(ft)	Use	Remarks, other data
5/28- 8D2	do.	280	629	12,8,6	--	--	0	7/ 6/22	300	"0"/4 hrs	--	Ind.	L.
6/20- 1P1	S. Naught	2,980	20	72	--	--	4.50 7.55	6/22/75 6/14/77	--	--	--	D	
2A1	D. Johnson	3,062	40	72	--	alluvium	7.08	6/22/75	--	--	--	U	
2A2	do.	3,061	200	6	--	basalt	--	--	--	--	--	D	
4N1	J.C. Ingram	3,240	130	6	18-27 89-103	shale, basalt, claystone	19	9/18/71	45	--	--	D	L; temp 52°F
9J1	H.H. Wilson	3,140	82 167	6	--	alluvium	0.50	6/24/75	22	--	--	D	
9L1	C. Walling	3,155	10	--	--	alluvium	0.42	6/24/75	6	--	--	D	
11E1	D. Johnson	3,030	--	6	--	--	4.70	6/14/77	--	--	--	D	
12M1	R.R. Ferguson	2,935	20	72	--	--	3.33	6/24/75	6	--	--	D	
13H1	F.H. Naught	2,862	306	6	--	--	30.80	6/24/75	12	--	--	U	G.
13H2	do.	2,862	375	6	26-28, 372-375	basalt sandstone	40	8/27/69	60	300	.2	D	L; temp 52°F
15N1	R.J. Rupp	3,030	205	6	--	--	17	2/27/74	12	150/1 hr	.08	D	Temp 54°F; L.
17H1	E.R. Nelson	3,250	125	6	60-125	basalt	47.9	6/14/77	--	--	--	D	L.
21A4	L. Whitmore	3,030	235	6	213-235	basalt	64.9	8/ 5/75	60b	60	1	D	L; temp 54°F.
22C2	R. Van Nostern	2,990	147	6	--	--	6.24	9/13/76	--	--	--	U	
22D1	L.D. Whitmore	3,005	44	--	--	--	28.00	6/22/75	--	--	--	D	Hydrograph in fig.
22D2	L.D. Whitmore	3,002	175	6	--	basalt	78 97.30	1/29/74 6/24/75	13b	100	0.13	D	L; temp 54°F.
24R1	E.M. Brown	2,793	178	6	--	--	75.75	6/24/75	--	--	--	U	
24R2	do.	2,792	30	72	--	alluvium	3.00	8/24/75	--	--	--	U	
26D1	K. Jensen	2,920	180	6	--	--	15.58 23.9	6/22/75 6/28/77	3	--	--	D	
27N1	Gordon	2,940	100	--	--	--	13.70	6/24/75	--	--	--	S	
30K1	Cleveland Park	3,057	12	48	--	alluvium	3.50	6/23/75	--	--	--	PS	
30M1	Matsen Land Co.	3,140	190	6	169-176	basalt	120 100	5/25/73	2.5	--	--	S	L; temp 54°F.
6/20-30Q1	R. Van Nostern	3,040	--	36	--	alluvium	7.54	9/13/76	--	--	--	D	
30Q2	W. Savage	3,038	20	72	--	alluvium	4.75	6/23/75	--	--	--	D	
30Q3	do.	3,042	18	72	--	alluvium	8.42	6/23/75	--	--	--	D	
30Q4	C. Shannon	3,040	85	6	58-95	basalt	1.50	4/25/74	25b	60/1 hr	.42	D	L; temp. 52°F.
32B1	E. Lasly	3,022	62	72	--	--	48.30	6/23/75	--	--	--	S	
35B1	J.A. Jensen	2,845	227	8	--	--	23.4	6/24/75	15	--	--	S	
36B1	H. Coleman	2,780	408	6	--	--	12	10/30/69	5	--	--	S	L.
36P1	M. Larson	2,757	160	6	--	basalt	32.80	5/23/75	15	--	--	D	
6/21- 4M1	R.C. McBride	2,720	250	--	--	--	50r	--	--	--	--	D	
6L1	A.M. Matsen	2,845	12	72	--	alluvium	4.08	6/24/75	--	--	--	D	
6L2	do.	2,880	130	6	--	--	62.50	6/26/75	--	--	--	U	
7L1	S. Jensen	2,820	200	6	--	--	29.50	8/ 5/75	5	--	--	D	
14H1	J. Doosey	2,440	146	6	--	--	100	--	--	--	--	D	
15L1	L. Giles	2,560	12	72	--	--	6	8/ 6/75	6	--	--	S	
15L2	do.	2,565	220	6	207-220	basalt	149	10/30/73	30	50	.6	D	L; temp. 52°F
18E1	F. Naught	2,842	82	6	--	--	7.75	8/ 6/75	6	--	--	S	
18R1	C.W. Everetts	2,785	165	6	--	--	21.40	8/ 6/75	--	--	--	D,S	
19Q1	M.R. Matsen	2,765	865	6	--	basalt	700	7/22/74	15	150/1 hr	.10	D	Temp. 54°F; L

TABLE 16.--Records of wells - cont.

Well no	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min (ft)	Use	Remarks, other data
6/21-24A1	L. Roberts	2,225	103	8	--	--	40	1974	--	--	--	D	
28D1	E. Brown	2,670	310	6	--	--	276	8/31/76	--	--	--	U	G.
29R1	T. Gray	2,620	--	6	--	--	25.9	6/29/77	--	--	--	S	
30C1	M. Matsen	2,785	320	--	--	--	310	--	--	--	--	D	
31E1	H. Coleman	2,740	315	6	--	blue clay	207.25	9/13/76	--	--	--	D	L.
31F1	do.	2,738	278	6	--	--	196.60	9/13/76	--	--	--	D	
31F2	do.	2,740	300	--	--	--	260	12/--/75	--	--	--	U	G.
34N1	T. Gray	2,477	104	6	--	--	51.85	8/ 4/75	--	--	--	U	
35P1	do.	2,360	300	6	--	--	75	9/ 1/76	--	--	--	D	G.
6/22-25J1	M. Mercer	1,325	112	6	--	--	2.90	9/ 9/75	--	--	--	S	
6/23-11Q1	B. Andrews	1,000	208	8	154-208	basalt	--	--	200	--	--	I	L.
11Q2	do.	1,020	892	12,7	654-855 877-889	basalt	F(+80 ft) F	3/18/70 2/10/71	2,500F 2,200F	--	--	I	C, L; temp 74°F. 35 psi shut-in pressure.
15H1	do.	1,050	633 950 (deepened 1971)	12	303-351 377-405 658-938	basalt do. do.	1.00 F(+80 ft)	6/13/67 2/10/71	150 2,200F	--	--	I	L, G; 35 psi shut-in pressure.
6/23-16R1	Washington Dept. Natural Resources	1,090	950	16	--	basalt	40.8	7/22/76	--	--	--	I	G.
22J1	B. Andrews	982	1,069	12,10	--	basalt	380 293	7/22/76 2/ 9/78	1,700	19/8 hrs	90	I	G; L.
24N1	do.	870	965	16,10	--	basalt	F(+103)	10/ 7/77	4,000(flow)	--	--	I	L; 62 psi shut-in pressure
28J1	M. Mercer	863	16	48	--	alluvium	8.9	8/11/75	--	--	--	S	
34H1	D. Mercer	840	107	6	--	--	96.4	8/ 9/75	--	--	--	U	
34H2	do.	840	425	8	at 250, 400	basalt	231.4	8/ 9/75	200	--	--	D, S	
34H3	do.	840	550	6	--	--	287.7	8/ 9/75	--	--	--	D, S	
6/24-22H1	Columbia Farms	550	661	10	--	--	142	2/ 8/72	--	--	--	I	G.
23N1	G.A. Smith	605	220	6	--	--	110	1964	2	--	--	D	Poor well.
6/25-12K1	Lenzie Ranch	750	190	--	--	--	90	--	--	--	--	U	
12P1	do.	697	250	--	--	--	220	--	--	--	--	S	
15A1	do.	606	350	6	--	sand	49r	--	--	--	--	U	
24R1	do.	623	280	6	--	--	--	--	5	--	--	S	
34N1	do.	493	156	6	--	--	--	--	5	--	--	S	
6/26-9L1	Prior Land Co.	820	267	6	239-241, 250-259	basalt	205	10/--/46	30	--	--	D	L.
12F1	do.	899	340	6	--	basalt	--	--	7.5	--	--	S	
31R1	Columbia River Farms	650	358	6	292-358	basalt	290	3/15/77	35	70	.5	D	L.
6/27- 3F1	G.T. Powers	1,070	700	6	145-160	basalt	595	10/--/66	1.5	--	--	U	L.
17R1	do.	685	310	6	230-310	basalt	--	--	--	--	--	S	
23A1	Coffin Sheep Co.	729	320	6	--	basalt	295	1958	--	--	--	S	L.
6/28- 2B1	Sweany	1,067	14	--	--	--	12	--	--	--	--	S	
33H1	Coffin Sheep Co.	825	542	8	345-380 505-508	basalt gravel	508	--	--	--	--	S	L.
6/29- 8M1	do.	597	146	8	--	--	100	1959	--	--	--	D, S	L.
11P1	do.	1,400	1,110	8	--	--	1,070	11/11/58	5b	0	--	S	L.
23K1	O.J. Hellberg	1,075	330	8	--	--	309	--	25b	--	--	D	L.
6/30-12Q1	J. Blair	1,180	974	6	--	--	855	3/20/73	--	--	--	U	G.

TABLE 16.--Records of wells- cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aquifer depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/ft)	Use	Remarks; other data
6/30-19D1	Irrigro, Inc. (Hundred Circles Farms)	960	814	10,8,6	710-814	basalt	634	6/26/74	1,000	7/1 hr	143	D	L.
19N1	do.	990	736	6	--	basalt	475	--	11	20	--	Ind.	G; L; temp. 55°F.
7/21-25C1	C.L. Mains	2,670	404	6	--	--	--	--	10	--	--	D	
26C1	V. Linderman	2,750	220	6	--	--	160r	Spring '76	--	--	--	D	
30G1	A.N. Matson	2,750	400	10	395-398	basalt	15 50	12/16/68 4/-/69	320b	--	--	I	L.
7/22- 1P1	Wandling Bros.	1,630	32	6	--	basalt	9.05	6/14/77	--	--	--	D	
2J1	J.L. Sharp	1,270	90	--	--	--	--	--	--	--	--	D, I	
7K1	F. Wattenberg	2,010	90	6	--	--	25(est)	--	--	--	--	D	
13M1	I. Sharp	2,110	450	6	--	--	--	--	--	--	--	D	Two homes.
17D1	N.T. King	2,500	243	6	--	--	153r	--	.25	--	--	D	
18D1	Feezell Farm	2,040	160	6	--	--	60r	--	--	--	--	D	
19J1	R.R. Roberts (Chesley)	2,450	210	6	--	--	160r	--	6	--	--	D	
23B1	I. Sharp	2,120	1,000	10,6	at 350	basalt	320	--	1b	30/1 hr	.03	D	G; L; temp 52°F.
32D1	W.A. Johnson	2,405	140	--	--	--	--	--	11	--	--	D	
7/23-36R1	Chesley property, for Wash. Dept. Natural Resources	950	806	20,16	--	basalt	F(+92)	10/ 2/77	1780	--	--	I	G; L; 40 psi shut-in pressure
7/24- 6R1	Horrigan Farms	1,492	457	8	--	--	450	--	--	--	--	D	
8D1	do.	1,450	1,092	6	--	--	868	1/19/78	--	--	--	D	G.
17D1	Z. Young	1,300	437	6	--	--	190r 250r	"years ago" 1977	--	--	--	D	
7/25- 3A1	G. Bayne	1,000	360	6	--	--	80r	--	10	--	--	D	
35D1	Dr. Palmer	800	1,090	16	--	--	400	--	1,800	"little"	--	I	
36F1	J. Barber #2	753	867	18,16, 12	460-570, 800-820, 855-867	--	390	4/ 4/78	--	--	--	I	G.
36N1	Washington Dept. Ecology	730	860 236 736 825	10,8,6 1 1 1	(See table 17)	basalt sedimentary rocks	134 -- 374 373	11/--/72 -- 11/--/72 11/--/72	-- -- 690 650	-- -- 12 4	-- -- 58 163	T	Test observation well; three piezometers record water levels at three zones; G; L; temp. 71°F.
36N2	J. Barber property, for Wash. Dept. Natural Resources	730	860	18,16,8	70-85, 814-860	clay basalt	372 390	9/24/76 4/4/78	2,232	32/9 hrs	70	I	L.
7/26- 5B1	J. Moon	1,130	1,061	10,8	609-966: at 648, 655, 902, 966	basalt	403 607(after deepening from 780 to 1,061 ft)	4/17/69	162	97/8 hrs	1.67	I	Well deepened after 1969, water level dropped; L; G.
6J1	H.M. Travis	1,080	200	6	--	--	183r	--	3	--	--	D	
14B1	Anderson	1,100	350	6	--	--	225	--	--	--	--	D	
17A1	C.W. Bybee	1,020	350	8	--	--	300r	--	25	--	--	D	
28P1	R. Munn	960	684	8,6	673-684	basalt	--	--	--	--	--	D	L.
28R1	Sunheaven Farms	990	192	6	--	--	160r	--	--	--	--	D	
30A1	S. Moon	925	279	6	--	basalt	--	--	10	--	--	D	
7/27-17A1	B. Hartley	1,390	280	8	260-280	basalt	260r	--	--	--	--	D	
17A2	do.	1,385	700	8	--	basalt	--	--	--	--	--	D	
17N1	B. Schulteis	1,300	305	37,8	267-298	basalt	--	--	--	--	--	D	L.

TABLE 16.--Records of tables - cont.

Well no.	Owner or tenant	Alt. (ft)	Depth (ft)	Diam. (in)	Aquifer depth interval (ft)	Aqufier depth Material	SWL	Date	Yield (gal/min)	Drawdown (ft/hrs)	Specific capacity (gal/min/ft)	Use	Remarks; other data
7/27-28H1	Prior Land Co.	1,196	520	--	--	basalt	--	--	6.5	--	--	S	
29Q1	D. Prior	1,150	575	8	--	--	170	1/17/73	7	145/1 hr	.05	D	L; deepened from 157 ft.
36A1	Wash. Dept. Ecology	1,080	1,200	10	--	--	--	--	--	--	--	T	Dry hole.
7/29-23G1	H. Owens	1,800	475	--	--	--	175r	--	--	--	--	D	Pumps dry in 1 hr; hauls water.
28L1	Unknown	1,320	25	72	--	--	15.16	5/12/77	--	--	--	U	
7/30-29A1	Ebey Ranch	1,510	1,100	6	--	--	700	--	2	--	--	U	Lost water at 1,100 ft; abandoned, hauls water.
8/24-32R1	L. Beightol	1,510	898	8	at 500	--	872	--	3	--	--	D	Lost water when deepened.
35A1	G. Bayne	1,400	711	--	320-487	basalt, shale, clay	--	--	--	--	--	D	L.
8/25-1Q1	R.C. Barr	1,380	750	8	--	--	400r	--	--	--	--	D	
21D1	K.C. Burkhart	1,300	423	6	--	--	200r	--	--	--	--	D	L.
29R1	E. Walker	1,120	330	8	325-330	--	150r	--	10	--	--	D	
35D1	J.F. Moon	1,020	150	6	--	basalt	97.8	5/11/77	--	--	--	D	
8/26-5N1	Ray Gould Farms	1,346	460	6	--	--	220r	--	--	--	--	U	
16C1	County Well	1,320	832	--	--	--	300	--	3.5	--	--	PS	
16C2	do.	1,320	630	--	--	--	--	--	--	--	--	PS	
20B1	S. M. Smith	1,260	425	6	--	basalt	366.2	5/10/77	--	--	--	D	
33F1	J.J. Smith	1,180	132	--	--	--	30	--	--	--	--	D	Also supplies neighbors.
33F2	do.	1,180	150	--	--	--	--	--	--	--	--	D	
8/27-32J1	Pearson	1,450	329	--	--	--	310	--	0.8	--	--	D	

TABLE 17.--Drillers' logs

Material	Thickness (ft)	Depth (ft)
3/17-2C1. William Claussen. Altitude about 2040 ft. Drilled by O'Leary Well Drilling Co., 1973. Casing: 6 inches to 45 ft.		
Clay, brown	14	14
Clay, black	15	29
Basalt, brown, vesicular	9	38
Basalt, black, with red claystone	5	43
Conglomerate, and brown, fractured vesicular basalt, brown shale, vesicular brown shale, and green claystone, all water-bearing	12	55
3/17-12P1. S. P. and S. RR. Altitude about 400 ft. Drilled by Strassar Drilling Co., 1966. Casing: 16 inches to 15 ft, 12 inches 0-64 ft, 10 inches 58-145 ft.		
Fill	2	2
Sand and some rock	10	12
Basalt, gray to black, broken at 132-138 ft, 165-172 ft, 194-196 ft, and 210-212 ft, water-bearing at 194-196 ft, 314-325 ft.	313	325
3/19-2A1. C. D. Kelley. Altitude about 1100 ft. Drilled by O'Leary Well Drilling Co., 1972. Casing: 6 inches to 25 ft.		
Boulders	5	5
Clay, brown	4	9
Sand and gravel	6	15
Gravel, fractured basalt, and shale	8	23
Basalt, gray, fractured, water-bearing	7	30
3/19-2G1. C. D. Kelley. Altitude about 1240 ft. Drilled by O'Leary Well Drilling Co., 1972. Dry hole, not cased.		
Clay, sand, and brown boulders	25	25
Sand, clay, and brown gravel	110	135
Shale, brown	5	140
Basalt, gray, vesicular	70	210
Claystone, brown, and blue clay	100	310
3/19-18B1. R. A. Wesley. Altitude about 1270 ft. Drilled by Duft Well Drilling Co., Casing: 8 inches to 110 ft.		
Sand, clayey	110	110
Basalt, gray, green, and black	85	195
3/19-20Q1. U.S. Army Corps of Engineers (Rock Creek Rec. Area). Altitude about 280 ft. Drilled by Hansen Drilling Co., 1974. Casing: 10 inches to 50 ft, 8 inches to 279 ft. Perforations: 87-128 ft, 250-278 ft.		
Dirt, brown, sandy	6	6
Basalt,gray, to black	81	87
Basalt, black and brown, broken, and green claystone	25	112
Rock, green and black, sandy, and cemented in places	16	128
Basalt, black, and green claystone	12	140
Basalt, gray to greenish gray	117	257
Basalt, brown, black, and gray, broken	4	261
Basalt, gray to black	24	285

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
3/20-7E1. Horace White. Altitude about 780 ft. Drilled by H. T. Leonard, 1954. Casing: 10 inches to 39 ft.		
Soil	15	15
Rock, broken	35	50
Basalt, black, broken	40	90
Basalt, gray, soft	13	103
Basalt, water-bearing: Water level 20 ft	12	115
Clay, yellow	6	121
Clay, green	2	123
Basalt, broken, soft	16	139
Basalt, gray, hard	31	170
Basalt, gray, soft	13	183
Basalt, gray, hard	25	208
Basalt, black, soft Lost water at 210 to 212 ft, regained water in 30 min.	23	231
Basalt, black, hard	3	234
Basalt,	22	256
Clay, yellow	2	258
Basalt, black, soft	6	264
Basalt, black, hard	1	265
3/20-21L1. Sundale Orchards. Altitude about 320 ft. Drilled by O'Leary Well Drilling Co., 1975. Casing: 12 inches to 18 ft, 8 inches 0-30 ft.		
Sand, fine	3	3
Gravel, coarse	26	29
Basalt, gray	42	71
Basalt with shale seams, water-bearing	27	98
Basalt	67	165
Basalt, black, vesicular, water-bearing	45	210
Basalt, with some fractures	85	295
Basalt, gray	43	338
Basalt, black, fractured	4	342
Basalt, gray, with fractures, water-bearing	44	386
3/20-21Q1. Sundale Orchards, Inc. Altitude about 280 ft. Drilled by Duft Drilling Co. to 239 ft and completed by L. J. Storey Drilling Co., 1964. Casing: 12 inches to 70 ft.		
Sand and rock; some water 20-57 ft	57	57
Basalt	168	225
Basalt, fractured; water-bearing	2	227
Basalt, gray	24	251
Basalt, red, water-bearing	19	270
Basalt, gray	2	272
3/20-21Q2. Sundale Orchards, Inc. Altitude about 280 ft. Drilled by H. T. Leonard, 1952. Casing: 12 inches to 28 ft.		
Sand and rock	30	30
Basalt, gray, blue, and black	148	178
Basalt, black, water-bearing	14	192
Basalt, gray, medium to hard	78	270

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
3/21-9L1. U.S. Army Corps of Engineers. Altitude about 300 ft. Drilled by Jungmann Drilling Co., 1966. Casing: 14 inches to 15 ft, 10 inches 0-65 ft, 8 inches 162-184 ft; perforated 170-182 ft.		
Gravel and clay	2	2
Basalt, brown, broken	2	4
Basalt, gray	11	15
Basalt, black	34	49
Basalt, broken, mud	13	62
Basalt, black	30	92
Basalt, gray, hard	84	176
Basalt, black, soft, water at 176 ft	16	192
3/21-9N1. North Roosevelt Water Assn. altitude about 300 ft. Drilled by Duft Well Drilling Co. casing: 8 inches to 24 ft.		
Topsoil	2	2
Rock, broken	2	4
Basalt, gray, hard	51	55
Basalt, black, soft, porous	10	65
Basalt, black, hard	16	16
3/21-9N2. North Roosevelt Water Assn. Altitude about 300 ft. Drilled by Duft Well Drilling Co. Casing: 8 inches to 23 ft.		
Topsoil	2	2
Rock, broken	3	5
Baslat, gray	52	57
Basalt, black, soft, porous	16	73
Basalt, black, hard	15	88
3/21-17F1. Roosevelt Water Assn. Altitude about 350 ft. Drilled by Storey Drilling Co., 1961. Casing: 6 inches to 50 ft.		
Dirt	2	2
Basalt, gray: fractured 7-10 ft, 65-75 ft	128	130
Basalt, brown	10	140
Basalt, gray, hard	50	190
Basalt, black, and brown shale	10	200
Basalt, black, fractured, water-bearing	23	223
3/21-18J1. Norm Goree. Altitude about 375 ft. Drilled by O'Leary Well Drilling co., 1972.		
Basalt, black, vesicular	203	203
Basalt, gray	21	224
Basalt, gray, vesicular	26	250
4/17-2P1. Eleanor Dooley. Altitude about 2180 ft. Drilled by Gorge Contractors, Inc. (K. L. O'Leary), 1969. Casing: 6 inches to 5 ft.		
Topsoil	3	3
Basalt, some fractured	72	75
Shale, brown	3	78
Basalt, water-bearing at 82 ft	4	82
Slate and petrified wood	13	95
Claystone, blue, and gray basalt	6	101
Basalt	207	308

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
4/17-9F1. K. L. O'Leary. Altitude about 2410 ft. Drilled by owner. Casing: 6 inches to 131 ft.		
Clay, brown	3	3
Basalt and seams of shale	46	49
Cinder, red, and clay and brown shale	64	113
Basalt, vesicular, and shale and clay	13	126
Basalt, some fractures	194	320
Basalt, heavily fractured, and shale	20	340
Basalt, gray	15	355
4/17-9P1. O'Leary Well Drilling Co. Altitude about 2240 ft. Drilled by owner, 1973. Casing: 6 inches to 169 ft.		
Clay and shale	43	43
Shale and basalt	16	59
Basalt, gray	93	152
Clay, brown and black	12	164
Basalt, gray	368	532
Basalt, black, vesicular, water-bearing	22	554
4/17-10E1. Kenneth Demings. Altitude about 2270 ft. Drilled by O'Leary Well Drilling Co., 1975. Casing: 6 inches to 30 ft.		
Clay, brown	10	10
Clay, white, and brown shale	19	29
Basalt, with claystone seams	88	117
Basalt, with some fractures	225	342
Basalt, with voids	41	383
Basalt, with some fractures	337	720
Basalt, vesicular, and green claystone	21	741
Basalt, gray	19	760
Basalt, black vesicular, fractured, and green claystone, water-bearing	8	768
Basalt, gray	7	775
4/17-10P1. L. M. Moore. Altitude about 2170 ft. Drilled by O'Leary Well Drilling Co., 1975. Casing: 6 inches to 19 ft.		
Clay, brown, and brown shale	7	7
Basalt, gray	53	60
Basalt, black, vesicular, and green claystone; water-bearing	35	95
Basalt, gray	199	294
Basalt, black, vesicular	11	305
Basalt, gray	138	443
Basalt, gray, vesicular	16	459
Basalt, gray	1	460
4/17-22A1. F. L. Sanders. Altitude about 1985 ft. Drilled by O'Leary Well Drilling Co., 1975. Casing: 6 inches to 19 ft.		
Clay and shale, brown	5	5
Basalt and shale, brown	95	100
Basalt, gray, fractured	135	235
Basalt, black, vesicular, water-bearing	26	261
Basalt, gray	4	265

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
4/17-22N1. Fenton Bros. Altitude about 1990 ft. Casing: 6 inches to 41 ft.		
Clay	39	39
Rock, porous	2	41
4/17-23F1. J. D. Dumm. Altitude about 1960 ft. Drilled by O'Leary Well Drilling Co., 1975. Casing: 6 inches to 28 ft.		
Clay, sandy	10	10
Clay and shale, brown	10	20
Shale, brown	3	23
Basalt, gray	47	70
Basalt, vesicular, with green claystone	7	77
Basalt, gray	111	188
Basalt, brown vesicular	8	196
Basalt, gray	16	212
Basalt, gray and brown	8	220
Basalt, gray	7	227
Basalt, brown, vesicular	9	235
Basalt, gray	15	250
4/17-28H1. Cecil Schuster. Altitude about 1940 ft. Drilled by O'Leary Well Drilling Co., 1973. Casing: 6 inches to 77 ft.		
Clay, boulders, and fractured brown basalt	72	72
Basalt, fractured, vesicular; some water	188	260
Basalt, gray	170	430
Basalt, gray, vesicular, some water	46	476
Basalt, gray	14	490
Basalt, black, vesicular, fractured, water-bearing	18	508
4/18-4N1. Holter Bros. Altitude about 2000 ft. Drilled by R. J. Murray, 1977. Casing: 6 inches to 28 ft.		
Soil	2	2
Conglomerate	10	12
Clay, gray	9	21
Basalt, brown	5	26
Basalt, gray, hard	7	33
Basalt, brown	10	43
Basalt, gray	67	110
Clay, brown, water-bearing (1 gal/min)	16	126
Basalt, gray	233	359
Basalt, brown, water-bearing (1 gal/min)	15	374
Basalt, gray	36	410
4/18-17K1. Cecil Schuster. Altitude about 1720 ft. Drilled by O'Leary Well Drilling Co., 1970. Casing: 10 inches to 116 ft.		
Clay, black	6	6
Basalt, vesicular, and clay	4	10
Clay, brown	7	17
Shale and clay	10	27
Basalt, partly fractured	61	88

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
4/18-17K1.--Continued		
Clay, yellow, black and brown	23	111
Basalt, vesicular, water-bearing	67	178
Basalt, gray, hard	1	179
Basalt, fractured	1	180
Basalt, gray, hard	3	183
Basalt, vesicular	4	187
Basalt, hard	13	200
4/18-17D1. Holter Bros. Altitude about 1830 ft. Drilled by R. J. Murray, 1977. Casing: 6 inches to 40 ft.		
Soil	2	2
Clay, dark brown	11	13
Basalt, broken, damp	9	22
Basalt, gray, hard	72	94
Rock, brown, and yellow clay	2	96
Basalt, gray	8	104
Clay, yellow	122	226
Basalt, brown	26	252
Basalt, gray, with "void" 154-156 ft	4	256
Basalt, gray, vesicular, water-bearing	96	352
4/18-29G1. R. R. Brack. Altitude about 1660 ft. Drilled by Riebe Well Drilling Co., 1968. Casing: 10 inches to 83 ft, 8 inches 98-138 ft.		
Soil, sandy clay	2	2
Clay, brown, hard, and boulders	9	11
Clay, gray, and gravel and boulders; water at 83 ft	72	83
Basalt, gray, hard, creviced	67	150
Clay, yellow, and boulders with sand, gravel, broken basalt; water-bearing 160-170 ft	30	180
Basalt, gray, hard	40	220
Clay, brown, and boulders, broken basalt and shale with wood	57	277
4/20-3L1. Harland Berk. Altitude about 2225 ft. Drilled by King Well Drilling Co., 1970. Casing: 12 inches to 182 ft.		
Topsoil	4	4
Conglomerate	2	6
Basalt, brown, and clay	10	16
Basalt, broken	16	32
Boulders	70	102
Clay	8	110
Sandstone, soft	10	120
Sand	20	140
Sand and gravel	8	148
Clay	21	169
Clay and basalt	2	171
Sandstone, soft, water-bearing	6	177
Basalt, fractured	5	182
Basalt	20	202
Basalt, variegated	72	274

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
4/20-4D1. Berk Bros. Altitude about 2270 ft. Casing: 6 inches to 35 ft.		
Basalt, broken	60	60
Basalt	55	115
Clay	204	319
Basalt, water-bearing	16	335
4/20-18Q1. Bert Wilkins. Altitude about 2440 ft. Drilled by Gorge Contractors, Inc. (K. L. O'Leary), 1969. Casing: 6 inches to 19 ft.		
Topsoil	2	2
Clay, brown, and hardpan	10	12
Basalt, vesicular	33	45
Basalt, partly fractured	62	107
Basalt, fractured, and some yellow claystone	12	119
Clay, yellow soft	16	135
Sand, and layers of yellow clay	39	174
Claystone, yellow, soft	18	192
Claystone, bluish green, soft	13	205
Clay, gray	48	253
4/20-20Q1. Bob Powers. Altitude about 2220 ft. Drilled by O'Leary Well Drilling Co., 1973. Casing: 6 inches to 119 ft.		
Clay, brown and blue	110	110
Basalt, gray, vesicular and fractured, water-bearing	37	147
Basalt, gray	28	175
4/24-3A1. S., P., & S. RR. Altitude about 305 ft. Drilled by W. R. Ille Drilling Co., 1966. Casing: 16 inches 0-45 ft, 12 inches 0-85 ft, 8 inches 160-363 ft; screen 380-395 ft.		
Sand and gravel	85	85
Breccia	20	105
Basalt	135	240
Clay, blue	20	360
Basalt	25	385
Basalt, vesicular, water-bearing	13	398
5/17-23G1. Trans West Co. Altitude about 2560 ft. Drilled by O'Leary Well Drilling co., 1970. Casing: 6 inches to 54 ft.		
Clay, brown, sandy	2	2
Clay and hardpan, brown	7	9
Sandstone and brown clay	2	11
Basalt, fractured	27	38
Clay, white	3	41
Basalt, fractured, and seams of clay	9	50
Basalt, gray and brown, vesicular; water-bearing	13	63
Basalt, fractured	51	114
Basalt, gray	162	276
Basalt, vesicular and seams of green claystone	20	296
Basalt, fractured	64	360
Basalt, gray	10	370

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/20-9A1. Harmon Hooker. Altitude about 2780 ft. Drilled by O'Leary Well Drilling, Inc., 1971. Casing: 6 inches to 19 ft.		
Clay, brown	3	3
Basalt, gray and brown	28	31
Basalt, brown, fractured	13	44
Basalt, gray	36	44
Basalt, gray, fractured, water-bearing	16	96
Basalt, gray	19	115
Sandstone and brown claystone	9	124
Sandstone, brown, water-bearing	21	145
5/20-28B1. Berk Bros., Inc. Altitude about 2495 ft. Drilled by King Well Drilling co., 1969. Casing: 8 inches to 146 ft.		
Dirt	3	3
Basalt, brown and gray	96	99
Clay and basalt	12	111
Basalt	4	115
Sandstone, soft	23	138
Gravel, cemented	6	144
Basalt, black	24	168
Basalt, broken, water-bearing	8	176
Basalt, black and gray	36	212
Basalt, gray, and green shale	3	214
Basalt, gray, water-bearing 242-263 ft	48	263
Basalt, green, and shale	23	286
Shale, green	12	298
Basalt, porous, soft, and shale, water-bearing	13	311
Basalt, gray	19	330
5/20-28R1. Berk Bros., Inc. Altitude about 2400 ft. Drilled by King Well Drilling, 1970. Casing: 10 inches to 110 ft, 8 inches 220-300 ft; completed at 390 ft.		
Dirt	3	3
Boulders, some water	91	94
Shale	25	119
Clay	6	125
Clay and basalt	20	145
Basalt	43	188
Basalt, clay, and shale	11	199
Basalt	44	243
Basalt	30	273
Clay and shale	33	306
Shale, green	5	311
Basalt, water-bearing	10	321
Basalt and shale	14	335
Basalt	65	400
Basalt, broken; water-bearing	8	408
(No cuttings)	2	410
5/21-3J1. Tom Gray. Altitude about 2345 ft. Drilled by Gorge Contractors, Inc., 1968. Casing: 6 inches to 20 ft.		
Topsoil	2	2
Shale	17	19
Basalt	31	50
Shale, brown	8	58
Basalt	47	105

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/21-3J1.--Continued		
Cinder	1	106
Shale, brown	4	110
Basalt, fractured	93	203
Basalt, fractured, water-bearing	4	207
5/22-27P1. John Renta. Altitude about 1100 ft. Drilled by L. & L. Drilling Co., 1976. Casing: 12 inches to 343 ft, 8 inches 546-630 ft.		
Topsoil	2	2
Basalt, brown, broken	51	53
Clay, brown	90	143
Basalt, gray, hard	125	268
Clay, blue	57	325
Sand	11	336
Clay, blue	6	342
Basalt, brown, broken	8	350
Basalt	204	554
Basalt, black, water-bearing	14	568
Clay, green	37	605
Basalt, black and gray	154	759
Basalt, brown, broken, water-bearing	8	767
Basalt, gray, hard	3	770
Basalt, brown, broken, water-bearing	17	787
5/23-3A1. R. J. Petersen. Altitude about 716 ft. Drilled by Henry Bach, 1956. Casing: 6 inches to 36 ft.		
Gravel	26	26
Clay, blue, sandy	14	40
Basalt, black	40	80
Sand, water-bearing	1	81
5/23-3A2. R. J. Petersen. Altitude about 716 ft. Drilled to 250 ft by Storey Drilling co., 1966, deepened by Crowe Drilling Co., 1969. Casing: 12 inches to 58 ft, 10 inches 0-79 ft, 8 inches 226-321 ft. Perforations: 27-29 ft. 225-240 ft, 278-321 ft.		
Topsoil and gravel	50	50
Clay, yellow	5	55
Basalt, black	15	70
Basalt, black, fractured, water-bearing	10	80
Basalt, gray	155	235
Basalt, fractured	5	240
Clay, blue	42	282
Sandstone, white	16	298
Basalt, black, and blue clay	17	315
Basalt, black, porous	6	321
Basalt, black, and blue clay	51	372
Cinders, red	7	379
Basalt, black, fractured	33	412
Sandstone, white	4	416
Basalt, black and gray	55	471
Basalt, black, porous	14	485
Clay, blue	90	575
Well filled back with clay to finished depth of 555 ft.		

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/23-3L1. R. J. Petersen. Altitude about 825 ft. Drilled by Elmer Altman, 1956. Casing: 8 inches to 132 ft.		
Soil	1	1
Basalt	57	58
Clay and boulders	9	67
Clay and some gravel, loose	13	80
Clay, gray and blue	45	125
Basalt, black, broken	7	132
Basalt, hard	15	147
Basalt, broken	3	150
5/23-3L2. R. J. Petersen. Altitude about 825 ft. Drilled by Aqua Drilling and Development, Inc., 1976. Casing: 12 inches to 16 ft, 10 inches 0-150 ft.		
Silt	15	15
Basalt, broken	65	80
Clay, gray	55	135
Basalt, broken	15	150
Basalt, hard	110	260
Basalt, porous	5	265
Basalt, medium hard	18	283
Basalt, porous	5	288
Basalt, medium hard	12	300
Basalt, porous	13	313
5/23-29D1. Clarence McBride. Altitude about 870 ft. Drilled by 1977. Casing: 16 inches to 875 ft.		
Topsoil, caliche, and dirt	66	66
Basalt, black	85	151
Clay	16	167
Basalt, black	3	170
Clay and broken basalt	56	226
Basalt, red, soft	11	237
Basalt, black, medium	48	285
Basalt, hard	102	387
Basalt, brown, soft	1	388
Clay, yellow, brown, and green	132	520
Basalt, black and gray, hard	252	772
Clay	25	797
Basalt, black, hard	18	815
Basalt	60	875
5/23-30M1. Clarence McBride. Altitude about 860 ft. Drilled by E. E. Luhdorff Co., 1978. Casing: 22 inches to 730 ft, 14 3/4 inches to 843 ft.		
Topsoil, yellow and brown, soft	12	12
Basalt, black, weathered	17	29
Basalt, black, hard	13	42
Basalt, black, broken	18	60
Basalt, black, hard	40	100
Clay, white, soft	19	119
Basalt, black, broken, with clay	11	130
Clay, blue, sandy and soft	15	145
Clay, blue, hard	21	166
Basalt, broken, with clay	12	178

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/23-30M1.--continued		
Basalt, black and gray	24	202
Basalt, black and hard	22	224
Basalt, black, hard, and gray	72	296
Basalt, gray, hard	12	308
Basalt, black	16	324
Basalt, black, water-bearing	16	340
Clay, blue, and fractured basalt	15	355
Clay, blue, and streaks of black and brown basalt	55	410
Clay, blue, and streaks of soft basalt	12	422
Clay, blue, hard	2	424
Basalt, black, hard	6	430
Basalt, brown	10	440
Basalt, black, medium hard	55	495
Basalt, black, hard	50	545
Basalt, black, and streaks of clay	9	554
Basalt, gray	8	562
Shale, green, hard	5	567
Basalt, gray hard, fractured	18	585
Basalt, black, hard	26	611
Clay, blue	4	615
Basalt, black	6	621
Clay, blue	15	636
Clay with broken rock	48	684
Clay, with streaks of basalt	13	697
Basalt, black, soft	28	725
Basalt, black, medium hard, broken	66	791
Basalt, black, hard	2	793
Basalt, black, fractured, water-bearing (Air pressure jumped 150 to 390 psi, artesian water encountered)	--	--
Basalt, black, hard	14	807
Basalt, black, fractured	5	812
Basalt, black, hard	31	843
5/24-28A1. Three Wells Farms. Altitude about 490 ft. Drilled by Hansen Drilling Co., 1974. Casing: 12 inches to 183 ft, 10 inches 177-264 ft. Perforations: 203-208 ft, 218-228 ft, 238-264 ft.		
Dirt, brown, sandy, and rocks	8	8
Basalt, broken, and claystone	15	23
Basalt, broken	44	67
Sandstone, broken	10	77
Basalt, broken	13	90
Clay	45	135
Shale, reddish gray, and broken basalt	5	140
Basalt, broken, and brown clay	30	170
Basalt	20	190
Basalt, broken	41	231
Basalt, broken, and clay binder	7	238
Basalt, broken	34	272
5/25-22M1. Fred Milliman. Altitude about 400 ft. Drilled by Ralph Storey.		
Basalt, broken	73	73
Clay	63	136
Basalt, decomposed	10	146
Basalt, gray, hard	180	326
Basalt, decomposed, water-bearing	4	330
Clay	6	336

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/25-29B1. Sandpiper Land Co. Altitude about 460 ft. Drilled by Larry Burd Well Drilling Co., 1974. Casing: 8 inches to 18 ft. 6 inches to 157½ ft.		
Sand and boulders	4	4
Basalt, gray and brown	106	110
Clay, brown, soft	46	156
Basalt, gray, hard	69	225
Basalt and soapstone, water-bearing	10	235
Basalt, gray	65	300
Basalt, gray, and blue sandstone	10	310
Basalt, gray	40	350
5/25-29N1. Sandpiper Land Co. Altitude about 325 ft. Drilled by Burd Well Drilling Co., 1975. Casing: 6 inches to 20 ft.		
Sand and boulders	13	13
Basalt, gray, red, brown, black	97	110
Clay, gray	22	132
Basalt, gray	14	146
Clay, gray	29	175
Basalt, brown and white, and blue and gray clay	50	225
Basalt, black	6	231
Basalt, brown and white, and blue and gray clay	14	245
5/26-5D1. G.T. Powers. Altitude about 630 ft. Drilled by Storm Drilling Co., 1976. Casing: 16 inches to 18 ft, 12 inches to 370 ft, 9½ inches 508-645.		
Silt	9	9
Basalt, reddish brown, vesicular, fractured	11	20
Basalt, black	52	72
Basalt, dark gray, scoriaceous, fractured	16	88
Siltstone and claystone, some water	20	108
Basalt, dark gray, vesicular, fractured, water bearing	13	121
Basalt, black	158	279
Siltstone and claystone, and gravel; water-bearing	23	302
Siltstone, green, water-bearing	45	347
Siltstone and gravel, water-bearing	13	360
Basalt, fractured	23	383
Basalt	166	549
Siltstone and sandstone	50	599
Basalt, fractured, water-bearing	11	610
Basalt, dense	92	702
Basalt, vesicular, fractured	14	716
Basalt, black	118	834
Basalt, vesicular, fractured	14	848
Basalt, dense	101	949
Basalt, blue-gray, vesicular, fractured, water-bearing	25	974
Basalt, black, dense	28	1002

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/26-5N1. Town of Paterson. Altitude about 437 ft. Drilled by Moore and Anderson, 1964. Casing: 10 inches to 157 ft.		
Sand and gravel	9	9
Basalt, brown and gray	87	96
Clay, brown and blue	51	147
Gravel and clay	8	155
Basalt, gray and brown	171	326
Clay, gray, rocky	8	334
Shale, blue	20	354
Caved back to 347 ft after pumping.		
5/26-7B1. Paterson School District 50. Altitude about 440 ft. Drilled by Crowe Drilling Co., 1967. Casing: 8 inches to 148 ft.		
Sand	2	2
Basalt, brown and black, broken	20	22
Basalt, black, hard	56	78
Basalt, brown and black, fractured and honeycombed	24	102
Clay, brown and blue	22	124
Pumice, water-bearing (15 gal/min)	4	128
Clay, blue	19	147
Basalt, fractured	22	169
Basalt, gray, hard	160	329
Basalt, broken, honeycombed, and cinders, water-bearing (60 gal/min)	13	342
Clay, blue	5	347
5/26-8G1. S.P. & S. RR. Altitude about 300 ft. Drilled by R. J. Strasser, 1947. Casing: 6 inches to 108 ft.		
Topsoil and clay	5	5
Rock, granite (?)	20	25
Basalt, black and gray	13	38
Shale, dark gray and light green	59	97
Basalt, black and red	2	99
Shale, dark gray	6	105
Basalt, black	20	125
Basalt, gray, soft, water-bearing	5	130
Basalt, gray	13	143
5/27-4C1. Prior Land Co. Altitude about 410 ft. Drilled by Moore and Anderson, 1965. Casing: 10 inches to 140 ft.		
Sand	4	4
Basalt	81	85
Basalt, black, soft	5	90
Clay, blue	37	127
Clay, brown, and brown basalt	9	135
Clay, blue	4	139
Basalt, gray	155	294
Basalt, brown, water-bearing	4	298
Clay	22	320

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/27-8Q1. Joe Christy. Altitude about 370 ft. Drilled by Allison Drilling Co. (year not indicated). Casing: 8 inches to to 137 ft.		
Soil	4	4
Boulders	4	8
Gravel, cemented	92	100
Sand and gravel, water-bearing	37	137
5/27-9A1. Prior Land Co. Altitude about 395 ft. Driller not indicated. Casing: 10 inches to 161 ft.		
Sand and gravel	161	161
Basalt	115	276
5/27-9P1. Joe Christy. Altitude about 300 ft. Drilled by Hunter Enterprize, 1973. Casing: 20 inches to 80 ft.		
Soil	4	4
Boulders	2	6
Gravel, cemented	29	35
Sand and gravel	45	80
5/27-11M1. El Paso Natural Gas Co. altitude about 300 ft. Drilled by W. R. Ille and Co., 1956. Casing: 8 inches to 40 ft.		
Sand and gravel	40	40
Basalt, dense	36	76
Interbed (?)	34	110
Basalt	262	372
5/28-5D1. Coffin Sheep Co. Altitude about 500 ft. Drilled by Ben Dreyer Drilling Co., 1963. Casing: 8 inches to 116 ft.		
Soil, sandy	63	63
Clay, white, sandy	57	120
Basalt, gray, hard	154	274
Basalt, black, soft	10	284
Clay, green	51	335
Basalt, black	35	370
Boulders	48	418
Basalt, brown, water-bearing	6	424
Sand, black, water-bearing	4	428
Basalt, brown	12	440
Basalt, black, hard	15	455
5/28-6R1. Burlington Northern RR. Altitude about 325 ft. Drilled by N. C. Jannsen Drilling Co., 1951. Casing: 10 inches to 288 ft, 8 inches to 556 ft, perforated 505-525 ft.		
Sand	10	10
Gravel	10	20
Gravel and boulders	51	71
Basalt	160	231
Clay, blue, and quicksand	81	252
Shale	38	290
Basalt	127	417
Basalt, soft, water-bearing	5	422
Basalt	8	430
Basalt and shale	38	468
Basalt	79	547
Basalt, broken, and blue clay	9	556

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
5/28-7A1. B. F. Craig. Altitude about 290 ft. Drilled by Allison Drilling Co., 1975. Casing: 6 inches to 56.6 ft.		
Sand, brown	5	5
Clay and gravel	20	25
Sand and gravel	26	51
Basalt, black, broken	30	81
5/28-7F1. Beeler. Altitude about 300 ft. Drilled by F. A. Haden. Casing: 8 inches to 74 ft.		
Sand, grayish brown, silty	2	2
Gravel, coarse, loose	8	10
Silt, compact	1	11
Sand, fine, and some loose gravel	26	37
Gravel, cemented	13	50
Sand, fine to coarse, water-bearing	4	54
Gravel, coarse, and some sand, water-bearing	19	73
Sand, fine	1	74
Basalt	5	79
Basalt, broken, and loose rocks, water-bearing	8	87
Basalt, hard, and some softer basalt	88	175
Basalt, vesicular, water-bearing	17	192
5/28-7B1. B. M. Doyle. Altitude about 280 ft. Driller not indicated.		
Soil, sandy loam	8	8
Gravel	2	10
Gravel, water-bearing	16	26
5/28-8D1. S., P., & S. RR. Altitude about 280 ft. Driller not indicated. Casing: 12 inches to 47 ft, 10 inches 43-50 ft.		
Gravel	47	47
Basalt	9	56
Coal	3	59
Sand and gravel, water-bearing	13	72
Basalt	23	95
5/28-8D2. S., P., & S. RR. Altitude about 280 ft. Driller not indicated. Casing: 12 inches to 49 ft, 8 inches 195-427 ft, 6 inches 0-545 ft.		
Gravel	49	49
Basalt	146	195
Mud, blue	45	240
Basalt, gray and black	160	400
Mud, blue	22	422
Sand, green	8	430
Shale, blue	72	502
Basalt, gray, hard	90	592
Basalt, red and black, soft	37	629

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/20-4N1. J. C. Ingram. Altitude about 3240 ft. Drilled by O'Leary Well Drilling, Inc., 1971. Casing: 6 inches to 35 ft.		
Clay, brown	10	10
Clay, brown, and shale	8	18
Shale, vesicular, and brown clay, water-bearing	9	27
Shale, brown, hard	7	34
Basalt, gray, fractured	8	42
Shale and clay, brown	1	43
Basalt, fractured	12	55
Shale, brown	7	62
Shale, brown, and green claystone	12	74
Basalt, fractured	15	89
Basalt, gray, vesicular, and green claystone, water-bearing	14	103
Basalt, fractured	27	130
6/20-13H2. F. H. Naught. Altitude about 2862 ft. Drilled by Gorge Contractors, Inc., 1969. Casing: 6 inches to 25 ft.		
Clay, hard	5	5
Basalt, brown	3	8
Clay, brown	11	19
Clay and red basalt	2	21
Clay and shale	2	23
Basalt	3	26
Basalt, fractured, water-bearing (2 gal/min)	2	28
Basalt, blue	15	43
Basalt, fractured, and seams of blue claystone	37	80
Basalt, gray	25	105
Basalt, fractured, and seams of blue claystone	46	151
Basalt, vesicular	4	155
Basalt	9	164
Basalt, blue, fractured	14	178
Basalt, blue and gray	194	372
Sandstone, water-bearing (58 gal/min)	3	375
6/20-15N1. R. J. Rupp. Altitude about 3030 ft. Drilled by O'Leary Well Drilling, Inc., 1974. Casing: 6 inches to 22 ft.		
Clay and boulders	11	11
Basalt, gray	124	135
Shale, brown	30	165
Basalt, gray, fractured	40	205
6/20-17H1. E. R. Nelson. Altitude about 3250 ft. Driller not indicated. Casing: 6 inches.		
Gravel, cemented	60	60
Basalt, water-bearing	65	125
6/20-21A4. L. D. Whitmore. Altitude about 3030 ft. Drilled by O'Leary Well Drilling, Inc., 1974. Casing: 6 inches to 19 ft.		
Clay and shale, brown	15	15
Basalt, gray	119	134
Claystone, brown, and black gravel	37	171
Basalt, black	42	213
Basalt, vesicular, fractured, and shale	22	235

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/20-22D2. L. D. Whitmore. Altitude about 3002 ft. Drilled by O'Leary Well Drilling, Inc., 1974. Casing: 6 inches to 22 ft.		
Shale and clay, brown	9	9
Basalt, gray	17	26
Basalt, brown, vesicular, fractured	15	41
Basalt, gray	92	133
Basalt, vesicular, and brown shale; water-bearing	37	170
Basalt, gray	5	175
6/20-30Q4. Chet Shannon. Altitude about 3040 ft. Drilled by O'Leary Well Drilling, Inc., 1974. Casing: 6 inches to 63 ft.		
Clay, sand, and gravel, brown	22	22
Claystone, brown	36	58
Basalt, vesicular, and shale; water-bearing	27	85
6/20-30M1. Matsen Land co. Altitude about 3140 ft. Drilled by O'Leary Well Drilling, Inc., 1973. Casing: 6 inches to 19 ft.		
Clay and shale	16	16
Basalt, brown and gray	107	123
Basalt, gray, fractured, and green claystone	4	127
Basalt, vesicular	29	156
Claystone, white	13	169
Basalt, black, vesicular, water-bearing	7	176
Claystone, brown	1	177
Basalt, vesicular	13	190
6/20-36B1. Howard Colemen. Altitude about 2780 ft. Drilled by Gorge Contractors, Inc., 1969. Casing: 6 inches to 7 ft.		
Topsoil	5	5
Basalt, vesicular	10	15
Shale, brown, and yellow claystone	21	27
Basalt, gray and brown	89	116
Claystone, red and yellow	3	119
Claystone, red, and basalt	7	126
Basalt, blue, brown, and gray	210	336
Claystone, blue, green, and gray	29	365
Conglomerate, basalt, sandstone, and slate	10	375
Basalt, fractured	15	390
Sandstone, gray, hard	18	408
6/21-15L2. Laurence Giles. Altitude about 2565 ft. Drilled by O'Leary Well Drilling, Inc., 1973. Casing: 6 inches to 19 ft.		
Clay, brown, sandy	8	8
Basalt, black, fractured, and green claystone seams	199	207
Basalt, vesicular, fractured, water-bearing	13	220
6/21-19Q1. M. R. Matsen. Altitude about 2765 ft. Drilled by O'Leary Well Drilling, Inc., 1974. Casing: 6 inches to 53 ft.		
Clay, shale, and boulders	48	48
Basalt, gray	290	338
Basalt, gray, and green claystone	43	381
Basalt, brown, vesicular	11	392
Basalt, gray and black	308	700

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/21-19Q1.--Continued		
Basalt, vesicular, and black and white claystone	6	706
Basalt, gray	145	851
Basalt, black, fractured	5	856
Basalt, gray	9	865

6/21-31E1. Howard Coleman. Altitude about 2740 ft. Drilled by Gorge Contractors, Inc. Casing: 6 inches to 5 ft.

Material	Thickness (ft)	Depth (ft)
Topsoil	3	3
Basalt, gray	75	78
Shale, brown	2	80
Basalt, black	32	112
Basalt, and blue-green clay seams	90	202
Basalt, porous	6	208
Basalt, fractured, and green clay seams	26	234
Basalt, gray	6	240
Basalt, porous	17	257
Basalt, black	54	311
Claystone, blue-gray	40	351
Basalt, black, and blue claystone	7	358
Shale, brown	8	366
Basalt and green claystone	19	385
Claystone, blue and green	7	392
Basalt, gray	23	415

Well filled back to 315 ft.

6/23-11Q1. Bob Andrews. Altitude about 1000 ft. Drilled by Moore and Anderson, 1957. Casing: 8 inches to 150 ft.

Material	Thickness (ft)	Depth (ft)
Soil	7	7
Gravel and boulders	69	76
Clay, pink	15	91
Basalt, brown, and boulders	55	146
Basalt, gray	8	154
Basalt, light yellow, water-bearing	54	208

6/23-11Q2. Bob Andrews. Altitude about 1020 ft. Drilled by Moore and Anderson, to 670 ft in 1959, and to 892 ft in 1970. Casing: 12 inches to 155 ft, 7-inch liner 485-560 ft.

Material	Thickness (ft)	Depth (ft)
Topsoil	7	7
Gravel and boulders	25	32
Basalt, green	39	71
Clay, blue and pink	41	112
Basalt, brown, black, gray, and red	373	485
Mud, blue and green	68	553
Basalt, gray	101	654
Basalt, brown, water-bearing	16	670
Basalt, gray; water level at 120 ft	68	738
Basalt, gray; water level at 80 ft	62	800
Basalt, gray; water level at 58 ft	35	835
Basalt, gray; water flowing from well	20	855
Basalt, gray	22	877
Basalt, black and brown; flow 2500 gal/min at 887 ft	12	889
Basalt, gray	3	892

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/23-15H1. Bob Andrews. Altitude about 1050 ft. Drilled by Moore and Anderson to 633 ft in 1968, and to 950 ft in 1971. Casing: 12 inches to 128 ft, 10 inches 268-323 ft, 8 inches 440-560 ft.		
Topsoil	3	3
Hardpan	2	5
Basalt, brown, gray, black, and greenish-gray	77	82
Shale, gray, and clay	29	111
Basalt, black and gray	175	286
Basalt, gray-brown, and clay	7	293
Clay, yellow	10	303
Basalt, brown; water level at 101 ft	48	351
Basalt, black and gray	26	377
Basalt, black, water-bearing; water level at 103 ft	28	405
Basalt, black, water level at 77 ft	178	583
Basalt, brown; water level at 45 ft	5	588
Basalt, brown and black; water level at 37 ft	5	593
Basalt, brown and black; water level at 14 ft	2	595
Basalt, black; water level raised from 11 to 1 ft	29	624
Basalt, gray	34	658
Basalt, black; water flowing	17	675
Basalt, gray; flowing 500 gal/min	163	838
Basalt, black; flowing 2200 gal/min	100	938
Basalt, gray	12	950
6/23-22J1. Bob Andrews. Altitude about 982 ft. Drilled by Maddox and Moore, Inc., 1976. Casing: 12 inches to 800 ft, 10 inches to 1069 ft.		
Topsoil	5	5
Caliche	1	6
Basalt, brown and black	64	70
Basalt, black and brown, and hard brown clay	1	71
Basalt, black and brown	26	97
Basalt, black, and clay	7	104
Basalt, brown and blue, and clay	32	136
Basalt, black and brown	12	148
Basalt, black and brown, and clay	13	161
Basalt, black, gray, and brown	131	292
Basalt, brown, and yellow clay and caliche	59	351
Basalt, black	4	355
Basalt, black, broken, and clay	10	365
Basalt, gray	120	485
Basalt, black, broken	10	495
Basalt, gray	15	510
Basalt, black, broken, and a little clay	9	519
Basalt, gray and black	9	528
Basalt, black and pumice	3	531
Basalt, black, and gray soft to hard	69	600
Basalt, and clay	10	610
Basalt, black, hard to soft	196	806
Basalt, and green clay	9	815
Basalt, black to gray	254	1069

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/23-24N1. Bob Andrews. Altitude about 870 ft. Drilled by Moore Drilling Co., Inc., 1977. Casing: 16 inches to 552 ft, 10 inches to 965 ft.		
Topsoil	7	7
Caliche	1	8
Basalt, black, soft	2	10
Basalt, black, hard	55	65
Basalt, brown, soft, and dirt	8	73
Basalt, black, hard	14	87
Basalt, brown, soft	8	95
Sandstone, yellow and brown	21	116
Clay, blue	4	120
Clay, red	5	125
Clay, blue	7	132
Basalt, brown, soft	13	145
Basalt, black, soft	63	208
Basalt, black, hard	89	297
Clay, yellow	19	316
Clay, green	34	350
Basalt, black, hard	136	486
Basalt, black, broken and clay	2	488
Basalt, black, hard	47	535
Basalt, black, medium, broken	2	537
Basalt, black, hard	31	568
Clay and sandstone	62	630
Basalt, black, soft	4	634
Basalt, black, hard	5	639
Basalt, black broken, and clay seams	11	650
Basalt, gray, hard	90	740
Basalt, brown soft	5	745
Basalt, black, broken	3	748
Basalt, gray, hard	139	887
Basalt, black, hard	23	910
Basalt, gray, hard	17	927
Basalt, black, soft	37	964
Basalt, black, hard	1	965
6/26-9L1. Prior Land Co. Altitude about 820 ft. Drilled by Moore and Anderson, 1946. Casing: 6 inhces to 24 ft.		
Dirt	16	16
Basalt, gray-geeen, gray, and blue-black with crevices 60-80 ft	223	239
Basalt, brown, water-bearing	2	241
Basalt, gray	9	250
Basalt, brown, water-bearing	9	259
Basalt, gray	8	267
6/26-31R1. Columbia River Farms. Altitude about 650 ft. Drilled by H. & H. Drilling Co., 1977. Casing: 8 inches to 75 ft, 6 inches 0-358 ft, perforated 320-358 ft.		
Soil	20	20
Caliche	17	17
Sand and clay	29	66
Basalt, broken	9	75
Basalt, decomposed	57	132
Basalt, black	22	154
Basalt, fractured	23	177
Clay, gray	28	205
Sandstone, brown	13	218
Basalt, brown, decomposed	12	230
Basalt, black	4	234

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/26-31R1.--Continued		
Basalt, fractured	44	278
Basalt, black	14	292
Basalt, fractured, water-bearing (35-40 gal/min)	66	358
6/27-3F1. G. T. Powers. Altitude about 1070 ft. Driller not indicated.		
Silt and fine sand	40	40
Basalt, locally weathered to chocolate brown	60	100
Basalt, dark gray to black	45	145
Basalt, water-bearing	15	160
Basalt	30	190
Basalt, pillow, with palagonite	20	210
Tuff and local sand lenses	10	220
Basalt, dark gray	105	325
Claystone, blue green to gray	10	335
Basalt, dark gray	245	580
Basalt	120	700
6/27-23A1. Coffin Sheep Co. Altitude about 729 ft. Drilled by Ben Dreyer Drilling Co., 1958. Casing: 6 inches to 21 ft.		
Soil, sandy	5	5
Shale	17	22
Basalt, gray, hard to medium	42	64
Clay, yellow	19	83
Basalt, gray, medium to hard	161	244
Basalt, brown, blue, black, soft to medium	63	307
Basalt, black, soft	2	309
Basalt, black, hard	11	320
6/28-33H1. Coffin Sheep Co. Altitude about 825 ft. Drilled by Ben Dreyer Drilling Co., 1958. Casing: 8 inches to 98 ft.		
Soil	2	2
Clay, brown	30	32
Gravel	5	37
Clay, yellow	51	88
Gravel	10	98
Basalt	145	243
Clay, gray	32	275
Basalt, soft	16	291
Basalt, black	54	345
Basalt, red, soft, water-bearing	35	380
Basalt, black	70	450
Basalt, gray	12	462
Basalt, black, soft	8	470
Clay, green	35	505
Gravel, water-bearing	3	508
Basalt, black, coarse, soft	34	542
6/29-8M1. Coffin Sheep Co. altitude about 957 ft. Drilled by Ben Dreyer Drilling Co., 1957. Casing: 8 inches to 60 ft.		
Clay, sandy	50	50
Rock, white	11	61
Basalt, gray, hard	31	92
Basalt, red, soft; some water	12	104
Basalt, hard to soft	27	131
Basalt, black, hard to soft	15	146

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/29-11P1. Coffin Sheep Co. Altitude about 1400 ft. Drilled by Ben Dreyer Drilling Co., 1958. Casing: 8 inches to 99 ft.		
Sand and clay	86	86
Basalt, red, brown, black, and gray; broken 96-130 ft	183	269
Clay, brown	6	275
Basalt, gray, black, gray	65	340
Clay	5	345
Basalt, black	13	358
Basalt, broken	19	377
Clay, brown	19	396
Basalt, red and gray	120	516
Clay, brown	5	521
Basalt, black and gray	68	589
Basalt, gray, medium to hard	267	856
Basalt, brown and gray, soft to medium	22	878
Clay, brown	4	882
Basalt, black and gray, hard to soft	214	1096
Boulders and sand	4	1100
Basalt, black, soft	5	1105
Sand, brown	3	1108
Basalt, black, hard	2	1110
6/29-23K1. O. J. Hellburg. Altitude about 1075 ft. Drilled by Ben Dreyer Drilling co., Casing: 8 inches to 65 ft.		
Soil, sandy	20	20
Clay, sandy	44	64
Basalt, gray, hard	35	99
Basalt, red, soft	21	120
Basalt, gray, hard	28	148
Basalt, red, soft	14	162
Basalt, black and gray, medium	81	243
Basalt, brown, soft	3	246
Basalt, gray, hard	35	281
Basalt, red, soft	33	314
Basalt, gray, hard	16	330
6/30-19D1. Hundred Circles Farm, Irrigro Division. Altitude about 960 ft. Drilled by Hansen Drilling Co., 1974. Casing: 10 inches to 106 ft, 8 inches to 108 ft, 6 inches to 814 ft. Perforated 714-734 ft, 774-814 ft.		
Topsoil, sandy	4	4
Clay, sandy, and sandstone layers	37	41
Basalt, brown, broken	15	56
Basalt, brown, and gray, and claystone layers	5	61
Basalt, black and gray, broken	19	80
Basalt, black and brown, and green shale seams	110	190
Basalt, gray, green, brown, broken	114	304
Basalt, brown and gray, broken and some clay	14	318
Basalt, gray, green, red, black, broken	392	710
Basalt, gray and black, broken, water-bearing	90	800
Basalt, red and gray, broken	14	814
6/30-19N1. Hundred Circle Farms, Irrigro Division. Altitude about 990 ft. Drilled by Project Corp., 1973. Casing to 95 ft.		
Sand, fine, and soil	22	22
Sand, coarse, and fine gravel	33	55
Basalt, red, broken, and clay brecciation	40	95
Basalt, red, broken	49	144

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
6/30-19N1.--Continued		
Basalt, gray, hard	54	198
Volcanic ash, light brown, and red basalt	22	220
Basalt, gray, hard	80	300
Basalt, red and black, fractured	40	340
Basalt, gray, hard	80	420
Basalt, fractured, and clay and volcanic ash	22	442
Basalt, gray, hard	58	500
Basalt, red and gray, perforated and broken	27	527
Basalt, gray, hard	40	567
Clay, brown, dirty, and red and gray basalt	43	610
Basalt, gray, hard	90	700
Volcanic ash, light brown, and fractured red-gray basalt	36	736
7/21-30G1. A. N. Matsen. Altitude about 2750 ft. Drilled by Gorge Contractors, Inc., 1969.		
Unrecorded	220	220
Conglomerate, claystone, and shale; water-bearing	20	240
Basalt, black	55	295
Basalt, gray	100	395
Basalt, fractured, water-bearing	3	398
Basalt, gray	2	400
7/22-23B1. Ione Sharp. Altitude about 2120 ft. Drilled by O'Leary Well Drilling Co., 1970. Casing: 10 inches to 4 ft, 6 inches 2-70 ft.		
Topsoil	4	4
Basalt, blue and black	18	22
Basalt and gray marl	10	32
Sandstone, gray	8	40
Clay, brown, soft	32	72
Basalt, brown, vesicular	4	76
Basalt, brown, blue, and gray	79	155
Cinder, red	3	158
Shale, brown and black	16	174
Basalt, black and gray	161	335
Shale, brown	15	350
Sandstone, brown	10	360
Clay, brown, soft	10	370
Basalt, brown and blue, vesicular	22	392
Basalt, gray	80	472
Ash, crevice	8	480
Basalt, black, vesicular	28	508
Basalt, gray	14	522
Basalt, brown and black, vesicular	4	526
Basalt, black and blue, and claystone pockets	6	532
Basalt and green seams	6	538
Basalt, black	62	600
Basalt, black, vesicular	20	620
Basalt, gray	53	673
Basalt, black, vesicular, and clay pockets	5	678
Basalt, black	5	683
Basalt, black, vesicular	81	764
Basalt, blue and black, hard	45	809
Basalt, gray	2	811
Basalt, gray, very hard	164	975
Basalt, black, vesicular	25	1000

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
7/23-36R1. Chesley property, for Washington Dept. of Natural Resources. Altitude about 950 ft. Drilled by Adcock Drilling Co., 1977. Casing: 20 inches to 48 ft, 16 inches 0-68 ft, liner 400-485 ft.		
Boulders	10	10
Basalt, black	6	16
Clay	17	33
Basalt, brown	4	37
Basalt, black	30	67
Basalt, gray	111	178
Basalt, black	15	193
Basalt, gray	20	213
Basalt, red and brown	17	230
Basalt, black	5	235
Basalt, gray	34	269
Basalt, black	12	281
Basalt, gray	131	412
Basalt, black	24	436
Basalt, black and green	45	481
Basalt, gray	88	569
Basalt, black	4	573
Basalt, gray	12	585
Basalt, black	22	607
Basalt, gray, hard	143	750
Basalt, black	56	806
7/25-36N1. Washington Department of Ecology (Paterson test-observation well). Altitude about 730 ft. Drilled by Project Corporation, 1972. Casing: 10 inches to 105 ft; liner, 8 inches 456-716 ft; 6-inches open hole 740-860 ft; 1-inch piezometer pipes 0-236 ft, 0-736 ft, 0-825 ft. Screens 231-236 ft, 731-736 ft, 820-825 ft.		
Silt (loess)	8	8
Gravel, basaltic, medium to coarse	3	11
Top basalt flow:		
Basalt, medium hard, gray-black	17	28
Basalt, medium hard, light gray-green	16	44
Basalt, broken and weathered	7	51
Clay, brown and lenses of broken basalt	10	61
Basalt, broken and highly vesicular	12	73
Basalt, medium hard	6	79
Basalt, very vesicular; probably pillow zone	11	90
Uppermost sedimentary unit:		
No sample return, medium to soft	11	101
Second basalt flow:		
Basalt, hard, dense	36	137
Basalt, fractured, some water	3	140
Basalt, hard, dense, gray-black	91	231
Second sedimentary unit:		
Claystone, green and brown fragments; little water	47	278
Third basalt flow:		
Basalt, hard, dense, gray-black	201	479
Third sedimentary unit:		
Siltstone, brown; little sample return	9	488
Clay, sandy and sticky	22	510
Sandstone, fine-grained; water level dropped	8	518
Lower basalt formation:		
No sample, harder drilling	8	526
Basalt, medium hard, dark gray	20	546
Basalt, hard, dark gray	44	590

(continued)

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
7/25-36N1.--Continued		
Lower basalt formation:--continued		
Basalt, fractured, increased drilling rate, most water at 601 ft, estimated 100 gal/min	24	614
Basalt, medium fractured, gray-black	46	660
Basalt, fractured; total water estimated 200 gal/min	4	664
Basalt, fine grained, gray-black	41	705
Basalt, glassy or vesicular, soft	11	716
Basalt, fractured and broken in places	29	745
Basalt, medium hard, gray-black	67	812
Basalt, vesicular, chocolate brown and gray; some water	35	847
Basalt, hard, gray-black	13	860
7/25-36N2. John Barber property, for Washington Department of Natural Resources. Altitude about 730 ft. Drilled by Spokane Drilling Co., 1976. Casing: 18 inches to 20 ft, 16 inches 20-477 ft, 8 inches 477-485 ft.		
Overburden	7	7
Basalt, broken	10	17
Basalt	28	45
Basalt, soft, weathered, and brown clay	19	64
Basalt, gray, hard	6	70
Clay, brown, water-bearing	15	85
Basalt, gray, hard	145	230
Clay, gray	25	255
Basalt, gray, hard	225	480
Clay, tan	35	515
Basalt, gray, hard	90	605
Basalt, black, broken	25	630
Basalt, gray, hard	110	740
Basalt, black, broken	15	755
Basalt, gray, hard	59	814
Basalt, black, broken, water-bearing	46	860
7/26-5B1. John Moon. Altitude about 1130 ft. Drilled by Barnett Pumps & Irrigation, Inc., 1969. Casing: 10 inches to 20 ft, 8 inches 0-378 ft.		
Overburden	20	20
Basalt, broken, soft	25	45
Basalt, hard	9	54
Basalt, black, soft	21	75
Basalt, hard	25	100
Basalt, black, broken, soft	11	111
Basalt, hard	10	121
Basalt, medium-hard	14	135
Basalt, gray, hard	37	172
Basalt, broken, soft	25	197
Basalt, gray, hard	43	240
Sandstone	65	305
Sand and clay, white	80	385
Basalt, gray, hard	224	609
Basalt, broken, water-bearing	72	681
Basalt, gray, hard	67	748
Basalt, broken, soft	32	780
No log (deepened since 1969)	281	1061

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
7/26-28P1. Robert Munn. Altitude about 960 ft. Drilled by L. & L. Drilling Co., 1976. Casing: 8 inches to 20 ft, 6 inches 405-506 ft.		
Soil	41	41
Basalt, gray, hard	36	77
Basalt, brown, broken	18	95
Basalt, gray, hard	111	206
Basalt, brown, broken, and clay seams	41	247
Basalt, gray, hard	166	413
Clay seams, black, blue, and green	50	463
Basalt, gray, hard	97	560
Basalt, black, broken	26	586
Basalt, gray	87	673
Basalt, black, broken, water-bearing	11	684
7/27-17N1. Brent Schultheis. Altitude about 1300 ft. Drilled by L. & L. Drilling Co., 1976. Casing: 37 inches to 37 ft, 8 inches to 305 ft.		
Sand	33	33
Basalt, gray	82	115
Basalt, brown, broken	11	126
Basalt, black, porous	5	131
Basalt, gray	136	267
Basalt, brown, broken, water-bearing	31	298
Basalt, gray	7	305
7/27-29Q1. Dorothy Prior. Altitude about 1150 ft. Drilled by Project Corporation, 1973. Casing: 8 inches to 88 ft.		
Sand, coarse, and soil	15	15
Gravel, small, and sand	5	20
Gravel, broken basalt, and red clay	20	40
Basalt, red, broken, and clay	50	90
Basalt, red and black, becoming firm	10	100
Basalt, black, hard	48	148
Basalt, red, broken, perforated, and gravel	12	160
Basalt, hard	15	175
Basalt, broken, and coarse sand, gravel, and malt-colored volcanic ash	25	200
Basalt, broken, muddy	30	230
Basalt, black, hard	85	315
Chalk, blue, hard and broken	12	327
Basalt, fractured, and alluvial bed	13	340
Basalt, black, hard	80	420
Basalt, red, fractured, perforated	32	452
Basalt, black, very hard	56	508
Basalt, brown and red, broken, perforated and gravel beds	27	535
Basalt, black, very hard	40	575

TABLE 17.--Drillers' logs of wells in Horse Heaven Hills--continued

Material	Thickness (ft)	Depth (ft)
8/24-35A1. Glen Bayne. Altitude about 1400 ft.		
Boulders and soil	3	3
Clay, sandy, and boulders	67	70
Boulders and clay	8	78
Basalt, broken	114	192
Basalt, gray, very hard	55	247
Basalt, broken	56	303
Shale, clay, blue, broken	4	307
Clay, brown, and boulders	13	320
Basalt, broken, and clay and shale; some water	92	412
Basalt, boulders, and clay; water-bearing	75	487
Basalt, red, hard	15	502
Basalt, burned, hard, creviced	15	517
Basalt, porous, and hard clay	15	532
Basalt, and hard blue clay	6	538
"Void"	2	540
Basalt, and hard blue clay	7	547
Clay, hard	10	557
Basalt, hard	5	562
Clay and shale	40	602
Basalt and gray shale	20	622
Basalt, black, hard	30	652
Basalt, hard, broken	18	670
Basalt, gray, hard	3	673
Basalt, brown, soft	4	677
Basalt, fractured, medium-hard	15	692
Basalt, black, hard	19	711
8/25-21D1. K. C. Burkhart. Altitude 1300 ft.		
Soil	12	12
Basalt	88	100
Clay, white	100	200
Well reportedly 423 ft deep.		