Effects of Hydraulic and Geologic Factors on Streamflow of the Yakima River Basin Washington

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1595

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By HALLARD B. KINNISON *and* JACK E. SCEVA

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An evaluation of streamflow records as an index to basin runoff

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

EFFECTS OF HYDRAULIC AND GEOLOGIC FACTORS ON STREAMFLOW, YAKIMA RIVER BASIN, WASHINGTON

By HALLARD B. KINNISON and JACK E. SCEVA

ABSTRACT

The Yakima River basin, in south-central Washington, is the largest single river system entirely within the confines of the State. Its waters are the most extensively utilized of all the rivers in Washington.

The river heads high on the eastern slope of the Cascade Mountains, flows for 180 miles in a generally southeast direction, and discharges into the Columbia River. The western part of the basin is a mountainous area formed by sedimentary, volcanic, and metamorphic rocks, which generally have a low capacity for storing and transmitting water. The eastern part of the basin is formed by a thick sequence of lava flows that have folded into long ridges and troughs. Downwarped structural basins between many of the ridges are partly filled with younger sedimentary deposits, which at some places are many hundreds of feet thick. The Yakima River flows from structural basin to structural basin through narrow water gaps that have been eroded through the anticlinal ridges. Each basin is also a topographic basin and a ground-water subbasin. A gaging station will measure the total outflow of a drainage area only if it is located at the surface outlet of a ground-water subbasin and then only if the stream basin is nearly coextensive with the ground-water subbasin. Many gaging stations in the Yakima basin are so located. The geology, hydrology, size, and location of 25 ground-water subbasins are described.

Since the settlement of the valley began, the development of the land and water resources have caused progressive changes in the natural regimen of the basin's runoff. These changes have resulted from diversion of water from the streams, the application of water on the land for irrigation, the storage and release of flood waters, the pumping of ground water, and other factors. Irrigation in the Yakima basin is reported to have begun about 1864. In 1955 about 425,000 acres were under irrigation.

During the past 60-odd years many gaging stations have been operated at different sites within the basin. Only stations in the upper reaches, such as those below Keechelus, Kachess, or Cle Elum Lakes, give discharge records which are an accurate measure of the natural outflow of the drainage area. Farther downstream, as the utilization of water becomes more extensive, the records at a gaging station show the discharge passing a particular point, but they do not reflect the natural outflow of the basin. Large canals divert water for use on lands above a station or carry it around a station for irrigation downstream. The deep sedimentary deposits within subbasins and the overlying alluvial gravels permit downvalley movement of large subsurface flows which bypass the gaging stations, except in the near vicinity of the water gaps. At the water

gaps ground water rises to the surface, becoming streamflow, and can be accurately measured. The location of gaging stations within each subbasin is important, therefore, in determining whether the flow measured represents the total downvalley outflow or whether it is merely the surface-water component.

Surface and subsurface factors that may affect the discharge records at each gaging station in the Yakima River basin include a description of upstream diversions, surface return flows, bypass canals, storage reservoirs, subsurface bypass flows, ground-water withdrawals, and other items. The available data are not sufficiently complete to permit a quantitative determination of the total basin yield at most gaging stations. However, data on the existing bypass channels, such as canals and drainage ditches, and on related subsurface movement of water provide valuable information necessary to proper use and interpretation of the streamflow records.

INTRODUCTION

PURPOSE AND SCOPE

A record of river discharge, resulting from the operation of a gaging station, normally indicates the amount of water flowing in the stream channel at the gaging-station site. Whether or not this record is a measure of the total downvalley movement of water depends upon many factors. Manmade surface features, such as diversion canals, bypass channels around gaging stations, and storage reservoirs, affect the runoff characteristics of a stream and the magnitude of the flow at the gaging station. Besides these manmade features, subsurface conditions may influence runoff characteristics and control the amounts of subsurface bypass.

If sufficient data were available on the flow carried by the surface bypass channels, irrigation canals, drainage ditches, and on the magnitude of the subsurface movement of water, an exact determination of the total basin outflow and downvalley movement of water might be possible. This, however, is not feasible in the Yakima basin. The location of irrigation canals and drains is accurately known, but records of flow at all points in an extensive and involved network of canals, laterals, wasteways, and drains is impracticable of attainment. The interchange between surface water and ground water in the irrigated portions of the Yakima basin is extensive and complex, and complete quantitative determination of such water movement is impossible. Records of the flow in canals at the point of diversion, of the flow of the Yakima River and tributaries at various points, and the constant attendance of watermasters are required to administer the irrigation system and distribute the water among irrigators. This report will facilitate the interpretation and evaluation of the water records of the basin by providing qualitative data on the surface and subsurface movement of water.

Studies of the water supply for a project utilizing surface water are based primarily on streamflow data obtained by operating gaging stations. Project design requires an estimate of the probable future water supply that may reasonably be expected during the life of the project. This can be achieved only through a study of records of past streamflow and other hydrologic events. Records covering a period of many years are necessary to evaluate the effect of vagaries of the weather adequately and to determine the yield during drought periods. If manmade structures have altered the normal regimen of the stream or have utilized consumptively a part of the water supply during the period of operation of a gaging station, the effects of these changes must be considered in analyzing the data to determine the possible future supply.

The primary purpose of this report it to evaluate each streamflow record in terms of the factors that influence or alter the flow of the Yakima River and its tributaries. Emphasis is on the factors influencing the runoff regimen and the gaging-station records without, in all cases, attempting a quantitative determination of their effect. These data are basic to quantitative water-supply studies and to the evaluation of the water resources of the basin.

Evaluations are given for each of the 43 gaging stations that have been operated in the Yakima River basin and for which records have been published by the U.S. Geological Survey. These evaluations include a brief description of the geologic setting of the gaging station, qualitative statements as to the surface diversions, surface and subsurface bypass, return flow, imported recharge, storage and regulation, and an appraisal of the adequacy of the records in representing outflow from their drainage basins.

ACKNOWLEDGMENTS

Valuable assistance was given by Cyril Lentz and Earl L. Smith, formerly of the U.S. Bureau of Reclamation, Yakima, in furnishing data and reviewing parts of the report.

Acknowledgment is also given to J. B. Caruthers and the late F. E. Moxley, U.S. Bureau of Indian Affairs, Wapato; the late C. J. Bartholet, former Supervisor of Division of Water Resources, Washington Department of Conservation and Development; Earl McMillan of the Northwest Improvement Co., Seattle; George Meek and the late J. S. Moore, watermasters; Wallace Owen, stream patrolman; and various well drillers in the area, for their valuable contributions of hydrologic and geologic information.

PREVIOUS INVESTIGATIONS

Many investigations have been made of the geology and hydrology in the Yakima River basin. The bibliography at the end of the report has been included for reference to those investigations. References to streamflow records in the Yakima River basin are given on pages 21 and 22.

GEOGRAPHIC SETTING

The Yakima River, a major tributary of the Columbia River, drains an area roughly triangular in form, situated slightly southeast of the geographic center of the State of Washington (fig. 1). The river has an overall length of about 180 miles and a drainage basin of about 6,000 square miles; it is the largest drainage basin entirely within the State. The river heads in the rugged mountainous area along the eastern slope of the Cascade Mountains in the western part of Kittitas County, flows generally southeastward into the semiarid region of central Washington across Yakima and Benton Counties, and joins the Columbia in the south-central part of the State.

Streams in the Yakima basin, especially those in the northwest section, combine certain characteristics of coastal streams of the Pacific Northwest with those of streams farther inland. Following the pattern of inland rivers, the greatest flood incidence is in May and June when the snow is melting rapidly at the higher altitudes; but, like the rivers on the western slopes of the Cascades, floods in the fall and winter months are common. These are the rain-type floods and characteristically have high peak flows of short duration; however, the danger from both types of flood has been materially lessened in the last 40 years by the storage reservoirs.

The average annual runoff in the basin ranges from 60 inches in the Cascades to less than 1 inch in the downstream or eastern part of the watershed. Thus, nearly all the water available for irrigation originates in the upper reaches of the watershed.

Altitudes in the Yakima River basin range from 8,200 at Goat Rocks to 320 feet at the mouth of the river. Glaciers are present along the western edge of the basin in areas where the land surface is at about 7,000 feet. Melt water from these glaciers is effective in maintaining runoff of the mountain streams during the late irrigation season.

The Yakima River basin, one of the principal inland gateways to the Cascade Mountains and the port cities of Puget Sound, is an important tourist center and commercial traffic route.

Topographic quadrangle maps of various dates and scales covering the entire Yakima drainage basin have been published. In addition to these maps, a series of large-scale topographic maps (1:12,000) of

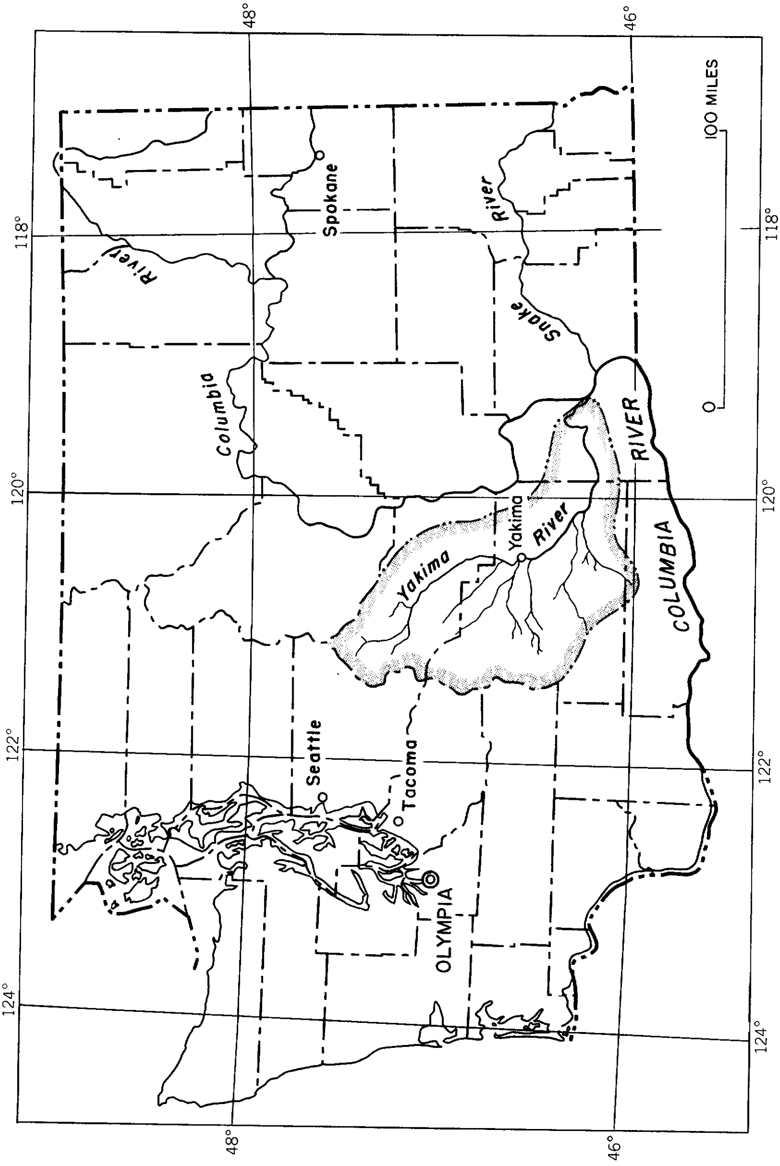

FIGURE 1.—Map of Washington showing the Yakima River basin.

the Kittitas drainage district located in and adjacent to Ellensburg have been published. Information as to the latest available maps may be obtained at any U.S. Geological Survey Information Office or through the Survey Map Information Office, Washington, D.C. 20242.

WELL-NUMBERING SYSTEM

Many references to wells and test holes occur throughout this report. These wells are numbered so as to show locations of the wells according to the rectangular system for subdivision of public land, indicating township, range, section, and 40-acre tract within the section. For example, in the well number 12/19–15B1 the part preceding the hyphen indicates successively the township and range (T. 12 N., R. 19 E.) north and east of the Willamette base line and meridian. The first number following the hyphen indicates the section (sec. 15) and the letter (B) gives the 40-acre subdivision of the section as shown in

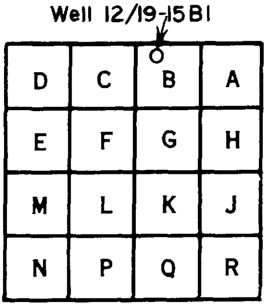

FIGURE 2.—Subdivision of a land section showing well-numbering system.

figure 2. The last number (1) is the serial number of the well in that particular 40-acre tract.

Because all townships in Washington are north of the Willamette base line, the letter *N* is omitted, and because most of the State is east of the Willamette meridian, the letter *E* is omitted for those ranges east of the Willamette meridian; but *W* is included when the range lies west of the Willamette meridian. Thus, the number 12/19–15B1 indicates the first well record in the NW¼NE¼ sec. 15, T. 12 N., R. 19 E.

GEOLOGIC SETTING

The Yakima River basin lies across two distinctly different geologic terranes. The eastern half of the basin is underlain by a thick sequence of lava flows known as the Columbia River basalt. This sequence of flows has been deformed into numerous southeast-trending anticlinal ridges and synclinal valleys. Clastic sedimentary materials partly fill the synclinal valleys to depths exceeding 1,500 feet in some of the larger valleys.

The western half of the Yakima River basin lies within the Cascade Mountains, an uplifted area that has been dissected by erosion into a rugged mountainous region. Most of the rocks that underlie this region are older than the rocks of the eastern half of the basin, and consist of consolidated fluviatile and lacustrine deposits, volcanic flows, and intrusive and metamorphic rocks (pl. 1, 2). A description of rock units will be found on page 98.

CLIMATE AND VEGETATION

The climate of the Yakima River basin is varied, but, in general, it has the characteristics of a continental climate, having hot dry summers and cool winters. Temperatures at Yakima, which are considered representative for the entire basin, have ranged from −25° F in February to 111° F in July. Temperature in the mountains are generally cooler during the summer and warmer during the winter. Precipitation also varies greatly over the basin, ranging from about 7 inches per year at lower altitudes in the eastern part of the basin to more than 100 inches in some parts of the headwater area.

The amount of precipitation in the western two-thirds of the basin increases markedly with increase in altitude on the eastern slope of the Cascade Mountains. Difference in altitude has less effect on the amount of precipitation in the eastern part of the basin.

Vegetation is a good index of the amount of precipitation that occurs over the basin. The higher areas, which receive large amounts of precipitation, are thickly forested with fir, pine, and larch. In areas of lesser precipitation, on the lower slopes, these thickly forested areas give way to sparse stands of ponderosa pine. In the eastern part of the basin where the lowest precipitation occurs, only sagebrush and grasses can survive.

AGRICULTURE AND INDUSTRY

The Yakima River basin is one of the most productive agricultural areas in the State, having more than 425,000 acres under irrigation in 1955 (table 1). The basin's annual crop of apples, pears, and peaches is more than half of that for the entire State. The raising of field and row crops and dairy production are other important phases of agriculture. The most important agricultural areas are in the Kittitas and the Upper and Lower Yakima basins.

The chief industry is the processing of the agricultural products, principally fruit packing and vegetable processing. A large beet-sugar refinery is located at Toppenish. Logging in the forested area in the western part of the basin has given rise to an important lumbering industry. Coal production in the Roslyn basin is the only notable mining industry in the area.

DEFINITION OF TERMS

Hydrologic terms and abbreviations used in this report are defined as follows:

Acre-foot (acre-ft). The volume of water required to cover 1 acre to a depth of 1 foot. It is equal to 43,560 cubic feet, or 325,851 gallons.

Cubic foot per second (cfs). A measure of streamflow. It is defined as the rate of discharge of a stream whose channel is 1 square foot in cross-sectional area, and whose velocity is 1 foot per second. It is equal to 448.8 gallons per minute, or 723.97 acre-feet per year.

Million gallons per day (mgd). A measure of streamflow. The rate of discharge of a stream when the volume of water passing a point is 1 million gallons per day.

Miner's inch. An indefinite measure of water discharge. Generally it is accepted to mean the quantity of water that will escape from an aperture 1 inch square through a 2-inch plank, under a head of 6 inches. The quantitative meaning varies from place to place. For Washington, 1 miner's inch equals 0.02 cfs. (In part from AGI glossary, 2d ed., p. 187.)

Outflow. The combined surface and subsurface flow out of a drainage area. It represents the contribution of that basin to downstream water supply and as such is affected by changes in consumptive use within that basin.

Permeability. The capacity of a rock material to transmit water under pressure. It is expressed in units that represent volume of discharge per unit of time, per cross-sectional area of materials, under a standard hydraulic gradient.

Porosity. The amount of interstitial space in a rock or soil. It is the ratio, expressed as a percentage, of the aggregate volume of voids to the total volume of material. Effective porosity is the volume of water that will drain under any specified hydraulic condition from a volume of saturated material. Effective porosity is expressed as a percentage. It is always less than porosity owing to retention of some water in the rock by molecular attraction.

Runoff. The surface flow out of a drainage area, under natural conditions.

HYDROLOGY

SURFACE WATER

Irrigation is by far the largest use of water in the Yakima River basin. The Yakima Project is the largest block of irrigated land in the State, except for the Columbia Basin Project which is now under development. In 1955, a total of about 425,000 acres was under irrigation in the basin. Consumptive use by irrigation increased from 5 percent of the average flow at Kiona in 1900 to about 35 percent in 1955. Irrigation in the basin is shown in figure 3.

Some of the earliest irrigation in the Northwest occurred in the Yakima basin. Settlement by white men occurred as early as 1852, when a Roman Catholic mission was established on Ahtanum Creek. Although it has been questioned that the mission founders practiced irrigation, it is well established that they farmed successfully. If the missionaries did not use supplemental water for their crops during the 1850's, then, perhaps the first verifiable irrigation by white men in Yakima valley was that reported by A. J. Splawn, of North Yakima, who stated (Libby, 1913) that in the year 1864 he saw a garden upstream from the Catholic mission on Ahtanum Creek which was irrigated by a ditch diverting from that stream.

The strong westward migration after the Civil War stimulated by completion of the transcontinental railroads, brought many settlers into the Pacific Northwest. The growth in population in the Yakima Valley during the latter part of the last century was steady and vigorous. Concurrent with the land settlement was the use of supplemental water for farming. The introduction of money-making crops gave a strong impetus to the irrigation development, and private enterprise was very active during the period on expanding irrigation facilities and promoting new projects. After the passage of the Federal Reclamation Act of 1902, the Bureau of Indian Affairs (then the Indian Service) and the Bureau of Reclamation (then the Reclamation Service) initiated their very successful irrigation project, which increased the irrigated area from 67,450 acres in 1900 to 335,000 acres in 1925; in 1955 there were about 425,000 acres of land irrigated in the Yakima River basin (table 1). Of this acreage about two-thirds is included in projects operated under the supervision of the two Federal agencies mentioned. Simons (1954) estimated that the annual consumptive use of surface water in this area was about 880,000 acre-feet in 1954.

Very little surface water is utilized in the Roslyn basin. At present only a few hundred acres of land are irrigated, most of the area being heavily forested. Keechelus, Kachess, and Cle Elum Lakes, with total

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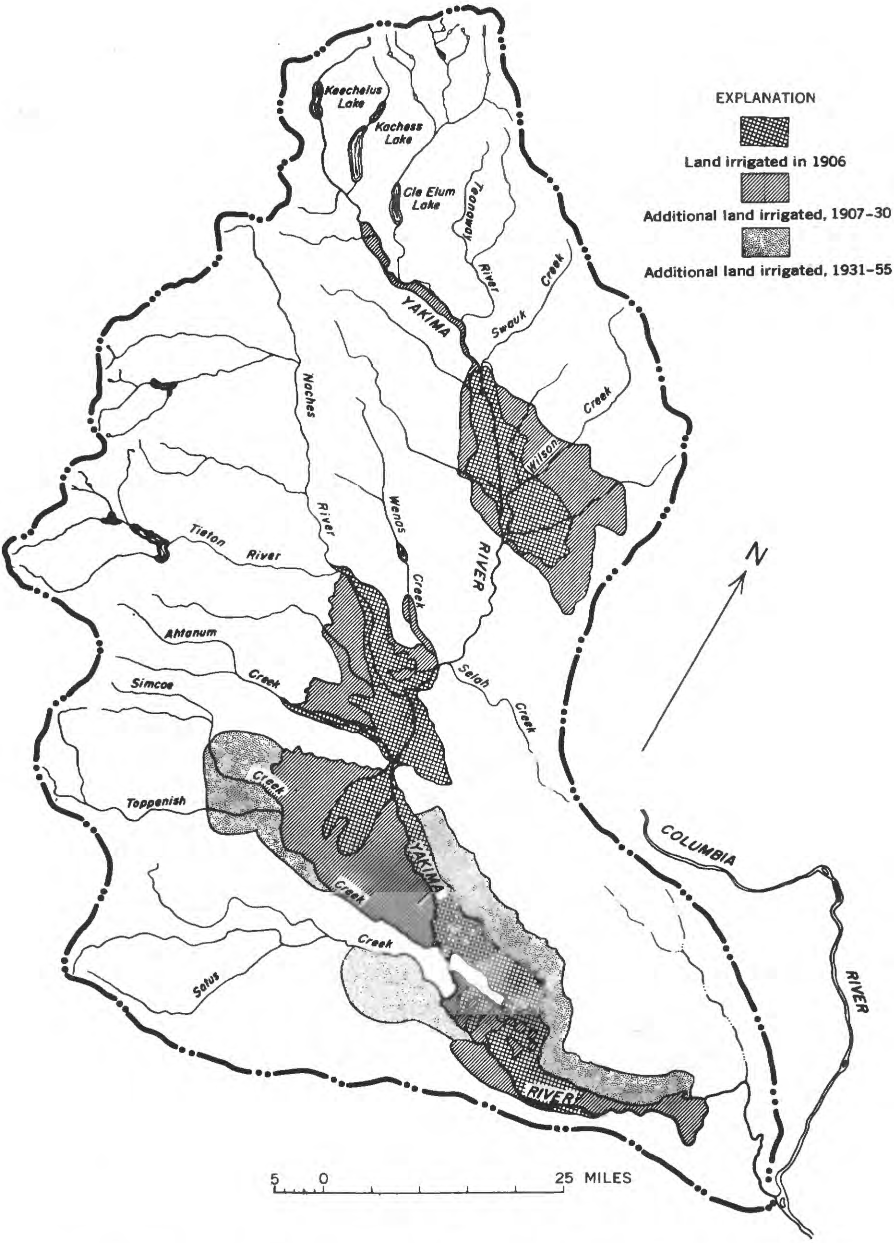

FIGURE 3.—Map showing development of irrigation in the Yakima River basin.

usable storage capacities of 854,000 acre-feet, store water for irrigation downstream.

Irrigation in the Kittitas basin has increased from 27,800 acres in 1900 to 75,000 acres in 1955 (table 1). The greatest increase came immediately after the construction of the Kittitas High Line Canal in 1930, which now irrigates 54,000 acres. The remainder of the area is served by numerous small ditches, the Cascade and the Ellensburg Water Co. canals, all diverting from the Yakima River. The Ellensburg power canal diverts about 700 cfs in the vicinity of Ellensburg, which is returned a short distance below point of diversion. There is no storage in this area.

The irrigated area in the Upper Yakima basin has increased from 21,500 acres in 1900 to 86,000 acres in 1955. Many canals divert water for use within this basin, and several canals divert water for use in the Lower Yakima basin.

The irrigated area in the Lower Yakima basin has increased from about 18,000 acres in 1900 to about 264,000 acres in 1955. About 15,000 acres are irrigated in the Cold Creek basin, mainly from the Kiona and Columbia Canals. The Richland Canal, formerly irrigating 10,500 acres, now serves as the municipal supply for Richland. Most of the flow of the Columbia Canal is used in the vicinity of Kennewick, outside the Yakima River basin.

Table 1 indicates a decrease of irrigated acreage in the upper part of the basin between 1946 and 1955. This is due to a slackening of the pressure of the war and postwar demands that had allowed marginal land to be brought under cultivation. By 1955, this demand had decreased until the farming of marginal lands was no longer profitable. The increase in irrigated acreage in the lower part of the basin is the result of extensions of Rosa and Sunnyside Canals.

TABLE 1.—*Land area under irrigation in the Yakima River basin for selected years*

[Areas given in acres. Adapted from Simons, 1954]

Year	Kittitas basin	Upper Yakima basin	Lower Yakima basin	Total
1900	27, 800	21, 500	18, 150	67, 450
1910	49, 860	53, 900	80, 530	197, 280
1920	54, 320	86, 800	164, 250	322, 490
1930	59, 810	88, 500	179, 770	345, 320
1940	110, 100	90, 180	194, 860	412, 700
1946	104, 640	93, 870	225, 920	439, 300
1955 [1]	75, 000	86, 000	264, 000	425, 000

[1] Figures for 1955 from W. D. Simons, oral communication, March 1959.

GROUND WATER

Ground-water withdrawals affect streamflow in many ways. Large withdrawals may reduce the amount of natural ground-water discharge and may reduce the base flow of a stream; conversely, withdrawals may return to a stream through return flow from irrigation, sewage-disposal plants, or other water-disposal systems and actually increase the amount of streamflow at periods of low flow. A large reduction in the volume of ground-water storage due to pumping may result in greater amounts of water entering the ground during periods of recharge, which reduces the amount of surface runoff during the period of recharge. Pumping from shallow ground-water bodies that are being discharged in part by evaporation and transpiration may lower water levels sufficiently to reduce the evapotranspiration losses to such an extent that the reduced amount of natural discharge to a stream, combined with greatly increased artificial discharge from waste-disposal systems may actually increase total runoff. Considering these various possibilities, it is apparent that the effect of ground-water withdrawal on streamflow cannot be evaluated easily. Aside from outflow the actual removal of water from a basin results only from evaporation, transpiration, surface and subsurface interbasin diversions, and negligible amounts incorporated in plant and animal tissue, and exports in industrial products.

Ground water withdrawn for irrigation is in large part evaporated or transpired into the atmosphere, a smaller part infiltrates into the ground and recharges ground-water bodies, and a small part may become direct surface runoff. The evapotranspiration losses and water used in building plant tissue are termed "consumptive use," as these represent the amount of actual water loss. Withdrawals for irrigation are generally confined to the irrigation season, which in the Yakima River basin is from April through September. Occasionally, irrigation water is used in the months of March and October.

Ground water withdrawn for industrial purposes in the Yakima River basin is discharged chiefly into municipal sewage systems. Because a large part of the industries in this area are related to food processing, large withdrawals occur during the harvest season.

Ground water withdrawn for municipal supplies is discharged chiefly into streams through sewage-disposal systems (table 2). Table 3 shows the monthly municipal withdrawals in 1953 for three of the smaller towns in the Yakima River basin. It shows that minimum withdrawals occur during the winter months, and that maximum withdrawals, which at times are more than double the minimum,

TABLE 2.—*Municipal water supplies and wasteways in the Yakima River basin*

[All data from respective city water superintendents or by field inspection in 1951, unless otherwise noted]

City	Source of water supply	Average Flow		Average output of sewage-treatment plant		Access to Yakima River
		Cfs	Mgd	Cfs	Mgd	
Cle Elum	Cle Elum River ½ mile below Cle Elum River near Roslyn gage.	3	1.9	3.4	[1,2]2.2	Ditch at south city limits.
Ellensburg	Nanum Creek since 1908 used only as supplemental source.	4–5	2.6–3.2	9.1	[2]5.9	
	Shallow well on bank of Yakima River in the SE¼SE¼ sec. 12, T. 18 N., R. 17 E. Established 1912.	8–16	5–10	10.8	[2]7.0	Wilson Creek (see Wilson Creek at Thrall).
Grandview	Drilled wells	.6	.39	3.7	[2]2.4	Drain 35.
Moxee City	do	.15	[3].1	.15	.1	Moxee drain carrying 15 to 30 cfs.
Prosser	do	.26	[3].172	1.1	[1,2].7	Ditch 150 yd below bridge south of town.
Richland	do	4	[1]2.5	4.6	3	Ditch at south end of city.
	Richland Canal	190	123			
Roslyn	Domerie Creek	2.3	[1]1.5	5	3.2	Ditch averaging about 10 cfs just below station, Yakima River at Cle Elum.
Selah	Wells	.3	.2	6.2	[1,2]4.0	Long ditch discharging in sec. 1, T. 13 N., R. 18 E.
Sunnyside	do	.38	[3].24	1.5	[1,2]1.0	Drain 7 already carrying 5–10 cfs.
Toppenish	do	1.2	[3].8	1.2	[1,2].8	Ditch to river.
Wapato	do	.4	.25	1.1	[1,2].7	Percolates into ground before reaching river.
Yakima	Naches River and wells.	11	[3]7	31	[1,2]20	Ditch to river.
Zillah	Wells	.3	[3].2	.3	[1,2].2	To drain with ½-cfs flow at south end of town.

[1] Rated plant capacity.
[2] Inventory of municipal and industrial waste facilities in Washington, 1956, by U.S. Public Health Service.
[3] Inventory of domestic Water and Health Facilities of Washington, 1945, by U.S. Public Health Service.

occur during the summer months. A large part of the water withdrawn during the summer months is used for sprinkling lawns. Much of the sprinkling water is evaporated or transpired into the atmosphere and is not discharged into the sewage-disposal systems. The average monthly distribution of withdrawals shown in table 3 probably is representative of most municipal systems in the Yakima River basin.

Table 4 shows the estimated annual ground-water withdrawal (1953) in each of the ground-water subbasins described in this report. These estimates were made on the basis of information obtained con-

TABLE 3.—*Monthly distribution of ground-water withdrawals by several municipal systems in the Yakima River basin, 1953*

[Millions of gallons]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year or period: Million gallons	Year or period: Acre-feet
Selah														
1937	------	------	------	------	------	------	------	------	------	6.28	5.91	5.28	} 80.10	246
1938	6.28	4.10	4.55	6.08	7.50	7.88	9.88	8.23	8.13	------	------	------		
Sunnyside														
1931	4.07	4.09	3.86	4.60	6.27	7.41	6.71	9.52	7.70	6.99	8.09	4.39	73.70	226
1932	4.44	4.17	3.69	6.39	4.47	6.39	5.96	5.51	5.63	4.56	3.85	3.83	58.89	181
1933	3.89	3.51	3.76	4.68	4.38	5.57	6.06	6.04	4.89	4.23	4.45	4.02	55.47	170
1934	3.76	4.01	4.13	4.15	4.81	7.00	5.13	5.62	5.53	3.90	3.56	3.77	55.37	170
1935	4.19	4.29	4.80	4.27	5.03	6.52	5.67	5.71	5.22	4.02	4.15	3.66	57.53	177
1936	3.71	4.22	4.76	5.48	5.97	6.02	5.93	6.35	6.57	5.14	5.46	5.19	64.80	199
1937	------	------	------	------	------	------	------	------	------	------	------	------	59.67	183
1938	4.81	4.15	4.77	5.18	6.64	7.21	9.01	6.89	5.86	5.54	4.43	4.27	68.76	211
1939	4.76	4.05	5.30	6.05	6.63	7.60	7.17	8.04	5.00	4.10	4.63	3.97	67.30	207
Wapato														
1937	------	------	------	------	------	------	------	------	------	8.59	6.77	6.55	------	------
1938	6.32	6.35	7.52	11.43	14.81	14.64	17.63	17.65	10.43	------	------	------	------	------
Average monthly distribution [1]	1.08	1.00	1.10	1.36	1.55	1.78	1.84	1.86	1.51	1.24	1.19	1.05	------	------

[1] Minimum shown as unity.

cerning ground-water appropriations by the State Division of Water Resources, reports of U.S. Public Health Service, and some direct information from municipal and industrial consumers. The total annual ground-water withdrawal for all uses in the Yakima River basin was estimated to be about 52,000 acre-feet per year in 1953, and little change has taken place since then.

TABLE 4.—*Estimated annual ground-water withdrawals, in acre-feet, in the ground-water subbasins of the Yakima River basin, 1953*

Subbasin	Irrigation	Industrial	Municipal supply	Domestic	Total
Ahtanum-Moxee	10,000	7,500	2,000	1,500	21,000
Black Rock	50	0	0	20	70
Bumping Lake	0	0	0	0	0
Cle Elum	500	200	0	200	900
Dry Creek	0	0	0	0	0
Ellensburg	1,000	500	2,000	500	4,000
Galena	0	0	0	0	0
Horse Heaven	0	0	0	0	0
Kachess	0	0	0	25	25
Keechelus	0	0	0	25	25
Lower Teanaway	150	0	0	25	175
Lower Wenas	5,000	100	0	200	5,300
Manastash	0	0	0	25	25
Naches-Cowiche	1,000	200	700	500	2,400
Prosser	2,000	1,000	1,500	1,000	5,500
Rattlesnake	0	0	0	25	25
Richland [1]	----------	----------	----------	----------	----------
Roza	100	0	0	25	125
Selah	500	100	100	200	900
Taneum	0	0	0	25	25
Toppenish	1,500	5,000	1,500	1,000	9,000
Umtanum	0	0	0	0	0
Upper Ahtanum	1,600	0	0	20	1,620
Upper Teanaway	0	0	0	0	0
Upper Wenas	500	0	0	50	550
Total	23,900	14,600	7,800	5,365	51,665

[1] Large part of this subbasin lies within the Hanford AEC Reservation. Utilization of ground water in this area is not known.

STORAGE RESERVOIRS

There are five major and two minor reservoirs in the Yakima River basin. The major reservoirs, Keechelus, Kachees, Cle Elum, and Bumping Lakes, and Tieton Reservoir together have sufficient capacity to store about 62 percent of the average annual runoff of the tributary areas. Table 5 shows the location, capacity, purpose, and other pertinent data regarding these reservoirs.

Adequate records of water-surface elevations and operations of these reservoirs have been maintained since regulation began. Such data are published by the U.S. Geological Survey, or are available in the files or reports of the U.S. Bureau of Reclamation, Yakima.

The two minor reservoirs listed in table 5, Clear Creek and Wenas, have a negligible effect on the regimen of the basin. No records have been published on their elevations or contents.

TABLE 5.—*Storage reservoirs in Yakima River basin*

Name	Location	Period of operation	Usable capacity		Remarks
			Period of acre-feet	Percent annual runoff (approx)	
Keechelus Lake	Staff gage in the NE¼ sec. 12, T. 21 N., R. 11 E., at outlet of Keechelus Lake 9½ miles northwest of Easton.	1906–55	157, 800	70	Reservoir is formed on natural lake by earth- and gravel-fill dam. Crib dam storing 19,000 acre-feet used 1906–14. Capacity from 1920 to 1952 was 153,000 acre-ft.[1]
Kachess Lake	Staff gage in the SW¼ sec. 34, T. 21 N., R. 13 E., at outlet of Kachess Lake and 2½ miles northwest of Easton.	1905–55	239, 000	120	Reservoir is formed on natural lake by earth- and gravel-fill dam completed in 1912. Crib dam, storing 21,000 acre-feet, used 1905 to 1911.[1]
Cle Elum Lake	Staff gage in the NE¼ sec. 10, T. 20 N., R. 14 E., at outlet of Cle Elum Lake 4 miles northwest of Roslyn, Wash.	1906–55	437, 000	70	Reservoir is formed on natural lake by earth- and gravel-fill dam completed in 1933. Crib dam, storing 25,000 acre-feet, used 1906–32.[1]
Bumping Lake	Staff gage in the SW¼ sec. 33 (unsurveyed) T. 16 N., R. 12 E., at outlet of Bumping Lake, 11½ miles above American River and 19 miles west of Nile.	1906, 1909–55	33, 710	20	Reservoir is formed on natural lake by earth-fill dam completed in 1910.[1]

Clear Creek Reservoir	Sec. 12 (unsurveyed), T. 13 N., R. 12 E., 1 mile west of Tieton Reservoir.	1915–25	5, 300	5	Reservoir has not been operated since 1925 when Tieton Reservoir was completed, except for occasional dry periods.
Tieton Reservoir	Staff gage in the SW¼ sec. 31 (unsurveyed), T. 14 N., R. 14 E., on spillway of Tieton Dam, 22½ miles southwest of Naches.	1925–55	197, 000	60	Reservoir is formed by earth- and gravel-fill dam completed in 1925.[1]
Wenas Creek Reservoir	SE¼ sec. 3, T. 15 N., R. 17 E., 18 miles northwest of Yakima.	1912–55	1, 050		Reservoir used to extend the irrigation season of many ranches and farms below.

[1] No consistent operating plan is used in the storage of water by the reservoir. The rate at which the reservoir is filled depends upon data from snow surveys, amount of early runoff, and other factors, and time required to achieve maximum storage at the end of the high runoff period, which generally occurs during June. Flood control is practiced when needed insofar as it does not interfere with the primary purpose of storing water for irrigational uses.

GROUND-WATER BASINS

A ground-water basin or subbasin is defined in this report as an area from which little or no water is discharged by underflow or within which all ground water converges to one or more relatively restricted discharge outlets. The boundaries of a ground-water basin, being dependent upon the geology of the area, do not necessarily coincide with the boundaries of the surface drainage area. A gaging station can measure the total outflow of a drainage area only if it is located near the surface outlet through which little ground water moves, and then only if the stream basin is nearly coextensive with the ground-water basin.

The Yakima River crosses four large structural basins, which are separated from one another by one or more large anticlinal or monoclinal ridges. The river transects these ridges through deep narrow canyons, the largest and longest of which is the Yakima Canyon (pl. 3) between Ellensburg and Yakima. Each of the four structural basins, including their surrounding drainage areas, forms a separate ground-water basin. Named in downstream order these basins are the Roslyn, Kittitas, Upper Yakima, and Lower Yakima (pl. 3). In addition to these four major basins, the drainage area of the Yakima River also includes three smaller ground-water basins: (1) the Upper Naches, which includes the headwater area of the Naches River; (2) the Yakima Canyon, which includes two small synclinal troughs that are drained by the Yakima River along its course through the Yakima Canyon; and (3) the Cold Creek, which includes the Cold Creek drainage area and a small area lying south of the Yakima River.

The Roslyn basin, located high on the eastern slopes of the Cascade Mountains, includes a drainage area of about 800 square miles. It is bordered by a mountainous region that contains some of the highest mountains in the Yakima River basin. A few small glaciers are present on some of the higher peaks. The central part of the Roslyn basin is formed by a broad dissected synclinal valley whose axis extends for 20 miles in an east-southeast direction. At the eastern end, 6 miles east of Cle Elum, it is ended abruptly by the cross-valley-monoclinal structure which forms Lookout Mountain (sec. 36, T. 20 N., R. 16 E.). Drainage into this valley is in part regulated by the outflow from three large mountain lakes: Lake Keechelus, drained by the Yakima River; and Lakes Kachess and Cle Elum, drained by the Kachess and Cle Elum Rivers, respectively, both tributary to the Yakima. The Teanaway River, Swauk Creek, and Cabin Creek are important tributary streams which drain small mountainous areas in this basin. The Yakima River leaves the Roslyn basin through a narrow canyon eroded through the basalt a few miles south of Lookout Mountain.

The Kittitas basin consists for the most part of the Kittitas Valley, a long broad synclinal valley lying just southeast of the Roslyn basin. The valley has a southeast trend and a length of about 30 miles. Manastash Ridge, a long anticlinal ridge, forms the southern boundary of the valley; and the Wenatchee Mountains, a low east-trending range which attains a maximum altitude of about 6,000 feet, form the northern boundary. An upland area west of the valley is drained by Manastash and Taneum Creeks and is included in the Kittitas basin.

The Yakima River enters the Kittitas basin at the northwestern end of the Kittitas Valley and flows along the southwestern edge of the valley to Yakima Canyon, a few miles south of Ellensburg. Numerous small tributary streams, which drain small areas in the Wenatchee Mountains, enter the Yakima River before it leaves the Kittitas basin.

Leaving the Kittitas basin the Yakima River flows south through the Yakima Canyon, a long, narrow canyon whose nearly vertical walls rise as much as 2,000 feet above river level. In its course through the canyon, the Yakima River transects two small synclinal troughs which together comprise the Yakima Canyon ground-water basin. These troughs, which have a southeast trend, are the Umtanum subbasin, drained by Umtanum and Squaw Creeks, and the Roza subbasin, drained by Burbank and Roza Creeks.

Upon emerging from the Yakima Canyon, the Yakima River flows southward across the Upper Yakima basin. This basin includes an area of about 1,080 square miles, and is bounded on the south by an east-trending anticlinal ridge known as the Rattlesnake Hills. The western end of this anticlinal ridge is known as the Ahtanum Ridge. Most of the area within the basin is west of the Yakima River. Wenas and Ahtanum Creeks, small east-flowing tributaries, drain small structural basins, but most of the western part is drained by the Naches River, the largest tributary of the Yakima River. The relatively small area lying to the east of the Yakima River is drained by several intermittent west-flowing streams.

The Naches River heads in a mountainous area northwest of the Upper Yakima basin. Its headwater area, about 640 square miles, is called the Upper Naches basin in this report. It is bounded on the west by the Cascade Divide and is separated from the Upper Yakima basin by the Cleman Mountain anticlinal ridge. The Naches River transects this structural ridge by flowing through the narrow canyon at Horseshoe Bend, about 20 miles west of the city of Yakima.

The Yakima River leaves the Upper Yakima basin through Union Gap, a short narrow canyon eroded through the Rattlesnake Hills anticline. This gap, which has a length of about 1 mile, has valley walls that rise 700 feet above the valley floor.

From Union Gap, the Yakima River flows southeastward through a broad structural valley which is the most prominent feature of the Lower Yakima basin. This valley is bounded on the north by the Ahtanum Ridge-Rattlesnake Hills anticline and on the south by Toppenish Ridge and the Horse Heaven Hills. Many small tributary streams, including Toppenish, Agency, Simcoe, and Satus Creeks, drain the surrounding upland areas. At the eastern end of the Lower Yakima basin, the Yakima River is confined to a narrow valley lying between the basaltic slopes of the Rattlesnake and Horse Heaven Hills. A few miles upstream from its mouth; the Yakima River leaves this narrow valley and flows across the broad alluvial plain of the Columbia River.

A tributary drainage area of about 500 square miles lies in the reach between the Lower Yakima basin and its mouth. This area, called the Cold Creek basin in this report, consists of three synclinal basins, and part of the broad alluvial plain of the Columbia River. The synclinal basins lie north of the eastern end of the Lower Yakima basin, and are drained by Cold Creek and Dry Creek. A small area lying south of the Yakima River also is included in the Cold Creek basin.

The Yakima River basin includes 7 ground-water basins which have been subdivided into 25 ground-water subbasins (pl. 3). The boundaries of these subbasins for the most part coincide with the topographic divides. The discharge of many of the tributary streams and the outflow of some of the subbasins have never been measured, but their descriptions are important to any analysis of the water resources and to any future expansion of the stream-gaging program in the Yakima River basin. See geologic description of subbasins on page 104.

HISTORY OF STREAMFLOW MEASUREMENT

Collection of streamflow data began in the Yakima Basin in 1893 when stream-gaging stations were established on the Naches River near its mouth and on the Yakima River at Union Gap. Three years later a station was established on the Yakima River at Kiona, which is still in operation today, although the record has not been continuous. Figure 4 lists both active and discontinued gaging stations in the basin and graphically shows their period of record. The locations of these gaging stations are shown on plate 3. Numbers shown on figure 4 correspond with numbers on plate 3 for each gaging station. Published papers on surface-water supply in the Yakima River basin, containing records from 1899 to 1955, are listed in table 6.

TABLE 6.—*Index to U.S. Geological Survey publications giving streamflow measurements in the Yakima River basin*

Year	Water-Supply Paper	Year	Water-Supply Paper
1899 [1]	38	1931	722
1900 [2]	51	1932	737
1901	66, 75	1933	752
1902	85	1934	767
1903	100	1935	792
1904	135	1936	812
1905	178	1937	832
1906	214	1938	862
1907–8	252	1939	882
1909	272	1940	902
1910	292	1941	932
1911	312	1942	962
1912	332–A	1943	982
1913	362–A	1944	1012
1914	392	1945	1042
1915	412	1946	1062
1916	442	1947	1092
1917	462	1948	1122
1918	482	1949	1152
1919–20	512	1950	1182
1921	532	1951	1216
1922	552	1952	1246
1923	572	1953	1286
1924	592	1954	1346
1925	612	1955	1396
1926	632	1956	1446
1927	652	1957	1516
1928	672	1958	1566
1929	692	1959	1636
1930	707	1960	1716

[1] Rating tables and index to U.S. Geol. Survey Water-Supply Papers 35–39 contained in Water-Supply Paper 39. Monthly discharge for 1899 in U.S. Geol. Survey 21st Ann. Rept., pt. 4.
[2] Rating tables and index to U.S. Geol. Survey Water-Supply Papers 47–52 contained in Water-Supply Paper 52. Monthly discharge for 1900 in U.S. Geol. Survey 22d Ann. Rept., pt. 4.

NOTE.—Records of flow of streams in the Yakima River basin before 1899 are published in U.S. Geol. Survey Water-Supply Papers 11, 16; Bull. 131, 140; 14th Ann. Rept., pt. 2, 18th Ann. Rept., pt. 4, 19th Ann. Rept., pt. 4, and 20th Ann. Rept., pt. 4.

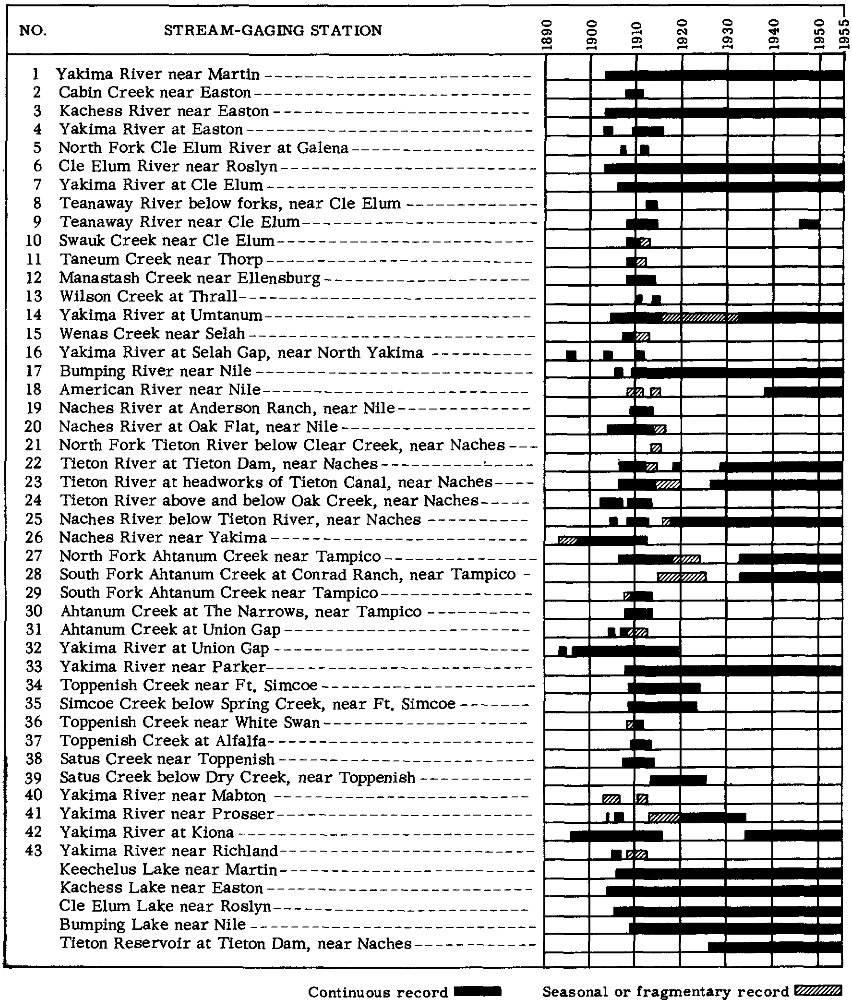

FIGURE 4.—Bar chart of streamflow records in the Yakima River basin.

Although the Geological Survey has carried on a substantial part of the stream gaging in the Yakima basin—much of it in cooperation with the State of Washington—other Federal agencies have done considerable work in this field. The U.S. Bureau of Reclamation and the U.S. Bureau of Indian Affairs have collected streamflow data in connection with their special requirements. These date are summarized in table 7.

The Yakima River basin is the most intensively studied basin in the State of Washington in respect to its surface-water resources. Collection of data cooperatively and individually since the 1890's has been undertaken by the U.S. Geological Survey, the State of Washington, the U.S. Bureau of Reclamation, and the U.S. Bureau of Indian Affairs.

The original gaging-station network was intended primarily to provide data for the design of the early irrigation projects of the Federal Government. As these irrigation projects were completed or the design definitely established, many of these stations were discontinued; others were retained primarily for operation of the existing projects. A few stations having long records provide a measure of the runoff from areas that have remained substantially undeveloped, and consequently these records provide a measure of the fluctuations of the natural runoff over a period of many years. Figure 5 is a map showing the location and duration of streamflow records collected by the U.S. Geological Survey.

At some gaging stations that have long records, progressive utilization has resulted in substantially increased consumptive use upstream, large diversions and bypass channels, and underground return flow at points often remote from the point of use. These factors have resulted in the streamflow records not being comparable during the period of operation and not being representative of the original flow of the river at that point. Studies to determine the adequacy of the safe water supply available for additional development require adjustment of past streamflow records for these factors. Data regarding these factors are often not available, particularly for early years. Table 8 is a summary of the regulation and diversion of streamflow that occur upstream from each gaging station.

TABLE 7.—*Streamflow records collected in the Yakima River basin by other agencies*

Name	Location	Period of record	Collected by	Where found and remarks
Cabin Creek near Easton	Sec. 9, T. 20 N., R. 13 E.	1909–15	U.S. Bureau of Reclamation.	Bureau of Reclamation office, Yakima, unpublished, 1911–15; prior to 1911 published by Geological Survey.
Yakima River at Easton	Sec. 11, T. 20 N., R. 13 E.	1904, 1910–15, 1940–55.	do	Bureau of Reclamation office, Yakima, unpublished since 1915; prior to that date published by Geological Survey.
Yakima River near Thorp	20 ft upstream from county bridge above Thorp.	1937–40 (fragmentary).	do	Bureau of Reclamation office, Yakima. Unpublished.
Yakima River at Ellensburg	Center sec. 10, T. 17 N., R. 18 E.	1937–50 (fragmentary).	do	Do.
Wilson Creek near Ellensburg (at Standly Ranch).	1 mile above Cherry Creek in sec. 19, T. 17 N., R. 19 E.	1924 (incomplete).	do	Do.
Nanum Creek near Ellensburg.	¼ mile below intake of Ellensburg water supply just below mouth of canyon.	Irrigation season of 1924.	do	Do.
Yakima River at Umtanum	NW¼ sec. 20, T. 16 N., R. 19 E.	1915–33	do	Bureau of Reclamation office, Yakima, 1915–33 unpublished (fragmentary); 1906–15, 1933–55 published by Geological Survey.
Wenas Creek below dam near Selah.	Sec. 11, T. 15 N., R. 17 E., ¼ mile below dam.	1925–27	do	Bureau of Reclamation office, Yakima. Unpublished.
Wenas Creek above dam	NW¼ sec. 3, T. 15 N	1942–44	U.S. Soil Conservation Service.	Soil Conservation Service, Yakima. Unpublished.
Wenas Creek below dam	SW¼ sec. 2, T. 15 N R. 17 E.	1942–44	do	Do.

Rattlesnake Creek	Sec. 3, T. 15 N	1922–23	U.S. Bureau of Reclamation.	Bureau of Reclamation office, Yakima. Unpublished.
Naches River at Nelson Bridge near Yakima.	NW¼ sec. 9, T. 13 N., R. 18 E.	Irrigation seasons of 1912–14.	do	Do.
Cowiche Creek near Yakima	At mouth, in sec. 10, T. 13 N., R. 18 E.	do	do	Do.
Wide Hollow Creek at Union Gap.	Sec. 8, T. 12 N., R. 19 E., at highway bridge.	1911–15 and 1922–33.	do	Do.
Reservation Drain near Alfalfa.	SW¼ sec. 29, T. 10 N., R. 21 E.	1912–55	U.S. Bureau of Indian Affairs.	Bureau of Indian Affairs office, Wapato, unpublished, 1923–55; prior to 1923 published by Geological Survey.
Toppenish Creek near Fort Simcoe.	Sec. 35, T. 10 N. R. 16 E.	1909–55	do	Bureau of Indian Affairs office, Wapato, unpublished, 1924–55; prior to 1924 published by Geological Survey.
Satus Creek near Toppenish	Sec. 24, T. 9 N., R. 19 E.	1913–55	do	Do.

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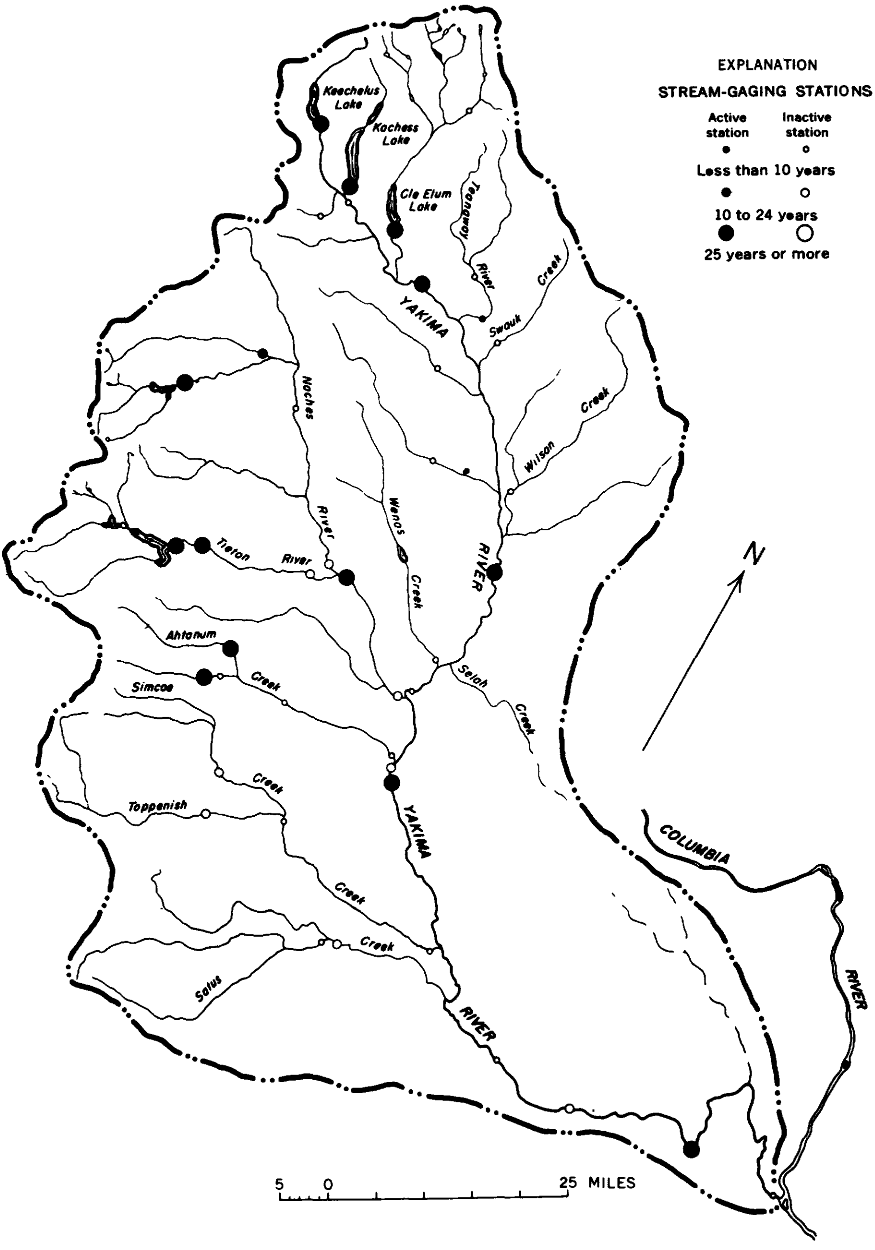

FIGURE 5.—Map showing location and duration of streamflow records.

TABLE 8.—*Regulation and diversion of streamflow in drainage areas upstream from gaging stations*

[For details of regulation, diversion, and other exceptions to natural yield see station descriptions beginning on page 31]

No.	Gaging station	Upstream regulation and diversion
1	Yakima River near Martin	Regulation and storage by Keechelus Lake.
2	Cabin Creek near Easton	None.
3	Kachess River near Easton	Regulation and storage by Kachess Lake.
4	Yakima River at Easton	Regulation and storage by two reservoirs; one major diversion.
5	North Fork Cle Elum River at Galena.	None.
6	Cle Elum River near Roslyn	Regulation and diversion by Cle Elum Lake.
7	Yakima River at Cle Elum	Regulation and storage by three reservoirs; one major and several small diversions.
8	Teanaway River below forks near Cle Elum.	Numerous small diversions.
9	Teanaway River near Cle Elum	Do.
10	Swauk Creek near Cle Elum	Do.
11	Taneum Creek near Thorp	One diversion.
12	Manastash Creek near Ellensburg	None.
13	Wilson Creek at Thrall	Numerous small diversions
14	Yakima River at Umtanum	Regulation and storage by three reservoirs; seven major and many minor diversions.
15	Wenas Creek near Selah	Regulation and storage by Wenas Reservoir; numerous small diversions.
16	Yakima River at Selah Gap, near North Yakima.	Regulation and storage by three major reservoirs; nine major and many minor diversions.
17	Bumping River near Nile	Regulation and storage by Bumping Lake.
18	American River near Nile	None.
19	Naches River at Anderson Ranch, near Nile.	Regulation and storage of one reservoir; diversions of two small ditches.
20	Naches River at Oak Flat, near Nile.	Regulation and storage of one reservoir; diversion of numerous small ditches.
21	North Fork Tieton River below Clear Creek, near Naches.	Infrequent regulation and storage by Clear Creek Reservoir.
22	Tieton River at Tieton Dam, near Naches.	Regulation and storage by Tieton Reservoir.
23	Tieton River at headworks of Tieton Canal, near Naches.	Regulation and storage by one major reservoir; one major diversion.
24	Tieton River above and below Oak Creek, near Naches.	Regulation and storage by one major reservoir; one major and several small diversions.
25	Naches River below Tieton River, near Naches.	Regulation and storage by two major reservoirs; three major diversions, all bypassing station, and several minor diversions.
26	Naches River near North Yakima	Regulation and storage by two major reservoirs; seven major and many minor diversions.

TABLE 8.—*Regulation and diversion of streamflow in drainage areas upstream from gaging stations*—Continued

No.	Gaging station	Upstream regulation and diversion
27	North Fork Ahtanum Creek near Tampico.	None of consequence.
28	South Fork Ahtanum Creek at Conrad Ranch, near Tampico.	Do.
29	South Fork Ahtanum Creek near Tampico.	Several minor diversions.
30	Ahtanum Creek at The Narrows, near Tampico.	Numerous minor diversions.
31	Ahtanum Creek near Yakima	Many minor diversions.
32	Yakima River at Union Gap, near Yakima.	Regulation and storage by five major reservoirs; many diversions.
33	Yakima River near Parker	Do.
34	Toppenish Creek near Fort Simcoe	None of consequence.
35	Simcoe Creek below Spring Creek, near Fort Simcoe.	Several minor diversions.
36	Toppenish Creek near White Swan	Numerous diversions.
37	Toppenish Creek near Alfalfa	Do.
38	Satus Creek near Toppenish	Several Diversions.
39	Satus Creek below Dry Creek, near Toppenish.	Do.
40	Yakima River near Mabton	Regulation and storage by five major reservoirs; many diversions.
41	Yakima River near Prosser	Do.
42	Yakima River at Kiona	Do.
43	Yakima River near Richland	Do.

Apparently there has been little coordinated effort to collect and preserve data regarding factors affecting the gaging-station record in a form available to the public. Although complete records of diversions and irrigated areas are commonly available for Federal projects and organized irrigation companies, such information is often lacking for private projects. Irrigation districts sometimes discard their records after a number of years on the assumption that such records are no longer of value. Records of utilization other than irrigation frequently are not available, and the need for them is not recognized until a water shortage or legal controversy occurs. The paucity of such data has been brought out in this investigation.

EVALUATION OF GAGING-STATION RECORDS

The following hydrologic and geologic data concerning the individual gaging-station sites were obtained from available published literature, unpublished engineering reports, and visits to the gaging stations. The exact location of a few of the older stations could not be found, but for most of these an evaluation could be made on the basis of the approximate location.

Information concerning the gaging stations on the Yakima River and its tributaries is presented in downstream order from headwaters to mouth, with stations on tributaries being inserted in the order in which the tributaries enter the stream. The locations of the stations are shown on plate 3 and figure 5.

Location.—The geodetic position is given to the nearest 5 seconds of arc, or to the nearest second, as scaled from Geological Survey topographic maps.

"Right bank" and "left bank" refer to the side of the stream on which the gage is located, as viewed when looking downstream. This specific connotation is standard usage in all Geological Survey reports and data collecting.

If the place name is for a small community that may be hard to find on a map, the distance to a larger community also may be given. Where a station is near a county line, the place name may be in the adjoining county.

The "drainage area" refers to the surface drainage area upstream from the gaging station within the topographic divides of the basin, and for most stations in the Yakima River basin it is about equal to the ground-water drainage area. Where this information is not available, this paragraph has been omitted.

Gage.—This paragraph gives the types of equipment used, the inclusive dates for each type if more than one, and the location with respect to the latest gage as described in the paragraph on "location." The datum is also given if known or the altitude is substituted.

Records available.—The period of time for which discharge or gage-height records are known to be available is stated. Unless another source is shown, these records are published in U.S. Geological Survey Water-Supply Papers as part 12 of the series, "Surface-Water Supply in the United States." (See table 6.)

Accuracy of record.—The degree of accuracy of the records is given "Excellent," indicating that, in general, the error in daily records probably is less than 5 percent; "good," less than 10 percent; "fair," less than 15 percent; and "poor," probably more than 15 percent. The records of monthly and yearly mean discharge are, in general, more nearly accurate than the daily records.

Geologic setting.—Emphasis has been placed on the geologic factors in the immediate vicinity of the gaging stations that could influence the station record. Geologic cross sections have been included where sufficient information is available. Logs of wells and test holes shown on these sections are given on pages 121–131.

Surface diversion.—Water removed from the natural channel by artificial means, such as a ditch, canal, pipe, or pump along the reach between the station described and the next station upstream is listed.

Here, "location" refers to the headgate or point at which water is removed from the stream. Although the larger canals and ditches have continuous water-stage recorders in operation during the irrigation season or a staff gage read by an observer, the accurate flow of most smaller diversions is not known. Therefore, the "approximate average flow" during the irrigation season is estimated. If a reliable estimate is not possible, the amount of the water right is given, even though this amount may not be equal to the amount used. When dates of establishment of canals and ditches are not available, an approximation is made with relation to the establishment of the gaging station. Although the capacities of ditches and canals are not given, some indication as to their size may be obtained from the "maximum recorded flow," which has been included where available. The purpose of the diversion is usually shown. Diversions for irrigation occur only during the irrigation season, generally from April through September. During the remainder of the year there may be little or no water diverted for irrigation.

Bypass channels.—Those ditches, canals, etc., which carry surface flow around the gaging station are listed. Such flow, therefore, is not measured at the gaging station and may not be included in the station record. In this report most such channels are canals or ditches that carry water past the station, or past several stations in succession, for use downstream. Any unusual circumstances in connection with the bypass flow are explained. At certain stations the flow of the canal is, or can be, added to that of the gaging station to give the total surface flow at that site; however, for most bypassing canals part of the water originally diverted is used upstream or lost through seepage and the amount actually bypassing the station is less than diverted.

Subsurface bypass.—The occurrence of valley underflow which bypasses the gaging stations is qualitatively described. Where possible, some notation of the magnitude of the bypass is indicated. The words "error in streamflow records," as used in this paragraph refers to the accuracy of the records as described above.

Surface return flow.—Water returning to the stream from irrigated tracts, by overland flow within the area indicated is listed. Locations of wasteways, their approximate flow, and source of the flow are listed if known.

Subsurface return flow.—Water returning to the stream by ground-water discharge is listed. Locations along the stream where large amounts of ground water enter the stream are delineated. There is no way to separate natural return flow from that caused by irrigation, although it is thought that the proportion due to natural ground water is very small.

Storage and regulation.—Operation of reservoirs or other structures that affect the normal regimen of flow at the particular gaging station is described. So considered, regulation is the alternate storage and release of water, excluding withdrawals by diversion from the stream channel. Regulation at the station also may be caused by structures in areas above successive upstream gaging stations, but such regulation is mentioned only in the records of the gaging station just below the structure.

Utilization.—The use of water in the area is indicated, regardless of the ultimate source of that water. Changes in utilization from its beginning to the present are given if known. The figures concerning ground-water withdrawals in this paragraph are estimates of the present annual withdrawal of ground water for the entire drainage area upstream from the gaging station. Only a part of the estimated ground-water withdrawal can be considered as consumptive use, as part of the ground water withdrawn eventually returns to the stream above the gaging station, and is measured as streamflow.

The paragraph concerning "imported recharge" delineates areas where surface diversions from one basin replenish ground-water bodies in adjacent basins.

Adequacy of record.—An evaluation of the degree to which the streamflow records represent the combined surface and subsurface outflow, or total outflow, from the drainage area is given. In some instances, the adequacy of the record as a measure of natural runoff is evaluated. In this paragraph a few sites are suggested where a more accurate measure of total outflow might be obtained. Spot measurements at these sites, during periods of low flow, would permit an estimate of the magnitude of subsurface bypass around existing gaging stations.

1. YAKIMA RIVER NEAR MARTIN

Location.—Lat 47°19′10″, long 121°20′10″, in NE¼ sec. 12, T. 21 N., R. 11 E., on left bank 800 ft downstream from dam at outlet of Keechelus Lake, 3½ miles northwest of Martin, and 12 miles northwest of Easton.

Drainage area.—55.8 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,422.40 ft above mean sea level (U.S. Bureau of Reclamation bench mark). Prior to July 20, 1923, staff gages at several sites within 2 miles of present site at different datums.

Records available.—October 1903 to September 1955.

Accuracy of records.—Excellent to good, except for periods of low flow, which are fair.

Geologic setting.—This station is on the outlet flume just downstream from Keechelus Dam, an earth structure which impounds additional water in Keechelus Lake. The dam was constructed on a glacial moraine that extends across the mile-wide Yakima Valley. This moraine, which is composed of stream-laid sand and gravel and ice-deposited till and boulders, forms a natural dam impounding the lake. The thickness of the morainal fill is not known, but permeable sands and gravels were encountered in test holes at depths of 40 ft. below the bottom of the outlet flume. Bedrock was not penetrated in these holes. A geologic section across the valley is shown in figure 6.

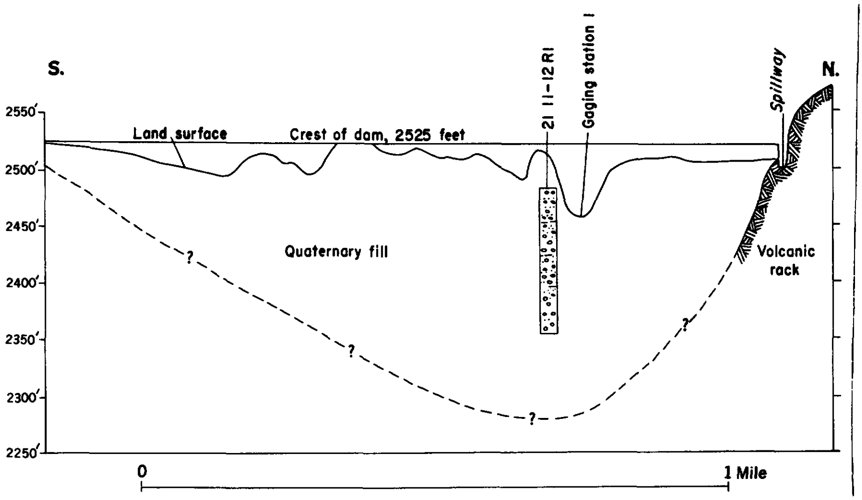

FIGURE 6.—Section along centerline of Keechelus Dam, near site of gaging station 1, Yakima River near Martin, Wash.

Surface diversions.—None.

Bypass channels.—Spillway from Keechelus Lake bypasses gage. Discharge is computed by weir formula and added to flow measured at gaging station to obtain total flow released from lake.

Subsurface bypass.—This station is bypassed by underflow through the morainal and fluviatile deposits beneath and adjacent to the dam. The amount of underflow is not known, but it may exceed the error in the streamflow record except during periods of high runoff.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—Since 1906, water stored in Keechelus Lake for irrigation downstream (table 5). The Geological Survey water-supply papers give monthly flow adjusted for change in contents of Keechelus Lake, as measure of natural runoff.

Utilization.—Little or none upstream from this station.

Imported recharge.—None.

Adequacy of record.—The record for this station accurately portrays the controlled discharge from Keechelus Lake, but the records do not completely represent the total outflow of the drainage area.

In the reach below the mouth of Cabin Creek, entire outflow of the Keechelus subbasin is confined in a narrow canyon eroded into volcanic rock. Measurements at this point would represent the total of the Keechelus subbasin.

2. CABIN CREEK NEAR EASTON

Location.—Lat 47°14'30", long 121°13'40", in sec. 9, T. 20 N., R. 13 E., on right bank at Northern Pacific Railway bridge, half a mile upstream from mouth, and 2¼ miles west of Easton.

Drainage area.—31.7 sq mi.

Gage.—Staff gage. Altitude of gage is 2,250 ft (from topographic map).

Records available.—May 1909 to December 1910; 1911, gage heights only.

Accuracy of record.—Generally fair to good.

Geologic setting.—This station was about a quarter of a mile upstream from the mouth of the stream. In this reach Cabin Creek flows through a small valley underlain with an unknown thickness of stream-deposited sand and gravel.

Surface diversions.—A 6-in. pipeline diverted water three-quarters of a mile above gage to Northern Pacific Railway shop for locomotives and domestic use at Easton. This pipeline was discontinued in 1945. No known records of diversion.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by underflow moving downvalley through the alluvial materials. The amount of bypass probably was small and within the error in the streamflow record during periods of high runoff, but it may have exceeded the error during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—Not known.

Storage and regulation.—None.

Utilization.—Until 1944, Eastern obtained water during the summer from the water-supply system of the Northern Pacific Railway. Small amount of water used for steam locomotives until 1945.

Imported recharge.—None.

Adequacy of record.—The records are fairly representative of the total outflow of the drainage area except for periods of low flow during late summer and early fall months.

3. KACHESS RIVER NEAR EASTON

Location.—Lat 47°15'30", long 121°11'50", in NE¼, sec. 3, T. 20 N., R. 13 E., on left bank three-quarters of a mile downstream from Kachess Lake and 2 miles northwest of Easton.

Drainage area.—63.6 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,188.10 ft (from Bureau of Reclamation bench mark). Prior to Oct. 8, 1927, staff and recording gages at several sites and datums within half a mile of present gage.

Records available.—October 1903 to September 1955.

Accuracy of record.—Good to excellent except for periods of low flow, which are fair.

Geologic setting.—This station is about 2,000 ft downstream from Kachess Dam. The dam is an earth- and gravel-fill structure that impounds additional water in Kachess Lake. It was constructed on a glacial moraine that extends across the Kachess Valley, forming a natural dam impounding Kachess Lake.

The Kachess River, in the reach just below the dam, flows along the northeastern edge of the inner valley, which was eroded into a much wider and older valley fill. This older fill, consisting of glacial and fluviatile sand, gravel, boulders, and till, has a width of about 2 miles and an unknown thickness. The floor of the small inner valley has a width of about 2,000 ft, and is underlain with an unknown thickness of sand, gravel, and boulder alluvium. The slopes of this inner valley rise steeply for 50 or 60 ft above the valley floor to the broad flat surface of the older valley fill. A geologic section across the Kachess Valley, at the site of this station, is shown in figure 7.

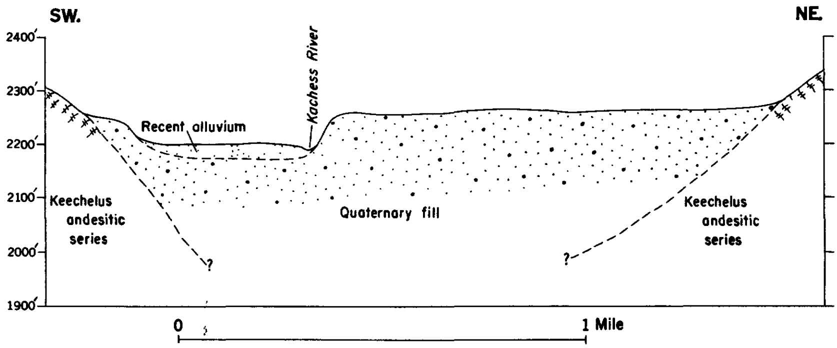

FIGURE 7.—Section through site of gaging station 3, Kachess River near Easton, Wash.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—This station is bypassed by flow passing beneath the dam through the moraine and older valley fill materials. The amount of bypass is unknown, but it may exceed the error in the streamflow record during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—Since 1905, water stored in and released from Kachess Lake for irrigation downstream (table 5). The Geological Survey water-supply papers give monthly flow adjusted for change in contents of Kachess Lake as a measure of natural runoff.

Utilization.—None.

Imported recharge.—None.

Adequacy of records.—The records give an adequate measure of the controlled discharge from Kachess Lake, but they are not completely representative of the total outflow of the drainage area. The combined outflow of the Keechelus and Kachess subbasins could be adequately measured at a station at the southeastern end of the Kachess subbasin.

4. YAKIMA RIVER AT EASTON

Location.—Lat 47°14′20″, long 121°10′40″, in SE¼ sec. 11, T. 20 N., R. 13 E., on right bank at Easton 20 ft downstream from highway bridge, a quarter of a mile downstream from Easton dam, and 1½ miles downstream from Kachess River.

Drainage area.—182 sq mi.

Gage.—Water-stage recorder. Altitude of gage is 2,140 ft (from river-profile map). Prior to Oct. 10, 1915, staff or chain gages at approximately same site at different datums.

Records available.—May to November, 1904, and February 1910 to October 1915 in records of Geological Survey. December 1940 to September 1955 in files of Bureau of Reclamation, Yakima.

Accuracy of record.—Generally excellent.

Geologic setting.—The station is just northwest of Easton. In this reach the Yakima River flows through a shallow inner valley eroded into the wider Yakima Valley. This broad valley is underlain by an unknown thickness of valley-fill materials. Well 20/13–11R1 (log, p. 128) at Easton, penetrated 120 ft of sand, gravel, boulders, and clay without encountering bedrock. The small inner valley occupied by the Yakima River barely exceeds the width of the stream, and is underlain with an unknown thickness of medium to coarse gravels.

Surface diversions.—Kittitas Highline Canal diverts in the SE¼NW¼ sec. 11, T. 20 N., R. 13 E. Entire flow bypasses gaging station and is used to irrigate about 54,000 acres downstream in the vicinity of Ellensburg. Operation of canal began in April 1930; a negligible quantity of stock water obtained from the canal throughout the year. Maximum recorded flow, 1,250 cfs; average flow, about 700 cfs. Record of this diversion in files of Bureau of Reclamation, Yakima. No other known diversion above station.

Bypass channels.—Kittitas Highline Canal bypasses station to irrigate land downstream. Published records of flow at station do not include bypass.

Subsurface bypass.—The station is bypassed by water moving down the Yakima Valley through the older valley-fill materials. The bypass probably is mainly subsurface flow from Kachess Lake.

Surface return flow.—None.

Subsurface return flow.—A large amount of natural ground-water discharge probably enters the Yakima River a few miles upstream from this station (plate 3).

Storage and regulation.—See table 8.

Utilization.—No irrigation upstream from this station. About 25 acre-ft of ground water withdrawn each year for domestic use.

Imported recharge.—None known.

Adequacy of record.—The published records, after adjustment for surface bypass in Kittitas Highline Canal, give a fairly adequate measure of the total outflow of the drainage area. Subsurface bypass was less than the error in the streamflow record, except during periods of low flow.

5. NORTH FORK CLE ELUM RIVER AT GALENA

Location.—Lat 47°28′, long 121°03′, just upstream from Camp Creek, a quarter of a mile north of Galena, and 28 miles north of Cle Elum.

Drainage.—37.9 sq. mi.

Gage.—Staff gage. Altitude of gage is 3,000 ft.

Records available.—June to December 1907, and June to September 1911 (gage heights only).

Geologic setting.—This station was about 12 miles north of Cle Elum Lake. In this reach the Cle Elum River flows through a deep valley eroded into the Swauk formation. The valley floor is narrow and is underlain by an unknown thickness of coarse-grained alluvial materials.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—This station was bypassed by small amounts of underflow moving downvalley through the alluvial materials.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—None.

Utilization.—None.

Imported recharge.—None.

Adequacy of record.—No continuous record of streamflow obtained. Discharge measurements of this site would be fairly representative of the total outflow of the drainage area.

6. CLE ELUM RIVER NEAR ROSLYN

Location.—Lat 47°14'30", long 121°03'50", in NW¼ sec. 11 T. 20 N., R. 14 E., on left bank 1,000 ft downstream from dam at Cle Elum Lake and 4 miles northwest of Roslyn.

Drainage area.—203 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,102.10 ft above mean sea level (U.S. Bureau of Reclamation bench mark). Prior to Apr. 20, 1953, staff gages or water-stage recorder at several sites and datums within half a mile of present site.

Records available.—October 1903 to September 1955.

Accuracy of Record.—Generally excellent for flow greater than 250 cfs, good for flow between 25 and 250 cfs, and poor below 25 cfs.

Geologic setting.—This station is 1,000 ft below Cle Elum Dam. In this reach the Cle Elum River flows through a narrow valley eroded into older valley-fill deposits. The small inner valley has a width of about 500 ft and a depth of about 120 ft. The valley slopes rise steeply to the broad flat upland surface of the older fill deposits. The floor of the inner valley is underlain by an unknown thickness of coarse gravel. The older fill materials are composed primarily of sand, medium to coarse gravel, and boulders. They have a thickness of several hundred feet, and underlie a valley, 1½ miles wide.

Cle Elum Dam is an earth- and gravel-fill structure constructed on a glacial moraine. This dam impounds additional water in Cle Elum Lake, a lake which is impounded naturally by the glacial moraine. Figure 8 is a section extending across the Cle Elum Valley through this moraine.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by subsurface flow which passes through the older fluviatile and morainal materials beneath and adjacent to Cle Elum Dam. The amount of bypass is not known, but it may exceed the error in the streamflow record during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—Since 1906, water stored in and released from Cle Elum Lake for irrigation downstream (table 5). The Geological Survey water-supply papers (table 6) give monthly flow adjusted for change in contents of Cle Elum Lake, as a measure of natural runoff.

Utilization.—Very small amount for domestic use.

Imported recharge.—None.

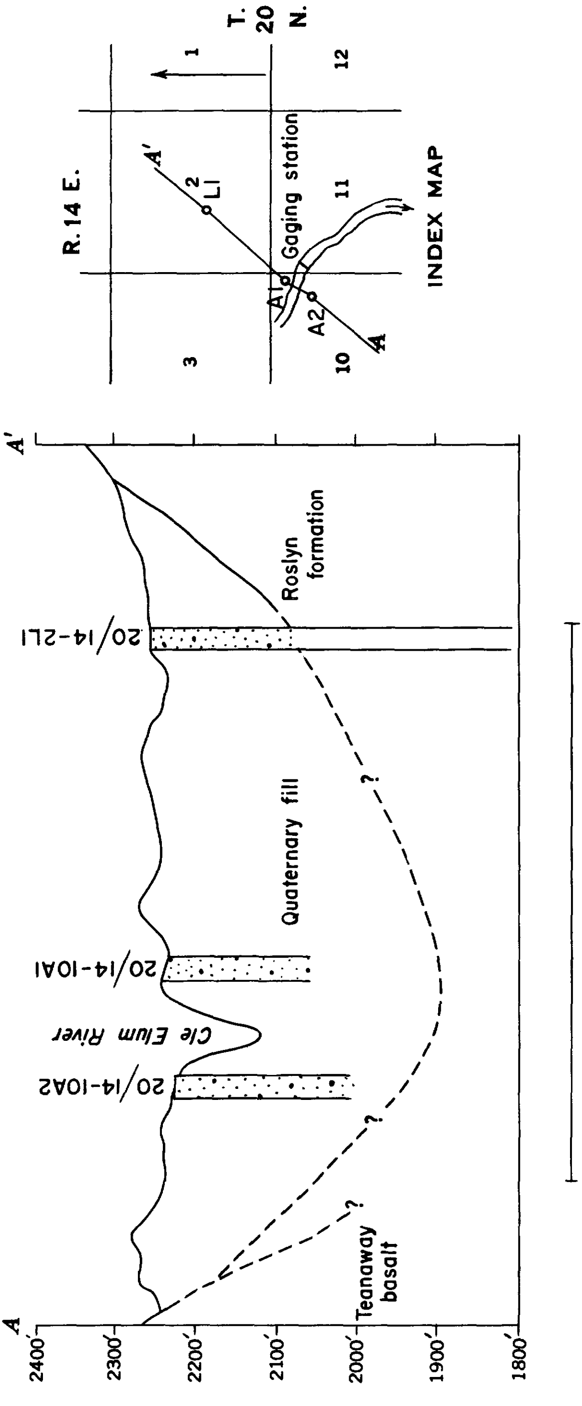

FIGURE 8.—Section through site of gaging station 6, Cle Elum River near Roslyn, Wash.

Adequacy of record.—The records give an adequate measure of the controlled discharge from Cle Elum Lake; but even with adjustments for regulation, they may not completely represent the total outflow of the drainage area during periods of low flow.

7. YAKIMA RIVER AT CLE ELUM

Location.—Lat 47°11′20″, long 120°56′40″, in sec. 27 T. 20 N., R. 15 E., on left bank at highway bridge at Cle Elum, just upstream from Roslyn Creek, and 7 miles upstream from Teanaway River.

Drainage area.—500 sq mi.

Gage.—Water-stage recorder. Datum of gage is 1,902.27 ft above mean sea level (levels by U.S. Bureau of Reclamation). Prior to Oct. 22, 1924, staff or chain gages, or water-stage recorder at approximately the same site and datum.

Records available.—August 1906 to September 1955.

Accuracy of record.—Good.

Geologic setting.—The gaging station is just west of the town of Cle Elum. In this reach the Yakima River flows along the northern edge of a flood plain, half a mile in width, forming the floor of a valley eroded into deposits filling an older and broader valley. The flood plain is underlain with an unknown thickness of coarse sand and gravel alluvium.

The older valley fill was deposited in a large valley which was eroded into the Roslyn formation. The fill consists of sand, gravel, boulders, and clay. Well 20/15-27Q1 (log, p. 130) located along the north bank of the Yakima River at the site of this gaging station, penetrated 450 ft of fill before encountering the Roslyn formation. The coarser, more permeable materials are generally encountered within the first 100 ft below the surface of the ground, the deeper materials usually being finer grained. Figure 9 is a section across the Yakima Valley beneath the site of the gaging station.

Surface diversions.—

1. Negligible amount pumped from Yakima River in Easton for supplying few remaining steam locomotives of the Northern Pacific Railway.
2. Negligible amount diverted from Silver and Hambright Creeks for Easton municipal supply.
3. Big Creek Adjudication Decree of 1924 allocates 1 miner's inch per acre for irrigation of 1,143 acres. Water supply probably inadequate, except for the early part of the irrigation season.
4. Town of Cle Elum diverts for municipal use an average flow of about 3 cfs from Cle Elum River half a mile below the Cle Elum River near Roslyn gaging station.
5. Municipal water supply of about 2 cfs for town of Roslyn is diverted from Domerie Creek.
6. Several small diversions for irrigation of a few hundred acres above station.

Bypass channels.—Kittitas Highline Canal bypasses station. Discharge figures since 1930 have been adjusted to show natural flow at station.

Subsurface bypass.—The station is bypassed by water moving downvalley through the coarse stream alluvium which underlies the flood plain and by water moving downvalley through the older unconsolidated valley-fill materials. A part of the subsurface bypass which moves through the older valley fill materials consists of subsurface outflow from Cle Elum Lake. The amount of bypass is not known, but it probably exceeds the error in the streamflow records during periods of low flow.

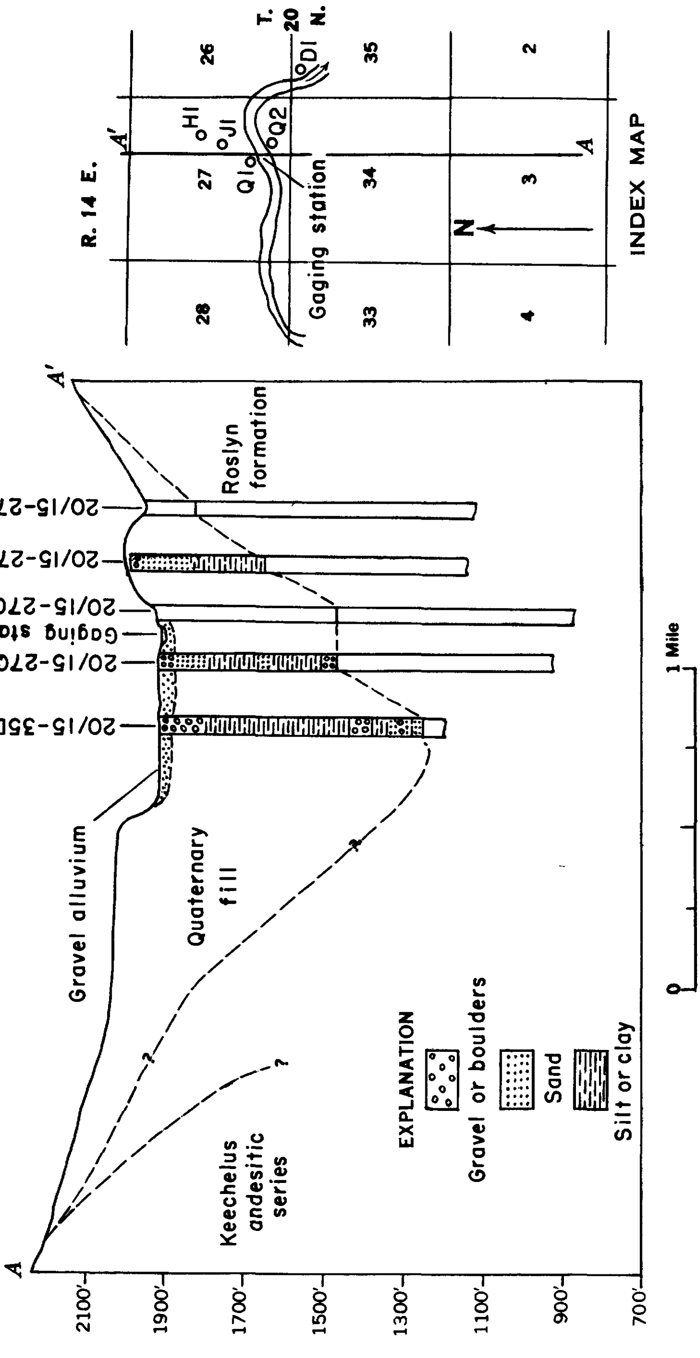

FIGURE 9.—Section through site of gaging station 7, Yakima River at Cle Elum, Wash.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—See table 8.

Utilization.—Water supplies of Roslyn and Cle Elum, utility supply for Northern Pacific Railway, and small amount for local irrigation. About 600 acre-ft of ground water per year is withdrawn chiefly for industrial and domestic use. Some mine water utilized for industrial purposes.

Imported recharge.—None known.

Adequacy of record.—The flow at this station is regulated by three upstream reservoirs. Adjusted records may not represent the total outflow of the drainage area as subsurface bypass may be considerable. Total yield of the Roslyn ground-water basin, except the flow in the Kittitas Highline Canal, could be measured in the narrow canyon just downstream from the mouth of Swauk Creek.

8. TEANAWAY RIVER BELOW FORKS, NEAR CLE ELUM

Location.—Lat 47°14′, long 120°51′, in NW¼ sec. 9, T. 20 N., R. 16 E., on left upstream side of diversion dam, 1 mile downstream from North Fork, 5 miles northeast of Cle Elum, and 15 miles upstream from mouth.

Drainage area.—174 sq mi.

Gage.—Staff gage. Altitude of gage is 2,160 ft (from topographic map).

Records available.—June 1911 to June 1912 (monthly discharge only in Water-Supply Paper 1316).

Geologic setting.—The station was about 2 miles below the forks. In this reach the Teanaway River flows southwest through a broad valley eroded into the Roslyn formation. The valley floor has a width of about 2,000 ft, and is underlain by an unknown thickness of sand and gravel alluvium.

Surface diversions.—Adjudication Decree of 1921 for Teanaway River considered 1,158 acres above gage irrigable and alloted water rights of 1 miner's inch per acre. No known records of diversions above station. Except for drought years, there has been ample water for all lands. In recent years water users may have been obtaining as much as twice the allotted amount without impairing the rights of those downstream (according to an oral report from George Meek, Kittitas County watermaster, 1951).

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by underflow moving downvalley through the alluvial materials.

Surface return flow.—Many of the upstream users divert the entire flow of the river. Return flow is sufficient to satisfy downstream requirements.

Subsurface return flow.—Surface diversion that recharges the alluvial aquifers beneath the valley floor is returned to the Tenaway River by ground-water discharge.

Storage and regulation.—None.

Utilization.—Irrigation, as noted under "Surface diversions." Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—Records at this site would not represent the total outflow of the drainage area, except during periods of high runoff, because of large quantities of subsurface flow bypassing gaging station.

9. TEANAWAY RIVER NEAR CLE ELUM[1]

Location.—Lat 47°11′40″, long 120°46′50″, in SW¼ sec. 25, T. 20 N., R. 16 E., on right bank 100 ft upstream from highway bridge, 4 miles upstream from mouth, and 8 miles east of Cle Elum.

Drainage area.—200 sq mi. At site Apr. 2, 1909, to Sept. 10, 1914, 205 sq mi.

Gage.—Water-stage recorder. Datum of gage is 1,931.91 ft above mean sea level, datum of 1929, supplementary adjustment of 1947. Apr. 2, 1909, to Sept. 30, 1914, chain gage 3½ miles downstream at different datum. Oct. 2, 1946, to Oct. 20, 1949, water-stage recorder 100 ft downstream at datum 32.08 ft lower.

Records available.—April 1909 to September 1914 and October 1946 to September 1952.

Accuracy of record.—Good to fair.

Geologic setting.—This station was 4 miles upstream from the mouth. In this reach the Teanaway River flows along the south edge of a valley 2,000 ft wide. The valley floor is underlain with an unknown thickness of sand and coarse gravel alluvium. The southern slope of the valley is formed by the Columbia River basalt, and the northern slope is formed by the older Roslyn formation. A geologic section, across the valley at this site, is shown in figure 10.

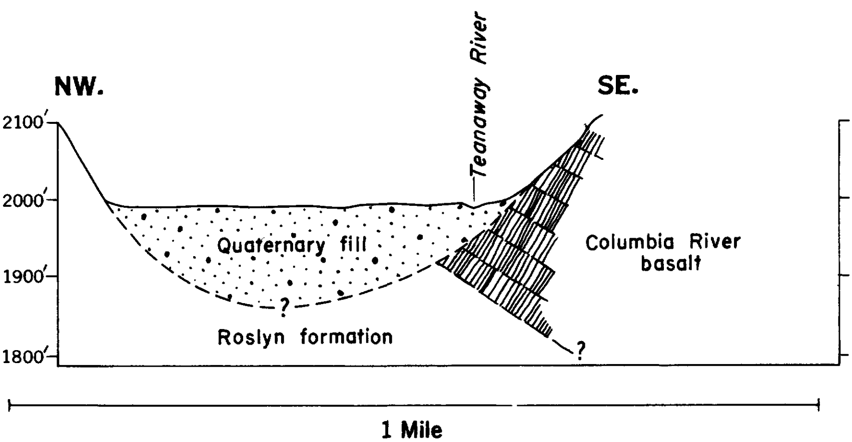

FIGURE 10.—Section through the site of gaging station 9, Teanaway River near Cle Elum, Wash.

Surface diversions.—Adjudication Decree of 1921 for Teanaway River classified 1,107 acres as irrigable between site of present gaging station and that of Teanaway River below forks Cle Elum. Allocation of 1 miner's inch per acre was made. No known records of amount diverted above station. See "Diversions" for station, Teanaway River below forks near Cle Elum.

Bypass channels.—None.

Subsurface bypass.—This station is bypassed by water moving downvalley through the alluvium.

[1] Published as Teanaway River near Clealum prior to 1913.

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Storage and regulation.—None.

Subsurface return flow.—Alluvial aquifers, which are recharged by surface diversions, discharge to the Teanaway River.

Storage and regulation—None.

Utilization.—Irrigation as noted under "Surface diversions." About 175 acre-ft per year of ground water withdrawn for domestic and irrigation use.

Imported recharge.—None.

Adequacy of records.—The records give a fairly adequate measure of total outflow of the drainage area. Bypass is within the accuracy of the records, except during periods of low flow.

10. SWAUK CREEK NEAR CLE ELUM

Location.—Lat 47°09′50″, long 120°40′00″, in the SE¼ sec. 5, T. 19 N., R. 17 E., on right bank, 2½ miles upstream from mouth and 12 miles east of Cle Elum.

Drainage area.—87.8 sq mi.

Gage.—Staff gage. Altitude of gage is 1,920 ft (from topographic map). Prior to Aug. 7, 1914, staff gage several hundred feet downstream at different datum.

Records available.—April 1909 to September 1911. (October 1911 to September 1912, gage heights and discharge measurements only.)

Accuracy of record.—Generally good to excellent.

Geologic setting.—The station was 2½ miles above the mouth. In this reach Swauk Creek flows through a narrow canyon eroded into the Columbia River basalt. The valley floor is narrow and is underlain with coarse gravel alluvium to an unknown depth.

Surface diversions.—A highline ditch diverts total flow of First Creek into Reeser Creek by way of Green Canyon, from which a diversion is made for irrigation (according to an oral report from George Meek, Kittitas County watermaster, 1951). Small amounts diverted from Swauk Creek for mining and local irrigation.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by underflow moving downvalley through the alluvium. The amount of underflow is not known, but it probably exceeded the error in the stream flow record during periods of low flow.

Surface return flow.—None known.

Subsurface return flow.—Probably small amount of return flow from local irrigation.

Storage and regulation.—None.

Utilization.—Local irrigation and small-scale mining. Small amount of ground water withdrawn above station for domestic use.

Imported recharge.—None.

Adequacy of record.—Because of the diversion from First Creek out of the basin, the records give only an approximate measure of the total outflow of the drainage area.

11. TANEUM CREEK NEAR THORP

Location.—Lat 47°05′10″, long 120°46′40″, in sec. 1, T. 18 N., R. 16 E., on left bank a quarter of a mile upstream from Bruton Canal and 5¾ miles northwest of Thorp.

Drainage area.—76.3 sq mi.

Supplemental records available.—November 1910 to September 1912, gage heights and discharge measurements only.

Gage.—Staff gage. Altitude of gage is 2,040 ft (from topographic map). Nov. 16, 1910, to Sept. 30, 1912, staff gage a quarter of a mile downstream (below Bruton Canal) at different datum.

Records available.—April to December 1909, and March to November 1910.

Accuracy of record.—Fair to excellent.

Geologic setting.—The station was about 3 miles above the mouth. In this reach Taneum Creek flows through a deep canyon eroded into the Columbia River basalt. The valley floor has a width of about 500 feet, and is underlain with an unknown thickness of coarse gravel alluvium.

Surface diversions.—Bruton Canal, constructed in 1874, diverts one-third of total flow (by decree) at a point 300 ft upstream during irrigation season. Canal carries about 40 cfs during early part of season. About June the diversion decreases, and is finally abandoned, water being drawn from the Kittitas Highline Canal thereafter (according to oral report from A. V. Harrell, secretary, Taneum Ditch Co., 1951). No records of flow available.

Bypass channels.—Bruton Canal bypasses station. Discharge records do not include flow of canal.

Subsurface bypass.—The station was bypassed by underflow moving downvalley through the alluvium. The amount of bypass is unknown, but it may exceed the error in the streamflow record during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—None.

Utilization.—None above station. Bruton Canal, which bypasses station, delivers water to about 500 acres in and adjacent to sec. 34, T. 19 N., R. 17 E., downstream from station. About 25 acre-ft of ground water is withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—If Bruton Canal is considered to carry one-third of the total flow during the first part of the irrigation season, a fair measure of the total outflow of the drainage can be calculated from the records, except during periods of low flow.

12. MANASTASH CREEK NEAR ELLENSBURG

Location.—Lat 46°58′00″, long 120°41′40″, in sec. 15, T. 17 N., R. 17 E., on left bank 1½ miles upstream from mouth of Manastash Canyon, 2 miles downstream from North Fork, and 8½ miles west of Ellensburg.

Drainage area.—75.8 sq. mi.

Gage.—Staff gage. Datum of gage is 2,117.70 ft above mean sea level, adjustment of 1912.

Records available.—April 1909 to September 1914.

Accuracy of record.—Generally good to excellent.

Geologic setting.—The station was 1½ miles upstream from the mouth of Manastash Canyon. In this reach Manastash Creek flows through a deep canyon eroded into the Columbia River basalt. The valley floor has a width of about 600 ft, and is underlain with an unknown thickness of coarse gravel alluvium.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by underflow moving downvalley through the alluvium. The amount of bypass is unknown, but it may exceed the error in the streamflow record during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—The development of a few hundred acre-ft of storage in Manastash Lake was attemped prior to 1915, but the project was found impractical and abandoned after 2 or 3 seasons (according to oral report from George Meek, Kittitas County watermaster, 1951).

Utilization.—No known surface diversions; about 25 acre-ft of ground water utilized per year for domestic use.

Imported recharge.—None.

Adequacy of record.—The records give a fairly adequate measure of total outflow of the drainage area, except during periods of low flow.

13. WILSON CREEK AT THRALL

Location.—Lat 46°56′, long 120°30′, in SE¼ sec. 30, T. 17 N., R. 19 E., at highway bridge, half a mile east of Thrall and 5 miles southeast of Ellensburg.

Gage.—Staff gage. Altitude of gage is 1,500 ft (from topographic map).

Records available.—August to October 1911 (gage heights only).

Geologic setting.—The station was in the south-central part of the Ellensburg subbasin, just north of the entrance to Yakima Canyon. In this reach Wilson Creek flows across the flood plain of the Yakima River. The flood plain is underlain with a considerable thickness of sand and gravel alluvium.

Surface diversions.—

1. Wilson Creek Adjudication Decree (Kittitas Superior Court Decree, Jour. 2, p. 143) allocates 1 miner's inch per acre for 2,738 acres. Most of this area lies below the Kittitas Highline Canal and has obtained water from it since its construction in 1930. Small farms not mentioned in the decree lying above the highline canal now take all remaining flow of Wilson Creek, which is not sufficient for their needs. (Oral report by George Meek, Kittitas County watermaster, 1951.)
2. The Bull Canal has diverted from Wilson Creek in sec. 11, T. 17 N., R. 18 E., since 1926. Prior to this time the canal (which was built in the 1890's) had diverted from the Yakima River. Part of the flow of Bull Canal consists of return flow from irrigation above. Discharge averages about 20 cfs, and the maximum recorded flow is 37 cfs. (Records for 1909–19 and 1922–55, in files of Bureau of Reclamation, Yakima, Wash.) An estimated 1,300 acres is irrigated (records in files of Washington Dept. of Conservation and Development.)
3. Tjossem small power ditch, diverting in center of sec. 13, T. 17 N., R. 18 E., carries an average of about 3 cfs and has a maximum recorded flow of 12.6 cfs. Since 1920 when powerplant was abandoned, it has been used for the irrigation of an estimated 100 acres. Miscellaneous measurements only in files of Bureau of Reclamation, Yakima, for 1914 and 1924–55.
4. Farrell ditch 1, diverting in the SW¼SE¼ sec. 13, T. 17 N., R. 18 E., carries an average flow of about 7 cfs and has a maximum recorded flow of 16 cfs. An estimated 250 acres is irrigated. Miscellaneous measurements in files of Bureau of Reclamation, Yakima, for 1914 and 1924–55.
5. Coleman Creek Adjudication Decree (Kittitas Superior Court, Jour. 21, p. 13) allocates 1 miner's inch per acre for 2,850 acres. Most of this

area lies below the Kittitas Highline Canal and has obtained water from this source since its construction in 1930. Small farms not mentioned in the decree lying above the canal now take all remaining flow of Coleman Creek, which is not sufficient for their needs. (Oral report by George Meek, Kittitas County watermaster, 1951.)

6. Nanum Creek Adjudication Decree (Kittitas Superior Court, Jour. 12, p. 413) allocates 1 miner's inch per acre for 5,730 acres. Most of this area lies below the Kittitas Highline Canal and has obtained water from this source since its construction in 1930. Small farms lying above the canal and not mentioned in the decree now take all remaining flow of Nanum Creek, which is not sufficient for their needs. (Oral report by George Meek, Kittitas County watermaster, 1951.) The city of Ellensburg occasionally diverts 4 to 5 cfs as a standby municipal supply. Diversion periods irregular. (Oral report by Ellensburg City engineer, 1951.) No records available.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water which moved downvalley through the alluvial materials and discharged directly into the Yakima River.

Surface return flow.—The city of Ellensburg sewage-treatment plant since 1938 has discharged about 8 cfs of effluent into Wilson Creek in the SW¼ sec. 2, T. 17 N., R. 18 E. (Oral report by Ellensburg City engineer, 1951.)

Waste from Tjossem's power ditch also returned to Wilson Creek in sec. 13, T. 17 N., R. 18 E.; the average flow prior to 1943 was about 65 cfs and the maximum recorded flow 109 cfs; but since the mill burned in 1943, average flow has been about 10 cfs. Records in files of Bureau of Reclamation, Yakima, for 1923–55.

Subsurface return flow.—The flow of Wilson Creek, its tributaries and diversions, are augmented by considerable subsurface return flow in the areas irrigated by the Kittitas Highline and Cascade Canals.

Storage and regulation.—None.

Utilization.—Ellensburg municipal supply (table 2). About 2,000 acre-ft of ground water withdrawn each year for municipal and domestic use. Considerable irrigation above gage.

Imported recharge.—See subsurface return flow.

Adequacy of record.—Discharge records at this site do not represent the total outflow of the drainage area because of the subsurface return flow mentioned above.

14. YAKIMA RIVER AT UMTANUM

Location.—Lat 46°51′45″, long 120°28′30″, in NW¼ sec. 20, T. 16 N., R. 19 E., on right bank at Umtanum, half a mile upstream from Umtanum Creek, and 10 miles south of Ellensburg.

Drainage area.—1,590 sq mi, approx.

Gage.—Water-stage recorder. Datum of gage is 1,300.00 ft above means sea level datum of 1929. Prior to Sept. 28, 1911, staff or chain gages at approximately same site at different datums. Sept. 28, 1911, to Nov. 23, 1936, water-stage recorder 300 ft upstream at datum 26.70 ft higher.

Records available.—August 1906 to September 1955 (fragmentary, October 1915 to March 1931).

Accuracy of record.—Excellent.

Geologic setting.—The station is about 7 miles downstream from the entrance to Yakima Canyon. In this reach the Yakima River flows through a deep narrow canyon eroded into the Columbia River basalt. The river channel occupies almost the entire width of the canyon floor and is underlain with an unknown thickness of gravel alluvium. A geologic section through this site is shown in figure 11.

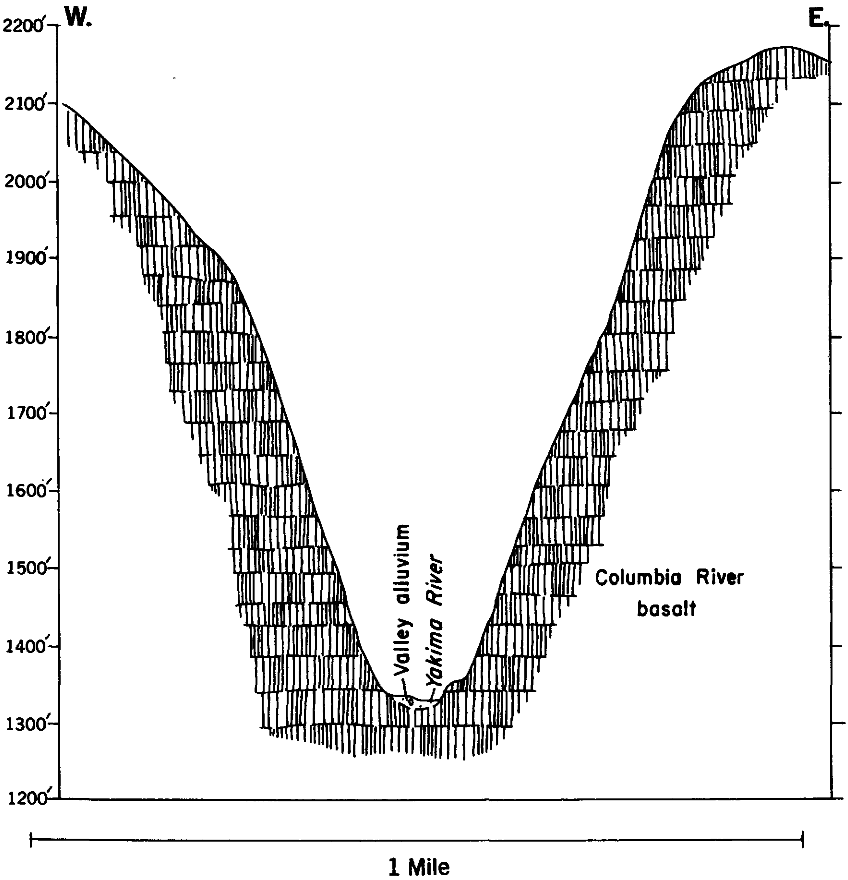

FIGURE 11.—Section through site of gaging station 14, Yakima River at Umtanum, Wash.

Surface diversions.—Diversions which average 1,020 cfs for irrigating 39,000 acres are listed in table 9. Not included in table 9 are the following:

1. Between the station on Teanaway River near Cle Elum and the confluence with Yakima River, the Adjudication Decree of 1921 for Teanaway River, considered 1,641 acres irrigable and allotted 1 miner's inch per acre. See "Diversions" under Teanaway River below forks near Cle Elum (station 8).

2. Manastash Creek, a tributary of Yakima River, according to Adjudication Decree, irrigates 6,134 acres for which an allocation of 1 miner's inch per acre was made. In an average year about 4,000 acres is irrigated. (Oral report by George Meek, Kittitas County watermaster, 1951.)

Bypass channels.—None.

Subsurface bypass.—This station is bypassed by a small amount of underflow moving downvalley through the valley alluvium.

Surface return flow.—Sewage waste from town of Roslyn (about 5 cfs), together with local seepage reaches the Yakima River through a surface drain just below the station Yakima River at Cle Elum (station 7). At its mouth the drain carries about 10 cfs, but varies according to season. Sewage from Cle Elum plus local seepage averages about 3 cfs in a surface drain to the Yakima River. Waste from Ellensburg Mill & Feed canal reaches Yakima River through Wilson Creek. During irrigation season most of Wilson Creek flow is diverted for irrigation. Waste from Mills & Sons power canal is returned to river in the SE¼ sec. 12, T. 18 N., R. 17 E. Waste from Ellensburg power canal reaches Yakima River in sec. 32, T. 18 N., R. 18 E.

Subsurface return flow.—Large amounts of ground water, which is mostly return flow from irrigation, enter the Yakima River in its reach just upstream from the entrance to the Yakima Canyon.

Storage and regulation.—See table 8.

Utilization.—Irrigated are is estimated at 75,000 acres (Simons, oral communication, March 1959) which includes area served by the tributaries in this section of the basin. Ellensburg powerplant diverted from the Yakima River until fall of 1951 when it was abandoned. Present annual withdrawal of ground water about 5,200 acre-ft for municipal, domestic, and irrigation use.

Imported recharge.—None.

Adequacy of records.—The records give a good measure of the total outflow of the drainage area above the gaging station.

TABLE 9.—*Diversions in the Yakima River basin between the Yakima River gaging stations at Umtanum and at Cle Elum*

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Younger ditch	NW¼NE¼ sec. 35, T. 20 N., R. 15 E.	1898	10	Irrigation	Daily discharge records 1912–14, miscellaneous measurements 1923–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 24 cfs. Irrigated area 280 acres.
Frazier ditch	NW¼SE¼ sec. 31, T. 20 N., R. 16 E.	Prior to 1906	3	do	Daily discharge records 1912–14, miscellaneous measurements 1923–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow 12.4 cfs. Irrigated area, 100 acres.[1]
O'Conner ditch	do	Prior to 1906	12	do	Daily discharge records 1912–14, miscellaneous measurements 1923–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 26 cfs. Irrigated area, 400 acres.[1]
DuBinsky pump	NW¼NE¼ sec. 14, T. 19 N., R. 16 E.	1900	1. 5	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 2.2 cfs. Irrigated area, 50 acres.[1]
Cascade Canal	NW¼NW¼ sec. 28, T. 19 N., R. 17 E.	1902	105	do	Daily discharge records 1905, 1909–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 138 cfs. Irrigated area, 12,500 acres.
Garrison ditch	Sec. 28, T. 19 N., R. 17 E.	1900	3	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 8.6 cfs. Irrigated area, 100 acres.[1]

Ellison and Burton ditch	SW¼NW¼ sec. 34 T. 19 N., R. 17 E.	Prior to 1906	5	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 12.6 cfs. Irrigated area, 180 acres.
West Side Canal	SE¼SE¼ sec. 35, T. 19 N., R. 17 E.	Prior to 1906	70	do	Daily discharge records 1905, 1914, 1919–50, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 100 cfs. Irrigated area, 7,000 acres.[2]
Taneum Ditch Co	Sec. 5, T. 18 N., R. 17 E., diverting from Taneum Creek.	Prior to 1906	No record	do	Allocated ⅓ total streamflow by decree. Sometime in June flow ceases to be adequate and water from Kittitas Highline Canal is utilized.[3]
Hutchinson ditch	SE¼NE¼ sec. 3, T 18 N., R. 17 E.	Prior to 1906	3	do	Miscellaneous discharge measurements 1925–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.5 cfs. Irrigated area, 100 acres.[1]
Mills & Sons power canal	do	1880	45	do	Discharge records 1912–15, 1923–55, in files of Bureau of Reclamation, Yakima. Burns, Thorp, Hutchinson 2, and Beal ditches divert a total average flow of 7 cfs to irrigate about 250 acres.[1] Mill burned in 1949, not rebuilt.
Ellensburg Water Co. canal.	NE¼SE¼ sec. 12, T. 18 N., R. 17 E.	1885	100	do	Discharge records 1904, 1909–15, 1922–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 124 cfs. Irrigated area, 10,000 acres.[2]

See footnotes at end of table.

TABLE 9.—*Diversions in the Yakima River basin between the Yakima River gaging stations at Umtanum and at Cle Elum*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Olson ditch	NE¼SE¼ sec. 12, T. 18 N., R. 17 E.	1875	15	Irrigation	Discharge records 1905, 1909–14, 1922–55 in files of Bureau of Reclamation, Yakima. Maximum recorded flow 27 cfs. Irrigated area, 1,200 acres.[2]
Stein & Stevens ditch	SW¼SW¼ sec. 7, T. 18 N., R. 18 E.	Prior to 1906	9	do	Miscellaneous discharge measurements 1914, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 18 cfs. Irrigated area, 360 acres.[1]
Ellensburg municipal water supply.	SE¼SE¼ sec. 12, T. 18 N., R. 17 E.	1912	12	Water supply.	Flow varies between 8 and 16 cfs according to season.[4]
Archer ditch	SW¼NW¼ sec. 18, T. 18 N., R. 18 E.	Prior to 1906	2	Irrigation	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 7.7 cfs. Irrigated area, 80 acres.[1]
Ellensburg power canal	NE¼SE¼ sec. 18, T. 18, N., R. 18 E.	1902	550	Power	Discharge records 1912–15, 1923–52, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 739 cfs. Since 1952 water used for irrigation with average flow estimated at 25 cfs.
Thomas ditch	NW¼SE¼ sec. 18, T. 18 N., R. 18 E.	Prior to 1906	8	Irrigation	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 21 cfs. Irrigated area, 340 acres.[1]

Reed ditch	SW¼SW¼ sec. 29, T. 18 N., R. 18 E.	Prior to 1906	3	do	Miscellaneous discharge measurements 1913–14, 1922–55, in files of Bureau of Reclamation. Maximum recorded flow, 6.1 cfs. Irrigated area, 100 acres.[1]
Ellensburg Mill & Feed canal.	do	Prior to 1906	25	do	Daily discharge records 1912–15, 1923–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 48 cfs. Irrigated areas, 442 acres.
Suver ditch	SE¼NW¼ sec. 33, T. 18 N., R. 18 E.	Prior to 1906	2	do	Miscellaneous discharge measurements 1912–14, 1924–55, in files of Bureau of Reclamation. Maximum recorded flow, 4.8 cfs. Irrigated area, 80 acres.[1]
Grinrod and Doughty Canal.	NW¼NW¼ sec. 3, T. 17 N., R. 18 E.	1884	8	do	Miscellaneous discharge measurements 1913–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 34 cfs. Irrigated area, 300 acres.[1]
Dyer ditch	NW¼SE¼ sec. 10, T. 17 N., R. 18 E.	Prior to 1906	2	do	Miscellaneous discharge measurements 1914, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.1 cfs. Irrigated area, 80 acres.[1] No river water diverted after 1930 when return flow seepage from Kittitas Highline became sufficient for needs.
Stonebraker ditch	NW¼NW¼ sec. 15, T. 17 N., R. 18 E.	Prior to 1906	1	do	Miscellaneous discharge measurements 1921–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.5 cfs. Irrigated area, 40 acres.[1] No river water diverted after 1930 when return flow seepage from Kittitas Highline became sufficient for needs.

See footnotes at end of table.

TABLE 9.—*Diversions in the Yakima River basin between the Yakima River gaging stations at Umtanum and at Cle Elum*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Clark ditch	NW¼SW¼ sec. 13, T. 17 N., R. 18 E.	Prior to 1906	5	Irrigation	Miscellaneous discharge measurements 1913–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 15.6 cfs. Irrigated area, 200 acres.[1]
Steen-McLeod ditch	do	Prior to 1906	6	do	Miscellaneous discharge measurements 1913–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 13.2 cfs. Irrigated area, 200 acres.[1]
Burkholder ditch	Center sec. 14, T. 17 N., R. 18 E.	Prior to 1906	5	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3 cfs. Irrigated area, 20 acres.[1]
Harris ditch	do	Prior to 1906	3	do	Miscellaneous discharge measurements 1913–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 11.4 cfs. Irrigated area, 100 acres.[1]
Vertrees ditch	do	1895	7	do	Miscellaneous discharge measurements 1913–14, 1924–50, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 19.5 cfs. Irrigated area, 250 acres.[1]
Macomber ditch	NE¼NW¼ sec. 23, T. 17 N., R. 18 E.	Prior to 1906	4	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 9 cfs. Irrigated area, 160 acres.[1]

					No river water diverted after 1930 when return flow seepage from Kittitas Highline became sufficient for needs.
Stegel ditch	do	Prior to 1906	3	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 9.1 cfs. Irrigated area, 100 acres.[1] No river water diverted after 1930 when return flow seepage from Kittitas Highline became sufficient for needs.
Tjossem's power canal	SE¼SW¼ sec. 11, T. 17 N., R. 18 E.	Prior to 1906	85	Power and irrigation.	Daily discharge records of 1912–15, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 121 cfs. Irrigated area, 20 acres, Tjossem's irrigation ditch diverts an average 3 cfs from canal, irrigating about 100 acres.[1] Since 1943, when mill burned, the diversion has averaged about 12 cfs.
Farrel ditch 2	NW¼NE¼ sec. 25, T. 17 N., R. 18 E.	1910	4	Irrigation	Miscellaneous discharge measurements 1914, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 17 cfs. Irrigated area, 160 acres.[1] Headgate washed out in 1948. Minor pumping since 1955.
Lewis ditch 1	E½ sec. 25, T. 17 N., R. 18 E.	1910	.2	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 4.7 cfs. Irrigated area, 10 acres.[1]

See footnotes at end of table.

TABLE 9.—*Diversions in the Yakima River basin between the Yakima River gaging stations at Umtanum and at Cle Elum*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Lewis ditch 2	E½ sec. 25, T. 17 N., R. 18 E.	1910	0.2	Irrigation	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 6.3 cfs. Irrigated area, 10 acres.[1]
Ringer Canal	W½ sec. 30, T. 17 N., R. 19 E.	Prior to 1906	1	do	Miscellaneous discharge measurements 1913–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.4 cfs. Irrigated area, 40 acres.[1]

[1] Estimated from information furnished by Bureau of Reclamation, Yakima.
[2] Washington Department of Conservation and Development.
[3] Harrel, A. V., secretary, Taneum Ditch Co., oral report, 1951.
[4] Ellensburg City Engineer, oral report.

15. WENAS CREEK NEAR SELAH

Location (revised).—Lat 46°42′, long 120°30′, in SE¼ sec. 18 T. 14 N., R. 19 E., on left bank half a mile upstream from mouth and 3½ miles northwest of Selah.

Drainage area.—190 sq mi.

Supplemental records available.—January 1910 to April 1912, gage heights only.

Gage.—Staff gage. Altitude of gage is 1,140 ft (from topographic map).

Records available.—April to December 1909.

Accuracy of record.—Fair to poor.

Geologic setting.—The station was half a mile above the mouth of Wenas Creek. In this reach Wenas Creek flows eastward through a shallow valley eroded into the Columbia River basalt. This small valley has a width of about 400 ft and a gradient of about 55 ft per mile. The valley sides are steep, in places being vertical cliffs of basalt which rise 50 to 60 ft above the valley floor. Shallow deposits of alluvial sand, gravel, and boulders underlies the entire valley floor.

Surface diversions.—Entire flow is now diverted for irrigation each summer, and Wenas Creek becomes dry at points below sec. 13, T. 15 N., R. 17 E. According to adjudication of the stream in 1921, it was decreed there were 9,491 irrigable acres, with entitlement of 1 miner's inch per acre. No known records of individual diversions except the fragmentary information given in table 10.

Bypass channels.—None.

Subsurface bypass.—This station was bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass may exceed the error in the streamflow record during periods of low flow.

Subsurface bypass may also occur by water percolating through the basalt that forms the barrier of the eastern end of the Lower Wenas subbasin. Such bypass would discharge directly into the Yakima River.

Surface return flow.—None known.

Subsurface return flow.—None known.

Storage and regulation.—Wenas Reservoir, in SW¼ sec. 2, T. 15 N., R. 17 E., constructed in 1912 for irrigation, has a capacity of 1,050 acre-ft. (Information in files of Conservation Division, Geological Survey, Tacoma.)

Utilization.—It is estimated that about 9,000 acres is under irrigation, mostly by surface-water diversions. About 5,850 acre-ft. of ground water is now withdrawn, chiefly for irrigation.

Imported recharge.—Part of the irrigation water, which is diverted from the Naches River by the Naches-Selah Canal, furnishes recharge to the aquifers in the southeastern part of the Wenas drainage basin.

Adequacy of record.—The records are not representative of the total outflow of the drainage area.

TABLE 10.—*Flow and estimated capacity of ditches diverting water from Wenas Creek, July 26, 1898*

[From Newell, 1899]

Locality	Flow, cfs	Estimated capacity, cfs
Quinn ditch, NE¼SE¼ sec. 13, T. 15 N., R. 17 E	0. 83	2. 5
Wenas Creek at crossing of county road, southeast cor. sec. 13	Dry	
Wenas Creek at forks, NE¼ sec. 13, T. 15 N., R. 17 E., on Mrs. Chambers' Ranch	. 81	
Mrs. Chambers ditch (Wenas west fork stopped by dam)	Dry	5. 0–7. 0
Do		6. 0
"Tom Taylor's" ditch, stopped by dam		2. 5
New "R. Smith", SW¼ sec. 12, T. 15 N., R. 17 E	. 826	2. 5
Old "R. Smith", NE¼ sec. 24, T. 15 N., R. 17 E	Dry	2. 5
Mrs. Chambers, SW¼ sec. 12, T. 15 N., R. 17 E	. 110	
D. N. Pollard, sec. 12, T. 15 N., R. 17 E	. 35	
S. Longmire, sec. 12, T. 15 N., R. 17 E	1. 28	4. 0
Kiser, sec. 11, T. 15 N., R. 17 E	. 837	2. 0
Kiser, sec. 2, T. 15 N., R. 17 E	. 623	2. 0
Sherman, sec. 3, T. 15 N., R. 17 E	. 38	2. 0
Do	. 188	. 5
Justus (right bank), sec. 33, T. 16 N., R. 17 E	3. 62	7. 0
Wenas Creek, middle of sec. 33, T. 16 N., R. 17 E	3. 80	
Justus (left bank), sec. 33, T. 16 N., R. 17 E	. 45	2. 0
Milton Burge, sec. 29, T. 16 N., R. 17 E	. 465	1. 25
Do	. 78	2. 0
Goodwin, sec. 29, T. 16 N., R. 17 E	Dry	. 40
Goodwin, sec. 20, T. 16 N., R. 17 E	Dry	. 40
Burge and Pressey, sec. 30, T. 16 N., R. 17 E	Dry	. 70
F. Candle, sec. 24, T. 16 N., R. 17 E	Dry	1. 00
Longmire & Moore, secs. 13 and 24, T. 16 N., R. 16 E	. 872	4. 0
W. W. Dickinson, sec. 14, T. 16 N., R. 16 E	. 36	1. 5–2. 0
Jack, secs. 11 and 14, T. 16 N., R. 16 E	. 42	. 75
Do	1. 2	2. 5
Rd. Sisk, secs. 11 and 14, T. 16 N., R. 16 E	. 27	. 75
Purdin Co. ditch, sec. 24, T. 15 N., R. 17 E	Dry	4. 0
R. Smith, sec. 24, T. 15 N., R. 17 E	Dry	. 45
Do	Dry	. 50

16. YAKIMA RIVER AT SELAH GAP, NEAR NORTH YAKIMA

Location.—Lat. 46°38′, long 120°31′, in NW¼ sec. 12, T. 13 N., R. 18 E., on right bank bridge pier a quarter of a mile upstream from Naches River and 1½ miles north of Yakima (formerly North Yakima).

Drainage area.—2,130 sq mi, approx.

Supplemental records available.—June to October 1905, gage heights only.

Gage.—Staff gage. Altitude of gage is 1,070 ft (from river-profile map). May 19 to Dec. 31, 1897, wire-weight gage 7 miles upstream at different datum.

Records available.—Irrigation seasons only, 1897, 1904, 1911, and 1912.

Geologic setting.—The station was located where the Yakima River flows through a fairly narrow gap that transects Yakima Ridge just north of the city of

Yakima. The valley floor in this gap is about 1,000 ft wide and is underlain with an unknown thickness of sand and gravel alluvium. The walls of this gap, which are composed of Columbia River basalt, rise 800 ft above river level.

Surface diversions.—

1. Roza Canal, diverting in the SW¼NW¼ sec. 33, T. 15 N., R. 19 E., for irrigation of land below station, has maximum recorded flow of 1,850 cfs and average flow of about 800 cfs during irrigation season. Its capacity is rated as about 1,700 cfs at headworks. Discharge records since 1941 in files of Bureau of Reclamation, Yakima. Constructed in 1940.
2. Selah-Moxee Canal, diverting in the NW¼NE¼ sec. 17, T. 15 N., R. 19 E., mostly for use on land downstream, has maximum observed flow of 132 cfs and average flow of about 76 cfs during irrigation season, 12 cfs of which is used to irrigate an estimated 450 acres above station. Discharge records for 1905, 1909 to 1915, 1919 to 1955 in files of bureau of Reclamation, Yakima.
3. Taylor Canal, diverting in the NE¼SW¼ sec. 19, T. 14 N., R. 19 E., has maximum recorded flow of 55 cfs. Average flow of about 17 cfs during summer season irrigates 1,635 acres above station. Discharge records for 1909–12, 1923–55 in files of Bureau of Reclamation, Yakima.

Bypass channels.—Roza Canal and Selah-Moxee Canal bypass station. Published records for station do not include flow of these canals.

Subsurface bypass.—This station was bypassed by water moving downvalley through the alluvium that underlies the floor of the gap. The amount of subsurface bypass probably was less than the error of the streamflow record.

Surface return flow.—None known.

Subsurface return flow.—Ground water, which is mostly return flow from irrigation, discharges into the Yakima River along the reach just upstream from Selah Gap.

Storage and regulation.—See table 8.

Utilization.—Irrigation of 1,635 acres under Taylor Canal and 450 acres from Selah-Moxee Canal at present. Present annual withdrawal of ground-water about 12,050 acre ft, chiefly for irrigation and municipal use.

Imported recharge.—Some aquifers in the Selah ground-water subbasin are now artificially recharged by irrigation water diverted from the Yakima River through the Taylor Canal and from the Naches River by the Selah-Naches Canal.

Adequacy of record.—The records of this station if adjusted for surface bypass would represent the total outflow of the drainage area above the gaging station.

17. BUMPING RIVER NEAR NILE

Location.—Lat 46°52′, long 121°18′, in NE¼ sec. 23, T. 16 N., R. 12 E., on left bank a quarter of a mile downstream from spillway of Bumping Lake Dam and 19 miles west of Nile.

Drainage area.—68.6 sq mi.

Gage.—Water-stage recorder. Datum of gage is 3,367.10 ft above mean sea level (Bureau of Reclamation bench mark). Prior to June 17, 1913, staff gages at several sites within half a mile of present site at different datums.

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Records available.—June and July 1906 and April 1909 to September 1955.
Accuracy of record.—Good.
Geologic setting.—The station is approximately a quarter of a mile downstream from the spillway of Bumping Lake Dam. In this reach the Bumping River flows through a fairly narrow valley eroded into older valley fill. The floor of the inner valley is underlain with an unknown thickness of gravel alluvium. The older valley fill is composed of unconsolidated sand and gravel and partially fills a mile-wide valley eroded into volcanic rock. A geologic section, across the valley, is shown on figure 12.

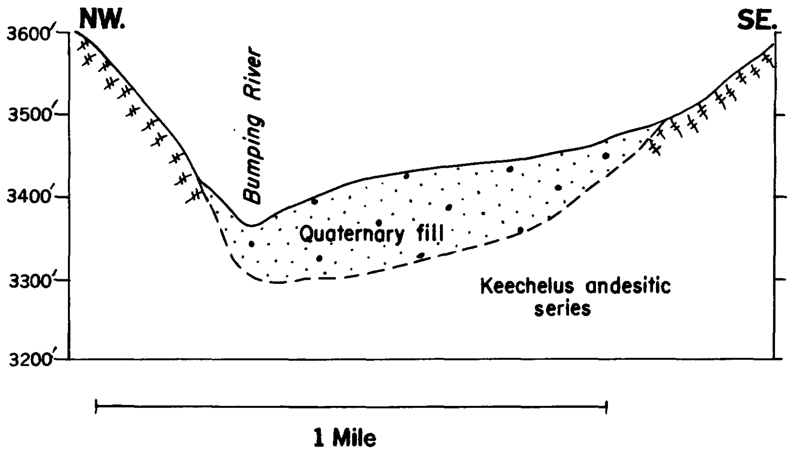

FIGURE 12.—Section through site of gaging station 17, Bumping River near Nile, Wash.

Surface diversions.—None.
Bypass channels.—None.
Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvium and older valley fill deposits. Most of the bypass originates as subsurface flow from Bumping Lake.
Surface return flow.—None.
Subsurface return flow.—None known.
Storage and regulation.—Since 1910 flow regulated by Bumping Lake (table 5). Water-supply papers give monthly flow adjusted for change in contents of the lake, as a measure of natural runoff.
Utilization.—None.
Imported recharge.—None.
Adequacy of record.—The records represent the controlled discharge from the Bumping Lake reservoir. The amount of subsurface bypass is probably less than the error of the streamflow record except during periods of low flow. Much less subsurface bypass occurs in the reach about 7 miles downstream where the Bumping River is confined to a narrow canyon eroded into the Keechelus andesitic series.

18. AMERICAN RIVER NEAR NILE

Location.—Lat 46°58'30'', long 121°10'10'', in SW¼ sec. 12, T. 17 N., R. 13 E., 300 ft upstream from Bumping Lake road crossing, three-quarters of a mile upstream from mouth, and 16 miles northwest of Nile.

Drainage area.—78.9 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,700.00 ft above mean sea level, adjustment of 1912. Apr. 25, 1909, to Sept. 11, 1915, staff gage at approximately same site at different datum.

Records available.—April 1909 to September 1911, July 1913 to September 1915 (fragmentary), and October 1939 to September 1955.

Accuracy of record.—Good.

Geologic setting.—The station is three-quarters of a mile upstream from the mouth. In this reach the American River flows through a deep canyon eroded into volcanic rock. The valley floor is underlain with an unknown thickness of sand, gravel, and boulder alluvium.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by underflow moving downvalley through the alluvium. The amount of subsurface bypass is less than the error of the streamflow records.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—None.

Utilization.—Little or none above station.

Imported recharge.—None.

Adequacy of record.—The records represent the total outflow of the drainage area.

19. NACHES RIVER AT ANDERSON RANCH, NEAR NILE

Location.—Lat 46°55', long 121°03', SE¼ sec. 35, T. 17 N., R. 14 E. (unsurveyed), on left bank at Anderson Ranch, half a mile downstream from Lost Creek, and 11 miles north of Nile.

Drainage area.—392 sq mi.

Gage.—Staff gage. Altitude of gage is 2,300 ft (from river-profile map).

Records available.—April 1909 to September 1914.

Accuracy of record.—Generally good to excellent.

Geologic setting.—The station was about 7 miles below the mouth of the Bumping River. In this reach the Naches River flows along the southwest side of a broad valley eroded into the Keechelus andesitic series. The valley floor has a width of about 1,000 ft, and is underlain with an unknown thickness of gravel and boulder alluvium.

Surface diversions.—

1. Fontaine ditch diverts water 1 mile upstream from Lost Creek for irrigation of land above station. Ditch was built in 1910, has maximum recorded flow of 3.8 cfs and an average flow of about 1.5 cfs during irrigation season. Discharge records consisting of several miscellaneous measurements during each irrigation season made by Bureau of Reclamation and are on file at Yakima for the years 1913 and 1924–55. No other known records.

2. Anderson ditch, diverting half a mile upstream from Lost Creek, was established prior to 1909. It has a maximum recorded flow of 9.3 cfs and an average flow of about 3 cfs during irrigation season. Several miscellaneous measurements made during irrigation seasons in 1913 and 1924–55 by Bureau of Reclamation, Yakima.

Bypass channels.—Anderson ditch bypass station. Published records for station do not include flow of this ditch.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of bypass is less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—Some return flow by ground-water discharge from areas irrigated by upstream diversions.

Storage and regulation.—See table 8.

Utilization.—Water diverted by Fontaine ditch and probably some of Anderson ditch used to irrigate an estimated 100 acres above station. Small amount of ground water utilized upstream from station for domestic use.

Imported recharge.—None.

Adequacy of record.—The records give a fairly adequate measure of the total outflow of the drainage area even if the bypass flow of Anderson ditch is neglected. A few miles upstream where the Naches River is confined to a narrow canyon eroded into lava flows of the Keechelus andesitic series, less subsurface bypass occurs.

20. NACHES RIVER AT OAK FLAT, NEAR NILE

Location.—Lat. 46°45′10″, long 120°49′10″, in NW¼ sec. 34, T. 15 N., R. 16 E., on left bank just upstream from Oak Flat, 2 miles upstream from Tieton River, and 7 miles northwest of Naches.

Drainage area.—638 sq mi.

Gage.—Water-stage recorder. Altitude of gage is 1,660 ft (from river-profile map). Prior to Apr. 13, 1909, staff gage at site 800 ft downstream at different datum. Apr. 13, 1909, to Sept. 19, 1911, chain gage at same site and datum.

Drainage area.—638 sq mi.

Records available.—June 1904 to November 1915, April to October 1916, and April to October 1917.

Accuracy of records.—Generally good to excellent.

Geologic setting.—The station was 2 miles above the mouth of the Tieton River. In this reach the Naches River flows through a deep canyon eroded into the Columbia River basalt. The valley floor has a width of about 700 ft, and is underlain with an unknown thickness of coarse gravel and boulder alluvium.

Surface diversions.—Fourteen small irrigation ditches divert a total average flow of about 40 cfs during irrgation season (table 11).

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving downvalley through the coarse alluvium. The amount of subsurface bypass was less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—Some return flow by ground-water discharge from areas irrigated by upstream diversions.

Storage and regulation.—See table 8.

Utilization.—Water diverted to irrigate about 785 acres above station. Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The record gives an adequate measure of the total outflow from the drainage area and from the Upper Naches ground-water basin.

21. NORTH FORK TIETON RIVER BELOW CLEAR CREEK, NEAR NACHES

Location.—Lat 46°38′40″, long 121°16′10″, in sec. 12, T. 13 N., R. 12 E. (unsurveyed), on left bank 1,000 ft downstream from Clear Creek Dam, a quarter of a mile upstream from Cold Creek, 7 miles upstream from South Fork, and 30 miles southwest of Naches.

Drainage area.—61.5 sq mi.

Gage.—Staff gage. Altitude of gage is 2,960 ft (from topographic map).

Records available.—May to October 1914 and July to September 1915.

Accuracy of record.—Generally excellent.

Geologic setting.—The station was just below the mouth of Clear Creek. In this reach the North Fork Tieton River flows through a fairly broad valley. The valley floor has a width of about 1,000 ft, and is underlain with an unknown thickness of gravel alluvium.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by underflow moving downvalley through the alluvium. The amount of subsurface bypass was less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—From July 1915 until 1925 flow slightly controlled by regulation in Clear Creek Reservoir; use of reservoir discontinued (in 1925), except for occasional dry periods.

Utilization.—None.

Imported recharge.—None.

Adequacy of record.—Records represent the total outflow of the drainage area.

22. TIETON RIVER AT TIETON DAM, NEAR NACHES [2]

Location.—Lat 56°39′30″, long 121°07′20″, in sec. 31, T. 14 N., R. 14 E. (unsurveyed), on left bank 900 ft upstream from Wild Cat Creek, 1,200 ft downstream from Tieton Dam, 19 miles upstream from Oak Creek, and 22 miles southwest of Naches.

Drainage area.—187 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,680.99 ft above mean sea level (Bureau of Reclamation bench mark). Aug. 25, 1908, to Sept. 30, 1914, staff gage at McAllister Meadows, 1,700 ft upstream at different datum. June 15, 1918, to Sept. 4, 1925, staff gage and Sept. 5, 1925, to Apr. 23, 1933, water-stage recorder 800 ft downstream at different datum.

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[2] Published as Tieton River at McAllister Meadows, near Naches, before 1915 and as Tieton River at Rimrock, 1919.

TABLE 11.—*Diversions in the Naches River basin between the Naches River gaging stations at Oak Flat near Nile and at Anderson Ranch near Nile*

Name	Point of diversion	Date of establishment	Approximate flow (cfs)	Purpose	Remarks
Emrich ditch	Center sec. 1, T. 16 N., R. 14 E., unsurveyed.	Prior to 1905	2	Irrigation	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 4.6 cfs. Irrigated area, 10 acres.
Benton ditch	SE¼SE¼ sec. 17, T. 16 N., R. 15 E.	Prior to 1905	1.5	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 9.5 cfs. Irrigated area, 50 acres.[1]
Valentine ditch	Center sec. 21, T. 16 N., R. 15 E.	1892	1	do	Miscellaneous discharge measurements 1913, 1924–55 in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.5 cfs. Irrigated area 35 acres.[1]
Markell ditch	SW¼SE¼ sec. 21, T. 16 N., R. 15 E.	1908	6	do	Miscellaneous discharge measurements 1912–13, 1924–48 in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 11 cfs. Irrigated area, 200 acres.[1] Washed out in 1948; not rebuilt.
Lindsey Canal	do	Prior to 1905	8	do	Miscellaneous discharge measurements 1912–13, 1924–55 in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 17.5 cfs. Irrigated area, 300 acres.[1]

Palmer ditch	SE¼NW¼ sec. 34, T. 16 N., R. 15 E.	Prior to 1905	2	do	Miscellaneous discharge measurements 1924–26, 1930–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 9.3 cfs. Irrigated area, 80 acres.[1]
Carmack and Parker ditch.	SW¼SW¼ sec. 2, T. 15 N., R. 15 E.	1905	2	do	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 7 cfs. Irrigated area, 80 acres.[1]
Fredricks and Hunting Canal.	do	1888	3	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 6.4 cfs. Irrigated area, 100 acres.[1]
Griffen Canal	NW¼SE¼ sec. 11, T. 15 N., R. 15 E.	Prior to 1905	5	do	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 2.7 cfs. Irrigated area, 20 acres.[1]
Stevens ditch	do	1888	5	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 22 cfs. Irrigated area, 180 acres.[1]
Meloy ditch	SE¼NW¼ sec. 18, T. 15 N., R. 16 E.	1892	1.5	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 4.3 cfs. Irrigated area, 50 acres.[1]

See footnote at end of table.

TABLE 11.—*Diversions in the Naches River basin between the Naches River gaging stations at Oak Flat near Nile and at Anderson Ranch near Nile*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Krober ditch	SW¼SW¼ sec. 17, T. 15 N., R. 16 E.	Prior to 1905	0.5	Irrigation	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 1.6 cfs. Irrigated area, 20 acres.[1]
Fechter and Janeck 1	SE¼SE¼ sec. 28, T. 15 N., R. 16 E.	Prior to 1905	.5	do	Miscellaneous discharge measurements 1931–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.3 cfs. Irrigated area, 20 acres.[1]
Fechter and Janeck 2	NE¼NW¼ sec. 34, T. 15 N., R. 16 E.	Prior to 1905	6	do	Miscellaneous discharge measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 11 cfs. Irrigated area, 200 acres.[1]

[1] Estimated from information furnished by U.S. Bureau of Reclamation, Yakima.

Records available.—August 1908 to September 1914 (fragmentary), October 1918 to March 1919, and April 1925 to September 1955 in reports of Geological Survey. September 1908 to December 1913, July to September 1914, October 1918 to September 1920, and May 1925 to September 1953 (mean monthly discharge) in State Water-Supply Bull. 5. Published as "at McAllister Meadows" 1908–14 and as "at Rimrock" 1918–19.

Accuracy of record.—Good, except for flow below 50 cfs, which is fair.

Geologic setting.—The station is 1,200 ft downstream from Tieton Dam. In this reach the Tieton River flows through a fairly narrow valley eroded into volcanic rock. The valley floor barely exceeds the width of the stream, and is underlain with coarse gravel alluvium. Small gravel terraces, remnants of a former valley filling, are located at low elevations along both sides of the valley. A geologic section extending across the valley, just upstream from this station, is shown in figure 13.

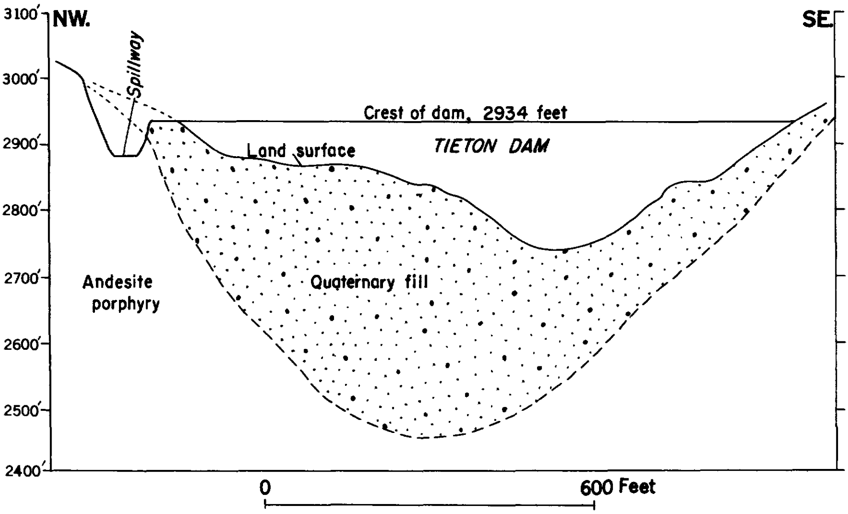

FIGURE 13.—Section through site of gaging station 22, Tieton River at Tieton Dam, near Naches, Wash.

Surface diversions.—None.

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvium and the terrace gravels. The amount of subsurface bypass is less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—Flow regulated by Tieton Reservoir since 1925 (table 9). Geological Survey water-supply papers (table 6) give monthly flow adjusted for change in contents of the lake, as a measure of natural runoff.

Utilization.—Very small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The records represent the total outflow of the drainage area subject to minor regulation by the Clear Creek Reservoir from 1915–25 and to regulation by Tieton Reservoir, since 1925.

23. TIETON RIVER AT HEADWORKS OF TIETON CANAL, NEAR NACHES

Location.—Lat 46°40'10", long 121°00'20", in sec. 30, T. 14 N., R. 15 E. (unsurveyed), on right bank 1,000 ft downstream from headworks of Tieton Canal, 12 miles upstream from Oak Creek, and 16 miles southwest of Naches.

Drainage area.—239 sq mi.

Gage.—Water-stage recorder. Datum of gage is 2,280.44 ft above mean sea level, unadjusted. Prior to July 28, 1909, staff gage at approximately same site and datum.

Records available.—April to September 1906 (fragmentary gage-height records) and July 1907 to September 1955.

Accuracy of record.—Good.

Geologic setting.—The station is located just below the intake to the Tieton Canal. In this reach the Tieton River flows through a deep valley eroded into volcanic rock. The valley floor is about 500 feet wide, and is underlain with coarse gravel alluvium. A geologic section extending across the valley, at the site of this station, is shown on figure 14.

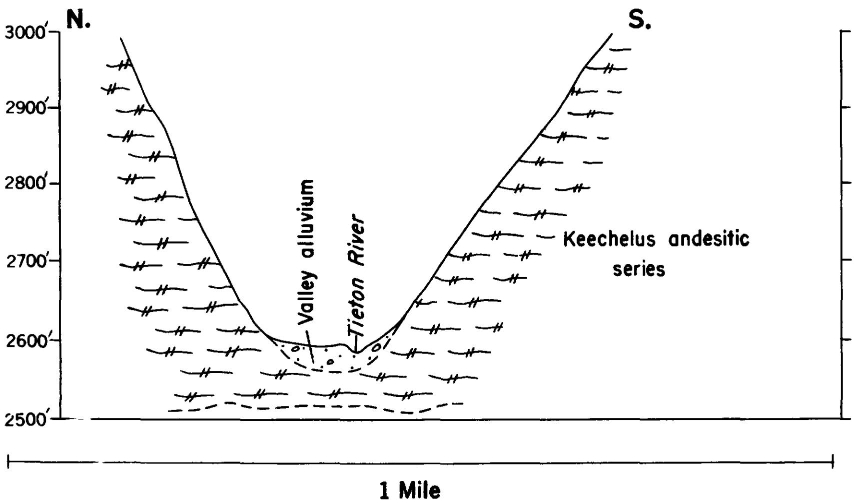

FIGURE 14.—Section through the site of gaging station 23, Tieton River at headworks of Tieton Canal, near Naches, Wash.

Surface diversions.—Tieton Canal, constructed in 1910, diverts 500 ft above station. Maximum recorded flow of 350 cfs and average flow of about 240 cfs during irrigation season. Records of flow in files of Bureau of Reclamation, Yakima.

Bypass channels.—Flow of Tieton Canal bypasses gaging station. Monthly records are published for combined flow of canal and river at this station. Daily discharge records do not include flow of canal. About 25,000 acres is irrigated by this canal.

Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass is less than error in the streamflow record, except for periods of very low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—See table 8.

Imported recharge.—None.

Adequacy of record.—The record represents the total outflow of the drainage area prior to construction of the Tieton Canal in 1910. Since 1910, the daily records give the flow remaining in the stream below the Tieton diversion. The flow has been regulated by the Tieton Reservoir since 1925.

24. TIETON RIVER ABOVE AND BELOW OAK CREEK, NEAR NACHES [3]

Location.—Lat 46°43'30", long 120°48'20", in SE¼ sec. 3, T. 14 N., R. 16 E., on left bank 200 ft downstream from Oak Creek, 2 miles upstream from mouth, and 8 miles northwest of Naches.

Drainage area.—296 sq mi. At sites Mar. 6, 1906, to Apr. 20, 1909, 264 sq mi.

Gage.—Chain or staff gage. Altitude of gage is 1,690 ft (from river-profile map). Mar. 6, 1906, to Apr. 20, 1909, staff gages at sites within 1 mile upstream at different datums.

Records available.—July 1902 to February 1906, March 1906 to September 1907 at site above Oak Creek, and October 1908 to November 1913.

Accuracy of record.—Generally good.

Geologic setting.—This station was about 1½ miles above the mouth. In this reach the Tieton River flows northeast through a deep valley eroded into the Columbia River basalt. The valley floor has a width of about 400 ft, and is underlain with an unknown thickness of gravel alluvium. Thick flows of Tieton andesite overlie the Columbia River basalt along the eastern slope of this valley. These flows are remnants of a former filling of the Tieton Canyon by volcanic rock.

Surface diversions.—A few small ditches divert an insignificant amount of water for local irrigation along Oak Creek. Four ditches divert an average of about 5 cfs from Tieton River during irrigation season (table 12).

Bypass channels.—Tieton Canal bypasses station. Records for station do not include flow of canal.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass was less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—Small amount of return flow by ground-water discharge from areas irrigated by upstream diversions.

Storage and regulation.—See table 8.

Utilization.—Irrigated area above station estimated at about 200 acres, according to U.S. Bureau of Reclamation records at Yakima. Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The record, prior to 1910, mainly represents the total of the drainage area. Neither the upstream reservoirs nor Tieton Canal was in operation prior to that date.

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[3] Published at Tieton River near North Yakima prior to 1906, as Tieton River near Naches, 1906–7, and as Tieton River at Cobb's Ranch, near Naches, 1909–13.

TABLE 12.—*Diversions in the Tieton River basin between the Tieton River gaging stations above and below Oak Creek near Naches and at headworks of Tieton Canal near Naches*

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Gnavaugh North Side ditch.	NW¼SW¼ sec. 8, T. 14 N., R. 16 E.	1913	1	Irrigation	Miscellaneous discharge measurements 1912–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.7 cfs. Irrigated area, 40 acres.[1]
Gnavaugh South Side ditch.	NE¼SW¼ sec. 8, T. 14 N., R. 16 E.	Prior to 1905	1	do	Miscellaneous discharge measurements 1912–14, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.3 cfs. Irrigated area, 40 acres.[1]
Upper Cobb South Side ditch.	SW¼NW¼ sec. 9, T. 14 N., R. 16 E.	Prior to 1905	.5	do	Miscellaneous discharge measurements 1912–14, 1922–44, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 1.2 cfs. Irrigated area, 20 acres.[1] Abandoned in 1944.
Cobb Upper Side ditch	SE¼NW¼ sec. 9, T. 14 N., R. 16 E.	Prior to 1905	1	do	Miscellaneous discharge measurements 1913, 1922–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.6 cfs. Irrigated area, 40 acres.
Sinclair and Cobb ditch	SE¼NW¼ sec. 10, T. 16 N., R. 16 E.	1902	2	do	Miscellaneous discharge measurements 1921–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 6.4 cfs. Irrigated area, 80 acres.[1]

[1] Estimated from information furnished by U.S. Bureau of Reclamation, Yakima.

25. NACHES RIVER BELOW TIETON RIVER, NEAR NACHES

Location.—Lat 46°44'40", long 120°46'00", in SW¼NE¼ sec. 36, T. 15 N., R. 16 E., on left bank half a mile downstream from Wapatox power canal, three-quarters of a mile downstream from Tieton River, and 3½ miles northwest of Naches.

Drainage area.—941 sq mi.

Gage.—Water-stage recorder. Datum of gage is 1,549.67 ft above mean sea level, datum of 1929, supplementary adjustment of 1947. Prior to Sept. 10, 1936, staff gages or water-stage recorder at site five-eighths of a mile upstream (above Wapatox power canal) at different datums.

Records available.—August to October 1905, November 1908 to October 1912, and May 1915 to September 1955. September 1905 and October 1908 to September 1912 (mean monthly discharge) in Washington Water-Supply Bull. 5.

Accuracy of record.—Good to Ecellent.

Geologic setting.—The station is located about 3½ miles upstream from the town of Naches. In this reach the Naches River flows through a broad deep valley. The valley floor has a width of about 1,500 ft, and is underlain with an unknown thickness of coarse gravel alluvium. The north slope of the valley is underlain with Columbia River basalt and the south slope by cemented gravel and overlying Tieton andesite. A geologic section, extending across the valley, is shown in figure 15.

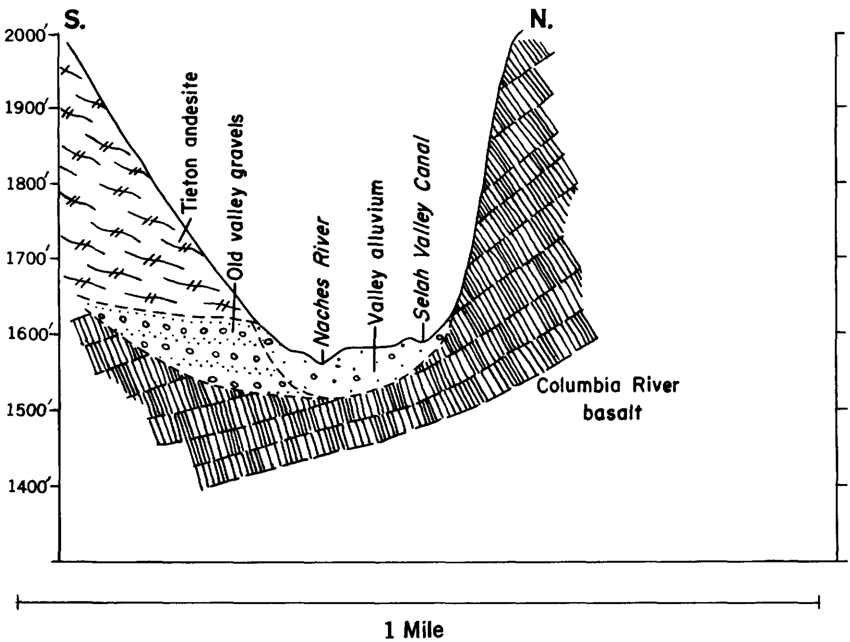

FIGURE 15.—Section through site of gaging station 25, Naches River below Tieton River, near Naches, Wash.

TABLE 13.—*Diversions in the Lower Tieton River and Naches River basins upstream from the gaging station "Naches River below Tieton River, near Naches, Wash."*

[Diversions in this table are those located between this station and the next stations upstream, Tieton River at Cobb's Ranch near Naches and Naches River at Oak Flat near Nile]

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Oak Flat diversion	NW¼ sec. 34, T. 15 N., R. 16 E.	1929	13	Yakima municipal supply.	Daily discharge records, 1929–55, available from city of Yakima Water Superintendent.
Naches-Selah Canal	SW¼NW¼ sec. 35, T. 15 N., R. 16 E.	1890	100	Irrigation	Daily discharge records, 1909–14, 1920–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 139 cfs. Irrigated area, 10,000 acres.
Sinclair and Parmentier ditch.	NE¼SE¼ sec. 3, T. 14 N., R. 16 E.	Prior to 1905	.6	do	Miscellaneous discharge measurements 1922–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.3 cfs. Irrigated area, 20 acres.[1]
Tennant ditch	SE¼NW¼ sec. 36, T. 15 N., R. 16 E.	Prior to 1905	.6	do	Miscellaneous discharge measurements 1912–13, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 15.2 cfs. Irrigated area, 200 acres.[1]
Wapatox power canal	do	Prior to 1905	430	Power and irrigation.	Daily discharge records, 1904–5, 1909–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 709 cfs. 2,000 acres irrigated above powerhouse. Between powerhouse and Gleed ditch 1,200 acres irrigated where it is known as Lower Wapatox Canal.

[1] Estimated from information furnished by U.S. Bureau of Reclamation, Yakima.

Surface diversions.—Oak Flat diversion, Selah Valley Canal, and Wapatox power canal divert water from Naches River and two small ditches divert from the lower Tieton River, all above station. An average of about 550 cfs is diverted as shown in table 13.

Bypass channels.—Tieton, Selah Valley (Naches-Selah), and Wapatox Canals, and Oak Flat diversion, all bypass gage. Daily discharge records do not include flow of these canals. Monthly discharges adjusted for diversions of Tieton and Selah Valley (Naches-Selah) Canals, Oak Flat diversion since 1929, and Wapatox power canal since 1936, in Geological Survey water-supply papers (table 6).

Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass is less than the error in the streamflow record, except during periods of very low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—See table 8.

Utilization.—Irrigation of about 220 acres on Tieton River above station. Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The record, if adjusted for surface bypass and storage regulation in Bumping and Tieton Reservoirs, would be fairly representative of the total outflow of drainage area.

26. NACHES RIVER NEAR YAKIMA

Location.—Lat 46°37′30″, long 120°31′10″, in sec. 12, T. 13 N., R. 18 E., on right bank half a mile upstream from mouth and 2 miles north of Yakima (formerly North Yakima).

Drainage area.—1,100 sq mi, approx.

Supplemental records available.—August 1893 to July 1896, gage heights and discharge measurements only.

Gage.—Chain gage. Altitude of gage is 1,070 ft (from river-profile map). Before June 19, 1908, staff gages at site about 800 ft downstream at different datums.

Records available.—August 1893 to February 1897 (fragmentary) and March 1898 to September 1912.

Accuracy of record.—Generally good to poor.

Geologic setting.—The station was half a mile upstream from the mouth. In this reach the Naches River flows along the north edge of a broad structural basin. The south slope of Yakima Ridge, which is composed of Columbia River basalt, rises steeply from the north bank of the river. To the south lies a wide valley underlain with several hundred feet of sand and gravel.

Surface diversions.—Twenty-two ditches and canals divert an average of about 60 cfs above station as shown in table 14. The Adjudication Decree of Cowiche Creek (1922) denotes 1,369 acres as irrigable, with an entitlement of 1 miner's inch per acre. Due to inadequacy of water supply during the late summer months, this land is mostly irrigated only during periods of the spring snow melt. During the early part of the irrigation season water also is diverted from Cowiche Creek by Yakima-Tieton Irrigation District for use on Naches Heights farms, averaging 2,000 acre-ft annually. District was organized in 1910. The headgate is located in the NE¼ sec. 11, T. 13 N., R. 17 E. Records in files of Yakima-Tieton Irrigation District office, Yakima.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water which moved downvalley through the alluvium and discharged directly into the Yakima River downstream from the mouth of the Naches River. The station was also bypassed by surface flow from irrigation.

Surface return flow.—A drain returns 1 to 15 cfs (depending on season) to Naches River above station in the SE¼ sec. 14, T. 14 N., R. 17 E. Two 12-in. drains return up to 6 cfs each above station in the SE¼ sec. 23, T. 14 N., R. 17 E. One drain returns up to 6 cfs above station in SE¼ sec. 25, T. 14 N., R. 17 E. (Records of Yakima County engineer, 1921 and 1922.)

Prior to 1942, when power operation ceased, the Fruitvale Power Waste discharged an average of about 45 cfs into Cascade Lumber Co. mill pond and thence into the Yakima River in center of sec. 18, T. 13 N., R. 19 E.; since 1942 it has averaged only about 10–15 cfs.

Subsurface return flow.—Small to moderate amount of return flow by groundwater discharge from areas irrigated by upstream diversions.

Storage and regulation.—See table 8.

Utilization.—The Tieton Canal irrigates 24,640 acres and the Selah Valley Canal irrigates 10,000 acres. (Bureau of Reclamation files, Yakima.) The small ditches as listed in table 14 irrigate about 20,000 acres. About 2,400 acre-ft of ground water is now withdrawn for irrigation and municipal use.

Imported recharge.—None.

Adequacy of record. The record is not completely representative of the total outflow of the drainage area owing to subsurface bypass.

27. NORTH FORK AHTANUM CREEK NEAR TAMPICO

Location.—Lat 46°33′40″, long 120°55′10″, in NW¼ sec. 2, T. 12 N., R. 15 E., on left bank 100 ft downstream from Nasty Creek, 3½ miles northwest of Tampico and confluence with South Fork, and 20 miles west of Yakima.

Drainage area.—68.9 sq mi.

Gage.—Water-stage recorder and concrete control. Altitude of gage is 2,450 ft (from topographic map). Aug. 26, 1907, to Apr. 1, 1913, and Aug. 20, 1915, to Sept. 5, 1916, staff gage at same site and datum.

Records available.—August 1907 to September 1924 and March 1931 to September 1955. No winter records 1907, 1908, and 1916–24.

Accuracy of record.—Generally good.

Geologic setting.—The station is about 3 miles northwest of Tampico. In this reach Ahtanum Creek flows through a narrow valley eroded into the Columbia River basalt. The valley floor is about 250 ft wide, and is underlain with an unknown thickness of sand and gravel alluvium. Ahtanum Creek flows along the south side of this valley, and is measured at a concrete weir. A geologic section, extending across the valley, at the site of this station, is shown in figure 16.

TABLE 14.—*Diversions in the Naches River basin between the Naches River gaging stations near North Yakima and below Tieton River near Naches*

[All data from records of Bureau of Reclamation, Yakima, unless otherwise specified]

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Johncox ditch	NE¼NE¼ sec. 6, T. 14 N., R. 17 E.	Prior to 1893	5	Irrigation	Daily discharge records 1922–55. Maximum recorded flow, 12 cfs. Irrigated area, 926 acres.[1]
Clark ditch	NW¼NW¼ sec. 5, T. 14 N., R. 17 E.	Prior to 1905	4	do	Daily discharge records 1905, 1908–11. Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 11 cfs. Irrigated area, 274 acres.[2]
Lowry Canal	Center sec. 5, T. 14 N., R. 17 E.	Prior to 1893	9	do	Daily discharge records 1909–14, 1921–55. Maximum recorded flow, 28 cfs. Irrigated area, 300 acres.[3]
Kelly Canal	do	Prior to 1893	10	do	Daily discharge records 1909–14, 1921–55. Maximum recorded flow, 47 cfs. Irrigated area, 375 acres.[2]
Upper Scott ditch	SE¼SW¼ sec. 4, T. 14 N., R. 17 E.	Prior to 1893	18	do	Daily discharge records 1905, 1909–14, 1921–55. Maximum recorded flow, 41 cfs. Irrigated area, 280 acres.[4]
LaFortune ditch	NE¼NE¼ sec. 9, T. 14 N., R. 17 E.	Prior to 1893	16	do	Daily discharge records 1905, 1909–14, 1921–55. Maximum recorded flow, 32 cfs. Irrigated area, 325 acres.[4]
Powell ditch (Lower Scott).	do	Prior to 1893	8	do	Daily discharge records 1905, 1910–14, 1921–55. Maximum recorded flow, 31 cfs. Irrigated area, 500 acres.[4]

See footnotes at end of table.

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TABLE 14.—*Diversions in the Naches basin between the Naches River gaging stations near North Yakima and below Tieton River near Naches*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Basket Ford ditch	Center sec. 14, R. 14 N., R. 17 E.	Prior to 1893	12	Irrigation	Irrigated area, 400 acres.[4]
Gleed ditch	SW¼NW¼ sec. 24, T. 14 N., R. 17 E.	Prior to 1893	50	do	Daily discharge records 1909–14, 1923–55. Maximum recorded flow, 92 cfs. Irrigated area, 1,800 acres.[5]
Morrisey ditch	SE¼SW¼ sec. 24, T. 14 N., R. 17 E.	Prior to 1893	6	do	Miscellaneous discharge measurements 1905, 1909, 1912–13, 1921–55. Maximum recorded flow, 16.7 cfs. Irrigated area, 214 acres.
Congdon Canal	SW¼NW¼ sec. 25, T. 14 N., R. 17 E.	Prior to 1893	47	do	Daily discharge records 1904–5, 1911–14, 1919–55. Maximum recorded flow, 69 cfs. Irrigated area, 4,300 acres.[1]
Schuller and Rodenbeck ditch.	SW¼SE¼ sec. 25, T. 14 N., R. 17 E.	Prior to 1893	3	do	Miscellaneous discharge measurements 1909–10, 1923–55. Maximum recorded flow, 12 cfs. Irrigated area, 120 acres.
White and Leach ditch	NW¼NW¼ sec. 36, T. 14 N., R. 17 E.	Prior to 1893	3	do	Miscellaneous discharge measurements 1909, 1921, 1924–55. Maximum recorded flow, 11 cfs. Irrigated area, 240 acres.
McCormick and Long ditch.	SW¼NW¼ sec. 37, T. 14 N., R. 18 E.	Prior to 1893	3	do	Miscellaneous discharge measurements 1905, 1909–11, 1921–55. Maximum recorded flow, 12 cfs. Irrigated area, 200 acres.
Long ditch	SE¼SE¼ sec. 31, T. 14 N., R. 18 E.	Prior to 1893	1.5	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 4.8 cfs. Irrigated area, 60 acres.[3]

Glaspey ditch	NW¼NW¼ sec. 5, T. 13 N., R. 18 E.	Prior to 1893	2	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 6.5 cfs. Irrigated area, 80 acres.[3] River water not diverted for many years, as there is sufficient return flow seepage for needs.
Chapman and Leach ditch	do	Prior to 1893	3	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 8.5 cfs. Irrigated area, 180 acres. River water not diverted for many years, as there is sufficient return flow seepage for needs.
Nelson ditch	SW¼NE¼ sec. 5, T. 13 N., R. 18 E.	Prior to 1893	3	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 6.2 cfs. Irrigated area, 150 acres. River water not diverted for many years, as there is sufficient return flow seepage for needs.
Small Nelson ditch	do	Prior to 1893	.5	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 3 cfs. Irrigated area, 30 acres. River water not diverted for many years, as there is sufficient return flow seepage for needs.
Jacobson ditch	NW¼SE¼ sec. 5, T. 13 N., R. 18 E.	Prior to 1893	2	do	Miscellaneous discharge measurements 1924–55. Maximum recorded flow, 4.4 cfs. Irrigated area, 80 acres.[3] River water not diverted for many years, as there is sufficient return flow seepage for needs.

See footnotes at end of table.

TABLE 14.—*Diversions in the Naches basin between the Naches River gaging stations near North Yakima and below Tieton River near Naches*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Naches-Cowiche Canal	SE¼NW¼ sec. 9, T. 13 N., R. 18 E.	Prior to 1904	32	Irrigation	Daily discharge records 1909–14, 1923–55. Maximum recorded flow, 50 cfs. Irrigated area, 2,000 acres.[1]
Nelson and Hess ditch	NW¼SE¼ sec. 9, T. 13 N., R. 18 E., from Cowiche Creek.	Prior to 1893	2.5	do	Daily discharge records 1913–14, miscellaneous measurements 1925–55. Maximum recorded flow, 6 cfs. Irrigated area, 90 acres.[3]
City meter	SE¼SE¼ sec. 9, T. 13 N., R. 18 E.	Prior to 1905	25	do	Daily discharge records 1910–14, 1924–55. Maximum recorded flow, 62 cfs. Irrigated area, 2,380 acres. Used for irrigation of lawns and other municipal uses in city of Yakima.
Fruitvale power canal	NW¼SW¼ sec. 10, T. 13 N., R. 18 E.	Prior to 1893	100	Primarily Irrigation.	Daily discharge records 1904–5, 1910–15, 1923–55. Maximum recorded flow, 308 cfs. Irrigated area, 550 acres.[1]
Old Union Canal	NE¼NE¼ sec. 15, T. 13 N., R. 18 E.	Prior to 1904	45	Irrigation	Daily discharge records 1904–5, 1910–15, 1923–55. Maximum recorded flow, 77 cfs. Irrigated area, 3,750 acres.[1]
Broadway Canal	From Wide Hollow Creek at south city limits.		3	do	Daily discharge records 1922–55. Maximum recorded flow, 6.4 cfs. Irrigated area, 275 acres. Discharge is return flow seepage from Wide Hollow Creek.

[1] Washington Department of Conservation and Development.
[2] U.S. Dept. Agriculture (1904, p. 267).
[3] Estimated from information furnished by Bureau of Reclamation, Yakima.
[4] Jayne (1906).
[5] U.S. Geological Survey, General Hydrology Branch, Tacoma.

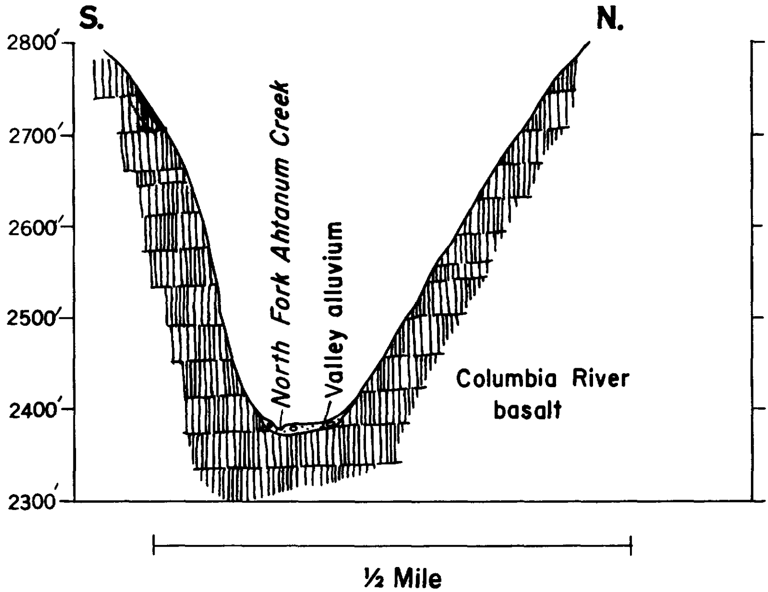

FIGURE 16.—Section through site of gaging station 27, North Fork of Ahtanum Creek near Tampico, Wash.

Surface diversions.—Small amount diverted above station.

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by underflow moving downvalley through the alluvium. Amount of underflow is less than the error in the streamflow record.

Surface return flow.—None.

Subsurface return flow.—Very small amount by ground-water discharge in area irrigated by upstream diversions.

Storage and regulation.—None.

Utilization.—Fifteen acres under irrigation in accordance with the adjudication decree of 1925. Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The record of this station gives an adequate measure of the total outflow of the drainage area.

28. SOUTH FORK AHTANUM CREEK AT CONRAD RANCH, NEAR TAMPICO

Location.—Lat 46°30′30″, long 120°54′50″, in SW¼ sec. 23, T. 12 N., R. 15 E., on left bank at Conrad Ranch, 2½ miles upstream from confluence with North Fork, 2¾ miles southwest of Tampico, and 20 miles southwest of Yakima.

Drainage area.—24.8 sq mi.

Gage.—Staff gage and concrete control. Altitude of gage is 2,400 ft (from topographic map). Prior to Aug. 9, 1918, at datum 1.00 ft lower.

Records available.—March 1915 to September 1924 (fragmentary) and March 1931 to September 1955.

Accuracy of record.—Generally good.

Geologic setting.—The station is 2¾ miles southwest of Tampico. In this reach Ahtanum Creek flows northeast through a fairly narrow valley. The valley floor has width of about 500 ft, and is underlain with an unknown thickness of sand and gravel alluvium. The stream is measured at a concrete weir. A geologic section, extending across the valley, is shown in figure 17.

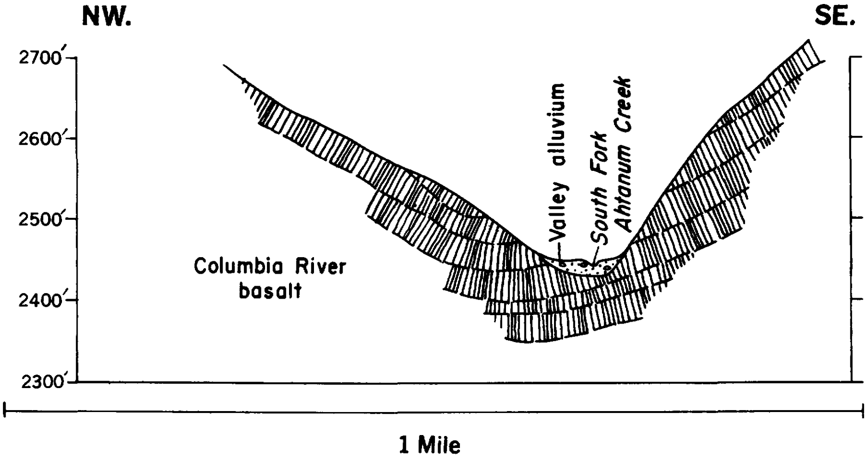

FIGURE 17.—Section through site of gaging station 28, South Fork Ahtanum Creek at Conrad Ranch, near Tampico, Wash.

Surface diversions.—About 1 cfs diverted from "flood waters" only, in accordance with adjudication decree of 1925.

Bypass channels.—None.

Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass is less than the error in the streamflow, except during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—Small amount by ground-water discharge in area irrigated by surface diversion.

Storage and regulation.—None.

Utilization.—About 55 acres irrigated above station. Little or no ground water withdrawn above station.

Imported recharge.—None.

Adequacy of record.—The record gives an adequate measure of the total outflow of the drainage area, except during periods of low flow.

29. SOUTH FORK AHTANUM CREEK NEAR TAMPICO

Location.—Lat 46°31'10'', long 120°53'20'', in NE¼ sec. 24, T. 12 N., R. 15 E., on right bank at Shannafelt Ranch, 1½ miles upstream from confluence with North Fork, and 2 miles southwest of Tampico.

Drainage area.—29.1 sq mi.

Gage.—Staff gage. Altitude of gage is 2,200 ft (from topographic map). Prior to Mar. 16, 1914, staff gage 100 ft downstream at different datum.

Records available.—January, February, and May 1908 to October 1914.

Accuracy of record.—Good.

Geologic setting. The station was about 2 miles southwest of Tampico. In this reach Ahtanum Creek flows through a fairly narrow valley. The flood plain has a width of about 300 ft. and is underlain with an unknown thickness of sand and gravel alluvium.

Surface diversions.—Several small ditches divert as much as 2 cfs total, from "flood waters" in accordance with adjudication decree of 1925.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvial materials. The amount of subsurface bypass was less than the error in the streamflow record, except for periods of low flow.

Surface return flow.—None.

Subsurface return flow.—Small amount by ground-water discharge in area irrigated by surface diversions.

Storage and regulation.—None.

Utilization.—About 86 acres irrigated. About 360 acre-ft of ground water is withdrawn for irrigation and domestic use.

Imported recharge.—None.

Adequacy of record.—The records are believed to give an adequate measure of the total of the drainage area, except during periods of low flow.

30. AHTANUM CREEK AT THE NARROWS, NEAR TAMPICO

Location.—Lat 46°31′40″, long 120°48′20″, in NE¼ sec. 15, T. 12 N., R. 16 E., on right bank at The Narrows 3 miles downstream from confluence of North and South Forks, 3½ miles east of Tampico, and 18 miles southwest of Yakima.

Drainage area.—121 sq mi.

Gage.—Staff gage. Altitude of gage is 1,830 ft (from topographic map).

Records available.—June 1908 to September 1913.

Accuracy of record.—Generally good.

Geologic setting.—The station was in The Narrows about 3⅓ miles east of Tampico. In this reach Ahtanum Creek flows along the north edge of a flood plain 700 ft wide. This flood plain is underlain with an unknown thickness of sand and gravel alluvium. The valley sides, which rise almost vertically from the flood plain, are composed of Columbia River basalt.

Surface diversions.—Water rights for 841 acres granted by adjudication decree of 1925, in the amount of 1 miner's inch per acre. (Oral report by Wallace Owen, ditch rider, 1951.) In addition, during the early part of the irrigation season, Johncox ditch diverts 7 to 8 cfs in the NW¼SW¼ sec. 7, T. 12 N., R. 16 E., to irrigate farmlands just below station whose water rights are junior to others under the decree.

Bypass channels.—Discharge records do not include flow in Johncox ditch which bypasses station.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of this bypass is not known, but was probably less than the error in the streamflow record, except during periods of low flow. Some additional bypass may occur by water percolating through the basalts and discharging in the lower valley area.

Surface return flow.—None.

Subsurface return flow.—Moderate amount by ground-water discharge from areas irrigated by surface diversions.

Storage and regulation.—None.

Utilization.—A total of 841 acres irrigated above station; however, only 188 acres receive adequate surface-water supply during normal year. About 1,600 acre-ft of ground water withdrawn, chiefly for irrigation.

Imported recharge.—None.

Adequacy of record.—The records give a fairly adequate measure of the total outflow of drainage area if adjustment is made for flow in Johncox ditch.

31. AHTANUM CREEK NEAR YAKIMA

Location.—Lat 46°32'10", long 120°28'20", in SW¼ sec. 8, T. 12 N., R. 19 E., on center pier of railroad bridge, 500 ft upstream from mouth and three-quarters of a mile south of Union Gap (formerly Yakima).

Drainage area.—171 sq mi.

Gage.—Staff gage. Altitude of gage is 940 ft (from topographic map). May 11 to Nov. 30, 1904, Aug. 27, 1907, to July 31, 1908, and Mar. 2 to Oct. 31, 1910, staff gages at approximately same site at different datums.

Records available.—May to November 1904, August 1907 to July 1908, March 1910 to September 1912 (fragmentary), and May 1951 to April 1953. Monthly discharges October 1912 to September 1914 published in Geological Water-Supply Paper 1316.

Accuracy of record.—Generally good.

Geologic setting.—The station was a quarter of a mile upstream from mouth. In this reach Ahtanum Creek flows along the western edge of the Yakima River flood plain, upstream from Union Gap. At the station site the flood plain is underlain with 30 to 50 feet of silt, sand, and gravel, which rest unconformably upon the Columbia River basalt. Farther north the flood plain is underlain with many hundreds of feet of alluvium and Ellensburg formation.

Surface diversions.—By the adjudication decree of 1925, 9,381 acres were considered irrigable and an allotment of 1 miner's inch per acre was made. Included are the 926 acres served by the Johncox ditch which bypasses the station Ahtanum Creek at The Narrows when water is plentiful. According to Wallace Owen (1951), ditch rider at Ahtanum Creek, of the 9,381 acres only 2,600 acres is irrigated under water rights adequate to insure water supply throughout the irrigation season of an average year.

This area is served by a maze of small ditches, many of which are interconnected, and individual tabulation appears impracticable. Although no quantitative records of water use are available, irrigation has been practiced for many years in this valley. The first irrigation in the Yakima River basin was in Ahtanum Valley, beginning in 1864.

The Yakima Indian Reservation to the south is entitled to a quarter of the total flow of Ahtanum Creek, by court decree. Most of this water is carried by the main Ahtanum Canal, built in 1908, diverting at the center of the E½ sec. 14, T. 12 N., R. 16 E., and carrying an average flow of about 30 cfs during the irrigation season. The maximum recorded flow is 92 cfs. The canal irrigates about 1,000 acres. (Information from files of Bureau of Indian Affairs at Wapato. Available record, 1909–13 (fragmentary), 1913–24, and 1926–55.) The Lower Ahtanum Canal diverting in center of the NE¼SE¼ sec. 7, T. 12 N., R. 18 E., carries an average flow of about 14 cfs. The flow is ground-water seepage mostly, from the Main Canal. (Information from files of Bureau of Indian Affairs at Wapato.) It was an old Indian ditch originally which was taken over and rebuilt in 1918 by the Indian Service.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving down the Ahtanum Valley through the valley alluvium and the underlying Ellensburg formation. Most of the bypass discharge directly into the Yakima River upstream from Union Gap.

Surface return flow.—Numerous drains return diverted irrigation water.

Subsurface return flow.—Large amount by ground-water discharge from irrigated areas.

Storage and regulation.—None.

Utilization.—About 9,000 acres under irrigation. About 8,000 acre-ft of ground water per year is now withdrawn, chiefly for irrigation.

Imported recharge.—Surface diversions for irrigation fom the Tieton and the Naches Rivers result in widespread artificial recharge. The flow of lower Ahtanum Creek is in part return flow from these diversions.

Adequacy of record.—The records of this station are not representative of the outflow of the drainage area because of subsurface bypass and the return flow from irrigation upstream.

32. YAKIMA RIVER AT UNION GAP, NEAR YAKIMA[4]

Location.—Lat 46°31′40″, long 120°28′20″, in NW¼ sec. 17, T. 12 N., R 19 E., on right bank 600 ft downstream from mouth of Ahtanum Creek, 600 ft upstream from New Reservation Canal intake, and 1 mile south of Union Gap (formerly Yakima).

Drainage area.—3,640 sq mi, approx.

Supplemental records available.—October 1893 to February 1896, gage heights only.

Gage.—Water-stage recorder. Altitude of gage is 930 ft (from river-profile map). Prior to Dec. 31, 1909, and Apr. 1, 1911, to July 28, 1912, staff gages at approximately same site at different datums.

Records available.—August 1896 to September 1919.

Accuracy of record.—Generally good.

Geologic setting.—The station was in Union Gap, the narrow water gap eroded through Ahtanum Ridge. The floor of this gap barely exceeds the width of the stream, and is underlain with 20 to 40 ft of sand and gravel. These materials rest on the bedrock floor of the gap which is composed of Columbia River basalt. A geologic section across Union Gap is shown in figure 18.

Surface diversions.—Fourteen ditches and canals divert a total average flow of about 108 cfs as shown in table 15. All water diverted is used for irrigation above gage, except for about 50 cfs in the Union Gap Canal.

Bypass channels.—Station bypassed by Union Gap and Roza Canals, flow of which is not included in station records. Geological Survey Water-Supply Paper 492 gives monthly flow adjusted for storage, diversion, and seepage return, as a measure of total outflow.

Subsurface bypass.—The station was bypassed by a small amount of water moving downstream through the alluvium.

Surface return flow.—Waste from the city of Yakima municipal water and sewage-treatment system is discharged into the river in sec. 29, T. 13 N., R. 19 E., near the south city limits. According to the Water Superintendent of Yakima, amount varies from 8 cfs in winter to 26 cfs during irrigation season. The Moxee drain ditch, which discharges in the NW¼SW¼ sec. 9, T. 12 N., R. 19 E., drains all the area around Moxee City, including the city's

[4] Published as Yakima River near Yakima prior to 1913.

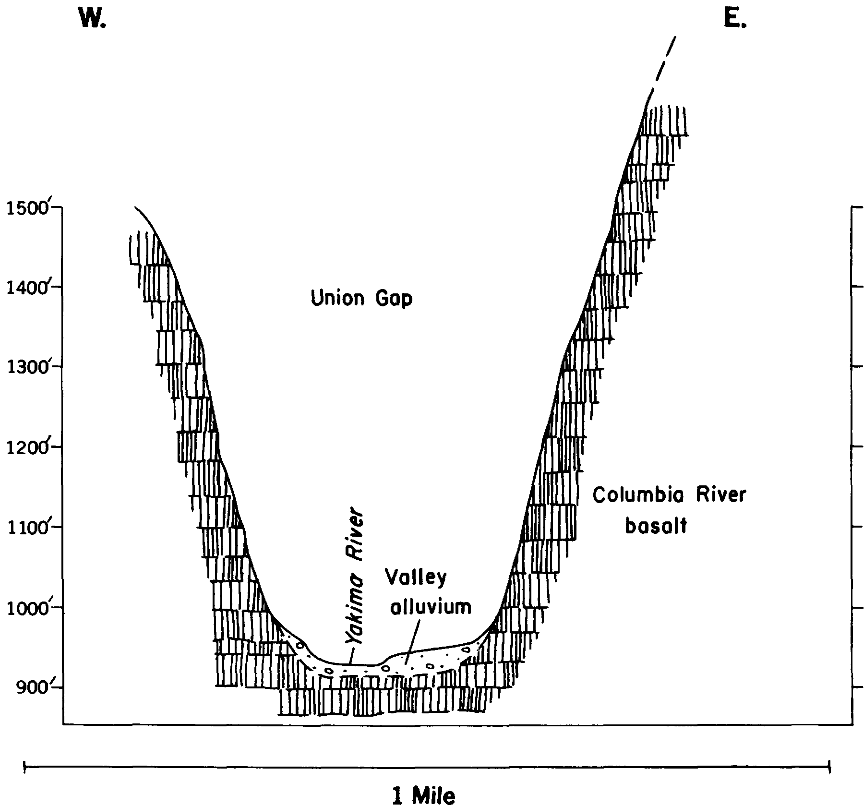

FIGURE 18.—Section through site of gaging station 32, Yakima River at Union Gap, near Yakima, Wash.

municipal waste. The total flow averages from 15 to 30 cfs depending on the season, according to the Moxee City marshall.

Subsurface return flow. A large amount of ground water discharges into the Yakima River along the reach just upstream from Union Gap. Most of this discharge is return flow from areas irrigated by upstream diversions.

Storage and regulation.—See table 8.

Utilization.—An estimated 6,000 acres are irrigated (table 15), according to data supplied by Bureau of Reclamation. This acreage is comparable with that irrigated when the station was discontinued. About 36,500 acre-ft of ground water per year is now withdrawn, chiefly for irrigation and municipal use.

Imported recharge.—None known.

Adequacy of record.—The records adjusted for flow in bypass channels give an adequate measure of the total outflow of the Upper Yakima basin.

TABLE 15.—*Diversion in the Yakima River basin between the Yakima River gaging stations at Union Gap and Selah Gap*

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Moxee Co. ditch	SE¼SE¼ sec. 7, T. 13 N., R. 19 E.	1893	11	Irrigation	Daily discharge records 1904–05, 1909–14, 1921–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 27 cfs. Irrigated area, 3,410 acres.[1]
Hubbard Canal	SW¼NE¼ sec. 17, T. 13 N., R. 19 E.	1893	19	do	Daily discharge records 1909–14, 1921–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 46 cfs. Irrigated area, 700 acres.[2]
Granger ditch	do	1893	6	do	Daily discharge records 1909–14, and miscellaneous measurements 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 20 cfs. Irrigated area, 200 acres.[2]
Bott ditch 1	do	1893	3	do	Discharge records as miscellaneous measurements 1912–14, 1921–27, 1946–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.6 cfs. Irrigated area, 100 acres.[2]
Union Gap Canal	do	1885	50	do	Daily discharge records 1909–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 80 cfs. Irrigated area, 4,000 acres below gage.

See footnotes at end of table.

TABLE 15.—*Diversion in the Yakima River basin between the Yakima River gaging stations at Union Gap and Selah Gap*—Continued

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Normanden ditch	SW¼NE¼ sec. 17, T. 13 N., R. 19 E.		0.8	Irrigation	Miscellaneous discharge measurements 1941–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 1.5 cfs. Irrigated area, 30 acres.[2]
Rich ditch 1	do	Water rights 1892	6	do	Miscellaneous discharge measurements 1926–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 3.8 cfs. Irrigated area, 20 acres.[2]
Richartz Canal	Center sec. 17, T. 13 N., R. 19 E.	1893	18	do	Miscellaneous discharge measurements 1912–13, 1921–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 24 cfs. Irrigated area, 700 acres.[2]
Scudder ditch	Center sec. 21, T. 13 N., R. 19 E.	1893	5	do	Miscellaneous discharge measurements 1912–13, 1922–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 8.5 cfs. Irrigated area, 200 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.
Parrish ditch 1	SW¼SE¼ sec. 28, T. 13 N., R. 19 E.	1893	.4	do	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 2.9 cfs. Irrigated area, 15 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.

Parrish ditch 2	SW¼NE¼ sec. 33, T. 13 N., R. 19 E.	1893	.1	do	Miscellaneous discharge measurements 1924–36, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 0.5 cfs. Irrigated area, 10 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.
Parrish ditch 3	do	1893	.3	do	Miscellaneous discharge measurements 1940–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 5.5 cfs. Irrigated area, 10 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.
Harter ditch	do	1893	2	do	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 14 cfs. Irrigated area, 70 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.
Price ditch	NE¼NW¼ sec. 4, T. 12 N., R. 19 E.	1886	2	do	Miscellaneous discharge measurements 1913, 1924–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 9.6 cfs. Irrigated area, 70 acres.[2] Discharge made up of return flow from Richartz Canal and Blue Slough.

[1] Washington Department of Conservation and Development, Olympia.

[2] Estimated from information furnished by Bureau of Reclamation, Yakima.

33. YAKIMA RIVER NEAR PARKER[5]

Location.—Lat 46°29′40″, long 120°26′10″, in sec. 28, T. 12 N., R. 18 E., on left bank 1,200 ft downstream from Sunnyside diversion dam, 1½ miles east of Parker, and 3 miles downstream from Ahtanum Creek.

Drainage area.—3,650 sq mi, approx.

Gage.—Water-stage recorder. Datum of gage is 886.05 ft above mean sea level (Bureau of Reclamation bench mark). Apr. 25, 1908, to Aug. 16, 1915, staff or chain gages and Aug. 17, 1915, to Oct. 20, 1940, water-stage recorder at several sites within 1,000 ft upstream, at different datums prior to Jan. 1, 1914, and at present datum thereafter.

Records available.—April 1908 to September 1955. October 1921 to September 1931, monthly discharge only.

Accuracy of record.—Good, except for flows below 250 cfs which are fair.

Geologic setting.—The station is just downstream from the Sunnyside diversion dam. In this reach the Yakima River flows along the north edge of the broad lower Yakima Valley. The valley is underlain with as much as several hundred feet of permeable sand and gravel, which in turn rests upon the Ellensburg formation. Figure 19 is a north-south section through the site of this station showing the relationship of the Yakima River to these underlying formations.

Surface diversions.—Three large canals and one small ditch divert an average of about 3,000 cfs during the irrigation season, as shown in table 17.

Bypass channels.—Roza, Union Gap, New Reservation, Old Reservation, and Sunnyside Canals bypass station to irrigate large acreages downstream. Records for station do not include the flow of these canals.

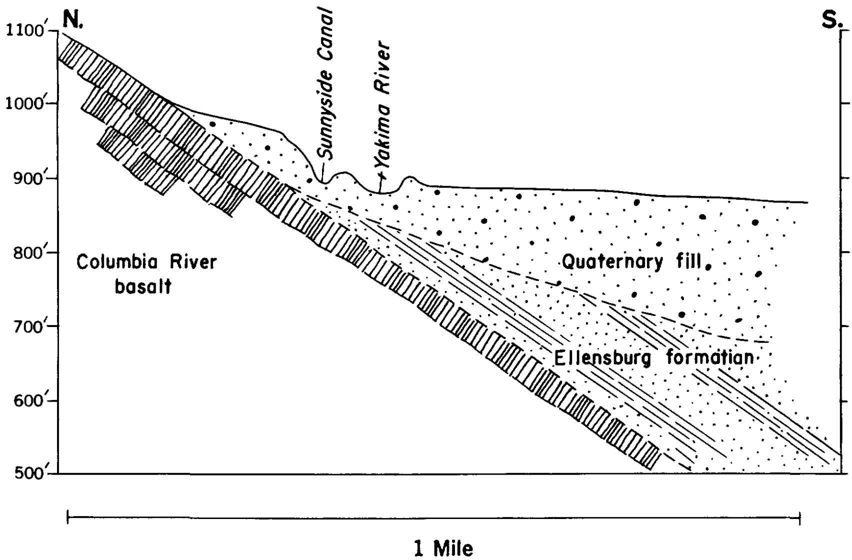

FIGURE 19.—Section through the site of gaging station 33, Yakima River near Parker, Wash.

[5] Published as Yakima River near Wapato prior to 1917.

Subsurface bypass.—Between this station and Union Gap large amounts of water infiltrate into the permable valley fill materials and move southward across the valley. Much of it returns to the Yakima River by way of Toppenish Creek and intervening drainage ditches.

Surface return flow.—None known.

Subsurface return flow.—None known.

Storage and regulation.—See table 8.

Utilization.—Thirteen acres irrigated under Goldsmith ditch. Irrigation of two or three hundred acres from Old and New Reservation Canals above station. In the entire Yakima basin above this station the irrigated area increased from 141,100 acreas in 1920 to 198,500 acreas in 1946. Simons (1954) estimated irrigated acreage in 1955 was 161,000. About 36,500 acre-ft of ground water per year is withdrawn upstream from this station.

Imported recharge.—Some recharge to ground-water aquifers in the lower Yakima basin by upstream diversions (Union Gap and Roza Canals).

Adequacy of record.—The record gives an adequate measure of the flow just below the Sunnyside Dam. Farther downstream large amounts of return flow from the Sunnyside and Roza diversions enter the river. The outflow from the upper Yakima basin cannot be accurately obtained by totaling the flow at Parker with the upstream surface diversions because of the subsurface bypass between this station and Union Gap. Total outflow from the upper Yakima basin could be more adequately obtained by measuring the flow of the Yakima River near the New Reservation diversion dam at Union Gap.

34. TOPPENISH CREEK NEAR FORT SIMCOE

Location.—Lat 46°18′40″, long 120°47′10″, in sec. 35, T. 10 N., R. 16 E., on left bank 30 ft upstream from dam and headworks of Toppenish feeder canal, 3 miles southeast of Fort Simcoe, and 5½ miles southwest of White Swan.

Drainage area.—120 sq mi. At sites prior to Oct. 1, 1922, 122 sq mi.

Gage.—Staff gage. Altitude of gage is 1,300 ft (from topographic map). Prior to July 23, 1913, chain gage 1¼ miles downstream at different datum. July 23, 1913, to Aug. 18, 1915, staff gage and Aug. 19, 1915, to Sept. 30, 1922, water-stage recorder 1½ miles downstream at different datums.

Records available.—February 1909 to September 1924.

Accuracy of record.—Generally good.

Geologic setting.—The station was located about 1 mile upstream from the entrance to Toppenish Canyon, a deep narrow canyon eroded into the Columbia River basalt. The floor of this canyon has a width of about 500 ft and is underlain with an unknown thickness of coarse alluvium.

Surface diversions.—Nicol, or Abe Lincoln, ditch diverting from 3 to 20 cfs depending on time of year, about 2 miles upstream from station, was built prior to 1900, and abandoned in 1921. The diversion was measured from April 1920 to May 1921.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass was less than the error in the streamflow record, except during periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None known.

Storage and regulation.—None.

TABLE 16.—*Diversions in the Yakima River basin between the Yakima River gaging stations at Union Gap and near Parker*

Name	Point of diversion	Date of establishment	Approximate average flow (cfs)	Purpose	Remarks
Goldsmith ditch	SE¼SW¼ sec. 17, T. 12 N., R. 19 E.	Prior to 1908	0.5	Irrigation	Miscellaneous measurements 1931–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 1 cfs. Irrigated area, 13 acres.
New Reservation Canal	SW¼SW¼ sec. 17, T. 12 N., R. 19 E.	1903	[1] 1,700	do	Daily discharge records 1904–55, in files of Bureau of Reclamation, Yakima. Maximum recorded flow, 2,320 cfs. Irrigated area under Old and New Reservation Canals, 106,659 acres at present.
Old Reservation Canal	Center sec. 28, T. 12 N., R. 19 E.	Prior to 1904	[2] 54.7	do	Daily discharge records 1904–55, in files of Bureau of Reclamation, Yakima. Maximum daily discharge, 386 cfs. Flow averaged 175 cfs or more until 1923 when water from New Reservation Canal began to irrigate land previously irrigated by Old Reservation Canal. In 1930, 1,920 acres were irrigated. About 100 cfs are diverted at present (1955) during "priming season," March–June. No diversion, July–October; Approximately 10 cfs diverted November–February for stock.

Sunnyside Canal	NW¼SE¼ sec. 28, T. 12 N., R. 19 E.	About 1902	1,300	do	Daily discharge records 1904–55, in files of Bureau of Reclamation, Yakima. Maximum daily discharge, 1,320 cfs. Land under irrigation in 1906 was 40,000 acres; at present, 82,000 acres.

[1] During recent years.

[2] Average yearly discharge.

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Utilization.—Small acreage irrigated by Abe Lincoln ditch from prior to 1909 to 1921. Little or no ground water withdrawn upstream from this station.
Imported recharge.—None.
Adequacy of record.—The record is believed to give an adequate measure of the total outflow of the drainage basin.

35. SIMCOE CREEK BELOW SPRING CREEK, NEAR FORT SIMCOE

Location.—Lat 46°23′40″, long 120°48′30″, in sec. 34, T. 11 N., R. 16 E., on left bank just downstream from Spring Creek, 4 miles northeast of Fort Simcoe, and 4 miles west of White Swan.
Drainage area.—81.5 sq mi. At site prior to November 1915, 79.9 sq mi.
Gage.—Water-stage recorder and concrete control. Altitude of gage is 1,150 ft (from topographic map). Before Nov. 20, 1915, staff or chain gages at site 600 ft upstream and above Spring Creek at different datum.
Records available.—February 1909 to September 1923.
Accuracy of record.—Generally fair to good.
Geologic setting.—The station was in the narrow canyon that connects Medicine Valley with the Lower Yakima Valley. This canyon was eroded into a northeast-trending ridge composed of Columbia River basalt. The floor of this canyon has a width of about 300 ft, and is underlain with an unknown thickness of alluvium.
Surface diversions.—Simcoe lateral, built in 1920 diverts from 0.1 to 6 cfs at a point in the NE¼SW¼ sec. 34, T. 11 N., R. 16 E., for irrigation of 766 acres. The maximum diversion occurs in May. (Information from records in files of Bureau of Indian Affairs, Wapato.) Other small diversions above station. No record of amount diverted.
Bypass channels.—Flow of Simcoe lateral combined with discharge at station after 1920 in Geological Survey water-supply papers (table 6).
Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvial material. The amount of subsurface bypass was probably less than the error in the streamflow record, except for periods of low flow. Also some ground-water above this station may discharge into Medicine Creek and flow out of Medicine Valley through the canyon located 3 miles northeast of this station.
Surface return flow.—None known.
Subsurface return flow.—The tributary streams, flowing off the upland area located west of Medicine Valley, lose a large part of their flow in recharging the alluvial materials that form large fans in Medicine Valley.
Storage and regulation.—None.
Utilization.—Some irrigation above gage. Small amount of ground water withdrawn.
Imported recharge.—None.
Adequacy of record.—The record gives only a fair measure of the total outflow of the drainage area.

36. TOPPENISH CREEK NEAR WHITE SWAN

Location.—Lat 46°22′30″, long 120°37′10″, in sec. 7, T. 10 N., R, 18 E., on left bank 1,000 ft downstream from Simcoe Creek, 5½ miles east of White Swan, and 11 miles southwest of Wapato.
Drainage area.—409 sq mi.
Supplemental records available.—October 1911 to March 1912, gage heights and discharge measurements only.

Gage.—Staff gage. Altitude of gage is 820 ft (from topographic map).
Records available.—March 1909 to September 1911 (fragmentary).
Accuracy of record.—Generally good.
Geologic setting. The station was about 1,000 feet downstream from Simcoe Creek. In this reach Toppenish Creek flows south in a broad valley eroded into the Quaternary fill materials of the Lower Yakima basin. The width of this inner valley is about 1½ miles. The thickness of the alluvial materials that underlie the inner valley is not known.
Surface diversions.—Toppenish feeder canal, diverts in sec. 35, T. 10 N., R. 16 E., 30 ft below gaging station on Toppenish Creek near Fort Simcoe. According to the late F. E. Moxley, of the Bureau of Indian Affairs at Wapato, during the winter it carries an average of about 10 cfs, and as much as 50 cfs during the summer, for irrigation of 1,640 acres above station. Discharge records in files of Bureau of Indian Affairs, Wapato.
Bypass channels.—None.
Subsurface bypass.—The station was bypassed by large amounts of water moving downvalley through the alluvium.
Surface return flow.—None known.
Subsurface return flow.—Flow is augmented by ground-water discharge from areas irrigated by upstream diversion including that of Old and New Reservation Canals.
Storage and regulation.—None.
Utilization.—According to Mr. Moxley, 806 acres irrigated by Simcoe lateral above station at present. Unknown amount of ground water withdrawn for domestic use and irrigation.
Imported recharge.—Water diverted from the Yakima River below Union Gap recharges aquifers upstream from this station.
Adequacy of record.—The record does not give an adequate measure of the total outflow of the drainage area, owing to subsurface bypass and return flow.

37. TOPPENISH CREEK AT ALFALFA

Location.—Lat 46°18′50″, long 120°13′00″, in sec. 32, T. 10 N., R. 21 E., on right side of highway bridge, 300 ft upstream from railroad bridge, 1 mile southeast of Alfalfa, and 2½ miles upstream from mouth.
Drainage area.—580 sq mi, approx.
Gage.—Staff gage. Altitude of gage is 690 ft (from topographic map).
Records available.—March 1909 to September 1912.
Accuracy of record.—Generally good.
Geologic setting.—The station was about 1 mile southeast of Alfalfa. In this reach Toppenish Creek flows across the broad valley floor of the Yakima Valley. The valley floor in this area is underlain with an unknown thickness of sand and gravel alluvium.
Surface diversions.—Rentchler ditch diverting in sec. 21, T. 10 N., R. 18 E., carries an estimated average flow of 6 cfs. Durham lateral, constructed prior to 1904, diverts from Toppenish Creek in the NE¼NE¼ sec. 31, T. 10 N., R. 21 E., carrying an average flow of 10 to 20 cfs for the irrigation of 385 acres. (Records of flow in files of U.S. Bureau of Indian Affairs, Wapato.) Toppenish Creek in its lower reaches serves as a drain channel for reservation farmland (see Lower Toppenish drain, table 17). Water is diverted from Main drain into Toppenish Creek in sec. 26, T. 10 N., R. 20 E. About 3 miles downstream in sec. 32, T. 10 N., R. 20 E., water is diverted into Satus Gravity Unit 1, irrigating 4,760 acres, and Satus Low-lift Pumping Unit 2,

which irrigates 5,700 acres. A major part of water diverted during April, May and June is natural flow; thereafter, it consists of drainage and seepage from upstream irrigation. Additions are to be completed in the near future to Unit 3, partly fed by Satus Creek, which will irrigate some 10,000 acres, the southern end of which will be near Mabton. Unit 3 now irrigates 5,350 acres.

Bypass channels.—Water diverted for Satus Irrigation Project, as noted above, bypass station and returns to the Yakima River above the gaging station near Mabton.

Subsurface bypass.—The station was bypassed by large amounts of water moving downvalley through the alluvium.

Surface return flow.—None.

Subsurface return flow.—Some ground-water discharge from area irrigated by upstream diversions.

Storage and regulation.—None.

Utilization.—385 acres are irrigated by Durham lateral above station in 1955. Probably little change since station was discontinued. Considerable water diverted to serve 16,000 acres downstream as noted in paragraph on "Diversions." After construction is complete, irrigated area will be considerably larger. About 1,000 acre-ft of ground water is now withdrawn each year for irrigation and domestic use.

Imported recharge.—Water diverted from the Yakima River below Union Gap recharges aquifers upstream from this station.

Adequacy of record.—The record is not representative of total outflow of the drainage area because of subsurface bypass.

38. SATUS CREEK NEAR TOPPENISH

Location.—Lat 46°14'20", long 20°24'40", in NW¼ sec. 26, T. 9 N., R. 19 E., on left bank 1 mile upstream from Dry Creek, 4 miles downstream from Logy Creek, and 10½ miles southwest of Toppenish.

Drainage area.—271 sq mi.

Gage.—Staff gage. Altitude of gage is 950 ft (from topographic map).

Records available.—November 1908 to June 1913.

Accuracy of record.—Generally poor to good.

Geologic setting.—The station was about 1 mile above the mouth of Dry Creek. In this reach Satus Creek enters a fairly shallow valley eroded into the Columbia River basalt. The valley floor has a width of about 500 ft, and is underlain with an unknown thickness of sand, gravel, and boulder alluvium.

Surface diversions.—According to F. E. Moxley, of the Bureau of Indian Affairs at Wapato, during July and August the entire flow of Satus Creek, about 5 to 10 cfs, is diverted above Logy Creek for irrigation. No records of diversions.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass was within the error of the streamflow records, except for periods of low flow.

Surface return flow.—None.

Subsurface return flow.—Some return flow by ground-water discharge from area irrigated by diversions.

Storage and regulation.—None.

Utilization.—Several hundred acres above station irrigated from Satus Creek. Small amount of ground water withdrawn for domestic use.

Imported recharge.—None.

Adequacy of record.—The record is fairly representative of the total outflow from the drainage area.

39. SATUS CREEK BELOW DRY CREEK, NEAR TOPPENISH

Location.—Lat 46°15′00″, long 120°22′40″, in sec. 24, T. 9 N., R. 19 E., on left bank at dam site, 1 mile downstream from Dry Creek, 6 miles downstream from Logy Creek, and 9 miles southwest of Toppenish.

Drainage area.—434 sq mi.

Gage.—Water-stage recorder. Altitude of gage is 880 ft (from topographic map).

Records available.—June 1913 to September 1924.

Accuracy of record.—Generally good.

Geologic setting.—The station was 1 mile downstream from Dry Creek. In this reach Satus Creek flows along the north side of a valley eroded into the Columbia River basalt. The valley floor has a width of about 600 ft, and is underlain with an unknown thickness of sand, silt, and boulder alluvium.

Surface diversions.—Same as for station 38.

Bypass channels.—None.

Subsurface bypass.—The station was bypassed by water moving downvalley through the alluvium. The amount of subsurface bypass was less than the error in the streamflow record, except for periods of low flow.

Surface return flow.—None.

Subsurface return flow.—None.

Storage and regulation.—None.

Utilization.—None except as noted for next station upstream.

Imported recharge.—None.

Adequacy of record.—The record gives a fairly adequate measure of the total outflow from the drainage area.

40. YAKIMA RIVER NEAR MABTON

Location.—Lat 46°13′00″, long 119°55′10″, in SE¼ sec. 34, T. 9 N., R. 23 E., on left bank at Rocky Ford rapids, 2,000 ft upstream from Mabton-Grandview highway bridge, 3 miles south of Grandview, and 4 miles east of Mabton.

Drainage area.—5,380 sq mi, approx.

Gage.—Staff gage. Altitude of gage is 630 ft (from topographic map). Prior to Aug. 1, 1911, at site 2,000 ft downstream at different datum.

Records available.—Irrigation seasons of 1911 to 1914.

Accuracy of record.—Generally good.

NOTE.—Because of the proximity to the next downstream station, data for surface diversions, bypass channels, and surface return flow, have been included with the data for Yakima River near Prosser (pp. 94–95).

Geologic setting.—The station was 4 miles east of Mabton. In this reach the Yakima River is confined to an inner valley, a quarter of a mile wide, which has been eroded into Columbia River basalt. The floor of this valley is mantled with an unknown thickness of permeable alluvium.

Surface diversions.—See station 41.

Bypass channels.—See station 41.

Subsurface bypass.—The station was bypassed by a small amount of water moving downvalley through the alluvial materials.

Surface return flow.—See station 41.

Subsurface return flow.—A large amount of subsurface return flow from irrigation enters the river between this station and the next upstream at Parker.

Ground-water withdrawals.—About 48,500 acre-ft per year.

Adequacy of records.—The record gives a fairly adequate measure of the total outflow from the drainage area if adjusted for flow in bypass channels.

41. YAKIMA RIVER NEAR PROSSER

Location.—Lat 46°13'00'', long 119°45'00'', in SE¼ sec. 36, T. 9 N., R. 24 E., on right bank 1¼ miles northeast of Prosser and 1¼ miles downstream from Prosser Falls.

Drainage area.—5,440 sq mi, approx.

Gage.—Water-stage recorder. Altitude of gage is 600 ft (from topographic map). Before Jan. 31, 1906, chain gage at site 600 ft downstream from Prosser Falls, 1¼ miles upstream at different datum. Feb. 1 to Oct. 12, 1906, staff gage at approximately same site at different datum.

Records available.—April to October 1904, June 1905 to January 1906 (monthly discharge only), February to October, 1906, and August 1913 to February 1933 (monthly discharge only during winters 1916–1919).

Accuracy of record.—Generally good.

Geologic setting.—The station was below the diversion of the Chandler power canal, 1¼ miles northeast of the city of Prosser. In this reach the Yakima River flows through a narrow inner canyon eroded into the Columbia River basalt. The floor of this canyon, which barely exceeds the width of the stream, is underlain with an unknown thickness of coarse alluvium.

Surface diversions.—

1. Snipes and Allan ditch diverting in the SE¼NW¼ sec. 17, T. 11 N., R. 20 E., carries an average flow of about 20 cfs. Maximum recorded flow is 59 cfs. 500 acres irrigated (files of Washington Department of Conservation and Development, Olympia). Records available: 1923. and 1927–29, daily discharges; 1930–55, miscellaneous measurements (files of Bureau of Reclamation, Yakima).
2. The Shearer Canal diverts in the NW¼ sec. 13, T. 9 N., R. 20 E., from lower Satus Creek, 1 to 5 cfs during the irrigation season for use on about 580 acres in and about sec. 3, T. 9 N., R. 21 E. (Files of Bureau of Indian Affairs, Wapato.) Figures for Shattuck ditch diverting from it are included.
3. The Satus feeder canal diverting in the NW¼SW¼ sec. 7, T. 9 N., R. 21 E., is a part of Satus Low Lift Pumping Unit 2 and carries from 1 to 90 cfs during the irrigation season with maximum flow usually in May. See "Diversions," Toppenish Creek at Alfalfa (p. 91). (Information from files of Bureau of Indian Affairs, Wapato.)
4. The Chandler power canal, diverting directly opposite the town of Prosser, carries an average flow of 1,000 cfs (files of Bureau of Reclamation, Yakima) to its powerhouse 1½ miles downstream from station. Constructed in 1932.
5. Posser Falls irrigation canal diverting in vicinity of Prosser irrigated 4,000 acres until 1910 when it was taken over by Bureau of Reclamation. Since then, water has been obtained from Sunnyside Canal. (Files of Bureau of Reclamation, Yakima.)

Bypass channels.—Roza, Sunnyside, and Prosser power canals bypass gage. Published station records not adjusted for flow of canals.

Subsurface bypass.—The station was bypassed by a small amount of water moving downvalley through alluvium.

Surface return flow.—Seven main drains carry seepage from the Yakima Indian Reservation varying from a total average flow of about 550 cfs during winter to about 950 cfs during irrigation season as shown in table 17. Eight main drains and Sulphur Creek carry seepage and waste water to the river from the east, total winter flow averaging 64 cfs and summer flow averaging 192 cfs as shown in table 18. The municipalities of Wapato, Toppenish, Zillah, and Sunnyside discharge wastes into Yakima River as shown in table 2. The Prosser sewage-treatment plant discharges 0.1 to 0.3 cfs into the Yakima River 150 cfs below bridge at south end of town. (Prosser sewage-treatment plant operator, oral report.)

Subsurface return flow.—Some subsurface return flow from irrigation occurs between this station and the upstream station at Mabton.

Storage and regulation.—See table 8.

Utilization.—No record was found of breakdown of land area under irrigation which gave acreage irrigated above station. From information supplied by Bureau of Reclamation, Yakima, the irrigated area is estimated to be between 110,000 and 130,000 acres exclusive of the Yakima Indian Reservation.

TABLE 17.—*Discharge to the Yakima River from Yakima Indian Reservation drains*

[All information obtained from files of Bureau of Indian Affairs, Wapato]

Drain	Location of mouth	Maximum recorded (cfs)	Winter, approx. average flow (cfs)	Irrigation season, approx. average flow (cfs)
East Toppenish drain	SW¼NW¼ sec. 11, T. 10 N., R. 20 E.	200	11	35
Subdrain 35	Center sec. 21, T. 10 N., R. 21 E.	98	25	85
Main drain	NW¼NE¼ sec. 28, T. 10 N., R. 21 E.	1,500	290	460
Lower Toppenish Creek	NW¼SE¼ sec. 27, T. 10 N., R. 21 E.	1,600	100	155
Coulee drain	SW¼NW¼ sec. 6, T. 9 N., R. 22 E.	48	12	23
Lower Satus (Satus Creek)	SW¼SE¼ sec. 18, T. 9 N., R. 22 E.	2,500	105	180
South drain	NE¼NE¼ sec. 19, T. 9 N., R. 22 E.	800	9	11

TABLE 18.—*Average discharge from drains to Yakima River in lower Yakima County, 1921–22*

[All data from files of Yakima County engineer, Yakima]

Drainage District No.	Location of mouth	Winter, approx. average flow (cfs)	Irrigation season, approx. average flow (cfs)
2 25	Center sec. 21, T. 10 N., R. 21 E.	15	35
7	Center sec. 21, T. 9 N., R. 22 E.	5	30
12	Center sec. 22, T. 9 N., R. 22 E.	2	12
31	SE¼SE¼ sec. 25, T. 9 N., R. 22 E.	.5	5
35	SE¼SE¼ sec. 29, T. 9 N., R. 23 E.	.5	3
27	NW¼ sec. 21, T. 10 N., R. 21 E.	.2	2.5
32	SE¼ sec. 14, T. 14 N., R. 17 E.	1	15
Sulphur Creek	NW¼NW¼ sec. 26, T. 9 N., R. 22 E.	40	90

Imported recharge.—Some aquifers are recharged by return flow from Sunnyside and Roza canals.

Adequacy of record.—The record gives a fairly adequate measure of total outflow from the drainage area if adjusted for flow in bypass channels.

42. YAKIMA RIVER AT KIONA

Location.—Lat 46°15'10", long 119°28'50", in sec. 19, T. 9 N., R. 27 E., on left bank at highway bridge in Kiona, 3½ miles downstream from intake of Kiona Canal, and 25 miles upstream from mouth.

Drainage area.—5,600 sq mi.

Supplemental records available.—August to December 1895, gage heights only.

Gage.—Water-stage recorder. Datum of gage is 454.41 ft above mean sea level, datum of 1929, supplementary adjustment of 1947. Prior to Mar. 31, 1915, several staff or chain gages at approximately same site and datum. Feb. 6, 1933, to July 26, 1934, steel-tape gage at same site and datum.

Records available.—August 1896 to March 1915 and February 1933 to September 1955.

Accuracy of record.—Generally good to excellent.

Geologic setting.—The station is on the sharp bend of the Yakima River at Kiona. In this reach the Yakima River flows along the southern and eastern margin of a valley, a half mile wide eroded into the Columbia River basalt. The valley has an east by southeast trend upstream from Kiona, but it changes abruptly to a northward-trending valley at Kiona. As the Yakima River flows along the outer margin of the valley in this sharp bend, a valley floor, a mile wide, underlain with an unknown thickness of alluvium, extends in a northwesterly direction from this station. The record of a well 9/27-19G2 (log, p. 122) shows the alluvial materials at Kiona to be composed of strata of clay, sand, and gravel. Similar materials probably compose the alluvial fill located north of the river. A geologic section through the site of this gaging station is shown in figure 20.

Surface diversions.—The Kiona Canal, diverting in sec. 10, T. 9 N., R. 26 E., 5 miles west of Kiona, carries an average of about 32 cfs with a maximum recorded flow of 54 cfs. It was constructed prior to 1904, and records for 1904, 1909–14, and 1923–55 are in files of Bureau of Reclamation, Yakima.

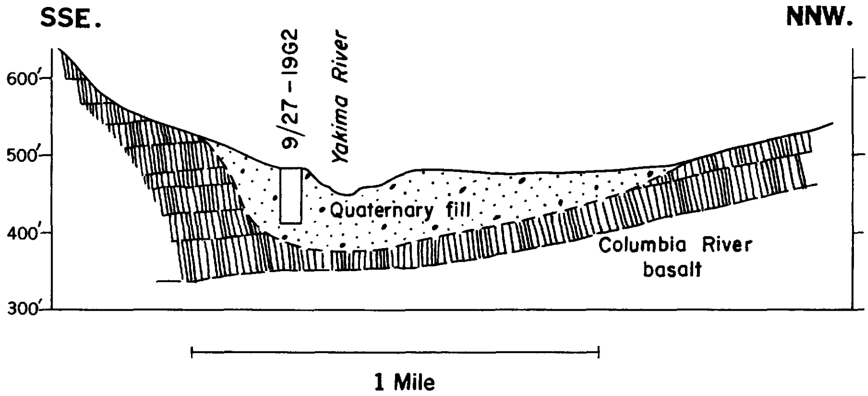

FIGURE 20.—Section through site of gaging station 42, Yakima River at Kiona, Wash.

Bypass channels.—About half of the flow of Kiona Canal bypasses gage; published records of flow do not include this bypass.

Subsurface bypass.—The station is bypassed by water moving downvalley through the alluvial materials.

Surface return flow.—Total flow of Chandler power canal returned to river above station, 6 miles below Prosser.

Subsurface return flow.—Considerable return flow from irrigation occurs upstream from station.

Storage and regulation.—See table 8.

Utilization.—Present irrigated area is estimated at about 25,000 acres, from data supplied by Bureau of Reclamation. Included is about 2,400 acres irrigated by the Kiona Canal above station which represents very little change in the irrigated area in the past 30 years. Total irrigated area in Yakima basin above station has increased from 305,370 acres in 1920 to 424,560 acres in 1955 (Simons, oral communication, 1955). About 51,000 acre-ft of ground water withdrawn above station.

Imported recharge.—Some aquifers are recharged by return flow from Sunnyside and Roza Canals.

Adequacy of record.—The record mainly gives a measure of the total outflow of the drainage area. Slightly more adequate records might be obtained 7 to 8 miles downstream, below all return flow, where the Yakima River is confined to a narrow channel eroded into the Columbia River basalt.

43. YAKIMA RIVER NEAR RICHLAND

Location.—Lat 46°15′10″ long 119°15′30″, in sec. 24, T. 9 N., R. 28 E., near left bank on highway bridge, half a mile upstream from mouth, and 1 mile south of Richland.

Drainage area.—6,120 sq mi, approx.

Supplemental records available.—August to December 1907, August to December 1908, gage heights only.

Gage.—Staff gage. Altitude of gage is 335 ft (from topographic map). July 28, 1906, to Oct. 31, 1909, staff gages at several sites within 2 miles upstream at different datums.

Records available.—Irrigation seasons, 1906, and 1909–11.

Accuracy of record.—Generally good.

Geologic setting.—The station was about 1 mile above the mouth of the Yakima River. In this reach the Yakima River flows across the broad alluvial fill of the Columbia River. The thickness and permeability of these alluvial materials is not known.

Surface diversions.—

1. The Richland and Columbia Canals, using the same diversion dam, located in sec. 3, T. 10 N., R. 27 E., divert an average flow of 190 and 250 cfs, respectively, whereas the maximum recorded flow for Richland Canal is 303 cfs and for the Columbia Canal, 324 cfs. Available records for Columbia Canal are 1904–5, 1910–14, and 1923–55 and for Richland Canal 1905, 1909–14, and 1923–55. (Files of Bureau of Reclamation, Yakima).
2. The Amon Canal (Benton Water Co.), built in 1905, diverted water for irrigation of 1,500 acres (Waller, 1909) just above gage until it was abandoned about 1925. No record of flow available.

Bypass channels.—Columbia and Kennewick Canals bypass gage site. Records as published in U.S. Geological Survey water-supply papers (table 6) do not include flow of canals.

Subsurface bypass.—The station was bypassed by water moving through the alluvial fill toward the Columbia River in the area north of this station. Amount of bypass is not known, but most of it originates in the Cold Creek basin.

Surface return flow.—Waste from Richland sewage-treatment plant, about 4 to 5 cfs. flows back into river upstream from gaging station. (Richland sewage-treatment plant operator). Points of reentry of seepage from irrigation above station not established.

Subsurface return flow.—Considerable return flow from irrigation enters stream above station.

Storage and regulation.—See table 8.

Utilization.—Richland Canal, built in 1904 has been used for municipal supply of city of Richland since 1943. It formerly irrigated about 10,500 acres. The Columbia and Kennewick Canals, diverting from it, serve a total of 11,600 acres, mostly below station (Washington Department of Conservation and Development, Olympia). Kiona Canal serves about 1,100 acres above station. Present irrigated area above gage estimated at about 3,500 acres. More than 51,000 acre-ft of ground water is now withdrawn each year in the Yakima River basin. Total irrigated area in Yakima River basin estimated at 439,300 acres in 1946 (Simons, 1954, p. 56).

Adequacy of record.—The amount of subsurface bypass may exceed the error in the streamflow records during periods of low flow. As the record is entirely in the period of low flow, the record does not represent the total outflow of the drainage area and of the entire Yakima River.

DESCRIPTION OF ROCK UNITS

The character and structure of the rock units that underlie a drainage area have a tremendous influence on the runoff characteristics of the area. Rock materials that have high effective porosity and permeability readily absorb precipitation and reduce the amount of direct surface runoff. These materials act as regulators, reducing the amount of streamflow during wet seasons and maintaining streamflow by ground-water discharge during dry seasons. Rock materials that have low effective porosity and permeability absorb only small amounts of water during wet periods, permitting large amounts of the precipitation to run off directly. Because these materials store little groundwater, runoff during dry periods is relatively low. However, as most drainage basins are underlain by several rock units with different hydrologic properties, the runoff characteristics of a stream are composites of the effects caused by each particular rock unit.

The following brief description of the rock units of the Yakima River basin will aid in any future analysis of the water resources of this area. Plate 1 is a generalized geologic map showing the areal distribution of the major rock units. Many of the publications that are listed in the bibliography at the end of this report contain more detailed geologic maps of some parts of the basin.

PRE-MIOCENE VOLCANIC, INTRUSIVE, AND METAMORPHIC ROCKS, UNDIFFERENTIATED

A large area of the western part of the Yakima River basin is underlain by metamorphic, volcanic, and intrusive rocks. Except for the Teanaway basalt, the areal distribution of these rocks is shown together on plate 1.

The metamorphic rocks include the Easton schist, Peshastin formation, and several unnamed metamorphic rock units. The Easton schist is an extremely crumpled quartz-mica rock underlying the south slope of the Yakima Valley near Easton. The Peshastin formation is composed of slate and chert, and underlies a small area along the North Fork of the Teanaway River. Other small areas in the western part of the Yakima River basin are underlain by unnamed metamorphic rocks (Smith, G. O., 1904, 1906).

The volcanic rocks include the Keechelus andesitic series, the Kachess rhyolite, and some unnamed rock units. The Keechelus andesitic series, which underlies much of the western half of the Yakima River basin, consists of a thick sequence of flows, tuffs, and agglomerates which formerly were believed to be younger than the Columbia River basalt (Smith, G. O., 1906). Walter Warren (1941) has shown that the Keechelus is older than the Columbia River basalt. The Kachess rhyolite consists of a thick sequence of white to yellow rhyolite lava flows exposed in the Kachess Valley along the northeast side of Kachess Lake.

The Snoqualmie and Mount Stuart granodiorites are intrusive rocks which underlie large areas in the northwestern part of the Yakima drainage basin.

The porosity and permeability of most of these formations are low. No wells are known that develop water from them.

EOCENE CONTINENTAL SEDIMENTARY FORMATIONS

Much of the headwater area of the Yakima River is underlain by consolidated sedimentary formations of Eocene age. These include the Guye, Swauk, Naches, Manastash, and Roslyn formations, which are composed chiefly of sandstone and shale. A brief description of the character, distribution, and hydrologic properties of each of these formations follows.

Guye formation.—This formation consists of a thick folded sequence of conglomerate, sandstone, shale, and a small amount of limestone and chert. Some flows of basalt and rhyolite are interbedded with these sedimentary rocks. The Guye formation, which has a thickness of about 3,500 feet (Smith, G. O., 1906), occurs in the Gold Creek drainage area northwest of Keechelus Lake. Here it lies unconformably upon the Keechelus andesitic series, and has been intruded by the Snoqualmie grandiorite.

The porosity and permeability of the Guye formation are believed to be low. No wells are known that develop water from this formation.

Swauk formation.—The Swauk formation is a thick sequence of sandstone, shale, and conglomerate underlying a large part of the Teanaway, Swauk, and Cle Elum River drainage basins. The thickness of the Swauk formation ranges from 3,500 to 5,000 feet. Strata consist principally of light-colored sandstone that is interbedded with black carboniferous shale. The basal section of this formation contains a large proportion of coarse conglomerate. All strata are well cemented and are believed to have low porosity and permeability. The Swauk formation will, in general, yield little or no water to wells.

Naches formation.—The Naches formation consists of interbedded sandstone and basalt underlying the high upland area that separates the Yakima River valley from the Naches River valley south of Easton. This formation may be as much as 4,000 feet thick. The lower part of this formation consists principally of sandstones which resemble those of the Swauk formation, for they are also well cemented and light gray in color. Some carbonaceous shale is interbedded with the sandstones. Very little conglomerate has been noted. Volcanic rocks are present in the upper part of the formation, and consist of basaltic sills, flows, and fragmental tuff agglomerates. The flow units exhibit highly honeycombed or vesicular upper surfaces which have resulted from expansion of gases in the zone of reduced pressure near the surface of the flows.

The porosity and permeability of the sandstone and shale of this formation are low. The basaltic members have somewhat higher permeabilities, especially in the fragmental and vesicular zones. No wells are known that develop water from this formation.

Roslyn formation.—This formation consists of a thick, folded, and faulted sequence of fine-grained sandstone, shale, and some coal strata. The formation underlies the Yakima and Teanaway River valleys in the vicinity of Cle Elum. The total thickness of the Roslyn formation probably exceeds 3,500 feet; it has supported a coal-mining industry in that area since 1886.

The porosity and permeability of the Roslyn formation are so low that pumps of small capacity can drain the coal mines. No wells are known that obtain water from this formation.

Manastash formation.—This formation consists of a thick folded sequence of sandstone and shale. Pebble layers, composed predominantly of white quartz, are associated with the sandstone layers, and some coal is interbedded with the shale. The formation exceeds 1,900 feet in thickness, and underlies the headwater areas of Taneum and Manastash Creeks.

The porosity and permeability of the Manastash formation are believed to be low. No wells are known that develop water from it.

TEANAWAY BASALT (EOCENE)

The Teanaway basalt is a series of lava flows with some interbedded tuffs and agglomerates. The basalt is a dense black rock which generally is rusty red on its weathered surface. It overlies the Swauk formation and underlies the Roslyn formation, and crops out in the upland area north of Cle Elum. The Teanaway basalt ranges in thickness from 300 to several thousand feet.

The overall porosity of the Teanaway basalt is believed to be low, and its permeability probably ranges from low to high. No wells are known that develop water from this formation.

TANEUM ANDESITE (MIOCENE)

The Taneum andesite is composed of volcanic tuffs, breccias, and loose-textured lavas; it overlies the Manastash formation in the upper Taneum and Manastash Creek valleys. The andesite ranges in thickness from about 300 feet in the Manastash Valley to as much as 1,500 feet in the Taneum Creek valley.

It has high permeability and contains a large amount of ground water where saturated. This formation, although it is important for the hydrology of the small Taneum and Manastash valleys, has such limited areal extent that it is not shown on plate 1.

COLUMBIA RIVER BASALT (MIDDLE MIOCENE)

The Columbia River basalt consists of a thick series of basaltic lava flows which underlies most of the southeastern part of the State. The total thickness of these flows is not known, but it exceeds 4,000 feet in some parts of central Washington. Deformation of the Columbia River basalt has produced many synclinal basins and anticlinal ridges. The basalt underlies the southeastern two-thirds of the Yakima River basin, but in some of the synclinal basins it is overlain by as much as 1,500 feet of sedimentary deposits.

The Columbia River basalt is a hard, dense rock, black or gray where observed on a freshly broken surface. Weathered surfaces are a reddish brown due to the oxidataion of iron present in the basalt. In general, the rock is partly crystalline, with individual crystals set in a matrix of black glass. The crystals are generally microscopic, or nearly so, in size.

Individual flows generally do not exceed 100 feet in thickness. The top layer, a few feet thick, is commonly composed of porous honeycombed or vesicular basalt. Besides these permeable zones, the flows are in some places divided into polygonal columns by a system of joints which formed during the cooling of the lava. A more irregular type of jointing that is present in some flows forms small irregular blocks called "brickbat basalt." In places some of the flows are separated by interflow sedimentary strata consisting of silt, sand, and gravel. These materials were deposited in lakes and streams during the long periods of time that separated many of the outpourings of lava in central Washington.

Water in the Columbia River basalt generally travels along the vesicular interflow zones. Well records show that water in the interflow zones is commonly separated hydraulically by the massive centers of the flows. However, some water does pass through the flows from one interflow zone to another, where permeable joints extend through the flows.

In the Yakima River basin most of the anticlinal structures in the Columbia River basalt form topographic ridges. As the lateral permeabilities of the basalts exceed the crossbed permeabilities, ground water moves downdip on each limb of these anticlinal structures producing ground-water ridges beneath the topographic ridges. The boundaries between many of the ground-water basins and subbasins therefore are formed by the anticlinal ridges of basalt.

The coefficient of storage in the Columbia River basalt is believed to range from 5 to 10 percent. The permeability ranges from very low to very high. The more permeable zones are important aquifers in the Upper and Lower Yakima basins.

ELLENSBURG FORMATION (MIOCENE AND PLIOCENE)

The Ellensburg formation is a thick series of clay, silt, sand, and some gravel which overlies the Columbia River basalt in most of the larger synclinal basins in the Yakima River basin. Compaction and cementation have changed some of these materials into their corresponding consolidated rock type, that is, claystone, siltstone, sandstone, and conglomerate. The total thickness of this formation exceeds 1,000 feet in some of the structural basins.

The Ellensburg formation exhibits an irregular discontinuous type of bedding, with crossbedding being very common. Within an individual stratum, siltstone may grade abruptly into sandstone, and sandstone into conglomerate. Rock particles are composed chiefly of pumice, volcanic ash, and purple and gray hornblende andesite.

The permeability of the Ellensburg formation changes from stratum to stratum and in short lateral distances within a stratum. These variations are due to difference in grain size and the amount of cementation of the materials. The average porosity in the Ellensburg formation is believed to be somewhat higher than that of the underlying Columbia River basalt.

The more permeable strata are important aquifers in the Kittitas and Upper and Lower Yakima basins.

TIETON ANDESITE (PLEISTOCENE)

The Tieton andesite consists of a series of lava flows that partly filled the ancestral Tieton and Naches River valleys. Much of this formation has been removed by erosion. In places along the lower reach of the Tieton and Naches Rivers this formation can be seen to rest on loose boulder gravels which represent the pre-Tieton valley alluvium.

The Tieton andesite is generally a dark-gray to purple rock, often containing numerous small vesicles. Jointing is similar to that in the Columbia River basalt. The porosity and permeability of the Tieton andesite are believed to be about the same as those of the Columbia River basalt.

QUATERNARY FILL

Recent stream alluvium and Pleistocene glacial and valley-train deposits partly fill all the larger synclinal basins and stream valleys in the Yakima River basin. These deposits are composed chiefly of unconsolidated silt, sand, and gravel. In places, they exceed 500 feet in thickness. The coarser grained members have permeabilities as great as any other geologic unit in the Yakima River basin, and serve as important aquifers in the area.

The alluvial and glacial deposits contain considerable effective ground-water storage, and are the most important geologic unit from the standpoint of affecting streamflow. They serve as conduits carrying most of the valley underflow, and their large storage capacity acts as a flywheel on an engine, maintaining streamflow during dry periods. The deposits are recharged by infiltration from streams during periods of high runoff, by direct precipitation, and by irrigation.

Much of the valley underflow moving through these deposits discharges into the streams in the reaches just upstream from valley constrictions, as above Union Gap, Selah Gap, and the Yakima Canyon. Outflow is confined almost entirely to streamflow in these constrictions.

DESCRIPTION OF GROUND-WATER BASINS

ROSLYN BASIN

The Roslyn basin is divided in this report into six ground-water subbasins which are as follows: Keechelus, Kachess, Galena, Cle Elum, Upper Teanaway, and Lower Teanaway.

KEECHELUS SUBBASIN

The Keechelus subbasin is the westernmost of the subbasins located within the Roslyn Basin. It is in effect a long south-trending glaciated valley, having an area of about 130 square miles. The western boundary is formed by the Cascade Divide and the eastern by Amabilis Mountain, Keechelus Ridge, and Rampart Ridge. The southern boundary is formed by the high ridge that separates the Cabin Creek drainage from the Big Creek drainage. The downstream, or southeast, boundary is formed by a ridge of volcanic rock which extends across the Yakima Valley, 1 mile upstream from Easton, just above the mouth of the Kachess River. In this reach, the Yakima River is confined to a narrow canyon eroded into volcanic rock.

The northern part of the Keechelus subbasin is underlain with consolidated sedimentary rocks, which contain some interbeds of rhyolite lava. These rocks belong to the Guye formation. The eastern and southwestern parts of the area are underlain by the Keechelus andesitic series; the southeastern part, including the southern end of Keechelus Ridge and Amabilis Mountain, is underlain by the Teanaway basalt. The headwater area of Cabin Creek, located in the extreme southern part of the subbasin, is underlain by the Naches formation. The ridge of volcanic rock that extends across the valley, forming the southeastern boundary, is composed of the Kachess rhyolite. The valley is underlain with an unknown thickness of unconsolidated sand, gravel, and glacial till. A glacial moraine, which extends across the valley in the central part of the subbasin, has impounded Lake Keechelus. Keechelus Dam, an earth structure built on the moraine, impounds additional water in the lake.

Precipitation ranges from about 50 inches per year in the lower altitudes to more than 100 inches per year in the higher areas. Most of the precipitation occurs in the winter months as snow.

Runoff is derived chiefly from snowmelt. Peak runoff usually occurs in May, and secondary peaks often occur in November and December as the result of late fall rains. Most of the runoff during the winter and last summer months is derived from ground-water discharge, chiefly from the soil and debris-mantled slopes and from the unconsolidated valley-fill deposits. Bedrock beneath the subbasin has low permeability and probably contributes only a small part of the winter and late summer flow.

Ground water moving downvalley in the northern part of the subbasin discharges into Keechelus Lake or its tributaries. Ground water in the valley-fill deposits, downstream from Keechelus Lake, is recharged from precipitation falling on the valley or the adjacent slopes, and by underground discharge from Keechelus Lake. Ground water in the Yakima River valley, downstream from Keechelus Dam, moves downvalley and discharges into the Yakima River above the constriction at the southeastern end of the subbasin. The total outflow from the Keechelus subbasin occurs as surface runoff in the Yakima River along this reach.

Streamflow records in the Keechelus subbasin consist of many years record of the controlled discharge from Keechelus Lake at station 1 and less than 2 years record of the flow of Cabin Creek at station 2. These records show that runoff has exceeded 110 inches per year for the drainage area above Keechelus Lake and averages 80 inches per year.

KACHESS SUBBASIN

The Kachess subbasin, about 125 square miles in area, is a long, narrow glaciated valley just east of the Keechelus subbasin. Its eastern boundary is formed by the high ridge that separates the Katchess River drainage from the Cle Elum River drainage. The southern boundary is formed by the ridge separating the Big Creek drainage from the Naches River drainage. The downstream, or southeastern boundary, is located about 2 miles up the Yakima River from the mouth of the Cle Elum River. In this reach the Yakima River is confined to a narrow valley.

Bedrock beneath the subbasin consists of formations that are believed to have low porosity and permeability. These include the Swauk and Naches formations, Teanaway basalt, and older metamorphic rocks (pl. 1). The valley floor is underlain with glacial deposits consisting of sand, gravel, and glacial till. Well 20/13–11R1, located at Easton, penetrated 120 feet of unconsolidated materials without encountering bedrock (log, p. 128).

A glacial moraine, which extends across the valley in the central part of this subbasin, has impounded Lake Kachess. An earth dam has been constructed on this moraine to impound additional water in the lake.

The runoff characteristics of the subbasin are similar to those of the Keechelus subbasin, except that the amount of runoff per square mile is somewhat lower because of the generally lower amount of an-

687-029 O—63——8

nual precipitation on the area. All ground water moving down the Kachess Valley, in the northern part of the subbasin, discharges into Kachess Lake or its tributaries. Ground water in the valley-fill materials downvalley from Kachess Lake is recharged by precipitation falling on the valley or adjacent slopes and from subsurface discharge from Kachess Lake. A small amount of water leaves the subbasin as underflow, but most of the ground water discharges into the Yakima River above the downstream boundary of the subbasin and leaves as streamflow. Under natural conditions, the combined outflow of the Keechelus and Kachess subbasins would be confined to the Yakima River in this reach, but a large part of the runoff is now diverted into the Kittitas Canal.

Recorders of streamflow in the Kachess subbasin consist of a long record of the controlled discharge from Kachess Lake at station 3 and a short record of the Yakima River below the mouth of the Kachess River at station 4.

GALENA SUBBASIN

The Galena subbasin is in the headwater area of the Cle Elum River and has an area of about 100 square miles. The downstream boundary of this subbasin is upstream from the resort community of Salmon Lasac where the Cle Elum River flows through a narrow canyon.

Bedrock beneath the Galena subbasin is composed chiefly of the Swauk formation, the Keechelus andesitic series, and older metamorphic rocks, all of which are believed to have low porosity and permeability. Shallow deposits of permeable valley alluvium and glacial materials underlie the narrow floors of the valleys in parts of the subbasin.

The runoff characteristics are similar to those of the Keechelus and Kachess subbasins. All outflow from the Galena subbasin occurs as surface flow in the Cle Elum River and moves into the Cle Elum subbasin. Records consist of gage heights only of the Cle Elum River at station 5; discharge records of the Galena subbasin are not available.

CLE ELUM SUBBASIN

The Cle Elum subbasin has an area of 140 square miles, and includes most of the synclinal valley that forms the chief structural feature of the Roslyn basin.

The northern part of the subbasin is underlain principally by the Swauk formation and Teanaway basalt. The southern part is underlain by the Roslyn formation, Columbia River basalt, and some older metamorphic rocks. The Cle Elum and the Yakima River valleys are underlain by a great thickness of unconsolidated materials. Well

20/15–35D1 (log, p. 130), located along the Yakima River just south of the town of Cle Elum, penetrated 649 feet of unconsolidated materials before encountering the Roslyn formation. Other wells have penetrated similar materials for depths of several hundred feet. The more permeable strata, which are sand and gravel, have generally been encountered within the first 100 feet of well penetration.

A glacial moraine extends across the Cle Elum River valley in the central part of the subbasin, impounding Cle Elum Lake. Cle Elum Dam, an earth structure, has been built on this moraine to impound additional water in the lake.

All ground water in the Cle Elum River valley upstream from Cle Elum Lake discharges into the lake or its tributaries. Ground water in the unconsolidated materials, downstream from the lake, is recharged by local precipitation and subsurface discharge from Cle Elum Lake. Almost all this ground water discharges into the Yakima River upstream from the entrance of the canyon that is located at the southeastern end of the Roslyn Basin.

All natural outflow from the Keechelus, Kachess, Galena, Upper and Lower Teanaway subbasins, except the flow of Swauk Creek, flows into the Cle Elum subbasin. All outflow from the Roslyn basin, except for surface bypass diversions, is confined to the Yakima River, where it flows through the narrow canyon in the reach just downstream from the mouth of Swauk Creek.

Streamflow records in the Cle Elum subbasin consist of long-term records of the controlled discharge from Cle Elum Lake at station 6 and the flow of the Yakima River, measured near the town of Cle Elum, at station 7.

UPPER TEANAWAY SUBBASIN

The Upper Teanaway subbasin has an area of about 45 square miles in the mountainous headwater area of the Teanaway River in the northern part of the Roslyn basin. The northern boundary is formed by the high ridge separating the Teanaway drainage from the northward-flowing Peshastin River drainage. The southern, or downstream boundary, is formed by an east-trending basaltic ridge through which the Teanaway River flows in a narrow canyon.

Bedrock beneath the subbasin is composed of the Swauk formation and older metamorphic rocks. The ridge that forms the southern boundary is composed of Teanaway basalt. Shallow deposits of alluvium mantle the narrow valley floors.

The runoff characteristics of this subbasin are believed to be similar to those of the subbasins previously described. Almost all the outflow is confined to the Teanaway River where it flows through the narrow canyon at the southern margin of the subbasin. No records of streamflow measurements in this subbasin are available.

LOWER TEANAWAY SUBBASIN

The Lower Teanaway subbasin comprises an area of about 260 square miles and includes most of the Teanaway River and Swauk Creek drainage basins. It is bounded on the north by the basalt ridge that separates this subbasin from the Upper Teanaway subbasin. The western boundary is formed by the high ridge that separates the Teanaway River drainage from the Cle Elum River drainage; the southern and eastern boundaries are formed by the basaltic ridge that forms the southeastern boundary of the Roslyn Basin.

Bedrock beneath the Lower Teanaway subbasin is composed of the Swauk and Roslyn formations and the Teanaway and Columbia River basalts. Deposits of coarse valley alluvium of unknown thickness underlie the valley floors.

Outflow is confined to the Teanaway River where it flows through the narrow valley located about 1½ miles northeast of the community of Teanaway and to Swauk Creek where it flows through the narrow canyon located a few miles south of the community of McCallum. Most of the ground water moving down the Teanaway River and Swauk Creek valleys discharge into these respective streams before they flow out of the subbasin. Because of the generally lower amounts of annual precipitation, runoff per square mile is much less than from the subbasins located farther west.

Streamflow records consist of a short record of the flow of Swauk Creek measured where it leaves the subbasin at station 10 and two short periods of record of the flow of the Teanaway River measured a few miles upstream from its mouth at stations 8 and 9.

KITTITAS BASIN

The Kittitas basin is composed of two small and one large groundwater subbasins which are known in this report as the Taneum, Manastash and Ellensburg subbasins.

TANEUM SUBBASIN

The Taneum subbasin, which is 76.3 square miles in area, is in the western part of the Kittitas basin. It is confined entirely to the drainage basin of Taneum Creek, a small eastward-flowing stream which drains a low mountainous area. The subbasin is separated by high ridges from the Yakima River to the north and from the Manastash drainage to the south.

Bedrock beneath the subbasin includes the Columbia River basalt, Manastash formation, Taneum andesite, and some older metamorphic rocks. Permeable alluvium is confined chiefly to the narrow valley floor.

Peak runoff from the area usually occurs in the late spring months, being dependent upon the time and rate of snowmelt in the headwater area. Late summer flow is derived almost entirely from ground-water discharge. All outflow from the subbasin enters the Ellensburg subbasin.

Streamflow records consist of a short record of the flow of Taneum Creek, measured in Taneum Canyon at station 11, just upstream from the outlet of the subbasin.

MANASTASH SUBBASIN

The Manastash subbasin, which is 75.8 square miles in area, is in the headwater area of Manastash Creek. The subbasin is separated by high ridges from the Taneum Creek drainage to the north and Wenas and Naches drainage to the south.

Bedrock beneath the subbasin includes the Manastash formation, Taneum andesite, and Columbia River basalt. Some coarse alluvium underlies the narrow valley floor in the Manastash Valley.

The runoff characteristics are similar to the adjacent Taneum subbasin. Streamflow records consist of a short record of the flow of Manastash Creek measured in the Manastash Canyon at station 12, just upstream from the outlet of the subbasin. All outflow enters the Ellensburg subbasin.

ELLENSBURG SUBBASIN

The Ellensburg subbasin, just downstream from the Roslyn basin, has an area of about 50 square miles and includes the large structural valley known as the Kittitas Valley. The subbasin is bounded on the south by Manastash Ridge and on the east by the upland area that separates the Yakima River drainage from the Columbia River drainage.

The surrounding upland areas are underlain by the Columbia River basalt. These same lava flows underlie the entire subbasin, though many hundreds of feet of sedimentary materials overlies the basalts in the central part of the Kittitas Valley. Well 18/18–36P1, located at Ellensburg, penetrated to a depth of 1,210 feet without encountering basalt (log, p. 125). The upper few feet of sedimentary materials are believed to be sand and gravel of Quaternary age, and the underlying materials are believed to be Ellensburg formation.

Surface diversions from the Yakima River recharge the sedimentary materials beneath the floor of the Kittitas Valley and maintain a fairly shallow water table. Much of the flow of Taneum and Manastash Creeks also infiltrates into the sedimentary materials that underlie the Kittitas Valley. Ground water discharges into the many surface drains and into the Yakima River, upstream from the entrance to the Yakima Canyon.

The outflow from the Kittitas basin is accurately measured at gaging station 14, a few miles downstream from the entrance to Yakima Canyon. Gaging station 13, which was on Wilson Creek, was greatly affected by return flow from irrigation waters diverted from the Yakima River and abandoned when a good streamflow record could not be obtained.

YAKIMA CANYON BASIN

The Yakima River in its traverse through the Yakima Canyon crosses two synclinal troughs. Each of these troughs forms a ground-water subbasin that is tributary to the Yakima River. These are called the Umtanum and Roza subbasins in this report.

UMTANUM SUBBASIN

The Umtanum subbasin has an area of about 180 square miles and consists of an upland trough located between Manastash and Umtanum Ridges. It has a southeast trend and is about 32 miles long and about 6 miles wide. The Yakima River flows south across the central part of the subbasin.

The Umtanum subbasin is underlain by a great thickness of Columbia River basalt. In several small areas, in the extreme western part of the area, the basalt is overlain by the Ellensburg formation.

The area lying west of the Yakima River is drained by the eastward-flowing Umtanum Creek, and the area lying east of the Yakima River is drained by the intermittently flowing Squaw Creek. Ground water moves toward and discharges into the Yakima River. Most of the ground-water discharge occurs downstream from the Yakima River gaging station located near Umtanum. No measurements of the flow of Umtanum or Squaw Creeks are on record. The water yield of the Umtanum subbasin possibly could be obtained by measuring the increment in the flow of the Yakima River in the reach within this subbasin.

ROZA SUBBASIN

The Yakima River, after flowing through the deep narrow gorge eroded through Umtanum Ridge, flows south across the small southeastward-trending synclinal trough that forms the Roza subbasin. This subbasin has a length of about 14 miles and an area of about 42 square miles, all of which is underlain with Columbia River basalt. The area lying west of the Yakima River is drained by Roza Creek, and the area lying east of the Yakima River is drained by Burbank Creek.

Ground water is recharged by local precipitation, and moves toward and discharges into the Yakima River. No measurements of the flow of Roza or Burbank Creeks are on record. The water yield of the Roza subbasin possibly could be obtained by measuring the increment to the flow of the Yakima River in the reach within this subbasin, though diversion in the Roza Canal would have to be considered.

UPPER YAKIMA BASIN

The Yakima River, after leaving the Roza subbasin through a deep gorge, flows southward across the Upper Yakima basin. This basin is divided into six ground-water subbasins which, in this report, are known as the Selah, Upper Wenas, Lower Wenas, Naches-Cowiche, Upper Ahtanum, and Ahtanum-Moxee.

SELAH SUBBASIN

The Selah subbasin consists of a west-trending synclinal trough located in the northeastern part of the Upper Yakima basin. It has a length of about 20 miles, a width of about 6 miles, and an area of about 125 square miles, most of which lies east of Yakima River. It is bounded on the north by Umtanum Ridge and on the south by Yakima Ridge, both anticlinal ridges of Columbia River basalt. In the central part of the subbasin the basalt is overlain by several hundred feet of Ellensburg formation.

The Yakima River flows south across this subbasin and leaves through Selah Gap, a narrow water gap eroded through the Yakima Ridge.

Surface drainage of the eastern part of the subbasin is by the intermittently flowing Selah Creek. The drainage area to the west, which includes the Upper and Lower Wenas subbasins, is drained by Wenas Creek, a small stream that discharges into the Yakima River in the central part of the Selah subbasin.

Ground water beneath the area lying east of the Yakima River, which is recharged chiefly by precipitation, moves westward and discharges into the Yakima River upstream from Selah Gap. Ground water beneath the area lying west of the Yakima River is in part recharged by irrigation water diverted from the Naches River by the Naches-Selah Canal. Appreciable ground water enters the Yakima River upstream from Selah Gap.

Gaging stations have been operated for short periods on the Yakima River at Selah Gap at station 16 and on Wenas Creek, a short distance above its mouth, at station 15.

UPPER WENAS SUBBASIN

The Upper Wenas subbasin is in the headwater region of Wenas Creek in the northwestern part of the Upper Yakima basin, and is about 110 square miles in area. It consists principally of an east-trending synclinal valley that is bounded on the north by Umtanum Ridge and on the south by Cleman Mountain; both anticlinal ridges are composed of Columbia River basalt. The western boundary is the high upland area that forms the foothills of the Cascade Mountains. The downstream boundary is a small anticlinal ridge that extends across the Wenas Valley. Wenas Creek transects this ridge in a short narrow canyon eroded into the Columbia River basalt which forms the core of the anticline. A small earth dam, which impounds water in the Wenas Reservoir, has been constructed at the upstream end of this canyon. Upstream from the reservoir, the Wenas Valley is filled with as much as 400 feet of alluvium and the Ellensburg formation.

Wenas Creek heads in the mountainous area in the western part of the subbasin. The North Fork rises in the upland area north of Umtanum Ridge and flows south across the Umtanum anticline by way of a narrow water gap about 9 miles upstream from the lower end of the subbasin. The drainage area of about 33 square miles above this gap can be considered as a separate ground-water subbasin, but it has been included with the Upper Wenas subbasin in this report. The South Fork heads in the upland area near the western end of Cleman Mountain.

Valley underflow discharges into the North Fork in the reach just upstream from the water gap that is cut through Umtanum Ridge. Valley underflow in the eastern part of the subbasin discharges into Wenas Creek or Wenas Reservoir just upstream from the boundary of the subbasin.

Gaging stations were operated during the years 1942–43 in the reaches just above and just below Wenas Reservoir. These records are on file with the U.S. Soil Conservation Service at Yakima.

LOWER WENAS SUBBASIN

The Lower Wenas subbasin, just east of the Upper Wenas subbasin, consists of a synclinal basin about 83 square miles in area. It is bounded on the north by Umtanum Ridge, on the west by Cleman Mountain, and on the south by the broad upland formed by the eastward-trending Selah-Wenas anticline. Near the eastern end of the subbasin the axis of the anticline swings north and crosses the Wenas Creek valley about 1 mile above the mouth of Wenas Creek, forming the downstream boundary of the Lower Wenas subbasin. In this reach, Wenas Creek is confined to a narrow valley eroded into the Columbia River basalt.

The basalt underlying the central part of the subbasin is overlain by more than 700 feet of the Ellensburg formation and alluvium. A northward-plunging synclinal flexture, just east of Cleman Mountain, extends from the Naches Valley into the central part of the subbasin. Future large ground-water withdrawals in this subbasin possibly could induce subsurface diversion from the Naches Valley by way of this synclinal trough.

Most of the ground water in the Lower Wenas subbasin, which is in part recharged by surface diversions, discharges into Wenas Creek in the reach just upstream from the eastern boundary of the subbasin.

Streamflow records consist of a short record of the flow of Wenas Creek measured a short distance above the mouth at station 15.

NACHES-COWICHE SUBBASIN

The Naches-Cowiche subbasin, about 480 square miles in area, is the largest within the Upper Yakima basin, and lies just south of the Lower Wenas subbasin. It contains the Tieton River and Cowiche Creek drainage basins and the lower part of the Naches Valley. This subbasin is bounded on the west by the Cascade Divide and on the south by Cowiche Mountain and Divide Ridge. Its downstream boundary is formed by the Yakima Ridge anticlinal structure, through which the Naches River flows in a relatively narrow canyon.

The eastern part of the subbasin is underlain by older undifferentiated volcanic, sedimentary, and metamorphic formations which have low porosity and permeability. The eastern part is underlain by the Columbia River basalt and Ellensburg formation. The type section of the Ellensburg formation is exposed along the northern slope of the lower Naches Valley.

Small areas in the Tieton, Cowiche, and Naches Valleys are underlain with Tieton andesite. These small bodies of andesite are remnants of flows that filled the ancestral Tieton and lower Naches Valleys.

Unknown thicknesses of permeable sand and gravel of Quaternary age underlie the valley floors throughout the subbasin. Large quantities of ground water move down the lower Naches Valley and discharge into the Naches River upstream from the valley constriction at the southeastern end of the subbasin.

Streamflow records in the subbasin consist of records of flow of the Tieton River above and below the Tieton Reservoir at stations 21 and 22, at the headworks of the Tieton Canal at station 23, and downstream near its mouth at station 24. Records have also been obtained on the Naches River where it enters this subbasin at station 20 and further downstream below the mouth of the Tieton River at station 25.

UPPER AHTANUM SUBBASIN

Ahtanum Creek is an eastward-flowing stream which enters the Yakima River just upstream from Union Gap. The Upper Ahtanum subbasin with an area of 121 square miles is in the southwestern part of the Upper Yakima basin. The downstream boundary of the subbasin is formed by a minor anticlinal cross-valley structure that has brought the Columbia River basalt to the surface. Ahtanum Creek has eroded a narrow transecting channel, called The Narrows, through this structure.

Ahtanum Creek forks a few miles upstream from The Narrows. The North Fork, which drains a fairly large area lying northwest of the Cowiche Mountain anticline, flows southeast through a narrow canyon that transects the anticline. The 69 square miles of drainage area above this gap could be considered as a separate ground-water subbasin, but it is included with the Upper Ahtanum subbasin in this report. The South Fork drains a small area between Ahtanum Ridge and Sedge Ridge.

The Upper Ahtanum subbasin is underlain by the Columbia River basalt. In the broad valley area upstream from The Narrows, near Tampico, the basalt is overlain by as much as 200 feet of the Ellensburg formation and alluvium.

Most of the ground water moving downvalley through the alluvium and Ellensburg formation discharges into Ahtanum Creek in the reach just upstream from The Narrows. Some ground water moves into the downstream Ahtanum-Moxee subbasin through the alluvium and basalts that underlie The Narrows.

Stream-gaging records in this subbasin consist of long records on both the North and South Forks at stations 27, 28, and 29, and a short record on the flow of Ahtanum Creek measured at The Narrows at station 30.

AHTANUM-MOXEE SUBBASIN

The Ahtanum-Moxee subbasin consists of a large east-west trending synclinal trough located between Yakima Ridge to the north and Ahtanum Ridge and the Rattlesnake Hills to the south. It has a length of about 30 miles, a width of about 9 miles, and an area of about 270 square miles. The Yakima River enters this subbasin by way of Selah Gap. It flows south across the central part of the subbasin and out through Union Gap. The area lying east of the Yakima River, the Moxee Valley, is drained by intermittently flowing streams. The area lying west of the Yakima River, the lower Ahtanum Valley and Wide Hollow, is drained by Ahtanum and Wide Hollow Creeks. The

Naches River flows into this subbasin and joins the Yakima River just downstream from Sellah Gap.

The ridges surrounding the Ahtanum-Moxee subbasin are composed of the Columbia River basalt, but in the central part of the subbasin, the basalt is overlain by 1,500 to 2,000 feet of the Ellensburg formation and Quaternary deposits.

Irrigation of large areas in the subbasin with water diverted from the Tieton and Yakima Rivers produces considerable recharge to the underlying aquifers. Ground-water return flow enters the Yakima River and its tributaries upstream from Union Gap.

All outflow from the Upper Yakima basin is through Union Gap, except for surface diversions bypassing the Gap. Streamflow records indicate the flow of the Naches River near its mouth at station 26, Yakima River in Union Gap at station 32, and a short record of the flow of Ahtanum Creek near its mouth at station 31.

UPPER NACHES BASIN

The headwater area of the Naches River is in the Cascade Mountains northwest of the Upper Yakima basin. For this report this area is divided into two large ground-water subbasins: the Bumping Lake, which includes the northwestern part of the basin, and the Rattlesnake, which includes the southeastern part.

BUMPING LAKE SUBBASIN

The Bumping Lake subbasin is a mountainous area in the Cascade Mountains and has an area of about 380 square miles. It is bordered on the west by the Cascade Divide, on the south and east by the high ridge that separates the Bumping River drainage from the Rattlesnake Creek drainage, and on the north by the high ridge that separates the Naches River drainage from the Roslyn basin. The downstream boundary of the Bumping Lake subbasin is located near Edgar Rock, just upstream from gaging station 19. Here the Naches River is confined to a narrow canyon eroded into the Keechelus andesitic series.

Bedrock within the subbasin consists principally of volcanic and metamorphic formations which have low permeabilities. The valley areas, the Naches, American, and Bumping River valleys, are underlain with unknown thicknesses of permeable sand and gravel deposits of Quaternary age. In the Bumping River valley a glacial moraine, which extends across the valley, impounds Bumping Lake. An earth dam has been constructed on the moraine to store additional water in the lake. Some subsurface leakage from the lake recharges the Quaternary sediments that underlie the valley downstream from the dam.

Streamflow records in the subbasin have been obtained on Bumping River below the dam at station 17 and on American River just upstream from its mouth at station 18. Total outflow from the Bumping Lake subbasin is fairly accurately measured by the surface flow at station 19, located about a mile downstream from the boundary of the subbasin.

RATTLESNAKE SUBBASIN

The Rattlesnake subbasin lies southeast of the Bumping Lake subbasin, and is separated from it by a high ridge composed of the Keechelus andesitic series. The subbasin has an area of about 255 square miles, half of which is drained by Rattlesnake Creek, a tributary to the Natches River. The Rattlesnake subbasin is separated from the Naches-Cowiche subbasin to the south by Bethel Ridge, and from the Upper Wenas subbasin to the east by Cleman Mountain. The Naches River leaves this subbasin through a narrow canyon eroded through the south limb of the Cleman Mountain anticline.

Bedrock beneath the subbasin is composed of the Keechelus andesitic series, the Columbia River basalt, and the Ellensburg formation. Unknown thicknesses of permeable sand and gravel of Quaternary age underlie the Naches River valley along the reach near the community of Nile.

The outflow from the entire Upper Naches basin (both Bumping Lake and Rattlesnake subbasins) is carried into the Upper Yakima basin by the Naches River and is fairly accurately measured by the surface flow at gaging station 20, at Oak Flat near Nile.

LOWER YAKIMA BASIN

The Lower Yakima basin, with an area of about 2,030 square miles, is divided into two large ground-water subbasins: the Toppenish in the northwestern part of the basin and the Prosser in the southeastern part.

TOPPENISH SUBBASIN

The Toppenish subbasin consists of a large synclinal valley located between the Ahtanum Ridge-Rattlesnake Hills anticline on the north and the Toppenish Ridge anticline on the south. The western end of the subbasin is in the foothills area of the Cascade Mountains which are composed of the Columbia River basalt. The basalt underlies the entire subbasin, but in the central part the basalt is overlain by a great thickness of the Ellensburg formation and as much as 300 feet of sand and gravel of Quaternary age. Much of the sand and gravel was deposited by the ancestral Yakima River in a broad alluvial fan that extends from Union Gap south across the subbasin.

The Yakima River enters the subbasin through Union Gap and flows southeastward along the northeastern margin of the valley floor. The upland area to the west is drained by Simcoe, Medicine, and Toppenish Creeks.

Considerable water infiltrates into the alluvial fan from the Yakima River in the reach just downstream from Union Gap and together with excess irrigation water that seeps downward into the fan move south to southeast across the fan and discharge into Toppenish Creek and the intervening drainage ditches.

Several large diversion canals, two of which import water from the Upper Yakima basin (Union Gap and Roza Canals) supply water to irrigate large areas on the fan on both sides of the river. Irrigation water percolates downward and recharges the ground-water body, whose surface lies at shallow depth beneath the fan. Hydrographs of two wells near Wapato are shown in figure 21. These hydrographs show that the water table is sustained at a high level throughout the

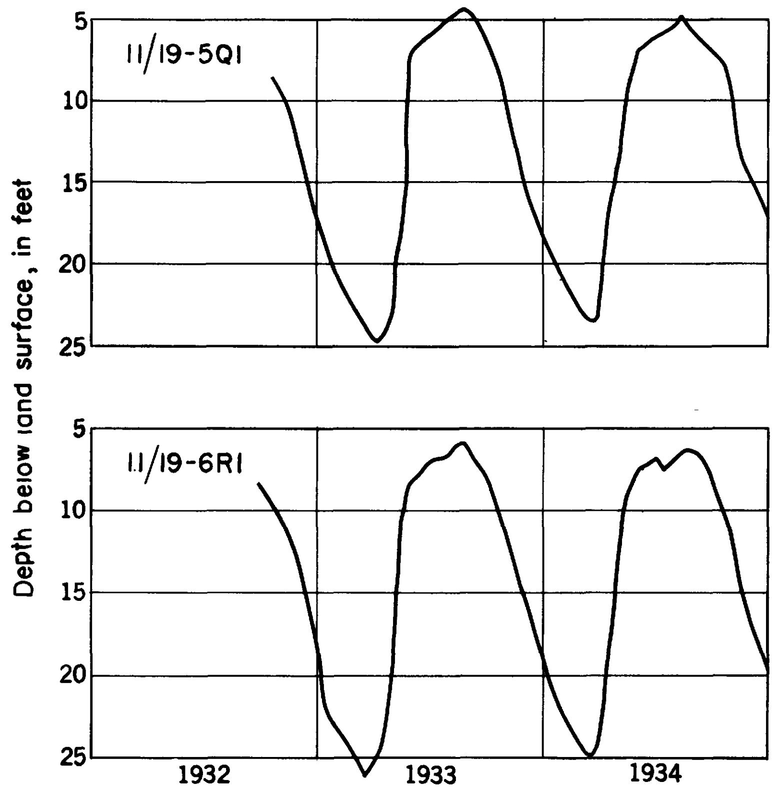

FIGURE 21.—Hydrographs of two wells near Wapato showing the effects of irrigation on the water table. Data from the U.S. Bureau of Indian Affairs.

irrigation season, and declines rapidly with the cessation of irrigation. The water table beneath a large area, along the lower valley slope north of the Yakima River, is similarly sustained by irrigation.

Irrigation with surface water of parts of the north slope of the Lower Yakima basin began in the latter part of the 19th century. Table 19, taken from Jayne (1906), shows the effect that the early irrigation had on the water table near Sunnyside.

TABLE 19.—*Effect of the early irrigation upon the water table near Sunnyside*

Well	Date of digging	Depth to water when dug (feet)	Depth to water in 1902 (feet)
1	1890	80	5.0
2	1900	90	20.0
3	1899	42	.0
4	1892	54	4.0
5	1894	50	3.5
6	1893	53	.0
7	1900	15	1.0
8	1899	40	6.0
9	1898	53	15.0

The downstream end of the Toppenish subbasin is formed by a valley constriction located between the eastern end of Toppenish Ridge and Snipes Mountain.

Records of streamflow in the subbasin have been obtained on Toppenish Creek at stations 34, 36, and 37, Simcoe Creek at station 35, and the Yakima River below the Sunnyside diversion dam at station 33.

PROSSER SUBBASIN

The Prosser subbasin lies just southeast of the Toppenish subbasin. The Yakima River enters by way of the valley constriction between the end of Toppenish Ridge and Snipes Mountain, flows southeastward across a large synclinal valley, and enters a narrow valley lying between the Rattlesnake and Horse Heaven Hills. The large upland area located in the southern part of the subbasin is drained by Satus Creek and its tributaries. The drainage area of Satus Creek above gaging station 39 might be considered as a separate ground-water subbasin, but it has not been separated from the Prosser subbasin in this report.

The uplands that surround the subbasin are composed of the Columbia River basalt. In the synclinal valley, the basalts are overlain by several hundred feet of the Ellensburg formation and sand and gravel deposits of Quaternary age. The valley of Satus Creek and the valley of the Yakima River in the eastern part of the subbasin are underlain by only shallow deposits of alluvial material.

Inflow into the subbasin is by way of the Yakima River and the Roza and Sunnyside Canals. Irrigation of the north slope, by water diverted in these canals, results in considerable recharge to the underlying aquifers. Return flow enters the Yakima River along its entire reach in this subbasin.

Streamflow records have been obtained on Satus Creek at stations 38 and 39, Yakima River at Mabton at Station 40, Yakima River near Prosser at station 41, and Yakima River at Kiona at station 42. The record at Kiona closely approximates the outflow from the entire Yakima River basin.

COLD CREEK BASIN

Most of the 500 square miles of drainage area, located downstream from the lower Yakima basin, lies in the tributary Cold Creek drainage area. The Cold Creek basin, as this area is called, is divided into the Black Rock, Dry Creek, and Richland ground-water subbasins in this report. A small area located on the south slope of the Yakima Valley is called the Horse Heaven subbasin.

BLACK ROCK SUBBASIN

The Black Rock subbasin consists of a small synclinal valley between Yakima Ridge and the Rattlesnake Hills. It has an area of about 70 square miles, and is drained by the intermittently flowing Dry Creek, a tributary of Cold Creek.

The surrounding ridges are composed of Columbia River basalt. In the central part of the subbasin, the basalt is overlain by an unknown thickness of the Ellensburg formation and alluvium.

Dry Creek leaves this subbasin by flowing through a narrow water gap eroded through the Rattlesnake Hills anticline. All outflow from this subbasin passes through this gap. No measurements of the flow of Dry Creek are on record.

DRY CREEK SUBBASIN

The Dry Creek subbasin is formed by a synclinal basin located just downstream from the Black Rock subbasin, and is about 50 square miles in area.

The surrounding ridges are composed of Columbia River basalt. In the central part of the subbasin the basalt may be overlain by some Ellensburg formation, but for the most part it is overlain by a thin cover of alluvium.

All outflow from the Black Rock subbasin moves into this subbasin. Drainage is by the intermittently flowing Dry Creek, which flows eastward and out of the subbasin in a narrow canyon cut through a basaltic ridge. Much of the ground water moving through the subbasin discharges into Dry Creek in the reach just upstream from this canyon. No measurements of the flow of Dry Creek are on record.

RICHLAND SUBBASIN

The Richland subbasin, in its western part, consists of a large eastward-plunging synclinal trough located between Umtanum and Yakima Ridges. The Cold Creek valley, which occupies this trough, opens to the east onto the broad alluvial plain of the Columbia River. Cold Creek, after leaving the valley area, flows southeastward and joins the Yakima River a few miles above its mouth.

The headwater area of Cold Creek is underlain by Columbia River basalt. Downstream, the basalt is overlain by the Ellensburg formation and Quaternary deposits which thicken eastward to possibly as much as 1,000 feet beneath the Columbia River plain.

Large amounts of water, moving down the Cold Creek valley, infiltrate into the alluvial materials that underlie the Columbia River plain. Whether any of this underflow moves northward and discharges into the Columbia River is not known, for the exact location of the ground-water divide between the Cold Creek basin and the Columbia River drainage is not known. This ground-water divide may deviate considerably from the topographic divide.

All outflow from the Dry Creek subbasin moves into the Richland subbasin. The surface discharge of Cold Creek probably represents only a small part of the discharge of the Richland subbasin, for a large amount of ground-water discharge enters the Yakima River in the reach downstream from the mouth of Cold Creek. Streamflow records have been obtained for short periods of time on the Yakima River (near Richland) at station 43.

HORSE HEAVEN SUBBASIN

The Horse Heaven subbasin, which lies almost entirely outside the Yakima River basin, is a large area along the south slope of the Horse Heaven Hills that drains south into the Columbia River. However, it includes a small area in the Yakima River basin near Kiona. The subbasin is underlain by southward-dipping Columbia River basalt. Surface runoff from the small area lying within the Yakima River basin flows northward into the Yakima River, but water infiltrating into the basalt moves southward down the dip of the basalt and out of the Yakima River basin. Precipitation is low and the amount of such subsurface interbasin diversion is believed to be small. This subbasin is included with the Cold Creek basin in this report merely for the sake of convenience.

SELECTED WELL LOGS

Well logs are a collection of recorded facts having to do with the drilling of a well and the materials penetrated. Logs are of many different types depending upon the type of information being collected. Water wells, however, generally include a record of the rock materials penetrated, drilling progress, depth of water, occurrence of minerals or fossils, and amount and type of casing and (or) screen used. By noting the exact location of each well, correlating the information from the well log, and, when possible, examining the rock cuttings from the well itself, the ground-water hydrologist can frequently interpret the subsurface geology and relate it to the occurrence and (or) absence of water at different depths. Drillers in the State of Washington, therefore, are requested to submit to the State geologist at Olympia the location and log of each well drilled.

8/22-1G2

[City of Mabton, well 2. Altitude about 715 ft. Drilled by A. A. Durand & Son, 1935]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill and Ellensburg formation:		
Ash and soil	40	40
Gravel, fine to coarse	19	59
Sand	21	80
Gravel, coarse	12	92
Sand	17	109
Gravel, fine	4	113
Clay and sand	207	320
Columbia River(?) basalt:		
Basalt, angular fragments	([1])	([1])
Clay, sandstone, basalt	([1])	759
Basalt, dense, black	38	797
Sediments, fine-grained	7	804
Basalt, dark-gray	48	852
Basalt, silt, clay	213	1,065
Basalt, broken and vesicular	15	1,080

[1] No record.

687-029 O—63——9

8/24–2

[City of Prosser, well 2. Altitude about 640 ft. Drilled by A. A. Durand & Son, 1944]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill:		
Dirt and rocks	8	8
Boulders	10	18
Gravel	15	33
Columbia River basalt:		
Basalt	45	78
Sandstone	20	98
Clay, blue	82	180
Clay, blue, and basalt	5	185
Basalt	211	396
Clay	4	400
Sand	28	428
Clay	32	460
Shale, crumbling	25	485
Hard and soft rock	17	502

9/27–19G2

[Northern Pacific Ry. Co. Altitude about 490 ft. Drilled, 1917]

Quaternary fill:		
Clay, sandy	18	18
Gravel	4	22
Clay, sandy	13	35
Clay, sandy, and rock	13	48
Gravel	12	60
Gravel and water	4	64
"Limestone"	1	65
"Sandstone"	5	70
Gravel and water	1	71

10/20–3M1

[City of Toppenish, well 4. Altitude about 760 ft. Drilled, 1946(?)]

Quaternary fill:		
Soil	2	2
Gravel	40	42
Gravel and clay	5	47
Gravel, coarse	5	52
Gravel and clay	5	57
Gravel	7	64
Gravel and clay	27	91
Gravel and sandy clay	20	111
Gravel, coarse	5	116
Gravel, coarse, and sandy clay	21	137
Gravel and sand	7	144
Gravel and sandy clay	9	153
Gravel, coarse	7	160
Boulders and clay	60	220
Ellensburg(?) formation:		
Clay, sandy	35	255
Clay	5	260
Sand, hard, and sandstone	25	285
Clay, pink	5	290
Gravel, coarse	5	295

10/20-3M1—Continued

Materials	Thickness (feet)	Depth (feet)
Ellensburg(?) formation—Continued		
Clay and boulders, small	7	302
Gravel, cemented, and boulders	39	341
Sand, clay, and gravel	116	457
Gravel and clay	3	460
Gravel and firm sand	5	465
Sand, firm	5	470
Clay, yellow	35	505
Sand and gravel	12	517
Gravel, cemented, hard, and sand	13	530
Gravel and firm sand	15	545
Gravel, cemented, hard, and sand	5	550
Clay, yellow	13	563
Sand, firm, some clay	24	587
Sand, hard; gravel and clay	20	607
Sand and gravel	3	610
Clay, yellow	10	620
Clay, blue, and small "rock"	10	630
Sand, firm, and a little clay	75	710
Clay, blue	30	740
Sand, firm, and gravel	2	742
Clay, blue	3	745
Clay, blue, and gravel	30	775
Gravel and fine sand	1	776
Sand, gray	6	782
Sand and gravel	18	800

11/19-15A2

[City of Wapato. Altitude about 860 ft. Drilled, 1927]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill:		
No record	36	36
Gravel, coarse	13	49
Gravel, cemented	16	65
Sand	2	67
Gravel, cemented	102	169
Gravels and boulders, loose, water-bearing	12	181
Gravel, boulders, and clay	28	209
Clay and boulders	36	245
Gravel, clay, and boulders	18	263
Clay and boulders	23	286
Ellensburg(?) formation:		
Gravel, cemented	86	372
Clay, yellow	5	377
Gravel, cemented	48	425
Clay and gravel	8	433
Gravel, cemented	13	446
Clay, sticky	6	452
Gravel, cemented	38	490
Clay, sticky	35	525
Clay, yellow, sticky	15	540
Clay, sandy	15	555
Clay, sticky	4	559
Sand, loose	15	574
Sand, brown, and gravel	20	594

11/19-15A2—Continued

Materials	Thickness (feet)	Depth (feet)
Ellensburg(?) formation—Continued		
Sand, brown	17	611
Clay, yellow	11	622
Clay, blue	34	656
Sand, blue, water-bearing	49	705
Shale, sandy, blue, hard	125	830
Shale, blue, sticky	137	967
Shale, blue, hard	6	973
Sand, gray, loose	2	975

12/19-5N1

[City of Union Gap, well 3. Altitude about 970 ft. Drilled by N. C. Jannsen, 1949]

Quaternary fill:		
Earth	6	6
Gravel	15	21
"Rock" and gravel	6	27
"Hardpan" and gravel	28	55
"Rock" and gravel	9	64
Gravel, hard	3	67
"Rock" and gravel	9	76
Gravel, hard	6	82
"Rock" and gravel	105	187
"Rock", hard, and sand	20	207
Gravel and sand	154	361
Clay	9	370

12/19-17C1

[Miocene Petroleum Co. Altitude about 940 ft. Drilled, 1929]

Quaternary fill: Sand and gravel	21	21
Columbia River basalt: Basalt	2, 879	2, 900

16/17-29M1

[B. C. Newland. Altitude about 2,025 ft]

Quaternary fill and Ellensburg formation:		
Gravel	25	25
Sandstone	80	105
Clay	300	405
Columbia River basalt: Basalt	---	---

18/17-11H1

[Northern Pacific Ry. Co. Altitude about 1,645 ft]

Quaternary fill:		
Soil	6	6
Gravel and sand	6	12
"Hardpan"	48	60
Clay and boulders	30	90
Clay, sandy	20	110
Sand	18	128

18/17-11H1—Continued

Materials	Thickness (feet)	Depth (feet)
Ellensburg(?) formation:		
Sandstone	17	145
Sand	5	150
Clay	20	170
Sandstone, coarse	15	185
Sand	5	190
Sandstone	4	194
Clay	27	221
Sand	1	222
Shale, brown	4	226
Sandstone	21	247
Sand and pebbles	2	249

18/18-36P1

[City of Ellensburg. Altitude about 1,570 ft. Drilled by A. A. Durand & Son, 1945]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill and Ellensburg(?) formation:		
Loam	2	2
Gravel and round "rock"	8	10
Sand, coarse, and gravel	1	11
Ellensburg(?) formation:		
Clay, yellow	9	20
Gravel, fine	7	27
Gravel, fine, and clay	27	54
Gravel, fine, clay and sand	6	60
Clay and gravel	8	68
Clay	25	93
Clay and fine gravel	5	98
Gravel	21	119
Gravel, rocks, and clay	1	120
Sand and some gravel	2	122
Rocks and heavy clay	3	125
Gravel	2	127
Gravel and clay	3	130
Gravel	6	136
Gravel and clay	34	170
Clay	5	175
Clay and some sand	8	183
Gravel and clay	2	185
Gravel	6	191
Gravel and clay	13	204
Gravel	10	214
Gravel and clay	8	222
Clay	10	232
Gravel	18	250
Sand and cemented gravel	14	264
Gravel and sand	3	267
Clay, heavy, yellow	5	272
Clay and gravel	19	291
Gravel	7	298
Sand and clay	14	312
Clay and some sand	12	324
Sand and gravel; some clay	5	329
Gravel and clay	5	334
Sand and gravel	3	337
Clay and gravel	7	344

18/18-36P1—Continued

Materials	Thickness (feet)	Depth (feet)
Ellensburg(?) formation—Continued		
Clay, heavy, yellow	3	347
Gravel, fine, and sand	1	348
Gravel, fine, and coarse sand	4	352
Clay	10	362
Clay and sand	7	369
Clay and fine gravel	3	372
Sand and clay	4	376
Clay, sand, and gravel	4	380
Sand and gravel	4	384
Sandstone, coarse; fine gravel and hard clay	3	387
Sand and gravel	3	390
Clay	3	393
Clay, fine gravel, and sand	7	400
Gravel and sand	3	403
Clay	7	410
Sandstone, soft, gray, and brown clay	14	424
Gravel	5	429
Gravel and fine sand	2	431
Clay and fine gravel	3	434
Clay, sandy	14	448
Clay, sandy, yellow and gray	5	453
Clay and some sand	5	458
Clay	7	465
Sand and gravel	4	469
Gravel, fine, and clay	1	470
Gravel	5	475
Gravel, fine, and clay	2	477
Gravel	5	482
Clay	21	503
Clay, sandy, and fine sand	2	505
Clay, gray, and fine sand	2	507
Gravel, cemented	2	509
Gravel, fine; coarse sand and some clay	2	511
Clay and sand	6	517
Clay, sandy	7	524
Gravel, fine, and coarse sand	2	526
Gravel	3	529
Clay and sand	7	536
Sand, coarse, and clay	2	538
Sand and clay	3	541
Sand, coarse, and clay	9	550
Clay, some sand	21	571
Clay, sandy	23	594
Gravel	6	600
Clay, sandy	7	607
Clay	9	616
Clay, sandy	29	645
Sand	5	650
Sand, fine	24	674
Sand and gravel	12	686
Clay	4	690
Clay, sandy	24	714
Sand	2	716
Clay, sandy	38	754
Gravel	2	756
Gravel and sand	1	757
Sand and clay	12	769
Sand and gravel	1	770

18/18-36P1—Continued

Materials	Thickness (feet)	Depth (feet)
Ellensburg(?) formation—Continued		
Sand	6	776
Sand, heaving	4	780
Gravel and sand	2	782
Gravel, fine, and sand	1	783
Gravel	7	790
Gravel and fine sand	1	791
Gravel and sand	3	794
Clay and sand	32	826
Clay, sand, and gravel	2	828
Clay and sand	16	844
Clay, sandy	5	849
Sand, heaving	6	855
Clay, sandy	6	861
Sand, red	4	865
Clay and sand	21	866
Clay, sandy	22	908
Clay and sand	10	918
Sand, gravel, and clay	18	936
Clay	5	941
"Quicksand"	1	942
Clay	1	943
Clay, yellow, sticky	5	948
Clay and sand	6	954
Clay, yellow	15	969
Sand, heaving	7	976
Mud, blue, and gumbo	5	981
Clay, blue	24	1, 005
Clay	5	1, 010
Clay, blue	7	1, 017
Sand, fine	7	1, 024
Clay, blue	16	1, 040
Gravel, coarse	6	1, 046
Clay, blue	18	1, 064
Sand, fine	4	1, 068
Clay, blue	16	1, 084
Mud, blue, sticky	6	1, 090
Clay, blue	10	1, 100
Clay	4	1, 104
Clay, blue	23	1, 127
Clay, brown	8	1, 135
Clay, blue	8	1, 143
Clay, sticky	10	1, 153
Sand	3	1, 156
Clay, sticky	4	1, 160
Clay, blue	10	1, 170
Sand and gravel	3	1, 173
Sand	4	1, 177
Shale, blue	1	1, 178
Mud, green	4	1, 182
Mud, greenish-gray	6	1, 188
Mud, green	2	1, 190
Mud	5	1, 195
Sand	2	1, 197
Sand and gravel	4	1, 201
Not recorded	2	1, 203
Sand	2	1, 205
Shale	2	1, 207
Mud, greenish-gray	3. 5	1, 210. 5

20/13-11R1

[Northern Pacific Ry. Co. Altitude about 2,170 ft]

Materials	Thickness (feet)	Depth (feet)
Fill: Cinders	2	2
Quaternary fill:		
Clay	3	5
Clay, yellow, and boulders	3	8
Sand, coarse	2	10
Gravel, cemented	9	19
Clay, yellow, and boulders	41	60
Gravel, blue	3	63
Clay, blue; boulders and gravel	12	75
Gravel, fine	5	80
Clay, soft, blue, and gravel	24	104
Sand, blue, and gravel	3	107
Sand, fine	13.5	120.5

20/14-2L1

[Northwest Improvement Co., bore hole 34. Altitude about 2,254 ft]

Quaternary fill:		
Gravel	10	10
Boulders	10	20
Gravel	110	130
Boulders	29	159
Gravel	14	173
Roslyn formation	272	445

20/14-10A1

[U.S. Bureau of Reclamation, Cle Elum Dam, test hole 52. Altitude about 2,237 ft]

Quaternary fill:		
Soil	5	5
Sand and gravel	2	7
Clay, sand, and gravel	5	12
Clay	4	16
Sand, clay, and gravel	11	27
Clay and sand	20	47
Clay, sand, gravel, boulders, water-bearing	30	77
Sand, gravel, and clay	90	167

20/14-10A2

[U.S. Bureau of Reclamation, Cle Elum Dam, test hole 53. Altitude about 2,230 ft]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill:		
Gravel and boulders	8	8
Clay, gravel, and boulders	2	10
Clay and gravel	7	17
Sand and gravel	2	19
Clay and gravel	9	28
Sand and gravel, coarse	1	29
Clay and gravel	5	34
Sand and gravel	4	38
Sand, gravel, clay, and boulders	4	42
Sand, clay, gravel, and boulders	9	51
Sand, clay, and gravel	88	139
Clay and gravel	5	144
Sand, clay, and gravel	32	176
Sand, coarse	15	191
Clay	25	216

20/14-13L1

[Northwest Improvement Co., bore hole 35. Altitude about 2,203 ft]

Quaternary fill:		
Gravel	282	282
Roslyn formation	634	916

20/15-27H1

[Northwest Improvement Co., bore hole 17. Altitude about 1,942 ft. Drilled, 1892]

Quaternary fill	110	110
Roslyn formation	721	831

20/15-27J1

[Northwest Improvement Co. bore hole 49. Drilled, 1914]

Quaternary fill:		
Sand and gravel, coarse	21	21
Sand and gravel	7	28
Clay and sand	69	97
Sand	14	111
Clay and sand	31	142
Clay, hard, sandy	21	163
Clay, sandy	41	204
Sand, very fine	31	235
Sand, fine	18	253
Clay	15	268
Clay, hard	16	284
Sand and clay	14	298
Clay	14	312
Clay, hard, sandy	14	326
Sand and pebbles	9	335
Roslyn formation	505	840

20/15-27Q1

[Northwest Improvement Co., bore hole 15. Altitude about 1.914 ft. Drilled, 1891]

Materials	Thickness (feet)	Depth (feet)
Quaternary fill: Drift	450	450
Roslyn formation	1, 050	1, 500

20/15-27Q2

[Northwest Improvement Co., bore hole 59. Altitude about 1,912 ft]

Quaternary fill:		
Gravel and boulders	43	43
Sand, fine, and boulders	77	120
Sand and gravel, fine	1	121
Sand, blue	11	132
Clay, blue	4	136
Clay and fine sand	97	233
Sand, blue	32	265
Clay, blue	140	405
Gravel and boulders	35	440
Clay and boulders	3	443
Roslyn formation	537	980

20/15-35D1

[Northwest Improvement Co., bore hole 64. Altitude about 1,903 ft]

Quaternary fill:		
Sand and gravel	3	3
Boulders	6	9
Gravel and small boulders	7	16
Silt, blue, with gravel streaks	54	70
Boulders and gravel	3	73
Gravel and fine silt	8	81
Boulders, small, and clay	23	104
Silt, fine	296	400
Silt, fine, hard	40	440
Silt and clay	20	460
Clay and fine gravel	13	473
"Hardpan"	5	478
Clay, coarse sand, and "hardpan"	20	498
Sand and gravel	8	506
Clay	2	508
Clay "hardpan"	35	543
Sand and gravel	3	546
Clay, blue	12	558
Clay, fine gravel, and "hardpan"	4	562
Sand and gravel	4	566
Clay, "hardpan"	2	568
Clay, fine sand, and "hardpan"	14	582
Gravel and boulders	2	584
Sand, hardpacked	7	591
Sand, gravel, and "hardpan"	8	599
Boulders, small, and gravel	2	601
Sand, loose	3	604
Sand, hardpacked, dark	4	608
Gravel and "hardpan"	4	612
Clay	12	624
Sand and gravel and "hardpan"	1	625

20/15-35D1—Continued

Materials	Thickness (feet)	Depth (feet)
Quaternary fill—Continued		
Sand, fine	8	633
Sand and gravel and "hardpan", dark	6	639
Gravel, cemented	1	640
Sand, hard	5	645
Sand and boulders	1	646
Boulders	3	649
Roslyn formation	59	708

21/11-12R1

[U.S. Bureau of Reclamation, test pit 94 and drill hole in cutoff trench. Altitude about 2,484 ft]

Soil	2.5	2.5
Gravel, cemented	8.5	11
Clay and sand	2.5	13.5
Gravel and boulders, cemented	5	18.5
Gravel, cemented	12.5	31
Gravel and clay	9	40
Gravel and sand	20	60
Clay, sand, and gravel	28	88
Gravel and sand	1	89
Gravel, sand, and clay	13	102
Sand, fine	10	112
Clay	1.5	113.5
Sand, fine	4.5	118
Clay	2	120
Gravel, fine, and coarse sand	2	122
Sand, fine	3	125
Sand, coarse	2	127
Gravel	4	131

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