DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 369

WATER POWERS OF THE CASCADE RANGE

PART III. YAKIMA RIVER BASIN

BY

GLENN L. PARKER AND FRANK B. STOREY

Prepared in cooperation with the

Washington State Board of Geological Survey

Ernest Lister, Chairman
Henry Landes, Geologist

WASHINGTON
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WATER POWERS OF THE CASCADE RANGE.

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By Glenn L. Parker and Frank B. Storey.

INTRODUCTION.

This report is the third of a series entitled "Water powers of the Cascade Range," prepared by the United States Geological Survey under a cooperative agreement with the Washington State Board of Geological Survey. Part I, containing data on the drainage basins of Klickitat, White Salmon, Little White Salmon, Lewis, and Toutle rivers, in southwestern Washington, was prepared by John C. Stevens and was published in 1910 as Water-Supply Paper 253. Part II, relating to the drainage basins of Cowlitz (except the Toutle), Nisqually, Puyallup, White, Green, and Cedar rivers, on the west side of the Cascade Range, was prepared by Fred F. Henshaw and Glenn L. Parker and was published in 1913 as Water-Supply Paper 313. The Yakima River basin, described in this report, lies east of the Cascade Range. The location of the areas covered by Parts I, II, and III is shown in figure 1, and a map of the Yakima basin forms Plate I.

The data on which this report and the others are based consist of stream-flow records, river plans and profiles, reservoir surveys, and field reconnaissances of the rivers and the various tributaries, obtained by the United States Geological Survey and the United States Reclamation Service, supplemented by a large amount of information furnished by private parties. The physical characteristics, economic conditions, and industrial development of the region are described rather fully in order that the limitations to the development of power may be more clearly understood. Arranged in the order of their probable consequence, the reasons for those limitations are as follows:

1. The greater utility of a large part of the water supply for future irrigation. With one exception (Bumping Lake) all of the reservoirs contemplated in the Yakima project are of sufficient capacity to regulate the entire tributary flow during normal years, so that it will be necessary to manipulate the storage in such a manner as to render the main stream of little value for continuous power.

2. The inaccessibility of the power sites and the high cost of development. Most of the principal power sites are situated on tributary streams, at a considerable distance from railroads and market centers, so that the cost of development will be burdened with heavy transportation charges and with a large initial outlay for transmission lines. The topography at a large number of the power sites considered in the power summaries (pp. 107, 114, 126) is so rough and rugged that construction will be difficult and expensive. Moreover,

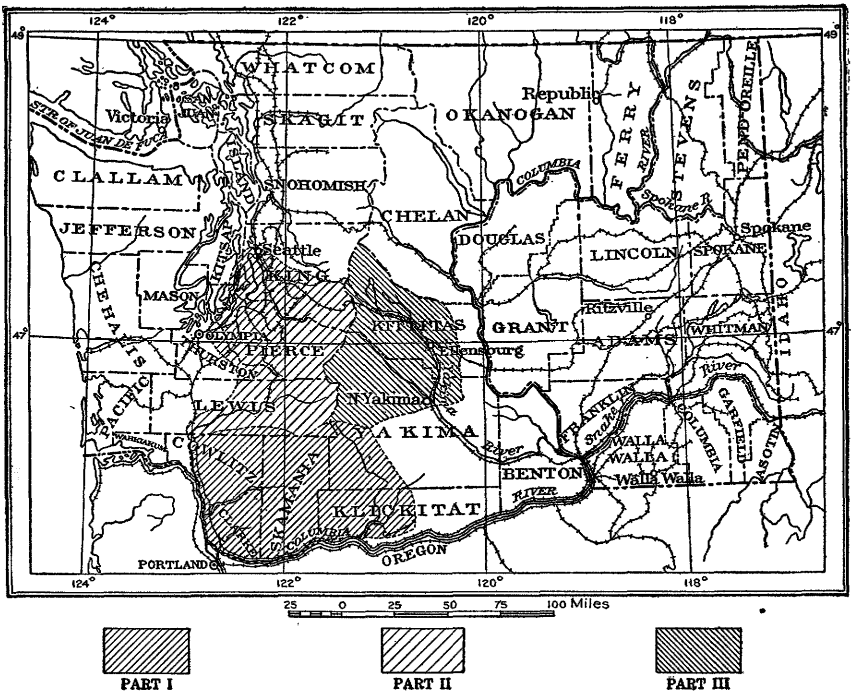


FIGURE 1.—Sketch map of Washington, showing areas covered by reports on water powers of the Cascade Range.

the prevailing basaltic formation may be unsuited for dam sites as well as for unlined conduits, and large expenditures may be necessary to prevent excessive seepage. The feasibility of power development at all of the sites depends largely on the provision of storage for supplementing the low-water flow and the utilization of the reservoir sites available for this purpose will be rather expensive.

3. The proximity of the Roslyn coal field in the upper Yakima Valley. (See pp. 159–161.) The coal in this field is of good quality and can be easily and cheaply mined. So far as known no careful comparison has been made of the relative economy of hydroelectric and steam-power development in the basin, but the economic relation between the two methods of producing energy is without doubt more favorable to steam power than in any other part of the State.

4. The lack of centralization of power utilization. The Yakima Valley industries will always be essentially agricultural, and intensive farming methods will undoubtedly be more prevalent than at present. As the products of intensive farming do not require the use of continuous power for preparation for the market, a hydroelectric distribution system to serve all demands would extend over a large area including a number of small localized market centers. This condition may prove favorable to small-unit steam-power plants for the smaller centers of distribution until the cost of fuel becomes prohibitive.

The increasing practice of pumping water for irrigation has opened a large field for the utilization of energy. The development of much of the power listed as available during the irrigation season will not be feasible until all the land that can be irrigated by gravity is under cultivation and the value of land is greater than at present, but the possibility of reclaiming in this manner the large amount of arid land that can not in any other way be made productive is too important to be neglected in a comprehensive treatment of the subject.

The complexity of the stream-flow data due to the storage of water and diversion for irrigation has made it necessary to adopt a basis for determining the water supply different from that chosen for Parts I and II of this series, in which the minimum flow for one week was used in estimating the water available for power development. The power summaries in this volume are based on the minimum record flow for one calendar month. The method will doubtless give relatively larger values of minimum flow than those published in the prior reports, but the results obtained, where storage is considered, will be comparable to those in the other reports. As the feasibility of all power development considered in this unit of the series is greatly dependent on possible storage, the difference in methods will not be important.

No attempt has been made to present details of separate power projects, but the analyses and summaries indicate the approximate power resources of the area and show in a general way the relative value of chosen sections of the river system. An effort has been made to outline a scheme of power projects consistent and harmonious with the highest ultimate development of the basin. The fact that in the Yakima basin irrigation is of far greater economic importance than power development can not be too strongly emphasized. Court decisions and the trend of legislation in the State of Washington very properly recognize the use of water for irrigation as higher than that for power, and this recognition is especially justifiable in a State whose power resources have been estimated[1] as greater than those of any other State in the Union.

[1] Water-power development in the United States, pp. 55-56, Dept. of Commerce and Labor, Mar. 14, 1912.

COOPERATION.

The Washington State Legislature passed acts during the sessions of 1911 and 1913 authorizing the Washington State Board of Geological Survey to continue cooperating with the United States Geological Survey, and appropriating $37,500 and $35,000 to serve that purpose during the biennial periods ending March 31, 1913, and March 31, 1915, respectively. The board, which consists of the governor, lieutenant governor, treasurer, and the presidents of the State University and the State Agricultural College, elected Henry Landes State geologist and gave him authority to enter into cooperative contracts with the Director of the United States Geological Survey. The money appropriated by the State was met by equal Federal allotments for topographic mapping and for water-supply investigations.

The preparation of this series of reports is conducted by the water-resources branch of the United States Geological Survey in connection with studies of the daily stream flow of the principal rivers of the State. The river surveys for determining the plan and profile of Naches and Clealum rivers and the principal tributaries of these streams were made by the topographic branch of the United States Geological Survey. The river surveys were run by W. B. Lewis and T. H. Moncure under the direction of T. G. Gerdine, geographer. An approximate plan and profile of Yakima River from Lake Keechelus to Union Gap has been obtained from a detailed map indicating all irrigation diversions, furnished by the United States Reclamation Service, supplemented by water levels obtained by Howard Kimble, junior engineer, United States Geological Survey. The river elevations were determined by running lines of levels between the water surface and the Northern Pacific Railway Co.'s grade and comparing the profile furnished to the Survey by the company with the United States Geological Survey bench marks.

Investigations of stream flow in the Yakima basin were begun by the United States Geological Survey in 1893, and the data are so important in the apportionment of water that the records have been extended to perhaps greater detail and higher accuracy than in any other basin of similar size in the United States. After the separation of the Reclamation Service from the Geological Survey in 1906, and prior to April, 1912, the work was carried on by the Survey in cooperation with the Reclamation Service, and was directed by John C. Stevens and Fred F. Henshaw, district engineers. In April, 1912, the collection of stream-flow records was taken over by the Reclamation Service and placed under the direction of Charles H. Swigart, supervising engineer, with Paul Taylor, junior engineer, in charge.

ACKNOWLEDGMENTS.

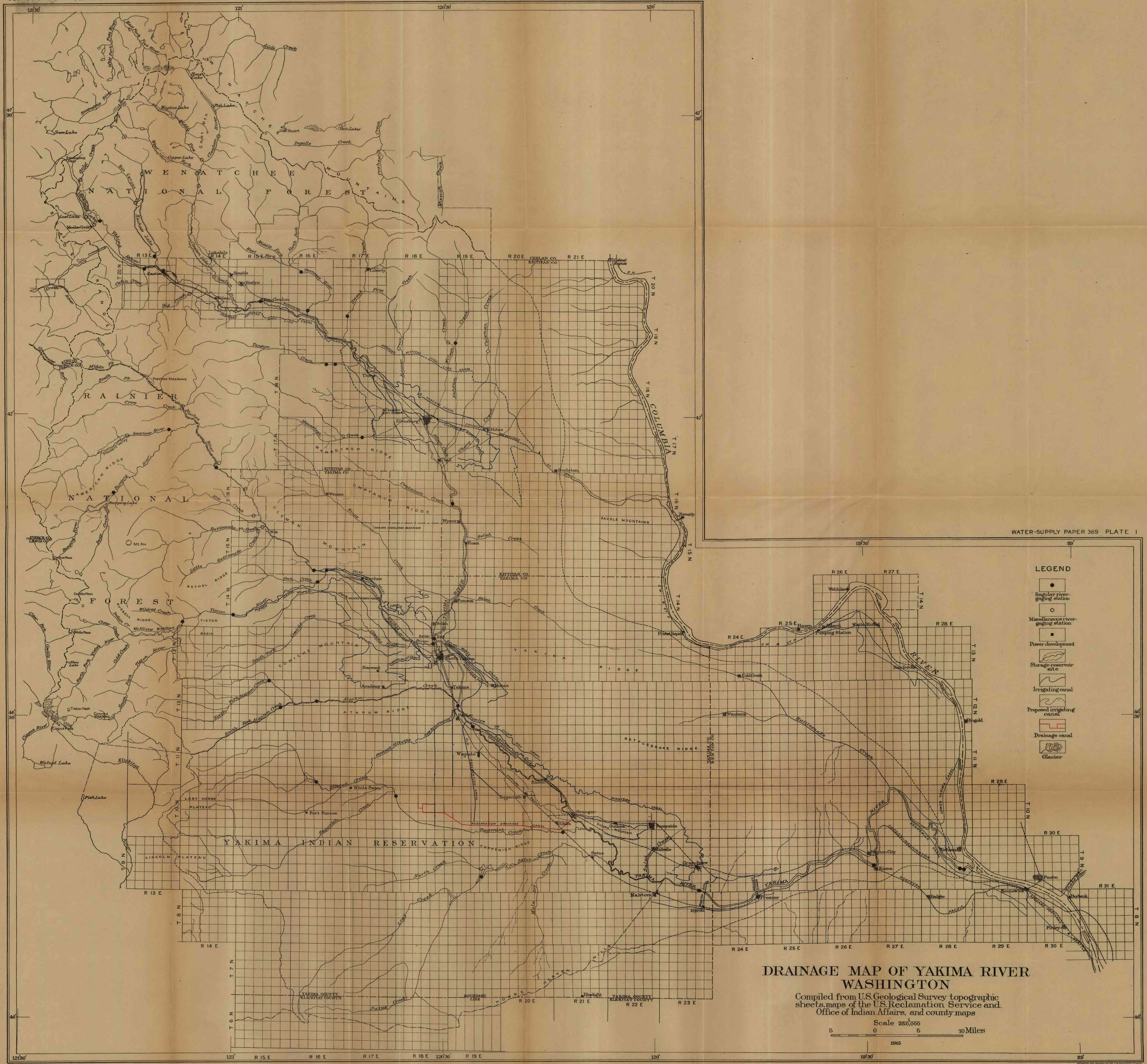
The field reconnaissances made to determine the physical and economic conditions to be considered in studying the power possibilities, together with the preparation and revision of stream-flow data, were conducted in connection with the maintenance of stream-gaging stations in Washington and Oregon under the direction of Fred F. Henshaw, district engineer. Helpful assistance in the revision of early stream-flow records was rendered by Edwin S. Fuller, office engineer, and A. H. Tuttle, assistant office engineer.

Special acknowledgment is due to Prof. Henry Landes for the kindly relations fostered under the cooperative agreement between the Washington State Board of Geological Survey and the United States Geological Survey.

A large amount of the detailed information contained in this report was furnished by the United States Reclamation Service, represented by Charles H. Swigart, supervising engineer. A section of the report entitled "Scheme of development and utilization of stored water" was furnished by Mr. Swigart, and another section entitled "Settlement and development of the Yakima Valley" was contributed by Philo M. Wheeler, field clerk of the United States Reclamation Service.

The writers are greatly indebted to Edwin J. Saunders, assistant professor of geology, Washington State University, for the sections entitled "Geologic history," "Physiography and river history," "Climate," and "Production of coal."

A large amount of information, without which it would have been very difficult to present the subject matter included in the following pages intelligently, has been furnished by private parties, officials of companies, and corporations. Acknowledgment is due to the following individuals for furnishing miscellaneous data and helpful suggestions: D. C. Henny, consulting engineer, Portland, Oreg.; J. E. Davidson, general manager Pacific Power & Light Co., Portland, Oreg.; D. F. McGee, chief engineer Pacific Power & Light Co.; J. H. Siegfried, superintendent of power Pacific Power & Light Co., Kennewick, Wash.; E. L. Butler, superintendent city lighting department, Ellensburg, Wash.; L. M. Holt, superintendent of irrigation, United States Indian Service, North Yakima, Wash.; Frank C. Kelsey, chief engineer Kittitas reclamation district, Ellensburg, Wash.; Edward R. Bannister, engineer Yakima Valley Canal Co., North Yakima, Wash.; C. P. Devine, president Yakima Highlands Irrigation & Land Co., North Yakima, Wash.; Theodore Weisberger, engineer Atanum Water Users' Association, North Yakima, Wash.; John J. Rudkin, Northern Pacific Irrigation Co., Kennewick, Wash.; C. O. Barnes, Kiona-Benton Land & Water



House Doc. 1087; 63d Cong., 2d Sess.

Co., Seattle, Wash.; A. E. Poole, general manager Central Washington Investment & Power Co., North Yakima, Wash.; R. A. Jennings, secretary Yakima Commercial Club, North Yakima, Wash.; Quincy Scott, secretary Commercial Club, Ellensburg, Wash.

GEOGRAPHY OF THE YAKIMA BASIN.

Yakima River drains an area roughly triangular in form, situated slightly southeast of the geographic center of the State of Washington and comprising 5,970 square miles. The western boundary of the basin, forming one side of the triangle, extends north and south along the Cascade Range for nearly 100 miles; the other two sides are approximately parallel to Columbia River above and below a point a short distance below the mouth of Yakima River, at which the course of the larger waterway changes abruptly from southeasterly to westerly. The area is somewhat larger than the State of Connecticut, represents 8.9 per cent of the total land area in the State of Washington, and is more than twice as large as any other drainage basin wholly within the State.

The western section of the basin adjoins Wenatchee basin on the north and Klickitat basin on the south. The remainder of the adjacent drainage on the east side of the divide seeks Columbia River directly through small intermittent tributaries.

The main stream heads in a section of the Cascade Range in the vicinity of Snoqualmie Pass, where the water is collected from the mountainous area by numerous laterals draining into Keechelus Lake (Pl. II), lying at an elevation of 2,454 feet. The river proper pursues a general southeasterly course from Keechelus Lake for approximately 180 miles (by river) and enters the Columbia near the southern boundary of the State, 12 miles above the mouth of Snake River. The general relations of the drainage system are shown on the map forming Plate I.

The principal tributaries of the river from source to mouth on the left (or northeast) side of the basin are Kachess, Clealum, Teanaway rivers, Swauk and Wilson creeks; those from the right (or southwest side) are Cabin, Taneum, Manastash, Umptanum, and Wenas creeks, Naches River, Atanum, Toppenish, and Satus creeks.

Naches River, the most prominent of the tributaries, drains about two-thirds of the section of the Cascade ridge forming the western boundary of the entire basin and embraces slightly less than 19 per cent of the total drainage area. The Naches basin also is triangular in shape, and its sides are roughly parallel to the boundary lines of the larger basin. The river heads in the northwest corner of the triangle, is about 60 miles long, and follows the northeastern side very closely. It joins Yakima River at North Yakima, 94 miles by river below Keechelus Lake. The principal tributaries, Bumping

River, Rattlesnake Creek, Tieton River, and Cowiche Creek, enter from the southwest. Bumping and Tieton rivers contribute most of the water, for the areas drained by the other streams embrace only a small part of the mountainous region and yield a proportionately small share of the total run-off. At the head of Tieton River are Goat Rocks, the highest part of the Cascade Range in the Yakima basin, reaching an elevation of 8,200 feet above sea level. A large glacier, covering several square miles, extends down the slopes of Goat Rocks, Old Snowy Mountain, and Ives Peak, and is very effective in maintaining a high rate of run-off during the irrigation season—much more so than the smaller glaciers that feed the headwaters of Clealum River. Flat valleys, contracted at the lower end, constitute a noteworthy topographic feature of the upper Naches basin and furnish favorable opportunities for storage.

Clealum River, second in size among the tributaries of the Yakima, heads in the northwestern corner of the basin, in Hy[illegible], at an elevation of 3,480 feet above sea level, and flows so[illegible] about 36 miles by river to its junction with the main stream, 25 miles below Lake Keechelus. The upper river with its principal confluents, Middle Fork and West Fork, receives the drainage from very high ridges in the main divide, reaching an elevation of nearly 8,000 feet. In this section of the mountains, about 15 miles long, are four small glaciers which aid materially in maintaining a high run-off during the irrigation season. A large water supply and possibilities for storage afforded by Clealum Lake, which is situated 8 miles above the mouth at an elevation of 2,128 feet, greatly enhance the economic importance of this river.

Kachess River drains an area encircled by the Clealum basin and the head of the Yakima above Keechelus Lake. This area nowhere touches the Cascade divide, but a large part of the upper basin reaches an elevation nearly as great as that of the main divide. The river follows a general southeasterly course and is only about 16 miles long. About 1.5 miles above its mouth is Kachess Lake, which lies at an elevation of 2,226 feet and affords the most favorable opportunities for storage in the basin. This storage has already been developed. (See p. 91.)

The following list shows the drainage areas of Yakima River and tributaries at selected points as carefully determined by planimeter on the best available maps. The drainage areas of the upper river above Taneum Creek and of Naches basin are most accurate, as those sections of the river system are shown on topographic maps of the Survey. The location of drainage lines for the lower parts of the basin could only be approximately determined, and the areas given are therefore subject to inaccuracies. It is probable, however, that the percentage of error for areas above Union Gap is less than 5 per cent.

Drainage areas in Yakima basin.[1]

	Square miles.
Yakima River below Lake Keechelus	55
Yakima River below Kachess River	182
Yakima River below Clealum River	486
Yakima River below Teanaway River	743
Yakima River below Taneum Creek	951
Yakima River at entrance to Yakima Canyon near Thrall	1,600
Yakima River below Naches River	3,270
Yakima River at Union Gap below Atanum Creek	3,550
Yakima River at Kiona	5,520
Yakima River at mouth	5,970
Cabin Creek at mouth	31.7
Kachess River at mouth	65
Big Creek at mouth of canyon	26.2
North Fork of Clealum River below Fish Lake	18.2
North Fork of Clealum River below Camp Creek	41.0
Clealum River below Middle Fork	103
Clealum River below West Fork	152
Clealum River below Clealum Lake	202
Clealum River at mouth	222
Middle Fork of Clealum River at Waptus Lake dam site	26.6
Middle Fork of Clealum River at mouth	53
West Fork of Clealum River at Cooper Lake dam site	28.5
West Fork of Clealum River at mouth	39.7
Teanaway River at mouth	205
Swauk Creek at mouth	97
Taneum Creek at mouth	87
Manastash Creek at elevation of 2,130 feet	76
Naneum Creek at mouth of canyon	±73
Umptanum Creek at mouth	±54
Wenas Creek at mouth	193
Naches River at lower end of Naches Meadows	64
Naches River below Bumping River	342
Naches River below Rock Creek	422
Naches River below Rattlesnake Creek	610
Naches River below Tieton River	942
Naches River at mouth	1,120
Crow Creek at mouth	40.7
Bumping River below Bumping Lake	68
Bumping River below American River	189
Bumping River at mouth	193
American River below Pleasant Valley	71
American River at mouth	81
Rattlesnake Creek at mouth	133
Tieton River at McAllisters Meadows dam site	187
Tieton River at mouth	298
North Fork of Tieton River at mouth	98
South Fork of Tieton River at mouth	87
Cowiche Creek at mouth	120

[1] Relation of tributaries indicated by indention.

Altitudes in the Yakima basin range from 8,200 feet at Goat Rocks, in the southwest corner, to 330 feet at the mouth of the river. At the northern and southern limits of the Cascade divide the general elevation of the ridges is close to 8,000 feet, and glaciers have formed along the slopes. Glacial action has ceased in the central section of the divide, where the elevation of the ridges is only 5,000 to 5,500 feet. Snoqualmie Pass, the lowest passageway in the Cascade divide in the State of Washington, is situated at the northern limit of the central section of the divide between 3,000 and 3,100 feet above sea level. The mountainous section in the Yakima basin parallels the divide and is only about 25 miles wide. The extremely rough and irregular topography in this stretch merges into rolling highlands, well rounded by erosion and, at the lower altitudes, covered with a deep soil.

The Yakima traverses a number of broad valleys separated by ridges that approach the stream course from either side. The highest of these valleys in elevation is the wide, rolling area below the lakes and surrounding Clealum. In places this area is heavily timbered and only a small part of the available agricultural land is under cultivation. Below this section for a distance of about 10 miles the river flows through a canyon which opens into Kittitas Valley surrounding Ellensburg. Kittitas Valley is about 25 miles long and in places is 10 to 12 miles wide. Its soil is very productive and there is little waste land. The Yakima Canyon, about 16 miles long, separates Kittitas Valley from Selah Valley, which is somewhat smaller than the other inclosed lowlands of the basin. The broad, gently sloping area tributary to North Yakima and Yakima City, which borders Naches River and the main stream near the mouth of Naches River, is connected with Selah Valley and the Wapato-Sunnyside Valley by Selah Gap and Union Gap, respectively. The "gaps," which are prominent topographic features, were formed by the river cutting through Yakima Ridge to the north and Atanum Ridge to the south. The Wapato-Sunnyside Valley embraces much more irrigable land than all the other valleys combined. It stretches from Union Gap to the vicinity of Kiona near the mouth of the river, a distance of about 60 miles. The broad portion of the valley, at the upper end, extends toward the right-hand side of the river and lies almost entirely in the Yakima Indian Reservation. At the lower end of the valley the most of the irrigable land stretches away from the left side of the river and is embraced in the Sunnyside unit of the Yakima project. Both of the lower valleys are highly productive and by intensive farming methods are made to yield large returns per acre. The valley narrows appreciably in the vicinity of Kiona and widens again near the mouth to merge with the flat area bordering Columbia River.

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The higher parts of the drainage area are heavily forested below the timber line. Yellow pine, fir, hemlock, and cedar are the principal species. An area of 600 square miles in the northern portion of the basin contiguous to the Cascade Range is included in the Wenatchee National Forest. The mountainous region on the west side of the basin is included in the Rainier National Forest, which comprises an area of slightly more than 1,000 square miles. The total area thus controlled represents about 27 per cent of the entire watershed. It is estimated that the combined stand of merchantable timber in the two national forests contains 3,200,000,000 board feet of lumber. A proper regulation of these reserves insures a continued and well-sustained lumber industry and will preclude the possibility of a marked change in regimen of stream flow resulting from unwise deforestation. In addition to the area in the national forests, 1,380 square miles of the Yakima basin is included in the Yakima Indian Reservation which is situated in the southwestern part of the drainage basin. The part of the reservation adjoining the Klickitat basin is heavily timbered, but this section covers only a small part of the reservation. The timber extending along the slopes of the divide is displaced by scrubby pine on the rolling lowlands and merges into the characteristic sagebrush of the Wapato-Sunnyside Valley.

Because of the small amount of precipitation the lower reaches of the basin lying below the mountainous section naturally produce little vegetation except sagebrush.

GEOLOGIC HISTORY.[1]

By Edwin J. Saunders.

PRE-TERTIARY TIME.

The oldest rocks exposed in the Yakima basin are the Easton schist, typically a silver-gray or green rock composed principally of quartz and mica; the Peshastin formation, consisting of black slate with grit or conglomerate and bands of black chert with lenses of light-gray limestone interbedded with the slate; and the Hawkins

[1] More detailed descriptions of the geology and physiography of this region appear in the following reports:

Russell, I. C., A geological reconnaissance in central Washington: U. S. Geol. Survey Bull. 108, pp. 15–19, 1893. Contains a good description of physiography of region.

Russell, I. C., A preliminary paper on the geology of the Cascade Mountains in northern Washington: U. S. Geol. Survey Twentieth Ann. Rept., pt. 2, pp. 83–210, 1900.

Smith, G. O., Geology and water resources of a portion of Yakima County, Wash.: U. S. Geol. Survey Water-Supply Paper 55, 1901.

Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), 1903. Geography of Yakima Valley in part.

Smith, G. O., Geology and physiography of central Washington: U. S. Geol. Survey Prof. Paper 19, pp. 9–39, 1903.

Smith, G. O., Anticlinal mountain ridges in central Washington: Jour. Geology, vol. 2, pp. 166–177, 1903.

Smith, G. O., U. S. Geol. Survey Geol. Atlas, Mount Stuart folio (No. 106), 1904.

Smith, G. O., U. S. Geol. Survey Geol. Atlas, Snoqualmie folio (No. 139), 1906.

formation, consisting of dark-colored green or purple volcanic rocks. The age of these formations is doubtful but all are pre-Tertiary. The complex record of sedimentation and volcanism furnished by these rocks is much obscured by close folding resulting from orogenic movements and by igneous intrusions. After these older formations were uplifted and folded, but still in pre-Tertiary time, great masses of peridotite, now largely altered to serpentine, and of granodiorite were intruded into them. The pre-Tertiary rocks are found in the mountainous western part of the basin, the rugged topography of which is due to their dissection by the streams.

TERTIARY PERIOD.

EOCENE EPOCH.

Early in the Eocene the older rocks were deeply eroded, and the waste was deposited about the eroded highlands as thick beds of gravel, coarse sands, and mud, which form what are now called the Swauk and the Naches formations. As they contain no marine fossils these deposits are believed to have been formed in large lakes. They had, however, been uplifted and considerably eroded before volcanic activity resulted in covering large areas in the northern part of the basin with successive flows of lava, which were known collectively as the Teanaway basalt and which in places attain an aggregate thickness of more than 5,000 feet. The lava reached the surface through hundreds of fissures in the sandstone and other underlying rocks, and the material congealed in these openings forms one of the most remarkable dike systems known. Considerable andesite and rhyolite were erupted during this same period.

The period of volcanic activity was followed by a period of erosion in the highlands and of sedimentation in several distinct basins. The most important mass of sediments thus accumulated is the Roslyn formation, which comprises about 3,500 feet of sandstone and shale. In the upper part of this formation are several beds of coal (see p. 159), the lowest of which has been highly productive. The Manastash formation, which is exposed south of Yakima River, is somewhat similar to the Swauk, but probably a little younger. It also contains thin beds of coal, little of which has been mined.

MIOCENE EPOCH.

A decided unconformity between the Eocene and the Miocene formations indicates a long period of erosion between the uplift and folding of the Eocene formations and the outpouring of the immense flows of Miocene lava which are known as the Yakima basalt. This lava issued quietly through numerous fissures and flooded a large area to a depth ranging from 200 to 2,500 feet or more. Where the underlying rocks have since been exposed the conduits may be seen as diabase dikes or stocks.

In the northwestern part of the basin sedimentation was going on during the Miocene, possibly contemporaneously with the lava eruptions farther south. The grits, sandstones, shales, and cherty limestones of the Guye formation were formed at this time. After they had been folded, uplifted, and eroded, volcanic activity was renewed and large areas were covered with andesitic lavas and tuffs, known as the Keechelus andesitic series. The abundance of tuff in this series indicates explosive eruption from central volcanoes rather than quiet fissure eruptions like those that gave rise to the basaltic flows already described. Into the Keechelus and Guye formations was intruded the Snoqualmie granodiorite, exposed at high altitudes in the northwestern part of the basin.

Even before the last flows of basalt were erupted sedimentation began in the Yakima basin. Over the low basalt plains was spread a thick series of volcanic sediments, known as the Ellensburg formation. The beds comprised in this formation range in texture from conglomerate to silt. The material is in large part waterworn. By far the greater part of it is andesitic in composition, pebbles and fragments of a nearly white andesitic pumice being especially characteristic. The coarseness of much of the material, the presence of stream bedding, and the andesitic nature of the fragments indicate the action of powerful streams flowing from the uplands to the west and carrying great loads of sand and gravel (probably derived in large measure from contemporaneous eruptions) out over the lower lava plains. The heavily laden streams built up large alluvial fans spreading for miles over the flat surface and interbedded with lake deposits. Some of the ash beds interstratified with gravel were formed by the dust exploded from active craters far to the west.

PLIOCENE EPOCH.

During the later part of the Tertiary period there seems to have been a folding and uplift that accelerated erosion. This erosion was continued until the whole region was reduced to a slightly rolling lowland surface or peneplain that is well preserved in the region about Kittitas Valley and has been fully described by Smith.[1] Yakima River and its tributaries flowed over this surface with little regard to rock structure and developed meandering courses on hard and soft rocks alike.

Then followed an uplift of the whole Cascade Mountain mass to form what has been called the "Cascade Plateau." The uplift

[1] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), 1903.

was accompanied by warping of the peneplain on old axes of folding, which caused a number of low ridges to be raised athwart the general southeastward course of Yakima River. Across these ridges the river and its stronger tributaries were able to maintain their courses. The principal topographic features of the lower part of the Yakima basin are the result of the action of the rivers in cutting deep canyons in the uplifted basaltic ridges and in opening broad valleys in the down-warped areas where the softer younger formations are exposed. The upper part of the river, with its larger tributaries, has cut out valleys that maintain a remarkably low gradient nearly back to the main divide.

QUATERNARY PERIOD.

The work of sculpturing the elevated land mass into the present land forms has been carried forward actively (though with some interference by volcanic eruptions in the southwestern part of the basin) by rivers and glaciers during Quaternary time. Owing to heavy precipitation in the mountainous portions of the basin the erosive work has been very rapid, and the head of the basin, although elevated during Pliocene time, is maturely dissected. Because of the varying attitude and hardness of the rock exposed to stream erosion and also to glaciation many modifications have been effected in the drainage since the deformation that gave rise to the main topographic features.

Early in the Quaternary period the climate became colder. Deep snows collected on the mountains north and west of the Yakima basin and gave rise to glaciers that crept down the higher valleys. The longest occupied the three valleys now occupied by Lakes Keechelus, Kachess, and Clealum, which are held in by terminal moraines. The Clealum River valley probably contained a glacier about 25 miles long. The topography in the upper parts of the basin gives many evidences of former extensive glaciation. The valleys are steep-walled or U-shaped with truncated interstream spurs. The smaller tributaries cascade into the main streams from hanging valleys, where the smaller glaciers were not able to erode so quickly as the larger glaciers in the main valleys. The valleys head in steep-walled basins, known as cirques, divided by sharp ridges and peaks. Many of the cirques are still occupied by remnants of the former glaciers or by small rock-rimmed lakes. Little evidence of glaciation is found in the mountains immediately south of the Yakima basin.

In the river valleys below the limits of glaciation the stream waters were overloaded with detritus from the melting ice front and deposited gravel in the valley bottom to a depth that amounted in places to 200 or 300 feet. After the glaciers receded the load of the rivers diminished and they began to reexcavate their valleys in the glacial gravels. The result of this work, which is still going on, is a series of terraces along Yakima River and its larger tributaries.

Landslides have considerably modified the topography of the valley. Large masses, sliding down the steep sides of the basaltic plateaus, or flat-topped hills, have come to rest in the form of steps. In a few places small lakes or ponds are found between the landslide mass and the cliff from which it was derived. These forms are especially common in Yakima Valley about Table Mountain and Lookout Mountain, but are found also in the lower valley. North of Thorp a mass, 100 or 200 acres in area, has fallen from the edge of the mesa-like ridge of Ellensburg formation along Yakima River, and a large mass has also fallen from the northwestern face of Toppenish Ridge. Landslides are also found in the older rock areas, but they are less extensive than in the younger formations.

PHYSIOGRAPHY AND RIVER HISTORY.

By Edwin J. Saunders.

The general topographic relations in the Yakima basin indicate that Yakima River and some of its larger tributaries had well-established courses on a well-graded surface—the Pliocene peneplain (see p. 18)—before that surface was uplifted and warped. During the deformation the rivers were able to maintain their courses across the main axes of folding, and they have therefore been called antecedent streams, but that the valleys are to some extent consequent on the later movements is indicated by the fact that the upper Naches follows a depression between two axes of uplift, and the upper Yakima also occupies an area of depression. This may account for the remarkable fact that their broad low-grade valleys extend so far back into the Cascade Range. Earlier axes of deformation may have determined the position of these valleys and later warping probably followed the lines of earlier deformation.

That the main axis of this elevation was not along the present summit ridge of the Cascade Mountains is shown by the fact that Yakima River and its two main tributaries flow southward almost parallel to the Cascade summit. At Martin, for example, some 15 miles below the head of the river, the valley is only about a mile from the summit at Stampede Pass.

Because of the heavy precipitation on the higher elevations erosion by the headwaters of the Yakima has been very rapid. The upraised peneplain, or, as it has been called, the "Cascade Plateau," has been dissected to such an extent that the former approximately even surface has become a complicated series of sharp ridges and irregular peaks. The Yakima has eroded a deep, fairly low grade valley far back into the former plateau surface. Lake Keechelus, for instance, only a few miles from the summit, has an elevation of only 2,454 feet, while the highlands about it are 5,000 feet high. The larger tributaries have also extended their low-grade valleys far back between the interstream uplands, but many of the smaller tributaries are still mountain torrents from source to mouth. Clealum River affords a good example of the larger tributaries. Its valley extends about 30 miles from the main stream, and at Hyas Lake, a few miles from its source, is 2,500 feet below the surrounding summits.

Glaciation has materially aided the rivers in this work of erosion and has also greatly modified the features of the northern part of the Yakima basin. The glaciated valleys, cirques, numerous lakes, hanging valleys, and cascades produced in this section, and the aggrading work of the streams as they flowed away from the glaciers, have already been described (pp. 19–20).

Below Bristol, where Yakima River leaves this maturely dissected region, its antecedent character is well shown. Here it has cut a narrow canyon 1,200 to 1,500 feet deep, across the uplifted northwestern edge of the great basalt plateau. For a distance of over 10 miles it has intrenched its valley with well-developed meanders below the warped surface of the old plateau on which the meanders were developed. The glacial gravel filling (p. 20) extends through this gap, and above the present river level are finely developed gravel terraces.

From the canyon in the basalt the river enters a large structural valley with rocks dipping inward on all sides. Here softer rocks, lying over the basalt, are exposed to river erosion, and an oval-shaped valley, known as Kittitas Valley, is the result. Yakima River flows near the western side of the valley, receiving from the western slope two large tributaries, Taneum and Manastash creeks. From the eastern slope Naneum Creek is the only tributary of importance. On account of the low annual precipitation—about 15 inches—tributaries are fewer and general erosion has been much slower here than in the upper part of the basin. But the river has effectively lowered the floor of the old structural valley and has left remnants of the former higher level, as seen in the mesas east of Thorp and east of Ellensburg.

In many parts of the valley the rock formations are covered with a thick mantle of stream deposits. This is especially true around the borders of the basin where the mountain streams with heavy loads of sediment have built large alluvial fans, joining to form a piedmont fan sloping gently toward the river. These fans are covered, in their lower portion at least, with rich soil and, being favorably situated for irrigation from the streams which built them, furnish large tracts of good agricultural land.

South of Kittitas Valley the river has cut a deep canyon through several anticlinal ridges that were raised across its course. These are known as the Manastash, Umptanum, Cleman, and Cowiche mountains or ridges. That the river had reduced the surface to a flat, in which it could meander at will before the folding, is nicely shown in the well-developed meanders of the canyon intrenched 2,000 feet below the old surface.

Many diversions of drainage have occurred since the uplift of the peneplain, some of them due to glacial barriers, but more of them due to the capture, effected by vigorous streams at the cost of the feebler, or by those cutting in soft rocks at the cost of those whose channels were in more obdurate material.

Modification of drainage by glaciation appears at Snoqualmie Pass, where moraines have evidently caused the diversion of the waters of Commonwealth and Guye creeks, formerly draining into Yakima River, westward into the South Fork of Snoqualmie River. Diversion by capture has affected Teanaway River,[1] one of the larger upper tributaries of the Yakima which flows into the main stream on sandstone northwest of Lookout Mountain. Formerly the Teanaway flowed into the Yakima by way of Swauk Prairie and through the valley now occupied by Swauk Creek, which then flowed in basalt through Horse Canyon and was tributary to the lower Teanaway. But a tributary of the Teanaway, a stronger stream working in the softer sandstone, captured the headwaters of Swauk Creek; and finally the still more vigorous Yakima captured the headwaters of the Teanaway, by means of a tributary from the east, advantageously situated on the contact between basalt and sandstone.

First Creek, which formerly flowed through Green Canyon, northwest of Ellensburg, has clearly been beheaded by a tributary of Swauk Creek, whose headwaters cut down through a narrow mass of sandstone more rapidly than First Creek could sink in the hard basalt of Green Canyon. The waters of First Creek are still taken out through Green Canyon for irrigation.

CLIMATE.

By Edwin J. Saunders.

GENERAL CONDITIONS.

The Yakima River basin, situated on the eastern slope of the Cascade Mountains, is shut off to some extent from the effects of the moderating, moisture-bearing westerly winds from the Pacific, and for this reason the annual precipitation is low. The southeastern part of the basin, in which the rainfall is less than 10 inches, lies in what is known as the arid belt of Washington, and as it also lacks the protection that the Cascade Mountains offer to valleys on the west slope,

[1] See Mount Stuart topographic sheet, U. S. Geol. Survey.

it is subject to the extremes of temperature characteristic of the interior, especially the cold waves of winter, that spread from the northeast over this section. However, on account of the proximity of the basin to the Pacific Ocean, the westerly winds have a slight moderating effect, in spite of the mountain barrier, and prevent such prolonged cold spells and heavy snows as those to which the States of the Middle West in the same latitude are exposed.

PRECIPITATION.

The average annual precipitation for the entire Yakima basin can not be determined for lack of precipitation records in the mountainous region, but the great variation in different sections of the basin render this a matter of small importance. The greatest average rainfall recorded at the Weather Bureau stations in the area, from which an average for any significant length of time can be obtained, is 25.91 inches at Clealum; the least is 6.34 inches at Kennewick. At Lake Keechelus, observations for the five-year period give an annual average of 60.45 inches. Hence there is a variation from 60.45 inches to 6.34 inches between Keechelus Lake and the mouth of the river.

This peculiar distribution of precipitation is accounted for by the fact that the moisture-laden air from the Pacific is cooled to such an extent by forced ascent in passing over the Cascade Mountains that the greater part of its moisture is deposited on the western slopes and near the summit on the eastern slope. In descending the eastern slopes the precipitation decreases rapidly. The air is dynamically warmed by increase of pressure at lower levels and the capacity for moisture is greatly increased, thus favoring clear skies and scant precipitation. Thus the annual precipitation gradually decreases as the air seeks lower levels toward Columbia River, and the lowest rainfall recorded at Weather Bureau stations in Washington is found at Kennewick. The whole basin may be considered as located in the rain shadow of the Cascade Mountains, and whatever precipitation occurs must come as a result of cyclonic or convectional storms, and these with relatively dry air to start with. The following table has been prepared from United States Weather Bureau statistics to indicate the average monthly and yearly precipitation of various points in the valley.

Average monthly and yearly precipitation at United States Weather Bureau rainfall stations in Yakima Valley.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Keechelus	8.71	8.27	6.26	3.36	2.39	1.19	0.80	0.49	2.81	4.24	12.70	9.23	60.45
Clealum	4.26	3.54	2.48	1.40	.97	.98	.35	.38	.96	1.88	4.46	4.31	25.91
Fort Simcoe	2.50	1.65	1.01	.40	.74	.50	.09	.21	.37	.73	2.37	2.24	12.81
Ellensburg	1.49	1.09	.57	.58	.68	.68	.28	.28	.48	.53	1.64	1.49	9.79
Moxee	1.48	.97	.58	.46	.80	.65	.26	.20	.42	.52	1.22	1.11	8.67
Sunnyside	.93	.78	.37	.35	.58	.36	.23	.22	.46	.53	1.00	.84	6.65
Kennewick	.94	.74	.41	.26	.50	.28	.13	.21	.31	.57	.93	1.06	6.34

The monthly distribution of rainfall, as diagrammatically shown by figure 2, is vastly more important to the engineer and the farmer than the average annual precipitation. The prevalence of a wet season from November to March, inclusive, and a dry season from April to October, inclusive, shows the effect of proximity to the western coast. The contrast between the two seasons is much less marked than in western Washington, and a secondary period of maximum rainfall with precipitation less than in the winter months, appearing usually in May and June, shows the effect of continental control.

The winter maximum is accounted for by the greater number and activity of the cyclonic or storm areas during the winter season, the movement of the warm moist air from the ocean over a cooler continent, and the fact that, although deprived of most of its moisture in passing over the Cascade Mountains, the air, under cyclonic control, is cooled to a still lower temperature in moving toward the interior, and thus yields additional precipitation. The secondary summer maximum is explained by the convectional summer storms that cause heavy showers and occasional cloudbursts in this valley. These showers bring the summer average up much higher, as compared to the winter average, than it is on the coast. Farther inland the summer precipitation is found to exceed the winter precipitation. In this particular case, then, there is evidence of the two controls, the oceanic with a winter maximum and the continental with a summer maximum. The former is more pronounced because of the proximity to the Pacific coast.

The snowfall throughout the basin varies from 426 inches a year at Snoqualmie Pass to 10 inches a year at Kennewick. The highest recorded snowfall for any winter season occurred during the winter of 1912–13 at Snoqualmie Pass and amounted to 540 inches, or 45 feet. The largest yearly fall recorded for Lake Keechelus is 293 inches, or 24.4 feet, while the largest fall ever recorded at Kennewick is 19.3 inches, or about 1.6 feet. Occasionally at Kennewick a winter will pass with only a trace of snow, so scattered through the winter months that little collects to cover the surface. Snowfall at the mountain stations occurs commonly during eight months of the year, but the greater part of the fall is confined to the three winter months. In the upper valleys, especially where protected by vegetation and the position of the valley, snow stays on the ground until late in the summer, and in a few of the higher valleys there is perpetual snow or regular ice fields. This snow is an important factor in the storage of water and causes the high water to occur in June, or when the irrigation season is far advanced. High water is caused earlier at times by heavy warm rains or heavy rains occurring when the ground is still frozen, thus causing immediate run-off.

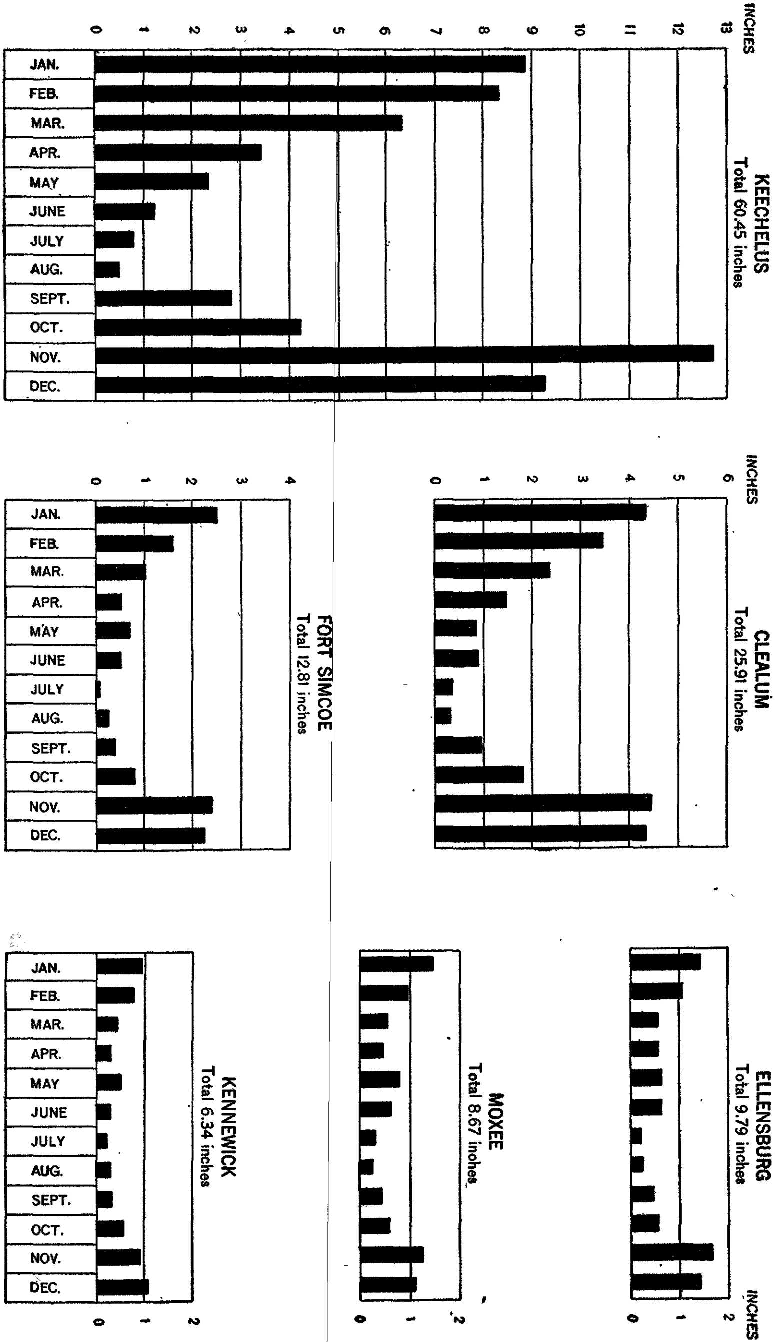


FIGURE 2.—Diagram showing average monthly precipitation at points in Yakima River basin.

TEMPERATURE.

The mean annual temperature of the Yakima basin is 49°, but this mean is not indicative of the effective temperature throughout the year, an adequate idea of which can be obtained only by studying the annual, monthly, and daily ranges.

The average temperature of the coldest month ranges from 25.3° at Ellensburg to 31.2° at Kennewick, with an average for the various stations of about 29°. The average temperature for the warmest month ranges from 63.8° at Clealum to 77.6° at Kennewick, thus giving an average for the basin of about 70°. Hence, the average yearly range is 41°, or double that of western Washington, where the range is 20° between summer and winter, or from 40° to 60°.

The highest and lowest temperatures recorded often show an absolute annual range of 120°, or from −20° to 100°, and temperatures as low as 28° below zero and as high as 115° have been recorded in the valley. These extremes occur at rare intervals, however, and on account of the low humidity of the air are not so unbearable as they would be in moist air. During the warmest weather the evenings are cool and pleasant, and during the coldest the days are bright and clear.

The cold wave of winter and the warm wave of summer are both due to the presence of a well-developed high pressure farther east, in the first case causing the cold air from the interior, and in the second causing the warm air from the interior to move over this section. Both are frequently broken up by winds from the west and south, warm in the winter and cool in the summer.

The daily range of temperature is high in both summer and winter, often showing changes of 45° to 50° in 24 hours.

The wide annual, monthly, and daily ranges of temperature are explained first by the very slight moderating influence exerted by the ocean winds because of the Cascade Mountains; second, by the fact that this section, lacking the protection of the Cascades, is subject to continental extremes of temperature; third, by the fact that the dry, clear air allows rapid radiation of heat during the night and during the winter, thus increasing the daily and annual ranges of temperature.

The following table indicates the relative average precipitation, snowfall, clear and cloudy days, and days without frost at different elevations. The data have been prepared from climatologic records of the United States Weather Bureau:

Relative average precipitation, snow fall, clear and cloudy days, and days without frost at different elevations in Yakima basin.

Station.	Elevation (feet).	Total precipitation (inches).	Snow-fall (inches)	Days with rain.	Clear days.	Latest frost.	Earliest frost.	Days without frost.
Lake Keechelus	2,480	60.45	240.5	120	100	....	....	....
Clealum	1,930	25.91	95.0	116	130	June 9	Sept. 7	90
Ellensburg	1,570	9.79	29.2	61	205	May 23	Sept. 21	121
Moxee, near North Yakima	1,000	8.67	22.0	59	170	May 23	Sept. 21	121
Sunnyside	740	6.65	8.2	50	186	May 7	Oct. 8	154
Kennewick	367	6.34	10.8	48	193	Apr. 28	Oct. 15	170

KILLING FROSTS.

From the dates at which the earliest killing frosts in the fall and the latest killing frosts in the spring have occurred at the different stations, the average dates at which frosts may be expected are worked out as shown in the foregoing table. The actual date of first or last frost usually accompanying a well-developed anticyclonic area will, of course, vary considerably from year to year, but the table shows approximately the dates at which first and last frosts may be expected.

The earliest frosts in the fall may be expected at Clealum as early as September 7, but at Kennewick not until October 15. Frosts have occurred as early as August 12 at Clealum and as early as September 25 at Kennewick. The latest frosts in the spring may be expected at Clealum about June 9 and at Kennewick about May 1, but frosts have occurred at Clealum as late as July 26 and at Kennewick as late as May 25.

WINDS.

Owing to irregularities in topography, the prevailing direction of the wind varies slightly for different stations, but in general the winds blow from the northwest and west. During the fall and spring, and occasionally during the summer, the winds are strong and disagreeably cool and dry as they blow down the valley, raising clouds of sand and dust. After several warm days the air moves down the eastern slope of the mountains, and these winds may continue to blow for several days at a time, often attaining a velocity of 30 or 40 miles an hour. When they first begin, usually about noon or late in the afternoon, the temperature will fall from 10° to 30° in a short time. Such winds are quite a relief after a few real hot summer days, which they usually follow.

During the winter months there is very little strong wind, but occasionally, after the passage of a cyclonic area to the east, the air moving into it from the south and southwest moves down the eastern slope of the Cascades and is warmed dynamically by increased pressure due to its forced descent. Having lost most of its moisture as it passed over the mountains, it blows over the valleys east of the mountains as a warm, dry wind called the "chinook," often causing the sudden breaking up of a cold, stormy spell of weather and rapidly melting any snow or ice that may be present.

SUMMARY.

The climate of this section seems to be the result of a combination of oceanic, continental, and mountain climatic characteristics. The high temperatures of summer, the low temperatures of winter, and the summer maximum of rainfall in May and June, which is of immense importance to the agricultural sections of the country, are all characteristics of the climate of the interior. The winter maximum of rainfall and the fact that the summer warm waves and the winter cold waves are not as severe nor of as long duration as farther east are evidence of the oceanic influence. The clear, dry, exhilarating air and the strong mountain winds are the result of the situation on the east slope of the Cascade Mountains.

SETTLEMENT AND DEVELOPMENT OF YAKIMA RIVER BASIN.

By Philo M. Wheeler.

Probably the first white men who made Yakima Valley their home were Eugene Cassimir Chirrouse and Father D'Herbonner, who, in 1852, as representatives of the Bishop of Nisqually, established a Roman Catholic mission on Atanum Creek.

During the next 10 or 15 years a few persons drifted to the Yakima Valley from the Klickitat country, which had been originally occupied by people from the older settlements of Oregon. They were undoubtedly attracted by the comparatively mild climate and the excellent range the country afforded for cattle and horses, for great stretches of the bench lands were covered with bunch grass, and the bottom lands furnished excellent feeding grounds.

After the close of the Civil War, however, and especially after the opening of the first transcontinental railroad, in 1869, emigration to the Pacific coast increased and people began coming to the Yakima Valley in greater numbers.

Some doubt exists as to when and where irrigation was first practiced in Yakima Valley, but it is probable that the first recognized attempt at irrigation was made in 1867, when George Nelson constructed a ditch that diverted water from Naches River. In the following year a stock company of settlers started a small ditch, diverting from Naches River about a mile above the mouth. The work of construction was very slow, but the ditch was finally enlarged and developed into the Union canal.

In 1872 Lauber and Schanno made an attempt to irrigate the land around Yakima from Wide Hollow Creek, but the water supply failed when the snow went off. In the next year construction was started on a ditch from Naches River. The Schanno ditch was the first conduit of large size and public utility in the valley. It was 8 miles long and required much puddling, and as seepage losses were high the water was not brought to Yakima until 1875.

The areas watered by these small ditches were restricted to gardens and small orchards, with grain and hay fields in patches. Though these ventures in irrigation had proved satisfactory, greater development along this line did not begin until the early eighties.

The excellent range had made stock raising a very lucrative business, the most serious handicap being the necessity for providing feed for the winter months. Irrigation had made possible the raising of alfalfa, the value of which as a winter forage plant became evident during the winter of 1881, which was exceptionally severe. With increase in acreage devoted to growing this product, larger and more costly ditches were needed.

The construction of the Northern Pacific Railway, which had begun several years earlier, was completed as far as Yakima in December, 1884. Shortly afterward the rails were laid to North Yakima, which was established by the railway company at about that time. The company offered to move the buildings of all who wished from Yakima to the new town site. There was much opposition, but finally some 50 or 60 buildings were transferred, among them the courthouse and First National Bank. For several months the community was strung out along the road, with an increasing aggregation at one end and a decreasing group at the other. Business never ceased, however, although many a customer at the store or bank tied his horse to the sagebrush, transacted his business, and stepped from the building to find his mount a hundred yards down the road. The western terminus remained at North Yakima for two years, during which time important development took place in the surrounding country. Naturally, the products of the region found a market to the east, that being the path of least resistance.

The completion of the Cascade division to the coast exercised a much more powerful influence on the development of central Washington, rendering easily accessible the markets of the Puget Sound country and the ocean. Incidentally it spelled the decline of stock raising, for it became evident that the highest development of the Yakima country must be by way of irrigation.

The admission of Washington into the Union as a State in 1889 stimulated all industrial activities in the new Commonwealth to a great extent. Moreover, public attention was directed to the Yakima Valley in particular by the contention of Ellensburg and North Yakima for the location of the State capital, so that the splendid opportunities for profitable investment in the Yakima and Kittitas valleys were realized and larger irrigation enterprises were begun.

The irrigation of lands on the north side of Yakima River below Union Gap, which is now included in the Sunnyside unit of the Yakima project of the United States Reclamation Service, was one of the earliest of the larger schemes to be considered. The first survey of the Sunnyside canal was made in 1885, but construction was not actually begun until 1891, when a corporation, known as the Northern Pacific, Yakima & Kittitas Irrigation Co., began the excavation of a canal to divert water from Yakima River just below Union Gap. The main canal was built to the forty-second mile, and water was first delivered to the settlers in April, 1892. The operations on the Sunnyside canal were suspended in 1893 owing to the widespread financial depression, and after many difficulties the system passed into the hands of the Washington Irrigation Co., from whom the Government acquired it.

The Tieton scheme, involving the diversion of water from Tieton River to irrigate lands lying west of North Yakima, was first investigated in 1890. About that time an irrigation district law was passed by the State legislature, under which the Cowiche and Wide Hollow irrigation district was formed. On January 9, 1892, this district held an election and voted to issue bonds for a half million dollars for the construction of an irrigation system to take water out of Tieton River, by a canal 10.5 miles long, to irrigate about 46,000 acres of land west of North Yakima. About $4,000 was expended in investigations, but owing to failure to collect assessments for the survey work and the subsequent financial panic of 1893, the scheme was abandoned. Several other attempts were made to irrigate a portion of the lands included in this scheme, but actual development was brought about only by the United States Government through the Reclamation Service.

The earliest irrigation in Kittitas County was from small ditches, diverting from Manastash and Taneum creeks. In 1885 the Ellensburg Water Co. was incorporated and began the construction of the first large canal undertaken in Kittitas County. This is now known as the Town canal. Construction was slow, and after 10 miles of the ditch had been completed work was suspended until 1891.

Among the more important developments made about this time were the Yakima Valley (or Congdon) and the Selah Valley canals, both of which were completed in 1894. The construction of these two canals to irrigate valuable bench lands in the vicinity of North Yakima may be considered the beginning of the commercial fruit-growing industry in the valley, although some fruit was cultivated as early as 1870. The Yakima Valley canal, enlarged in 1903, covers some of the most valuable orchard land in the Northwest.

The Yakima Irrigation & Improvement Co. began the construction of the Kennewick canal in 1892 and completed it in 1894, but this canal was also involved in the financial difficulties following the panic of 1893. In 1902 it was entirely reconstructed, enlarged, and extended by the North Pacific Irrigation Co.

The Selah-Moxee canal, constructed in 1900, diverts from the east side of the Yakima River about 7 miles above North Yakima.

In 1902 a number of business men of Ellensburg organized a corporation known as the Cascade Canal Co. In 1903 contracts were let for the construction of the Cascade canal, and the work was completed in April, 1904. Filings were made on Lake Kachess, with the intention of constructing a low crib dam for storage, but the company subsequently disposed of this right to the Reclamation Service. The construction of the main canal embraced about 7 miles of flume and some 850 feet of tunnel.

The Grosscup canal, built in 1904 to irrigate lands on the farm of Mr. Grosscup, was later taken over by the Benton Water Co. and enlarged to cover 17,000 acres in what is known as "The Horn," between Yakima and Columbia rivers.

The year 1902 is a memorable one in the development of Yakima Valley, owing to the fact that during that year the reclamation act was passed, and the possibility of the Federal Government's taking over the comprehensive development of this section was first brought to the attention of its citizens. At that time approximately 121,000 acres of land were being irrigated by private canals in the valleys of Yakima River and its most important tributaries.

In response to a petition from the citizens of Yakima County to the Secretary of the Interior, dated January 28, 1903, setting forth the very favorable opportunities for construction, under the reclamation act, of a system for the irrigation of the lands now included in the Tieton unit, investigations were begun by the Reclamation Service which have resulted in large development.

Under the State law it was necessary to file an appropriation of water before beginning construction of an irrigation system. It had been the custom to make filings covering an amount far in excess of the appropriator's needs or ability to use, and in addition many filings were made with speculative intent. As a result the natural flow was over-appropriated, and it was evident that the time was not far distant when, owing to the constantly increasing demands, the supply would be insufficient during the low-water period. It was therefore apparent that further development of the irrigable lands of the valley would depend largely on two considerations:

1. A comprehensive treatment of the water-right situation, involving a cooperative effort among the various appropriators, with a view to determining their actual needs.
2. Investigations with a view to determining the most feasible opportunities for storing the flood waters of the various streams to supplement the low-water flow during the irrigation season.

These investigations were carried on by the Reclamation Service during 1903, 1904, and the early part of 1905, the general purpose being to determine the feasibility of undertaking extensive reclamation work. In gathering this information, particular attention was paid to the amount and source of water supply, amount of irrigable land, general status of water rights, and other features.

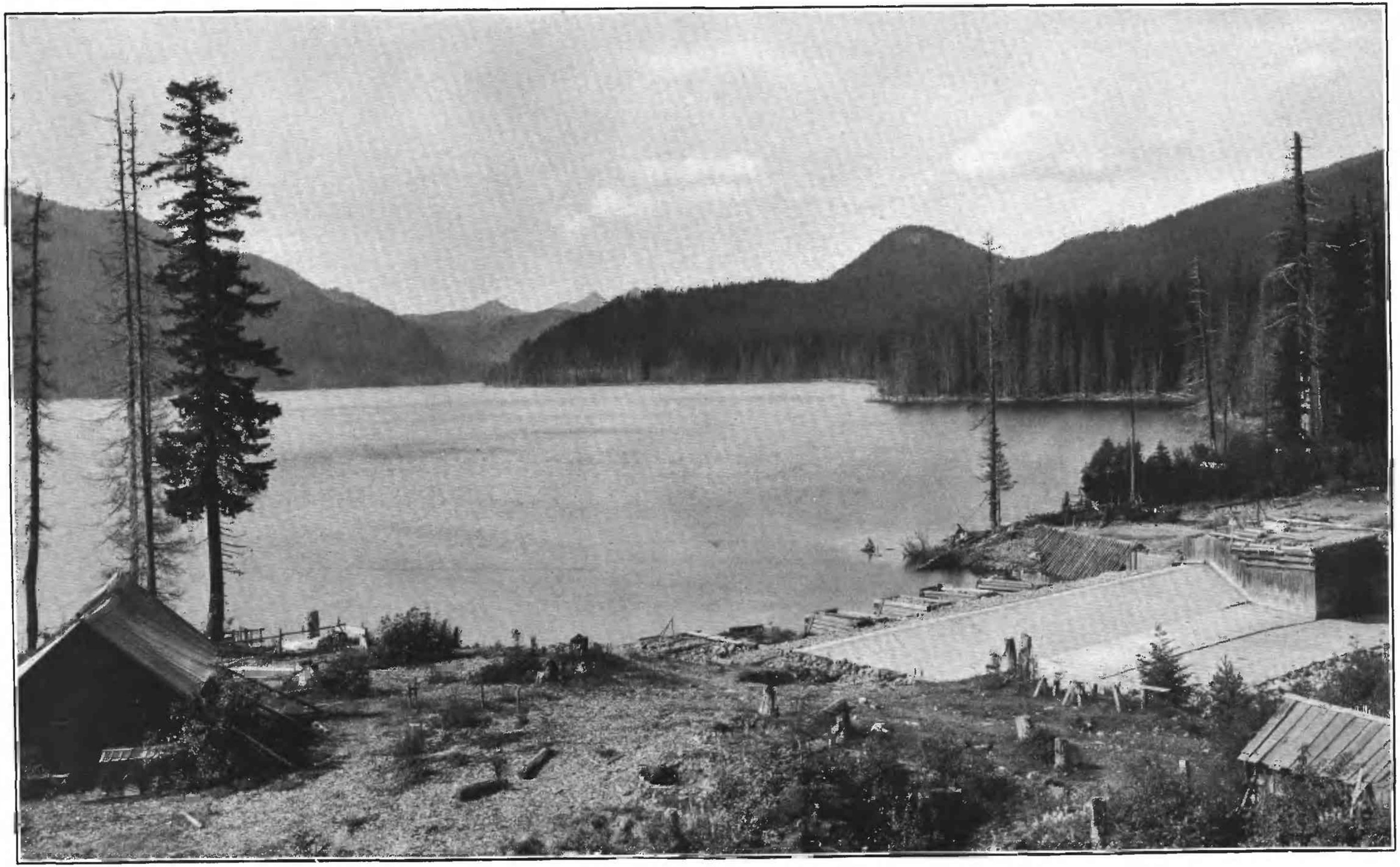
Early in 1905 a board of consulting engineers, with this material before it, considered the situation, and recommended that the United States enter upon the development of storage and the irrigation of lands in the Yakima Valley as soon and as extensively as funds would permit, providing an agreement was entered into by the various irrigators, limiting their claims.

Earnest efforts were made in the meantime to secure the passage of an act by the State legislature which would enable the United States to withdraw and control the unappropriated flood waters of the Yakima basin. This act was passed on March 4, 1905, and on May 4, 1905, and April 23, 1906, notices of intention to make examinations and surveys for the utilization of these waters were filed by the Reclamation Service with the State commissioner of public lands. On April 18 and December 17, 1906, certificates of feasibility of the projects mentioned in the former notices were filed with the commissioner. These notices had the effect of withdrawing from all forms of appropriation all unappropriated waters in Yakima River and its tributaries.

The settlement of the water rights was brought about largely through the realization that the entrance of the Reclamation Service into the valley was dependent on such a settlement. The required agreements were obtained in 1905 and the early part of 1906. They were voluntary and cover most of the principal canals diverting water from Yakima and Naches rivers.

By the middle of March, 1906, the signing of the agreements had advanced to so satisfactory a stage that the Secretary of the Interior considered that this requirement had been fully complied with, and accordingly authorized the commencement of construction.

To provide storage for use during the first years of the construction period, the Reclamation Service decided to construct temporary crib



KEECHELUS LAKE, SHOWING TEMPORARY CRIB DAM.

dams at the outlets of Lakes Keechelus (Pl. II and Pl. VII) and Clealum and to purchase the temporary dam which had been constructed by the Cascade Canal Co. at the outlet of Lake Kachess. Construction was carried on at Lake Keechelus during the fall of 1906 and the following winter and at Lake Clealum during 1907. The dam at Lake Keechelus afforded storage for about 15,000 acre-feet of water, and that at Lake Clealum for about 23,000 acre-feet.

A contract was entered into with the Cascade Canal Co., by the terms of which the company obtained a perpetual right to 16,800 acre-feet of storage during the irrigation season of each year. In return the company agreed to pay the United States $10,000 in five annual installments, and also conveyed to the United States all interest in the dam at Lake Kachess, which impounded about 19,000 acre-feet of water.

With the advent of the Reclamation Service into the valley the Washington Irrigation Co. submitted to the United States an option for the purchase of the Sunnyside Canal. After careful investigation this canal and irrigation system were purchased by the United States, and the work of enlarging and extending it was immediately begun. The system originally contemplated the irrigation of some 60,000 to 70,000 acres of land. At the time of purchase by the United States about 40,000 acres was being irrigated. The canal as originally constructed had an intake capacity of 750 second-feet. This has been increased to 1,076 second-feet, and the canal has been extended until its present length is approximately 60 miles (p. 136).

The work of enlargement and extension is now practically completed for serving lands under the gravity system, the total area that can be reached in this way amounting to about 90,000 acres. There yet remains the construction of several pumping plants to irrigate approximately 13,000 acres more.

As heretofore stated, the attention of the Government was attracted to the Tieton unit by a petition from the landowners. As soon as it was evident that the question of water rights would be satisfactorily adjusted the Tieton Water Users' Association was organized (Mar. 10, 1906), and during the same month preliminary surveys were commenced. Actual construction was begun the latter part of that year.

The main canal of the Tieton unit (Pl. III, A, and p. 138), which is 12 miles long, embodied many engineering difficulties and was necessarily very expensive, owing to its location on the precipitous side hill of Tieton Canyon. It was completed in 1909, and flood water was delivered to a portion of the irrigable lands in 1910. The completion of the distribution system required three years, so that water was not available for the last unit until the irrigation season of 1912.

POPULATION.

The remarkable growth in population in Yakima Valley is due almost entirely to extension and enlargement of agricultural pursuits. The following table, compiled from the United States census report for 1910, shows the growth of population in the three Yakima Valley counties since 1890.

Population of counties including Yakima Valley from 1890 to 1910.

County.	1890	1900	1910
Benton	(a)	(a)	7,937
Kittitas	8,777	9,704	18,561
Yakima	b 4,429	b 13,462	41,709
Total	13,206	23,166	68,207
Per cent increase in total	....	75	195

a Benton County was included in Yakima and Klickitat counties prior to the census of 1910.
b Includes population of a part of the area now included in Benton County.

It will be noted that the population in the Yakima Valley nearly trebled during the intercensal period 1900 to 1910.

TRANSPORTATION.

Two transcontinental lines cross Yakima Valley and make it possible to ship the valley products to all parts of the world and to receive supplies not produced locally.

The Northern Pacific Railway—the main trunk line of the region—crosses the Columbia at Kennewick near the mouth of Yakima River and follows the river very closely almost to the source. A short branch line connects the main line at Clealum with the coal fields in the vicinity of Roslyn and Ronald. Another branch line joins the main line near Toppenish and extends into the Sunnyside district, with a terminal at Grandview. A third branch line is being constructed from Toppenish into the Yakima Indian Reservation. The total length of Northern Pacific lines in the Yakima basin is about 200 miles.

The Chicago, Milwaukee & St. Paul Railway crosses the eastern half of the drainage basin near Ellensburg and parallels the river to the source at Snoqualmie Pass. It was put into operation in 1910, but opened up very little territory that had not already been served by the Northern Pacific Railway. The total length of line in the basin is about 80 miles.

A branch line of the Oregon-Washington Railroad & Navigation Co. connects North Yakima with Walla Walla and other points in the southeastern part of the State. Surveys have been run by this company for a line extending up Naches and American rivers, across the Cascade divide and down White River to Puget Sound.

Two local companies are operating transportation lines in the vicinity of North Yakima. The North Yakima & Valley Railroad extends from North Yakima to Naches and Moxee, and a line is being constructed into the Cowiche Valley; and the Yakima Valley Transportation Co. operates an electric service into the Selah, Atanum, and Wide Hollow districts.

WATER SUPPLY.

NATURAL CONDITIONS AFFECTING STREAM FLOW.

The natural factors affecting the yield and delivery of the water supply in the Yakima basin may be summarized briefly in order of the probable consequence of each influence as follows: Variable precipitation and climate, topography, structure of rocks and soils, soil, ground storage, natural lake storage, forestation, and glaciation. The impossibility of analyzing these influences accurately has been discussed fully by Stevens[1] and will not be given further space in this paper. It is thought that no other basin in the State presents such marked differences in run-off from different sections of the river system. The run-off of the low-lying parts of the area is negligible; the yield of the mountainous region is almost as great as that of some streams west of the Cascade Mountains. The natural lake storage and increased low-water flow from melting glaciers and snow fields at high elevations combine to maintain a fairly high run-off for several months after water is needed for irrigation on the arid lands in the lower valleys.

Floods on Yakima River result from the same causes that operate to produce the highest stages on other rivers heading in the Cascade Range. They are preceded by heavy snowfall in the mountains and are precipitated by chinooks, or warm winds, by which the snow is melted within a short period. This condition usually occurs in November and follows closely the fall rains. Two such floods are noteworthy, one in November, 1896, and the other in November, 1906, that of 1906 being considerably larger than the earlier flood. The discharge of Yakima River at Union Gap during the flood of 1906 was about three times greater than normal high-water flow.

The minimum flow is the result chiefly of small precipitation throughout the summer months followed by rather cold and dry weather in October, during which the water in the mountainous part of the drainage area freezes. The water in the streams at such times is derived almost wholly from ground water and natural storage in lakes. For the river system as a whole the minimum flow of which there is record occurred in October, 1907. Estimates of discharge for the Yakima at Union Gap indicate that the flow for this month was

[1] Stevens, J. C., Water powers of the Cascade Range, Part I: U. S. Geol. Survey Water-Supply Paper 253, pp. 14-23, 1910.

lower than for any other month between 1896 and 1912. Unfortunately the accuracy of the low-water estimates of Yakima River at Union Gap for October, 1907, is doubtful for the reason that the rating curve used at that time was poorly defined. It seems highly probable, however, that October, 1896, and October 1897, are the only two months since 1896 during which the river fell to a stage comparable to that of October, 1907.

The total yearly flow depends to a greater extent on total precipitation than on the other conditions mentioned. Some regulation is effected by ground-water storage, but such regulation is not so noticeable in the Yakima basin as in other basins in which the rocks are more porous and variations in elevation are less marked. The climatic year showing the greatest total run-off since 1896 appears to have been 1909–10, and it is noteworthy that the greatest flood on record did not occur during the year of maximum total run-off. The climatic years of greatest deficiency in total run-off since 1896 appear to have been 1904–5, 1905–6, 1908–9, and 1910–11, the smallest quantity of water having been delivered in 1908–9.

STREAM-FLOW RECORDS.

SCOPE AND CHARACTER.

Hydrometric investigations have been conducted in the Yakima basin since 1893, chiefly to obtain data essential to irrigation projects and to the regulation of water stored in reservoirs. Gaging stations maintained directly below each of the constructed and proposed Yakima project reservoirs and at intervals along the main stream and on principal tributaries give records showing the yield and indicate the extent to which the unstorable run-off can be utilized to meet the demands of irrigation. Measurements have also been made of the water carried by the numerous diversion ditches along the river system, thus supplementing the records of flow in the natural channels.

Every possible care has been exercised to render the stream-gaging work accurate and thoroughly reliable. The fact that the gaging stations are not spread over a very large territory and that most of them are easily accessible has been of material assistance in maintaining a high standard. The stream channels at most of the stations are permanent at all except very high stages. The rating curves are defined by numerous measurements and any inaccuracies in the records are more often ascribable to discrepancies in gage heights than in the rating curve.

The estimates of monthly discharge of the river and its principal tributaries above Union Gap, presented in the following pages, are based on observations of gage heights and measurements of flow. These are analyzed by the methods ordinarily used by the Geological Survey and have been fully described in pervious reports.[1] In addition to the monthly values derived from observational data, the tables include estimates of discharge, corrected for regulation by storage and for diversion above the gaging stations, in order to indicate the unaffected flow of the streams at the point of measurement. The earlier records have been revised only to correct large discrepancies shown by comparison of rating curves.

Information regarding the probable accuracy of the computed results and special features considered in interpreting the records is presented in footnotes to the tables. These notes, which are very general in character, are based on the plotting of individual measurements with reference to the mean rating curve and on information concerning the reliability of gage observers and other factors. The rating in the column in the monthly discharge tables headed "Accuracy" applies to the monthly mean and not to the maximum or minimum discharge nor to the discharge for any one day. It is derived from consideration of the accuracy of the rating curve, the probable reliability of gage observers, and knowledge of local conditions. In this column A indicates that the estimate of mean monthly flow is probably accurate within 5 per cent, B within 10 per cent, C within 15 per cent, and D within 25 per cent.

Data concerning the discharge of the river below Union Gap have little bearing on the ultimate regulation of the river. Moreover, the complexity of factors to be studied and the small gradient of the lower section of the river do not seem to warrant consideration of the power available, especially as power can be developed easily and at relatively small cost elsewhere in the region. An attempt, however, has been made to render all results as nearly comparable as possible, and for that reason it seemed desirable to correct the records at Union Gap for irrigation depletion. The methods used are described in detail on pages 50–55. The records below the three lakes on the upper Yakima and below Bumping Lake are rendered slightly incomparable by the fact that the record for the period preceding the regulation of the stream by storage represents the natural regimen of the streams with the natural storage. No records of stage were kept on the lakes to indicate the extent of the natural storage prior to regulation.

[1] Methods of conducting stream measurements and analyzing stream-flow records are discussed in the introductions to the papers entitled "Surface water supply of the United States" (U. S. Geol. Survey Water-Supply Papers 261-272, 281-292, and 301-312).

PUBLICATIONS.

The records of stream flow in the Yakima basin, from which the monthly estimates here presented have been derived, have been published annually by the United States Geological Survey as shown by the following table:

[NOTE.—B=Bulletin, W=Water-Supply Paper, A=Annual Report.]

1893	A. 14, pt. II, pp. 132–134
1894	B. 131, pp. 73–74
1893–1895	B. 140, pp. 244–247
1896	W. 11, pp. 84–85; A. 18, Pt. IV, pp. 355–358
1897	W. 16, pp. 173–175; A. 19, Pt. IV, pp. 479–480
1898	W. 28, pp. 164–165, 169–170; A. 20, Pt. IV, pp. 500–503
1899	W. 38, pp. 372–374; A. 21, Pt. IV, pp. 425–427
1900	W. 51, pp. 440–442; A. 22, Pt. IV, pp. 444–447
1901	W. 66, pp. 133–135
1902	W. 85, pp. 188–196
1903	W. 100, pp. 376–386
1904	W. 135, pp. 90–105
1905	W. 178, pp. 43–47, 78–90; W. 214, p. 46
1906	W. 214, pp. 41–46, 52–66; W. 252, pp. 139, 142, 145, 160, 167, 170, 175
1907–8	W. 252, pp. 135–149, 158–183
1909	W. 272, pp. 152–163, 170–212; W. 292, p. 163
1910	W. 292, pp. 150–163, 169–209
1911	W. 312, pp. 171–263
1912	W. 332–A, pp. 196–272

YAKIMA RIVER AT OUTLET OF KEECHELUS LAKE, NEAR MARTIN, WASH.

Location.—800 feet below dam at outlet of Keechelus Lake (Pl. II), 4 miles northwest of Martin and 12 miles northwest of Easton, Wash.

Records available.—October 18, 1903, to November 14, 1903; January 28, 1904, to October 31, 1912.

Drainage area.—55 square miles.[1]

Gage.—Vertical staff.

Channel.—Gravel; shifting in floods. Logs sometimes lodge on riffle control.

Discharge measurements.—Made from cable 200 feet below gage or by wading near gage.

Winter flow.—Not seriously affected by ice.

Regulation.—Flow partly regulated by operation of dam at Keechelus Lake reservoir. Results corrected for storage since January 12, 1906.

Accuracy.—Records good.

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[1] Revised measurement.

Estimated monthly discharge of Yakima River at outlet of Keechelus Lake, near Martin, Wash., 1904–1912.

[Drainage area, 55 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1904.							
February	194	127	156	2.84	8,970	3.06	A.
March	194	127	159	2.89	9,780	3.33	A.
April	880	127	499	9.07	29,700	10.12	C.
May	1,040	454	733	13.3	45,100	15.33	C.
June	1,040	528	785	14.3	46,700	15.95	C.
July	642	148	339	6.16	20,800	7.10	B.
August	148	76	103	1.87	6,330	2.16	A.
September	76	51	58.6	1.07	3,490	1.19	A.
October	76	51	69.4	1.26	4,240	1.45	A.
The period (274 days)					175,000		
1904–5.							
November	566	76	230	4.18	13,700	4.66	B.
December	604	194	339	6.16	20,800	7.10	B.
January	240	106	143	2.60	8,790	3.00	B.
February	240	90	124	2.25	6,890	2.34	B.
March	700	274	522	9.49	32,100	10.94	B.
April	950	208	419	7.61	24,900	8.49	B.
May	1,000	388	603	11.0	37,100	12.68	B.
June	977	310	534	9.71	31,800	10.83	B.
July	310	90	169	3.07	10,400	3.54	A.
August	90	67	79.7	1.45	4,900	1.67	A.
September	153	66	80.9	1.47	4,810	1.64	A.
October	734	153	430	7.81	26,400	9.00	A.
The year	1,000	66	307	5.58	223,000	75.89	

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1905–6.										
November	288	138	191	11,400	(a)	11,400	191	3.47	3.87	A.
December	254	138	173	10,600	(a)	10,600	173	3.15	3.63	A.
January	492	134	250	15,400	+ 1,360	16,800	273	4.96	5.72	A.
February	357	185	255	14,200	− 340	13,900	250	4.55	4.74	A.
March	263	161	200	12,300	− 29	12,300	200	3.64	4.20	A.
April	968	326	581	34,600	+ 2,080	36,700	616	11.2	12.50	A.
May	1,000	438	682	41,900	− 715	41,200	670	12.2	14.07	A.
June	565	306	416	24,800	− 1,000	23,800	400	7.27	8.11	A.
July	302	86	177	10,900	− 1,380	9,520	155	2.82	3.25	A.
August	83	56	67.3	4,140	− 603	3,540	57.5	1.05	1.21	A.
September	86	52	68.9	4,100	+ 56	4,160	69.9	1.27	1.42	A.
October	565	83	265	16,300	+ 2,720	19,000	309	5.61	6.47	A.
The year	1,000	52	277	201,000	+2,150	203,000	280	5.09	69.19	
1906–7.										
November	6,150	0	979	58,300	+ 1,080	59,400	999	18.2	20.31	B.
December	770	0	272	16,700	+ 4,520	21,200	346	6.29	7.25	A.
January [b]	986	0	249	15,300	− 3,770	11,500	187	3.40	3.92	A.
February [b]	1,360	0	490	27,200	+ 1,420	28,600	515	9.36	9.75	A.
March [b]	567	149	360	22,100	− 2,200	19,900	324	5.90	6.80	A.
April [b]	577	0	267	15,900	+ 6,310	22,200	373	6.78	7.56	A.
May	1,400	452	886	54,500	+ 6,960	61,500	1,000	18.2	20.98	A.
June	1,270	321	548	32,600	− 1,050	31,500	529	9.62	10.73	A.
July	348	88	168	10,300	− 242	10,100	164	2.98	3.44	A.
August	317	68	172	10,600	− 4,610	5,990	97.4	1.77	2.04	B.
September	291	0	130	7,740	− 2,280	5,460	89.1	1.62	1.81	B.
October	287	0	144	8,850	− 4,300	4,550	74.0	1.35	1.56	A.
The year	6,150	0	387	280,000	+ 1,840	282,000	389	7.07	96.15	

[a] Range of stage in Lake Keechelus not observed prior to Jan. 12, 1906.
[b] Estimates of daily discharge for Jan. 19 to Apr. 16 were obtained by distributing the flow while the gates were open over the entire 24 hours.

Estimated monthly discharge of Yakima River at outlet of Keechelus Lake, near Martin, Wash., 1904–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage.)		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1907–8.										
November	361	103	153	9,100	+ 5,400	14,500	244	4.44	4.95	A.
December	395	268	348	21,400	− 268	21,100	343	6.24	7.19	A.
January	366	169	265	16,300	− 4,680	11,600	189	3.44	3.97	A.
February	164	136	147	8,460	− 780	7,680	134	2.44	2.63	A.
March	979	0	319	19,600	+12,800	32,400	527	9.58	11.04	A.
April	1,430	0	466	27,700	+ 343	28,000	470	8.55	9.54	A.
May	1,010	479	695	42,700	− 281	42,400	690	12.5	14.41	A.
June	1,860	548	884	52,600	− 68	52,500	882	16.0	17.85	A.
July	667	180	463	28,500	− 955	27,500	447	8.13	9.37	A.
August	592	101	261	16,000	− 7,850	8,150	133	2.42	2.79	A.
September	452	99	190	11,300	− 7,000	4,300	72.2	1.31	1.46	B.
October	151	69	88.7	5,450	+ 3,510	8,960	146	2.65	3.06	B.
The year	1,860	0	357	259,000	+ 171	259,000	357	6.49	88.26	
1908–9.										
November	316	0	117	6,960	+ 6,950	13,900	234	4.25	4.74	B.
December	291	0	46.5	2,860	+ 4,580	7,440	121	2.20	2.54	A.
January	366	134	209	12,900	− 135	12,800	208	3.78	4.36	A.
February	255	125	162	9,000	− 60	8,940	161	2.93	3.05	A.
March	261	112	148	9,100	+ 285	9,380	153	2.78	3.20	A.
April	650	198	305	18,100	+ 435	18,500	311	5.65	6.30	A.
May	1,230	426	664	40,800	+ 936	41,700	678	12.3	14.18	A.
June	1,940	465	942	56,100	− 861	55,200	927	16.8	18.74	A.
July	525	144	308	18,900	− 885	18,000	293	5.33	6.14	B.
August	592	90	228	14,000	− 7,490	6,510	106	1.93	2.22	A.
September	335	116	204	12,100	− 5,690	6,410	108	1.96	2.19	A.
October	134	108	121	7,440	− 140	7,300	118	2.14	2.47	B.
The year	1,940	0	288	208,000	− 2,080	206,000	285	5.18	70.13	
1909–10.										
November	4,370	0	1,010	60,100	+16,700	76,800	1,290.0	23.5	26.22	A.
December	1,580	172	405	24,900	− 3,210	21,700	353	6.42	7.40	A.
January	467	88	179	11,000	+ 450	11,400	186	3.38	3.90	A.
February	781	123	167	9,280	− 330	8,950	161	2.93	3.05	A.
March	1,060	239	553	34,000	+ 270	34,300	558	10.1	11.64	A.
April	1,800	266	623	37,100	+ 495	37,600	632	11.5	12.83	A.
May	1,960	484	871	53,600	+ 215	53,800	875	15.9	18.33	A.
June	800	207	408	24,200	− 950	23,200	390	7.09	7.91	A.
July	201	80	138	8,480	− 570	7,910	129	2.35	2.71	A.
August	450	62	144	8,850	− 6,440	2,410	39.2	.713	.82	A.
September	303	76	178	10,600	− 6,060	4,540	76.3	1.39	1.55	A.
October	699	100	419	25,800	+ 1,890	27,700	450	8.19	9.44	A.
The year	4,370	0	425	308,000	+ 2,460	310,000	429	7.80	105.80	
1910–11.										
November	2,200	0	511	30,400	+ 8,950	39,400	662	12.0	13.39	A.
December	342	196	257	15,800	− 1,740	14,100	229	4.16	4.80	C.
January	193	3	130	7,990	+ 3,800	11,800	192	3.49	4.02	A.
February	127	80	103	5,720	− 180	5,540	99.8	1.82	1.90	A.
March	590	77	153	9,410	+ 360	9,770	159	2.89	3.33	A.
April	705	153	250	14,900	− 1,290	13,600	229	4.16	4.64	A.
May	1,050	32	539	33,100	+ 2,950	36,000	585	10.6	12.22	A.
June	1,360	318	686	40,800	− 1,450	39,400	662	12.0	13.39	A.
July	645	135	293	18,000	− 5,320	12,700	207	3.76	4.34	A.
August	358	100	199	12,200	− 8,760	3,440	55.9	1.02	1.18	A.
September	104	3	20.0	1,190	+ 7,740	8,930	150	2.73	3.05	C.
October	3	3	3.0	184	+ 4,880	5,060	82.3	1.50	1.73	D.
The year	2,200	0	262	190,000	+ 9,940	200,000	276	5.02	67.99	
1911–12.										
November	4,860	3	827	49,200	− 660	48,500	815	14.8	16.51	A.
December	510	3	105	6,460	+ 1,800	8,260	134	2.44	2.81	C.
January	871	135	298	18,300	+ 690	19,000	309	5.62	6.48	A.
February	430	38	253	14,600	− 795	13,800	240	4.36	4.70	A.
March	204	95	122	7,500	+ 105	7,600	124	2.25	2.59	A.
April	435	196	288	17,100	+ 600	17,700	297	5.40	6.03	A.
May	1,610	412	917	56,400	− 1,100	55,300	899	16.3	18.79	A.
June	1,350	275	614	36,500	− 15	36,500	613	11.1	12.40	A.
July	282	92	173	10,600	+ 120	10,700	174	3.16	3.64	A.
August	545	106	248	15,200	− 9,070	6,130	99.7	1.81	2.09	A.
September	398	3	151	8,980	− 2,160	6,820	115	2.09	2.33	B.
October	416	5	127	7,810	+ 1,020	8,830	144	2.62	3.02	B.
The year	4,860	3	343	249,000	− 9,460	239,000	330	6.00	81.39	

YAKIMA RIVER AT EASTON, WASH.

Location.—In sec. 11, T. 20 N., R. 13 E., at highway bridge at Easton, 1½ miles below Kachess River and one-half mile below proposed intake of Kittitas High Line canal. (See p. 147.)

Records available.—May 12 to November 28, 1904; February 5, 1910, to October 31, 1912.

Drainage area.—184 square miles.

Gage.—Chain gage fastened to downstream guardrail of bridge. Prior to November 28, 1904, vertical staff gage 20 feet below bridge.

Channel.—Gravel; shifting in floods.

Discharge measurements.—Made from highway bridge or by wading near gage.

Winter flow.—Not affected by ice.

Regulation.—Flow partly regulated by operation of dams at Keechelus and Kachess reservoirs. Records corrected for storage.

Accuracy.—Records good.

Estimated monthly discharge of Yakima River at Easton, Wash., 1904, 1910–1912.

[Drainage area, 184 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Total in acre-feet.	Depth in inches on the drainage area.	
1904.							
May 12–31	2,680	1,230	1,970	10.7	78,300	7.56	B.
June	2,810	910	1,870	10.2	111,000	11.38	B.
July	1,230	402	690	3.75	42,400	4.32	A.
August	428	185	316	1.72	19,400	1.98	A.
September	337	175	311	1.69	18,500	1.89	A.
October	324	195	257	1.40	15,800	1.61	A.
November 1–28	910	175	357	1.94	19,800		A.
The period					305,000		

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1910.										
February 5–28	620	364	467	22,200	− 195	22,000	462	2.51	2.24	B.
March	3,180	882	1,740	107,000	+ 4,960	112,000	1,820	9.90	11.41	A.
April	4,360	1,260	2,030	121,000	+ 5,220	126,000	2,120	11.5	12.80	A.
May	4,200	1,700	2,490	153,000	− 2,760	150,000	2,440	13.3	15.33	A.
June	1,750	330	913	54,300	+ 1,500	55,800	938	5.10	5.69	A.
July	558	145	294	18,100	+ 690	18,800	306	1.66	1.91	B.
August	641	227	436	26,800	−19,800	7,000	114	.620	.71	A.
September	492	97	250	14,900	− 6,420	8,500	143	.778	.87	B.
October	1,150	114	753	46,300	+ 6,440	52,700	857	4.66	5.37	A.
The period				564,000	−10,400	553,000				
1910–11.										
November	3,220	336	1,280	76,200	+13,200	89,400	1,500	8.16	9.10	A.
December	1,120	424	646	39,700	− 7,440	32,300	525	2.85	3.29	A.
January	655	348	500	30,700	+ 2,820	33,500	545	2.96	3.41	A.
February	370	184	268	14,900	− 1,650	13,200	238	1.29	1.34	A.
March	920	202	396	24,300	+ 3,510	27,800	452	2.46	2.84	A.
April	1,420	620	828	49,300	+ 1,330	50,600	850	4.62	5.16	A.
May	2,090	803	1,330	81,800	+ 6,590	88,400	1,440	7.83	9.03	A.
June	2,580	551	1,140	67,800	+ 6,050	73,800	1,240	6.74	7.52	A.
July	1,220	443	568	34,900	− 9,460	25,400	413	2.24	2.58	A.
August	728	220	522	32,100	−20,000	12,100	197	1.07	1.23	A.
September	1,220	99	583	34,700	−13,500	21,200	356	1.93	2.15	A.
October	67	37	50.7	3,120	+ 7,880	11,000	179	.973	1.12	B.
The year	3,220	37	678	490,000	−10,700	479,000	663	3.60	48.77	

Estimated monthly discharge of Yakima River at Easton, Wash., 1904, 1910–1912—Con.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1911–12.										
November	5,900	59	1,170	69,600	+25,100	94,700	1,590	8.64	9.64	B.
December	5,500	495	1,050	64,600	−15,000	49,600	807	4.38	5.05	A.
January	1,810	303	800	49,200	+ 690	49,900	812	4.41	5.08	A.
February	1,350	295	844	48,500	−10,200	38,300	666	3.62	3.90	A.
March	801	177	536	33,000	−12,100	20,900	340	1.85	2.13	A.
April	1,450	801	1,030	61,300	− 1,500	59,800	1,010	5.49	6.12	A.
May	3,220	910	1,900	117,000	+36,000	153,000	2,490	13.5	15.56	A.
June	2,310	1,000	1,610	95,800	+ 1,060	96,900	1,630	8.86	9.88	A.
July	1,280	282	519	31,900	− 3,580	28,300	460	2.50	2.88	A.
August	1,430	493	879	54,000	−35,700	18,300	298	1.62	1.87	A.
September	868	60	402	23,900	−10,500	13,400	225	1.22	1.36	B.
October	505	210	309	19,000	− 2,610	16,400	267	1.45	1.67	B.
The year	5,900	59	920	668,000	−28,300	640,000	883	4.79	65.14	

YAKIMA RIVER AT CLEALUM, WASH.

Location.—In sec. 27, T. 20 N., R. 15 E., at highway bridge at Clealum, just above Roslyn Creek, 3 miles below Clealum River and 5 miles above Teanaway River.

Records available.—August 24, 1906, to October 31, 1912.

Drainage area.—500 square miles.

Gage.—Since August 12, 1910, an inclined staff on the right bank 30 feet below the bridge. A Friez automatic gage has been referred to inclined gage since July 12, 1911. Prior to August 12, 1910, a chain gage on the bridge.

Channel.—Rock and gravel; shifting in extreme floods.

Discharge measurements.—Made from highway bridge.

Winter flow.—Not seriously affected by ice.

Regulation.—Flow affected by operation of dams at Kachess, Keechelus, and Clealum reservoirs. Results corrected for storage.

Accuracy.—Records good.

Estimated monthly discharge of Yakima River at Clealum, Wash., 1906–1912.

[Drainage area, 500 square miles.]

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1906.										
August 24–30	505	472	501	7,950	....	....	....	....	....	
September	505	440	484	28,800	− 2,490	26,300	442	0.884	0.99	A.
October	6,620	472	1,420	87,300	+13,000	100,000	1,630	3.26	3.76	A.
The period	....	....	....	....	....	126,000	....	....	....	

Estimated monthly discharge of Yakima River at Clealum, Wash., 1906–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per spuare mile.		
1906–7.										
November	[a]25,600	981	[b]5,580	332,000	+ 5,200	337,000	[b]5,660	11.3	12.61	B.
December	....	....	[b]1,400	86,000	− 3,630	82,400	[b]1,340	2.68	3.09	B.
January	1,640	713	1,060	65,200	− 5,620	59,600	969	1.94	2.24	A.
February	3,790	688	1,920	107,000	+ 4,160	111,000	2,000	4.00	4.16	A.
March	1,850	970	1,310	80,600	− 7,250	73,400	1,190	2.38	2.74	A.
April	4,010	1,020	2,430	145,000	+17,900	163,000	2,740	5.48	6.11	A.
May	8,860	3,350	6,570	404,000	+16,500	420,000	6,830	13.7	15.79	A.
June	7,950	1,780	3,350	199,000	− 396	199,000	3,340	6.68	7.45	A.
July	2,060	569	1,170	71,900	− 2,970	68,900	1,120	2.24	2.58	A.
August	779	394	644	39,600	−10,100	29,500	480	.960	1.11	A.
September	765	408	593	35,300	− 9,720	25,600	430	.860	.96	A.
October	536	357	445	27,400	−11,400	16,000	260	.520	.60	A.
The year	[a]25,600	394	2,200	1,590,000	− 7,330	1,590,000	2,200	4.40	59.44	
1907–8.										
November	1,210	332	519	30,900	+11,400	42,300	711	1.42	1.58	A.
December	1,520	910	1,220	75,000	+ 2,130	77,100	1,250	2.50	2.88	A.
January	1,180	592	858	52,800	−10,900	41,900	681	1.36	1.57	A.
February	682	510	565	32,500	− 1,130	31,400	546	1.09	1.18	A.
March	5,350	452	2,180	134,000	+40,500	174,000	2,830	5.66	6.52	A.
April	7,360	1,670	3,460	206,000	+ 4,170	210,000	3,530	7.06	7.88	A.
May	5,980	3,510	4,760	293,000	+ 8,690	302,000	4,910	9.82	11.32	A.
June	9,480	2,800	5,290	315,000	+ 542	316,000	5,310	10.6	11.83	A.
July	5,620	1,140	3,050	188,000	− 4,080	184,000	2,990	5.98	6.89	A.
August	1,360	910	1,080	66,400	−21,200	45,200	735	1.47	1.70	A.
September	1,210	439	783	46,600	−23,000	23,600	397	.794	.89	A.
October	610	280	441	27,100	+ 1,570	28,700	467	.934	1.08	A.
The year	9,480	280	2,030	1,470,000	+ 8,700	1,480,000	2,040	4.08	55.32	
1908–9.										
November	1,520	368	712	42,400	+23,000	65,400	1,100	2.20	2.46	A.
December	1,000	485	650	40,000	+ 3,390	43,400	706	1.41	1.63	A.
January	965	598	755	46,400	− 1,000	45,400	738	1.48	1.71	A.
February	848	478	609	33,800	− 370	33,400	601	1.20	1.25	A.
March	1,750	554	890	54,700	+ 2,940	57,600	937	1.87	2.16	A.
April	3,490	1,330	2,080	124,000	+ 4,720	129,000	2,170	4.34	4.84	A.
May	6,300	2,920	3,820	235,000	+ 7,580	243,000	3,950	7.90	9.11	A.
June	9,720	2,560	5,080	302,000	+ 4,260	306,000	5,140	10.3	11.49	A.
July	2,780	1,160	1,780	109,000	− 6,440	103,000	1,680	3.36	3.87	A.
August	1,240	864	1,120	68,900	−33,100	35,800	582	1.16	1.34	A.
September	988	461	672	40,000	−11,500	28,500	479	.958	1.07	A.
October	579	425	495	30,400	− 1,580	28,800	468	.936	1.08	A.
The year	9,720	368	1,560	1,130,000	− 8,100	1,120,000	1,550	3.10	42.01	
1909–10.										
November	17,300	495	4,740	282,000	+65,600	348,000	5,850	11.7	13.05	A.
December	12,700	1,510	3,060	188,000	−36,300	152,000	2,470	4.94	5.70	A.
January	1,620	922	1,260	77,500	− 5,680	71,800	1,170	2.34	2.70	A.
February	1,420	938	1,080	60,000	− 490	59,500	1,070	2.14	2.23	A.
March	8,100	1,450	3,820	235,000	+18,700	254,000	4,130	8.26	9.52	A.
April	11,600	2,740	4,960	295,000	+ 7,020	302,000	5,080	10.2	11.38	A.
May	10,000	3,900	5,600	344,000	− 2,520	341,000	5,550	11.1	12.80	A.
June	4,480	1,350	2,520	150,000	− 540	149,000	2,500	5.00	5.58	A.
July	1,330	785	1,080	66,400	− 510	65,900	1,070	2.14	2.47	A.
August	1,490	800	1,050	64,600	−41,200	23,400	381	.762	.88	A.
September [c]	804	330	514	30,600	− 7,450	23,000	387	.774	.86	A.
October [c]	2,390	338	1,670	103,000	+20,700	124,000	2,020	4.04	4.66	A.
The year	17,300	330	2,630	1,900,000	+17,300	1,910,000	2,640	5.28	71.83	

[a] Estimated.
[b] Mean natural discharge taken as 25 per cent greater than combined natural discharge at Martin, Easton, and Roslyn, and the actual flow at the station computed from these values.
[c] The discharge has been revised from the original data.

Estimated monthly discharge of Yakima River at Clealum, Wash., 1906–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1910-11.										
November	10,000	1,340	3,000	179,000	+18,300	197,000	3,310	6.62	7.39	A.
December	2,390	1,040	1,530	94,100	−23,400	70,700	1,150	2.30	2.65	A.
January	1,220	680	910	56,000	+12,900	68,900	1,120	2.24	2.58	A.
February	692	470	564	31,300	+ 1,230	32,500	585	1.17	1.22	A.
March	2,420	428	1,010	62,100	+10,600	72,700	1,180	2.36	2.72	A.
April	3,920	1,560	2,280	136,000	+ 2,770	139,000	2,340	4.68	5.22	A.
May	5,120	2,560	3,560	219,000	+ 8,270	227,000	3,690	7.38	8.51	A.
June	7,380	2,020	3,870	230,000	+ 3,290	233,000	3,920	7.84	8.75	A.
July	1,960	1,030	1,530	94,100	−17,800	76,300	1,240	2.48	2.86	A.
August	1,560	752	1,010	62,100	−33,200	28,900	470	.940	1.08	A.
September	846	196	667	39,700	+ 1,240	40,900	687	1.37	1.53	A.
October	604	269	488	30,000	− 8,920	21,100	343	.686	.79	A.
The year	10,000	196	1,700	1,230,000	−24,700	1,210,000	1,670	3.36	45.30	
1911-12.										
November	9,410	242	2,410	143,000	+44,700	188,000	3,160	6.32	7.05	A.
December	2,280	1,120	1,560	95,900	−12,800	83,100	1,350	2.70	3.11	A.
January	2,630	742	1,480	91,000	+ 1,650	92,600	1,510	3.02	3.48	A.
February	2,270	1,260	1,680	96,600	−11,400	85,200	1,480	2.96	3.19	A.
March	1,770	615	1,050	64,600	−10,700	53,900	877	1.75	2.02	A.
April	3,410	1,900	2,500	149,000	+ 60	149,000	2,500	5.00	5.58	A.
May	8,650	2,940	5,180	319,000	+36,600	355,000	5,770	11.6	13.37	A.
June	5,840	2,640	4,030	240,000	− 495	240,000	4,030	8.06	8.99	A.
July	2,440	1,020	1,320	81,200	− 5,860	75,300	1,220	2.44	2.81	A.
August	1,730	1,020	1,270	78,100	−43,400	34,700	564	1.13	1.30	A.
September	1,310	500	889	52,900	−23,700	29,200	491	.982	1.10	A.
October	664	366	513	31,500	− 2,970	28,500	464	.928	1.07	A.
The year	9,410	242	1,980	1,440,000	−28,300	1,410,000	1,950	3.91	53.07	

YAKIMA RIVER AT UMTANUM, WASH.

Location.—In sec. 20, T. 16 N., R. 19 E. (unsurveyed), at Umtanum, in Yakima Canyon, half a mile above Umptanum Creek, and 13 miles south of Ellensburg.

Records available.—August 25, 1906, to May 20, 1907; August 10, 1907, to October 31, 1912.

Drainage area.—1,620 square miles.[1]

Gage.—Since June 26, 1908, cantilever chain gage, to which a Barrett-Lawrence automatic gage has been referred since September 28, 1911. Prior to June 26, 1908, staff gage in several sections at same datum.

Channel.—Rocks, gravel, and silt; shifting.

Discharge measurements.—Made from cable near gage.

Winter flow.—Not seriously affected by ice.

Regulation.—Flow affected by operation of dams at Keechelus, Kachess, and Clealum reservoirs.

Diversions.—Below all return waters from irrigation in Kittitas Valley and above all diversions for the Selah and Moxee valleys.

Accuracy.—Records good.

[1] Revised measurement.

Estimated monthly discharge of Yakima River at Umtanum, Wash., 1906–1912.

[Drainage area, 1,620 square miles.]

Month.	Observed discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1906.					
August 25–31	369	290	326	4,530	
September	502	302	368	21,900	A.
October	6,080	470	1,370	84,200	A.
The period				111,000	
1906–7.					
November	41,000	1,260	8,980	534,000	C.
December	4,660	1,690	2,570	158,000	A.
January [a]			1,590	97,800	C.
February [a]	5,470		3,490	194,000	B.
March	4,200	1,900	2,740	168,000	A.
April	8,010	1,740	4,450	265,000	A.
May [b]		5,060	8,420	518,000	B.
June [c]			3,520	209,000	B.
July [d]			1,170	71,900	B.
August [e]	770	398	577	35,500	A.
September	850	494	691	41,100	A.
October	676	478	554	34,100	A.
The period	41,000	478	3,220	2,330,000	
1907–8.					
November	1,360	494	676	40,200	A.
December	1,900	1,130	1,480	91,000	A.
January	1,500	910	1,160	71,300	A.
February	1,030	790	880	50,600	A.
March	9,290	910	3,440	212,000	A.
April	9,660	2,460	4,740	282,000	A.
May	6,970	4,450	5,730	352,000	A.
June	9,660	3,100	5,400	321,000	A.
July	5,200	1,260	3,060	188,000	A.
August	1,200	810	979	60,200	A.
September	1,130	510	770	45,800	A.
October	712	390	510	31,400	A.
The year	9,660	390	2,410	1,750,000	
1908–9.					
November	1,640	542	864	51,400	A.
December	1,130	658	813	50,000	A.
January [f]			886	54,500	C.
February [f]	2,030		942	52,300	B.
March	2,790	850	1,350	83,000	A.
April	4,260	2,030	2,840	169,000	A.
May	7,180	3,370	5,060	311,000	A.
June	10,300	2,380	5,420	323,000	A.
July	2,560	950	1,640	101,000	A.
August	1,060	750	900	55,300	A.
September	750	410	547	32,500	B.
October	705	490	583	35,800	B.
The year	10,300	410	1,820	1,320,000	
1909–10.					
November	24,500	678	6,880	409,000	B.
December	18,700	1,510	3,820	235,000	B.
January	2,680	990	1,500	92,200	B.
February	1,890	990	1,320	73,300	B.
March	16,700	3,520	7,840	482,000	B.
April	15,000	4,650	7,420	442,000	A.
May	11,400	4,260	6,800	418,000	A.
June	4,910	1,280	2,690	160,000	A.
July	1,240	604	992	61,000	A.
August	1,270	622	917	56,400	A.
September	765	358	503	29,900	A.
October	2,510	365	1,590	97,800	A.
The year	24,500	358	3,540	2,560,000	

[a] River was ice affected Jan. 1 to Feb. 9. Discharge estimate one and one-half times that of Yakima at Clealum.
[b] No gage heights reported from May 20 to May 31. Discharge estimated as one and one-fourth that of Yakima at Clealum.
[c] No gage heights reported. Discharge estimated as 1.05 that of Yakima at Clealum.
[d] No gage heights reported. Discharge estimated same as Yakima at Clealum.
[e] No gage heights reported from Aug. 1 to 9. Discharge estimated as 90 per cent of that of Yakima at Clealum.
[f] Discharges from Jan. 10 to Feb. 6 estimated by comparison with Yakima at Clealum.

Estimated monthly discharge of Yakima River at Umtanum, Wash., 1906–1912—Contd.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1910–11.					
November	10,200	1,600	3,340	199,000	A.
December	2,930	1,490	2,000	123,000	A.
January	1,350	825	1,170	71,900	B.
February	815	577	669	37,200	B.
March	3,250	568	1,560	95,900	B.
April	4,670	1,420	2,720	162,000	A.
May	5,330	2,650	3,810	234,000	A.
June	7,330	2,000	4,070	242,000	A.
July	2,000	1,060	1,440	88,500	A.
August	1,100	630	837	51,500	A.
September	1,050	359	818	48,700	A.
October	725	413	622	38,200	A.
The year	10,200	359	1,920	1,390,000	
1911–12.					
November	11,600	427	2,690	160,000	A.
December	2,600	1,500	1,920	118,000	A.
January	3,440	970	1,860	114,000	A.
February	3,440	1,880	2,460	142,000	A.
March	2,380	1,150	1,510	92,800	A.
April	5,920	3,260	3,910	233,000	A.
May	10,700	4,050	6,780	417,000	A.
June	5,830	2,820	4,180	249,000	A.
July	2,680	970	1,320	81,200	A.
August	1,340	1,070	1,160	71,300	A.
September	1,460	500	958	57,000	A.
October	850	450	596	36,600	A.
The year	11,600	427	2,440	1,770,000	

YAKIMA RIVER AT SELAH GAP, NEAR NORTH YAKIMA, WASH.

Location.—In sec. 12, T. 13 N., R. 18 E., one-fourth mile above Naches River and 1½ miles north of North Yakima.

Records available.—May 9 to October 31, 1904; July 1 to October 15, 1911; July 7 to September 30, 1912.

Drainage area.—2,150 square miles.[1]

Gage.—Vertical staff.

Channel.—Rocks and gravel; shifting at high stages.

Discharge measurements.—Made from bridge at gage, from a new highway bridge half a mile above the gage, or by wading 300 feet below the gage.

Regulation.—Flow affected by operation of dams at Keechelus, Kachess, and Clealum reservoirs.

Diversions.—Below all diversions for Kittitas and Selah valleys. The Selah-Moxee canal diverts water past the gage.

Accuracy.—Records good.

[1] Revised measurement.

Estimated monthly discharge of Yakima River at Selah Gap, near North Yakima, Wash., 1904, 1911, and 1912.

[Drainage area, 2,150 square miles.]

Month.	Observed discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1904.					
May 9-31	9,650	4,820	6,900	315,000	B.
June	8,170	3,500	5,700	340,000	B.
July	4,120	1,140	2,430	150,000	A.
August	1,140	441	663	40,800	A.
September	522	285	376	22,400	B.
October	690	522	608	37,400	A.
The period				906,000	
1911.					
July	2,100	967	1,400	86,100	A.
August	1,200	577	748	46,000	A.
September	1,010	480	755	44,900	A.
October 1-15	680	450	598	17,800	A.
The period				195,000	
1912.					
July 7-31	1,610	880	1,090	54,000	A.
August	1,400	960	1,100	67,600	A.
September	1,450	670	991	59,000	A.
The period				181,000	

YAKIMA RIVER AT UNION GAP, NEAR YAKIMA, WASH.

OBSERVED DISCHARGE.

Location.—In sec. 17, T. 12 N., R. 19 E., 600 feet below Atanum Creek, 600 feet above the intake of the New Reservation canal, and about 1 mile south of Yakima.

Records available.—Fragmentary records 1893 and 1894; August 19, 1895, to December 31, 1909; April 1, 1911, to October 31, 1912.

Drainage area.—3,550 square miles.[1]

Gage.—Since April 1, 1909, vertical and inclined staff, to which a Stevens automatic gage has been referred subsequent to July 29, 1912. Prior to December 31, 1909, several vertical staff gages referred to the same datum but differing from that of present gages.

Channel.—Gravel; shifting in floods. A secondary channel carries a small part of the flow at high stages.

Discharge measurements.—Made from cable at gage. Previous to 1908 made from cable 1,000 feet below old county bridge.

Winter flow.—Seriously affected by ice.

Regulation.—Flow affected by operation of dams at reservoirs and by irrigation above the station.

Diversions.—The Union Gap irrigation canal has diverted about 25 second-feet past the station since 1906.

Accuracy.—Records fair.

[1] Revised measurement.

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Monthly discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912.

[Drainage area, 3,550 square miles.]

Month.	Observed discharge in second-feet.			Observed run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1896.				
August	2,600	1,170	1,650	101,000
September	1,170	910	1,070	63,700
October	910	840	860	52,900
The period	....	....	....	218,000
1896–97.				
November	45,600	910	7,650	455,000
December	10,400	2,320	5,160	317,000
January	....	....	[a] 2,100	129,000
February	....	....	[a] 3,000	167,000
March	4,740	1,650	2,470	152,000
April	27,600	4,740	15,000	893,000
May	24,000	11,600	15,700	964,000
June	10,800	4,740	7,110	423,000
July	6,360	1,650	3,290	202,000
August	1,440	915	1,170	71,800
September	915	705	817	48,600
October	1,020	705	810	49,800
The year	45,600	705	5,340	3,870,000
1897–98.				
November	25,100	915	5,270	314,000
December	11,200	2,320	3,970	244,000
January	8,270	1,890	3,350	206,000
February	22,200	1,780	6,800	378,000
March	6,970	2,820	4,540	279,000
April	12,400	3,000	6,900	411,000
May	18,500	8,270	12,400	762,000
June	15,100	5,250	9,510	566,000
July	5,250	2,170	3,480	214,000
August	2,170	885	1,360	83,900
September	985	685	855	50,900
October	1,780	685	1,300	79,900
The year	25,100	685	4,960	3,590,000
1898–99.[b]				
November	2,640	1,320	1,970	117,000
December	10,100	985	1,990	122,000
January	10,400	1,770	4,660	287,000
February	7,940	3,390	4,770	265,000
March	3,810	2,170	2,780	171,000
April	6,360	2,320	4,210	251,000
May	13,800	4,500	9,390	577,000
June	18,400	10,800	14,100	839,000
July	10,800	5,310	8,470	521,000
August	5,310	2,600	3,720	229,000
September	2,600	1,640	2,000	119,000
October	3,170	1,390	1,980	122,000
The year	18,400	985	5,000	3,620,000
1899–1900.[c]				
November	13,200	2,420	5,290	315,000
December	15,500	2,250	6,670	410,000
January	21,400	4,060	8,910	548,000
February	4,800	3,170	3,850	214,000
March	11,200	3,600	7,280	448,000
April	11,600	4,800	7,500	446,000
May	10,400	3,830	6,870	422,000
June	4,800	2,970	3,910	233,000
July	2,780	1,170	1,720	106,000
August	1,170	790	942	57,900
September	1,390	910	1,120	66,600
October	6,410	990	2,260	139,000
The year	21,400	790	4,710	3,410,000
1900–1901.[c]				
November	4,300	2,970	3,580	213,000
December	13,700	4,300	6,950	427,000
January	8,270	2,780	4,400	271,000
February	10,400	2,090	3,780	210,000
March	23,900	4,220	8,390	516,000
April	5,950	3,980	5,080	302,000
May	19,500	6,550	11,400	701,000
June	15,900	5,950	8,480	505,000
July	5,950	2,810	4,430	272,000
August	2,660	1,230	1,770	109,000
September	1,450	1,020	1,200	71,400
October	1,230	1,070	920	65,800
The year	23,900	920	5,060	3,660,000
1901–2.[d]				
November	4,950	1,020	2,860	170,000
December	12,400	2,810	5,650	347,000
January	10,000	1,940	4,800	295,000
February	5,950	1,810	3,480	193,000
March	4,210	2,980	3,620	223,000
April	9,600	2,650	6,440	383,000
May	18,600	6,850	13,100	806,000
June	13,200	5,950	7,800	464,000
July	5,950	2,810	4,060	249,000
August	2,810	1,020	1,620	100,000
September	1,340	820	925	55,000
October	1,450	1,020	1,200	73,500
The year	18,600	820	4,640	3,360,000
1902–3.				
November	3,160	1,230	2,120	126,000
December	4,950	1,810	2,870	176,000
January	20,000	2,500	6,980	429,000
February	3,550	2,350	2,620	145,000
March	9,200	2,350	3,460	213,000
April	10,000	4,210	6,420	382,000
May	17,700	8,500	12,700	781,000
June	26,200	11,200	19,200	1,140,000
July	12,800	2,650	5,500	338,000
August	2,650	920	1,500	92,300
September	1,940	820	1,450	86,000
October	5,700	1,810	3,670	226,000
The year	26,200	820	5,700	4,130,000
1903–4.[e]				
November	8,500	2,500	3,920	233,000
December	11,600	2,650	5,030	309,000
January	5,200	1,940	3,170	195,000
February	2,660	1,820	2,190	126,000
March	6,850	1,690	3,150	194,000
April	27,900	2,980	16,400	976,000
May	21,300	9,170	14,400	886,000
June	16,400	7,030	11,500	681,000
July	8,440	2,180	4,940	304,000
August	2,050	920	1,290	79,100
September	960	800	868	51,600
October	1,180	920	1,040	63,700
The year	27,900	800	5,650	4,100,000

[a] Estimated.
[b] Discharge estimate from January to October revised from original data.
[c] Discharge estimate revised from original data.
[d] Discharge estimate for November and December revised from original data.
[e] Discharge estimate from January to April revised from original data.

Monthly discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912—Continued.

Month.	Observed discharge in second-feet.			Observed run-off in acre-feet.	Month.	Observed discharge in second-feet.			Observed run-off in acre-feet.
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
1904–5.					1908–9.[c]				
November	4,520	920	2,080	124,000	November	3,200	1,140	2,100	125,000
December	3,830	2,040	2,780	171,000	December	2,020	1,160	1,610	99,000
January	2,180	1,280	1,830	113,000	January	3,360	1,470	2,010	124,000
February	3,620	920	1,730	95,900	February	3,670	1,390	1,860	103,000
March	9,550	3,830	7,540	463,000	March	4,100	1,460	2,190	135,000
April	9,930	3,420	4,750	283,000	April	5,980	3,160	4,320	257,000
May	7,720	3,830	4,930	303,000	May	11,500	4,960	7,350	452,000
June	14,700	5,310	8,320	495,000	June	17,000	4,740	9,770	581,000
July	5,900	1,290	2,710	167,000	July	5,040	1,750	3,240	199,000
August	1,290	795	922	56,700	August	1,740	1,020	1,300	79,900
September	1,180	795	904	53,800	September	1,080	769	919	54,700
October	5,750	1,290	3,200	197,000	October	1,240	991	1,110	68,200
The year	14,700	795	3,480	2,520,000	The year	17,000	769	3,150	2,280,000
1905–6.					1909–10.[d]				
November	2,670	1,520	1,880	112,000	November	33,400	([e])	8,800	524,000
December	2,100	1,400	1,700	105,000	December	27,000	2,800	6,520	401,000
January	4,260	1,180	1,820	112,000	January	6,140	1,930	3,170	195,000
February	5,030	2,500	3,880	215,000	February	4,330	2,180	2,930	163,000
March	5,600	2,670	3,480	214,000	March	28,300	4,350	14,000	861,000
April	13,800	7,590	9,900	589,000	April	25,200	8,070	12,600	750,000
May	12,100	4,260	7,910	486,000	May	20,800	8,970	12,200	750,000
June	7,240	3,020	4,410	262,000	June	9,970	2,980	5,780	344,000
July	3,810	965	1,970	121,000	July	2,900	1,030	2,070	127,000
August	795	635	694	42,700	August	1,390	1,000	1,120	68,900
September	760	635	705	42,000	September	965	672	841	50,000
October	8,650	725	2,220	136,000	October	4,050	839	2,700	166,000
The year	13,800	635	3,370	2,440,000	The year	33,400	672	6,080	4,400,000
1906–7.[a]					1910–11.				
November	63,900	2,180	12,400	738,000	November [f]	15,700	2,310	5,800	345,000
December	6,550	2,500	3,920	241,000	December [f]	5,620	2,390	3,430	211,000
January	3,400	1,640	2,430	149,000	January [f]	2,750	1,720	2,120	130,000
February	12,800	1,890	6,740	374,000	February [f]	1,720	1,120	1,410	78,300
March	7,670	3,350	5,040	310,000	March [f]	6,040	1,140	3,000	184,000
April	14,300	3,530	8,430	502,000	April	7,710	3,590	5,190	309,000
May	19,800	9,350	14,100	867,000	May	8,400	5,640	7,090	436,000
June	15,900	4,780	7,640	455,000	June	12,900	4,300	7,760	462,000
July	4,560	1,110	2,470	152,000	July	4,050	1,550	2,470	152,000
August	1,110	765	930	57,200	August	1,510	1,210	1,330	81,800
September	1,330	900	1,110	66,000	September	1,990	1,280	1,640	97,600
October	950	810	884	54,400	October	1,470	928	1,150	70,700
The year	63,900	765	5,480	3,970,000	The year	15,700	928	3,540	2,560,000
1907–8.[b]					1911–12.				
November	2,460	900	1,170	69,600	November	12,500	928	3,620	215,000
December	2,990	1,580	2,160	133,000	December	3,810	2,240	2,790	172,000
January	2,300	1,220	1,710	105,000	January	6,370	1,320	3,160	194,000
February	1,580	1,160	1,340	77,100	February	5,600	2,950	4,030	232,000
March	17,600	1,450	5,570	342,000	March	5,300	2,010	2,760	170,000
April	16,500	3,530	7,090	422,000	April	9,200	4,300	6,220	370,000
May	12,000	7,570	9,750	600,000	May	15,500	6,500	10,900	670,000
June	17,400	6,140	10,400	619,000	June	10,300	4,800	7,870	467,000
July	10,300	2,320	6,490	399,000	July	4,800	1,390	2,410	148,000
August	2,170	1,260	1,580	97,200	August	1,910	1,400	1,600	98,400
September	1,480	1,030	1,190	70,800	September	2,300	1,240	1,710	102,000
October	1,540	915	1,120	68,900	October	1,520	1,030	1,190	73,200
The year	17,600	900	4,130	3,000,000	The year	15,500	928	4,010	2,910,000

[a] After the flood of November 15, 1906, velocities at the measuring section were very low at low water, and a small channel near the left bank was deepened and carried a considerable portion of the flow even at medium stages. The estimates are not very reliable. Those for low-water periods are probably too low.

[b] Discharges from May to October, 1908, were obtained by adding the flow of the Sunnyside, Old Reservation, and New Reservation canals to the flow over Sunnyside dam.

[c] Discharges were estimated by adding the flow of the Yakima near Wapato to the discharges of the Sunnyside, Old Reservation, and New Reservation canals. Estimates are liable to some error during the nonirrigating season when no records were kept on the canals.

[d] Discharge estimated by adding discharges of Yakima near Wapato, Sunnyside, Old Reservation, and New Reservation canals. The estimates for Union Gap thus obtained are liable to some error during the nonirrigating season when no records were kept of the flow in the canals.

[e] No records were obtained on Sunnyside Canal on Nov. 1 and 2. Minimum for month probably occurred at this time.

[f] The discharge has been estimated as the sum of the discharges of Yakima River near Wapato, Sunnyside, Old Reservation, and New Reservation canals.

ESTIMATED NATURAL DISCHARGE.

The records of discharge at Union Gap extend over a longer period than any other records in the Yakima basin, but the results are not comparable throughout the period covered because of the effect of storage and the increasing use of the stream for irrigation. In order that these records may be compared with other records extending over shorter periods, and thus afford a basis for determining the probable stream-flow history at other points in the valley, an attempt has been made to obtain an approximate estimate of natural discharge by correcting the observed flow for storage and irrigation.

The extent to which the flow of the river has been regulated by storage is determinable from the records, but the corrections to be applied on account of irrigation can be ascertained only approximately.

Methods of estimating the effect of irrigation on stream flow have been little studied and engineers might differ considerably as to which of several methods may be best. The effect is not accurately shown by the records of diversion of the irrigation canals, for they cover too short a period. Moreover, the amount of water wasted for regulation and other purposes has not been measured, and the diversion duty for many of the canals is so low as to make it evident that a large part of the water diverted reaches the river again very shortly after being applied to the lands.

The method adopted, after careful consideration of the many factors of the problem, uses as a basis for the corrections the depletion of water supply due to irrigation as indicated by stream-flow records for the years during which the most thorough hydrometric work has been conducted. A consideration of this depletion, of the irrigated area causing such depletion, and of the duty of water in some of the canals which use it most economically, has made it possible to derive a probable net diversion duty for the lands under cultivation above Union Gap. This net diversion duty has been applied to the estimated irrigated area for each climatic year during which records are available at Union Gap and distributed throughout the irrigation season, with allowances for a return flow as set forth more in detail in the succeeding discussion. The utility of this method would be doubtful if it were not for the fact that the volume of water passing Union Gap is large in comparison with the demands of irrigation. The actual irrigation demands may differ considerably from those computed as outlined without greatly affecting the estimated natural flow obtained.

An important factor in determining the effect of irrigation on the flow as indicated by the records is the acreage irrigated. Detailed estimates of acreage irrigated for three years have been made. The

United States Department of Agriculture made a careful study of irrigation practice in 1903, and published the results.[1] Estimates of lands irrigated from Yakima, Naches, and Tieton rivers were also made by the Geological Survey in 1905 and 1911 for the Reclamation Service, but the lands watered from smaller tributaries were not included. The estimates were based on statements obtained from canal owners and others. They may be subject to some error for separate projects, but the aggregate areas derived are probably reliable. The data collected in the three years mentioned, together with known extensions in the various canal systems in previous

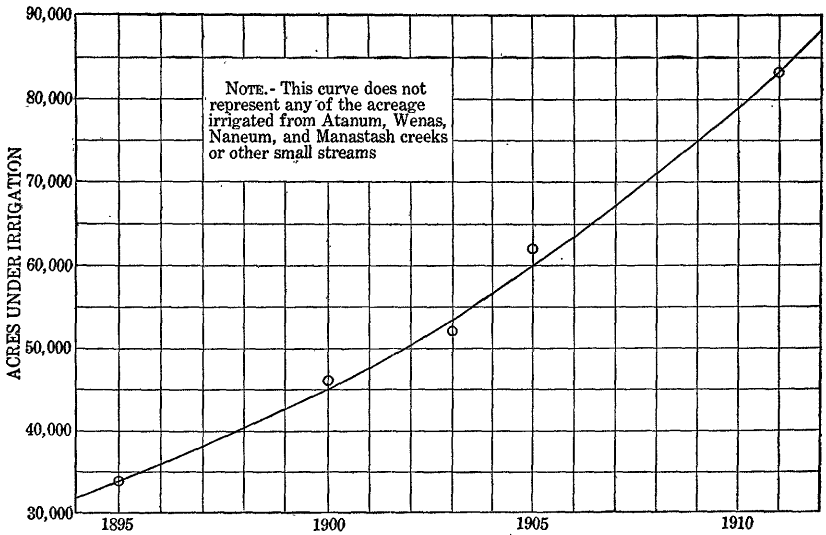


FIGURE 3.—Areas of land above Union Gap irrigated by water from Yakima, Naches, and Tieton rivers, 1894–1912.

years, form the basis of estimates made of acreage watered in 1895 and 1900.

A curve of irrigated areas above Union Gap supplied with water from Yakima, Naches, and Tieton rivers was prepared from the sources indicated above and forms figure 3. The values used in plotting this curve do not cover areas irrigated from Atanum, Wenas, Taneum, and Manastash creeks and other small tributaries in Kittitas County. About 40,000 acres receive some water from these streams, but the low-water flow is sufficient to irrigate properly only about 10,000 acres. The remaining 30,000 acres receive water for about one-third of the irrigation season, or an average of 10,000 acres in addition to the irrigated area supplied by the low-water flow if the irrigation season is considered as a whole. Hence, it has been

[1] Jayne, S. O., Irrigation in the Yakima Valley, Wash.: U. S. Dept. Agr. Bull. 188, p. 20, 1907.

assumed that the aggregate acreage watered by the smaller tributaries amounts to 20,000 acres. There has been no material increase in the area irrigated from the small tributaries in the last 20 years, and the effectively irrigated acreage supplied from these tributaries may be considered to have been 20,000 acres for the entire period covered by records at Union Gap.

The following table has been prepared by adding 20,000 acres to the values taken from the curve shown in figure 3:

Estimated acreage effectively irrigated by Yakima River and tributaries above Union Gap, 1895 to 1912.

	Acres.		Acres.		Acres.
1895	54,000	1901	67,500	1907	87,000
1896	56,000	1902	70,000	1908	91,000
1897	58,000	1903	73,000	1909	95,000
1898	60,500	1904	76,500	1910	99,000
1899	63,000	1905	80,000	1911	103,000
1900	65,000	1906	83,500	1912	108,000

Aside from the acreage irrigated, the other essential factors to be determined in estimating the effect of irrigation on the natural flow at Union Gap are the depletion of water supply on account of demands for irrigation, the probable net diversion duty, and the return flow. Records are available for Yakima, Naches, and Tieton rivers and nearly all the important minor tributaries from April, 1909, to October 31, 1912, the end of the period covered by this report. The only important catchment areas tributary to the river above Union Gap for which the run-off has not been determined by the Geological Survey are the basins of Wenas and Naneum creeks. The following table shows the method of estimating the yearly depletion of flow at Union Gap for the climatic years 1909–10, 1910–11, 1911–12. An attempt made to estimate also the depletion for the year 1908–9 proved unsatisfactory, owing to the lack of records on many of the streams during the first five months of the year and to uncertainty in the record at Union Gap due to the absence of data in regard to the winter flow of the Sunnyside and Old Reservation canals. Annual instead of monthly summaries were made for the reason that the channel storage in the river system and the lagging return of irrigation water through underground drainage affect monthly summaries appreciably.

Run-off and yearly depletion due to irrigation above Union Gap for climatic years 1909–10, 1910–11, and 1911–12.

Stream.	1909-10	1910-11	1911-12
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
Yakima River above Clealum	1,896,000	1,230,000	1,440,000
Teanaway River	350,000	226,000	247,000
Swauk Creek	75,800	28,500	34,300
Taneum Creek	62,300	29,000	37,900
Manastash Creek	65,200	29,100	40,300
Naneum Creek and adjoining streams [a]	127,000	58,000	78,100
Wenas Creek [a]	42,000	18,000	26,100
Tieton River at mouth	612,000	355,000	412,000
Naches River at Oak Flat	1,271,000	766,000	794,000
Atanum Creek at Narrows	123,000	52,900	58,700
Cowiche Creek [a]	30,600	13,200	14,700
Remaining area above Union Gap [a]	30,400	30,400	30,400
Sum (natural run-off) Yakima River at Union Gap	4,685,000	2,836,000	3,214,000
Observed run-off, Yakima River at Union Gap	4,400,000	2,557,000	2,912,000
Depletion due to irrigation	285,000	279,000	302,000
Estimated irrigated acreage	99,000	103,000	108,000
Duty (acre-feet per acre)	2.9	2.7	2.8

[a] Values estimated from the measured discharge of adjoining drainage basins.

The run-off from the basin of Naneum Creek and from adjoining drainage areas, shown in the preceding table, has been estimated from miscellaneous measurements obtained in 1911 and 1912, which seem to indicate that it is equal to the sum of that of Manastash and Taneum creeks. The run-off of Wenas Creek has been estimated from the records of Manastash Creek—a stream in the humid region having about the same drainage area. The basin of Cowiche Creek adjoins that of Atanum Creek, but a considerable part of the area does not extend so far back into the hills as that of Atanum Creek. It has been estimated to yield one-fourth as much run-off as Atanum Creek. Estimates of the flow of Teanaway River and Swauk Creek were also made for the summer months on account of the fact that a large proportion of the summer flow is diverted above the gaging stations during the irrigation season. The parts of the basin not drained by streams on which records have been maintained, nor by the streams mentioned above, comprise about 1,100 square miles of land, most of which lies at a low elevation and receives an annual rainfall of not over 8 inches. The yield from this area has been estimated at 0.5 inch over the drainage basin. This figure represents approximately the yield of Atanum Creek drainage basin between the two gaging stations on the forks of the streams and the station on the main stream at The Narrows. This area also lies at a relatively low elevation and is comparable to the larger arid region in respect to rainfall. It should be noted that the quantities estimated in the table represent only 4 to 6 per cent of the yearly totals in the summation and for that reason may be considerably in error without seriously affecting the accuracy of the totals.

The total depletion as determined above averages 2.8 acre-feet per acre irrigated. A study of the diversion into canals from which water is distributed and used most economically indicates a diversion duty of approximately 4 acre-feet per acre, and it is thought that this duty is as low or lower than economic use warrants. The use of a greater amount of water probably raises the ground-water level to such an extent that a condition nearly approaching surface drainage into the river system is brought about. If it is assumed that 4 acre-feet per acre is the normal diversion duty and that 2.8 acre-feet per acre is consumed in evaporation and in growing crops, there remains 1.2 acre-feet per acre, or 30 per cent of the diversion duty, to return to the river through underground drainage.

An estimate of the monthly distribution of the irrigation demand makes necessary several assumptions. At present about 30 per cent of the effectively irrigated area above Union Gap lies in the Kittitas Valley, about 60 per cent in the lower valleys in the vicinity of North Yakima, and the remaining 10 per cent is included in the partly irrigated area referred to elsewhere. It has been assumed that this relation has remained constant during the period covered by the record. It has also been assumed that the demand for irrigating water in the different parts of the valley is distributed throughout the season according to the percentages given in the fol owing table. The distribution of the demand for the entire irrigated area above Union Gap is represented by the average of the percentages given, weighted in respect to area as indicated. The distribution derived in this manner, as well as the assumptions made, is shown in the following table:

Monthly distribution of water diverted for irrigation.

Month.	Percentage of annual diversion.				Total diversion in acre-feet per acre.
	Kittitas Valley.	Naches, Selah, and Atanum-Moxee valleys.	Partly irrigated lands.	Total area.[a]	
April	1	7	20	6	0.24
May	19	17	50	21	.84
June	20	18	30	20	.80
July	22	20	....	19	.76
August	23	20	....	19	.76
September	15	13	....	12	.48
October	....	5	....	3	.12
	100	100	100	100	4.00

[a] The percentages for the total area have been weighted in respect to the area of the lands in the three classifications, namely, Kittitas Valley; Naches, Selah, and Atanum-Moxee valleys; and partly irrigated lands.

The amount of seepage water returning to the stream has been assumed to be 1.2 acre-feet per acre irrigated. Probably a large proportion of this return flow reaches the river within a short time after being applied to the lands, but this condition has not been conclusively proved. Seepage studies of the main Yakima River, made under the direction of Fred F. Henshaw, district engineer of the United States Geological Survey, in 1910 and 1911, show a return flow above Union Gap during the months of July and August amounting to about 40 per cent of the water diverted during those months, whereas the seepage return estimated for this discussion amounts to only 30 per cent of the net diversion adopted. However, the aggregate duty of canals considered in the seepage studies in 1910 and 1911 is considerably over 4 acre-feet per acre. The basis for estimating the return flow is shown in the following table:

Assumed distribution of seepage return water amounting to 1.2 acre-feet per acre.

Month.	Return acre-feet per acre.	Month.	Return acre-feet per acre.
May	0.10	August	0.30
June	.20	September	.20
July	.30	October	.10

It is realized that this assumption is based on very meager data and that a trustworthy estimate of return flow is at present impossible.

The estimated natural flow at Union Gap, computed by adding to the observed flow the diversion and subtracting the return flow, in accordance with the foregoing discussion, is shown in the following table. It has been carefully compared with flow indicated by observation at gaging stations above Union Gap for recent years. The comparison shows that the sum of the monthly means of the tributary streams, when corrected for storage, agrees fairly well with the estimated natural flow at Union Gap, although for certain months considerable discrepancy is apparent. The comparison indicates that an assumption of a value for return seepage higher than that chosen for October would result in an estimated natural flow at Union Gap smaller than the sum of the discharges at the upper gaging stations. One of the notable discrepancies is found for the month of October, 1907. The estimated natural flow amounts to 727 second-feet, whereas the sum of the discharge of Yakima River at Clealum, Naches River at Oak Flat, and Tieton River at Cobb's ranch amounts to 723 second-feet, leaving practically no margin for Teanaway River, Atanum, Naneum, and other small creeks, the aggregate flow of which was more than sufficient to bring the flow at Union Gap above 800 second-feet. However, the records at Union Gap in 1907 are not accurate. The current at the measuring station was very sluggish at low water, and the engineer reported "impossible to obtain reliable estimates of discharge." [1]

[1] Stevens, J. C., and Henshaw, F. F., U. S. Geol. Survey Water-Supply Paper 252, p. 147, 1910.

Estimated natural discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912.

[Drainage area, 3,550 square miles.]

Month.	Estimated run-off in acre-feet.					Estimated natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy of observed data.
	Observed.[a]	Stored.	Diversion for irrigation.	Seepage return.	Natural.	Mean.	Mean per square mile.		
1896.									
August	101,000	....	42,600	16,800	127,000	2,070	0.583	0.67	B.
September	63,700	....	26,800	11,200	79,300	1,330	.375	.42	B.
October	52,900	....	6,720	5,600	54,000	879	.248	.29	B.
The period	218,000	....	76,200	33,600	260,000	....	....	....	
1896–97.									
November	455,000	....	....	....	455,000	7,650	2.15	2.40	B.
December	317,000	....	....	....	317,000	5,160	1.45	1.67	B.
January	129,000	....	....	....	129,000	2,100	.592	.68	D.
February	167,000	....	....	....	167,000	3,000	.845	.88	D.
March	152,000	....	....	....	152,000	2,470	.696	.80	B.
April	893,000	....	13,900	....	907,000	15,200	4.28	4.78	C.
May	964,000	....	48,700	5,800	1,010,000	16,400	4.62	5.33	C.
June	423,000	....	46,400	11,600	458,000	7,700	2.17	2.42	B.
July	202,000	....	44,100	17,400	229,000	3,720	1.05	1.21	B.
August	71,800	....	44,100	17,400	98,500	1,600	.451	.52	B.
September	48,600	....	27,800	11,600	64,800	1,090	.307	.34	B.
October	49,800	....	6,960	5,800	51,000	830	.234	.27	B.
The year	3,870,000	....	232,000	69,600	4,040,000	5,580	1.57	21.30	
1897–98.									
November	314,000	....	....	....	314,000	5,270	1.48	1.65	B.
December	244,000	....	....	....	244,000	3,970	1.12	1.29	B.
January	206,000	....	....	....	206,000	3,350	.944	1.09	B.
February	378,000	....	....	....	378,000	6,800	1.92	2.00	B.
March	279,000	....	....	....	279,000	4,540	1.28	1.48	B.
April	411,000	....	14,500	....	426,000	7,160	2.02	2.25	B.
May	762,000	....	50,800	6,050	807,000	13,100	3.69	4.25	C.
June	586,000	....	48,400	12,100	602,000	10,100	2.85	3.18	C.
July	214,000	....	46,000	18,200	242,000	3,940	1.11	1.28	B.
August	83,900	....	46,000	18,200	112,000	1,820	.513	.59	B.
September	50,900	....	29,000	12,100	67,800	1,140	.321	.36	B.
October	79,900	....	7,270	6,050	81,100	1,320	.372	.43	B.
The year	3,590,000	....	242,000	72,700	3,760,000	5,190	1.46	19.85	
1898–99.									
November	117,000	....	....	....	117,000	1,970	.555	.62	B.
December	122,000	....	....	....	122,000	1,990	.561	.65	B.
January	287,000	....	....	....	287,000	4,660	1.31	1.51	C.
February	265,000	....	....	....	265,000	4,770	1.34	1.40	C.
March	171,000	....	....	....	171,000	2,780	.783	.90	B.
April	251,000	....	15,100	....	266,000	4,470	1.26	1.41	B.
May	577,000	....	52,900	6,300	624,000	10,100	2.85	3.29	B.
June	839,000	....	50,400	12,600	877,000	14,700	4.14	4.62	B.
July	521,000	....	47,800	18,900	550,000	8,940	2.52	2.90	B.
August	229,000	....	47,800	18,900	258,000	4,200	1.18	1.36	B.
September	119,000	....	30,200	12,600	138,000	2,320	.654	.73	B.
October	122,000	....	7,560	6,300	123,000	2,000	.563	.65	B.
The year	3,620,000	....	252,000	75,600	3,800,000	5,250	1.48	20.04	
1899–1900.									
November	315,000	....	....	....	315,000	5,290	1.49	1.66	B.
December	410,000	....	....	....	410,000	6,670	1.88	2.17	B.
January	548,000	....	....	....	548,000	8,910	2.51	2.89	D.
February	214,000	....	....	....	214,000	3,850	1.08	1.12	B.
March	448,000	....	....	....	448,000	7,280	2.07	2.39	B.
April	446,000	....	15,600	....	462,000	7,760	2.19	2.44	B.
May	422,000	....	54,600	6,500	470,000	7,640	2.15	2.48	B.
June	233,000	....	52,000	13,000	272,000	4,570	1.29	1.44	B.
July	106,000	....	49,400	19,500	136,000	2,210	.623	.72	B.
August	57,900	....	49,400	19,500	87,800	1,430	.403	.46	B.
September	66,600	....	31,200	13,000	84,800	1,430	.403	.45	B.
October	139,000	....	7,800	6,500	140,000	2,280	.642	.74	B.
The year	3,410,000	....	260,000	78,000	3,590,000	4,960	1.40	18.96	

[a] For other details of observed data, see pp. 47–49.

Estimated natural discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912—Continued.

Month.	Estimated run-off in acre-feet.					Estimated natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy of observed data.
	Observed.	Stored.	Diversion for irrigation.	Seepage return.	Natural.	Mean.	Mean per square mile.		
1900–1901.									
November	213,000				213,000	3,580	1.01	1.13	B.
December	427,000				427,000	6,950	1.96	2.26	B.
January	271,000				271,000	4,400	1.24	1.43	B.
February	210,000				210,000	3,780	1.06	1.10	B.
March	516,000				516,000	8,390	2.36	2.72	B.
April	302,000		16,200		318,000	5,340	1.50	1.67	B.
May	701,000		56,700	6,750	751,000	12,200	3.44	3.97	B.
June	505,000		54,000	13,500	546,000	9,180	2.59	2.89	B.
July	272,000		51,300	20,200	303,000	4,930	1.39	1.60	B.
August	109,000		51,300	20,200	140,000	2,280	.642	.74	B.
September	71,400		32,400	13,500	90,300	1,520	.428	.48	B.
October	65,800		8,100	6,750	67,200	1,090	.307	.35	B.
The year	3,660,000		270,000	80,900	3,850,000	5,320	1.50	20.34	
1901–2.									
November	170,000				170,000	2,860	.806	.90	B.
December	347,000				347,000	5,650	1.59	1.83	B.
January	295,000				295,000	4,800	1.35	1.56	C.
February	193,000				193,000	3,480	.980	1.02	B.
March	223,000				223,000	3,620	1.02	1.18	B.
April	383,000		16,800		400,000	6,720	1.89	2.11	B.
May	806,000		58,800	7,000	858,000	14,000	3.94	4.54	C.
June	464,000		56,000	14,000	506,000	8,500	2.39	2.67	C.
July	249,000		53,200	21,000	281,000	4,570	1.29	1.49	B.
August	100,000		53,200	21,000	132,000	2,150	.606	.70	B.
September	55,000		33,600	14,000	74,600	1,250	.352	.39	B.
October	73,500		8,400	7,000	74,900	1,220	.344	.40	B.
The year	3,360,000		280,000	84,000	3,550,000	4,900	1.38	18.79	
1902–3.									
November	126,000				126,000	2,120	.597	.67	B.
December	176,000				176,000	2,870	.809	.93	B.
January	429,000				429,000	6,980	1.97	2.27	B.
February	145,000				145,000	2,620	.738	.77	A.
March	213,000				213,000	3,460	.975	1.12	A.
April	382,000		17,500		400,000	6,720	1.89	2.11	A.
May	781,000		61,300	7,300	835,000	13,600	3.83	4.42	B.
June	1,140,000		58,400	14,600	1,180,000	19,800	5.58	6.23	B.
July	338,000		55,500	21,900	372,000	6,050	1.70	1.96	A.
August	92,300		55,500	21,900	126,000	2,050	.577	.67	A.
September	86,000		35,000	14,600	106,000	1,780	.501	.56	A.
October	226,000		8,760	7,300	227,000	3,690	1.04	1.20	A.
The year	4,130,000		292,000	87,600	4,340,000	6,000	1.69	22.91	
1903–4.									
November	233,000				233,000	3,920	1.10	1.23	A.
December	309,000				309,000	5,030	1.42	1.64	A.
January	195,000				195,000	3,170	.893	1.03	A.
February	126,000				126,000	2,190	.617	.67	A.
March	194,000				194,000	3,150	.887	1.02	A.
April	976,000		18,400		994,000	16,700	4.70	5.24	B.
May	886,000		64,300	7,650	944,000	15,400	4.34	5.00	B.
June	681,000		61,200	15,300	727,000	12,200	3.44	3.84	B.
July	304,000		58,100	23,000	339,000	5,510	1.55	1.79	B.
August	79,100		58,100	23,000	114,000	1,860	.524	.60	B.
September	51,600		36,800	15,300	73,100	1,230	.346	.39	B.
October	63,700		9,180	7,650	65,200	1,060	.299	.34	B.
The year	4,100,000		306,000	91,900	4,310,000	5,940	1.67	22.79	

Estimated natural discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912—Continued.

Month.	Estimated run-off in acre-feet.					Estimated natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy of observed data.
	Observed.	Stored.	Diversion for irrigation.	Seepage return.	Natural.	Mean.	Mean per square mile.		
1904–5.									
November	124,000				124,000	2,080	0.586	0.65	A.
December	171,000				171,000	2,780	.783	.90	A.
January	113,000				113,000	1,830	.515	.59	A.
February	95,900				95,900	1,730	.487	.51	A.
March	463,000				463,000	7,540	2.12	2.44	A.
April	283,000		19,200		302,000	5,080	1.43	1.60	A.
May	303,000		67,200	8,000	362,000	5,890	1.66	1.91	A.
June	495,000		64,000	16,000	543,000	9,130	2.57	2.87	A.
July	167,000		60,800	24,000	203,000	3,300	.930	1.07	A.
August	56,700		60,800	24,000	93,100	1,510	.425	.49	A.
September	53,800		38,400	16,000	76,200	1,280	.361	.40	A.
October	197,000		9,600	8,000	199,000	3,240	.911	1.05	A.
The year	2,520,000		320,000	96,000	2,750,000	3,800	1.07	14.48	
1905–6.									
November	112,000				112,000	1,880	.530	.59	A.
December	105,000				105,000	1,700	.479	.55	A.
January	112,000	+ 6,600			119,000	1,940	.546	.63	A.
February	215,000	− 2,080			213,000	3,840	1.08	1.12	A.
March	214,000	+ 1,080			215,000	3,500	.986	1.14	A.
April	589,000	+12,400	10,000		611,000	10,300	2.90	3.24	A.
May	486,000	+ 4,280	70,200	8,350	552,000	8,980	2.53	2.92	A.
June	262,000	− 3,070	66,800	16,700	309,000	5,190	1.46	1.63	A.
July	121,000	−12,300	63,500	25,000	147,000	2,390	.673	.78	C.
August	42,700	− 8,220	63,500	25,000	73,000	1,190	.335	.39	C.
September	42,000	− 2,490	40,100	16,700	62,900	1,060	.299	.33	C.
October	136,000	+13,000	20,000	8,350	161,000	2,620	.738	.85	C.
The year	2,440,000	+ 9,200	334,000	100,000	2,680,000	3,700	1.04	14.17	
1906–7.									
November	738,000	+ 5,200			743,000	12,500	3.52	3.93	C.
December	241,000	− 3,630			237,000	3,850	1.08	1.24	C.
January	149,000	− 5,620			143,000	2,330	.656	.76	C.
February	374,000	+ 4,160			378,000	6,810	1.92	2.00	C.
March	310,000	− 7,250			303,000	4,930	1.39	1.60	B.
April	502,000	+17,900	20,800		541,000	9,090	2.56	2.86	B.
May	867,000	+16,500	73,000	8,700	948,000	15,400	4.34	5.00	C.
June	455,000	− 396	69,600	17,400	507,000	8,520	2.40	2.68	B.
July	152,000	− 2,970	66,100	26,100	189,000	3,070	.865	1.00	B.
August	57,200	−10,100	66,100	26,100	87,100	1,420	.400	.46	B.
September	66,000	− 9,720	41,700	17,400	80,600	1,350	.380	.42	B.
October	54,400	−11,400	10,400	8,700	44,700	[a] 727	.205	.24	B.
The year	3,970,000	− 7,330	348,000	104,000	4,200,000	5,800	1.63	22.19	
1907–8.									
November	69,600	+11,400			81,000	1,360	.383	.43	B.
December	133,000	+ 2,130			135,000	2,200	.620	.71	B.
January	105,000	−10,900			94,100	1,530	.431	.50	C.
February	77,100	− 1,130			76,000	1,320	.372	.40	C.
March	342,000	+40,500			382,000	6,210	1.75	2.02	C.
April	422,000	+ 4,170	21,800		448,000	7,530	2.12	2.36	C.
May	600,000	+ 8,690	76,400	9,100	676,000	11,000	3.10	3.57	A.
June	619,000	+ 542	72,800	18,200	674,000	11,300	3.18	3.55	A.
July	399,000	− 4,080	69,300	27,300	437,000	7,110	2.00	2.31	A.
August	97,200	−21,200	69,300	27,300	118,000	1,920	.540	.62	B.
September	70,800	−23,000	43,700	18,200	73,300	1,230	.346	.39	B.
October	68,900	+ 1,570	10,900	9,100	72,300	1,180	.332	.38	B.
The year	3,000,000	+ 8,690	364,000	109,000	3,270,000	4,500	1.27	17.24	

[a] The sum of the mean monthly discharges of the Tieton near Naches, Naches at Oak Flat, and Yakima at Clealum amounts to 723 second-feet for this month. On this basis the true natural flow at Union Gap must have been at least 800 second-feet.

See footnote *a*, p. 49.

Estimated natural discharge of Yakima River at Union Gap, near Yakima, Wash., 1896–1912—Continued.

Month.	Estimated run-off in acre-feet.					Estimated natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy of observed data.
	Observed.	Stored.	Diversion for irrigation.	Seepage return.	Natural.	Mean.	Mean per square mile.		
1908–9.									
November	125,000	+23,000			148,000	2,490	0.701	0.78	A.
December	99,000	+ 3,390			102,000	1,660	.468	.54	A.
January	124,000	− 1,000			123,000	2,000	.563	.65	B.
February	103,000	− 370			103,000	1,850	.521	.54	A.
March	135,000	+ 2,940			138,000	2,240	.631	.73	A.
April	257,000	+ 4,720	22,800		285,000	4,790	1.35	1.51	B.
May	452,000	+ 7,580	79,800	9,500	530,000	8,620	2.43	2.80	A.
June	581,000	+ 4,260	76,000	19,000	642,000	10,800	3.04	3.39	A.
July	199,000	− 6,440	72,200	28,500	236,000	3,840	1.08	1.24	A.
August	79,900	−33,100	72,200	28,500	90,500	1,470	.414	.48	A.
September	54,700	−11,500	45,600	19,000	69,800	1,170	.330	.37	A.
October	68,200	− 1,580	11,400	9,500	68,500	1,110	.313	.36	A.
The year	2,280,000	− 8,100	380,000	114,000	2,540,000	3,510	.989	13.39	
1909–10.									
November	524,000	+65,600			590,000	9,920	2.79	3.11	B.
December	401,000	−36,300			365,000	5,940	1.67	1.92	A.
January	195,000	− 5,680			189,000	3,070	.865	1.00	A.
February	163,000	− 490			163,000	2,940	.828	.86	A.
March	861,000	+18,700			880,000	14,300	4.03	4.65	A.
April	750,000	+ 7,020	23,800		781,000	13,100	3.69	4.12	A.
May	750,000	− 2,520	83,100	9,900	821,000	13,400	3.77	4.35	A.
June	344,000	− 540	79,200	19,800	403,000	6,770	1.91	2.13	A.
July	127,000	− 510	75,300	29,700	172,000	2,800	.789	.91	A.
August	68,900	−41,200	75,300	29,700	73,300	1,190	.335	.39	A.
September	50,000	− 7,450	47,500	19,800	70,200	1,180	.332	.37	A.
October	166,000	+20,700	11,900	9,900	189,000	3,070	.865	1.00	A.
The year	4,400,000	+17,300	396,000	119,000	4,700,000	6,490	1.83	24.81	
1910–11.									
November	345,000	+21,200			366,000	6,150	1.73	1.93	A.
December	211,000	−27,100			184,000	2,990	.842	.97	A.
January	130,000	+14,000			144,000	2,340	.659	.76	A.
February	78,300	+ 839			79,100	1,420	.400	.42	A.
March	184,000	+11,200			195,000	3,170	.893	1.03	A.
April	309,000	+ 4,510	24,700		338,000	5,680	1.60	1.78	A.
May	436,000	+11,700	86,600	10,300	524,000	8,530	2.40	2.77	A.
June	462,000	+24,900	82,500	20,600	549,000	9,220	2.60	2.90	A.
July	152,000	−14,100	78,300	30,900	185,000	3,010	.848	.98	A.
August	81,800	−53,600	78,300	30,900	75,600	1,230	.346	.40	A.
September	97,600	− 8,790	49,500	20,600	118,000	1,980	.558	.62	A.
October	70,700	− 6,120	12,400	10,300	66,700	1,080	.304	.35	A.
The year	2,560,000	−21,400	412,000	124,000	2,820,000	3,890	1.10	14.91	
1911–12.									
November	215,000	+46,900			262,000	4,400	1.24	1.38	A.
December	172,000	−15,400			157,000	2,550	.718	.83	A.
January	194,000	+ 2,240			196,000	3,190	.899	1.04	C.
February	232,000	−11,800			220,000	3,820	1.08	1.16	A.
March	170,000	−11,000			159,000	2,590	.730	.84	A.
April	370,000	+ 893	25,900		397,000	6,670	1.88	2.10	A.
May	670,000	+52,700	90,700	10,800	803,000	13,100	3.69	4.25	A.
June	467,000	+14,400	86,400	21,600	546,000	9,180	2.59	2.89	A.
July	148,000	− 6,900	82,100	32,400	191,000	3,110	.876	1.01	A.
August	98,400	−51,000	82,100	32,400	97,100	1,580	.445	.51	A.
September	102,000	−40,300	51,800	21,600	91,900	1,540	.434	.48	A.
October	73,200	− 8,660	13,000	10,800	66,700	1,080	.304	.35	A.
The year	2,910,000	−27,900	432,000	130,000	3,190,000	4,390	1.24	16.84	

KACHESS RIVER BELOW OUTLET OF KACHESS LAKE, NEAR EASTON, WASH.

Location.—In sec. 3, T. 20 N., R. 13 E., one-fourth mile below the dam at outlet of Kachess Lake and about 2½ miles northwest of Easton.

Records available.—October 14, 1903, to October 31, 1912.

Drainage area.—63 square miles.

Gage.—Staff in two sections on left bank; lower section inclined, upper vertical.

Channel.—Gravel; shifting frequently.

Discharge measurements.—Made from cable at gage.

Winter flow.—Not affected by ice.

Regulation.—Flow partly controlled by operation of dam at Kachess reservoir. Records corrected for storage since September, 1905.

Accuracy.—Results good.

Estimated monthly discharge of Kachess River below outlet of Kachess Lake, near Easton, Wash., 1903–1912.

[Drainage area, 63 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1903–4.							
November [a]	530	....	364	5.78	21,700	6.45	A.
December	745	245	426	6.76	26,200	7.79	A.
January	390	195	286	4.54	17,600	5.23	A.
February	245	0	153	2.43	8,800	2.62	A.
March	420	0	227	3.60	14,000	4.15	A.
April [b]	980	0	473	7.51	28,100	8.38	A.
May [b]	900	0	578	9.17	35,500	10.57	B.
June [b]	1,020	220	745	11.8	44,300	13.17	B.
July	745	145	305	4.84	18,800	5.58	A.
August	145	65	113	1.79	6,950	2.06	A.
September	220	33	147	2.33	8,750	2.60	A.
October	315	73	138	2.19	8,480	2.52	A.
The year	1,020	0	329	5.22	239,000	71.12	
1904–5.							
November	345	57	141	2.24	8,390	2.50	A.
December	....	....	376	5.97	23,100	6.88	A.
January	310	44	179	2.84	11,000	3.27	A.
February	142	26	98.9	1.57	5,490	1.64	B.
March	516	167	427	6.78	26,300	7.82	A.
April	586	17	320	5.08	19,000	5.67	A.
May	766	37	324	5.14	19,900	5.93	A.
June	932	193	451	7.16	26,800	7.99	A.
July	297	68	147	2.33	9,040	2.69	B.
August	232	87	146	2.32	8,980	2.68	B.
September	284	130	203	3.22	12,100	3.59	A.
October	310	130	257	4.08	15,800	4.70	B.
The year	932	17	257	4.08	186,000	55.36	

[a] Discharge from Nov. 1 to 19 estimated as 370 second-feet, or 50 per cent of discharge of Clealum River near Roslyn.
[b] Estimate revised from original data.

NOTE.—Discharge affected by storage in Lake Kachess. No records of stage maintained on the lake; data can not be corrected.

Estimated monthly discharge of Kachess River below outlet of Kachess Lake, near Easton, Wash., 1903–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1905–6.										
November	258	154	192	11,400	− 2,460	8,960	151	2.40	2.68	B.
December	193	130	161	9,900	+ 2,820	12,700	207	3.29	3.79	B.
January	280	140	173	10,600	+ 3,190	13,800	224	3.56	4.10	B.
February	294	214	263	14,600	− 714	13,900	250	3.97	4.13	B.
March	266	176	206	12,700	− 1,590	11,100	181	2.87	3.31	B.
April	695	227	434	25,800	+ 7,340	33,100	556	8.83	9.85	A.
May	735	140	401	24,700	+ 7,110	31,800	517	8.21	9.46	A.
June	410	214	325	19,300	− 184	19,100	321	5.10	5.69	A.
July	322	71	211	13,000	− 7,830	5,170	84.1	1.33	1.53	B.
August	176	62	131	8,060	− 6,610	1,450	23.6	.375	.43	B.
September	140	62	92.8	5,520	− 3,350	2,170	36.5	.579	.65	B.
October	475	62	168	10,300	+ 6,900	17,200	280	4.44	5.12	B.
The year	735	62	229	166,000	+ 4,620	170,000	235	3.73	50.74	
1906–7.										
November *a*	1,760	62	695	41,400	+ 5,580	47,000	790	12.5	13.95	A.
December	580	240	337	20,700	− 7,540	13,200	215	3.41	3.93	A.
January	253	176	202	12,400	− 1,240	11,200	182	2.89	3.33	B.
February	410	201	303	16,800	+ 2,130	18,900	340	5.40	5.62	B.
March	308	164	229	14,100	− 3,020	11,100	181	2.87	3.31	A.
April	458	164	301	17,900	+ 4,980	22,900	385	6.11	6.82	A.
May *a*	980	442	780	48,000	+ 6,510	54,500	886	14.1	16.26	A.
June *a*	940	42	368	21,900	+ 5,140	27,000	454	7.21	8.04	A.
July	294	29	143	8,790	− 1,470	7,320	119	1.89	2.18	A.
August	272	29	123	7,560	− 5,530	2,030	33.0	.524	.60	A.
September	183	159	170	10,100	− 7,440	2,660	44.7	.710	.79	A.
October	230	42	111	6,820	− 5,640	1,180	19.2	.305	.35	A.
The year	1,760	29	312	226,000	− 7,540	219,000	303	4.81	65.18	
1907–8.										
November	266	54	113	6,720	+ 3,450	10,200	171	2.71	3.02	A.
December	322	176	226	13,900	+ 1,770	15,700	255	4.05	4.67	A.
January	308	96	185	11,400	− 3,890	7,510	122	1.94	2.24	B.
February	118	76	92.5	5,320	− 351	4,970	86.4	1.37	1.48	A.
March *a*	752	67	365	22,400	+ 6,380	28,800	468	7.43	8.57	A.
April	715	240	432	25,700	+ 2,150	27,800	467	7.41	8.27	A.
May	615	253	486	29,900	+ 8,000	37,900	616	9.78	11.28	A.
June *a*	1,230	350	713	42,400	+ 368	42,800	719	11.4	12.72	A.
July *a*	734	201	393	24,200	− 478	23,700	385	6.11	7.04	A.
August	227	76	193	11,900	− 7,920	3,980	64.7	1.03	1.19	A.
September	380	12	167	9,940	− 7,860	2,080	35.0	.556	.62	B.
October	118	39	69.5	4,270	− 632	3,640	59.2	.94	1.08	B.
The year	1,230	12	287	208,000	+ 987	209,000	289	4.59	62.18	
1908–9.										
November	253	45	119	7,080	+ 2,360	9,440	159	2.52	2.81	B.
December	176	122	140	8,610	− 956	7,650	124	1.97	2.27	A.
January	146	111	134	8,240	− 630	7,610	124	1.97	2.27	B.
February	136	92	116	6,440	− 70	6,370	115	1.83	1.91	B.
March	175	106	121	7,440	+ 1,220	8,660	141	2.24	2.58	B.
April	366	175	232	13,800	+ 3,320	17,100	287	4.56	5.09	A.
May	744	366	526	32,300	+ 4,480	36,800	599	9.51	10.96	A.
June	1,020	64	612	36,400	+ 7,040	43,400	730	11.6	12.94	A.
July	412	69	192	11,800	+ 396	12,200	198	3.14	3.62	A.
August	448	96	230	14,100	−11,500	2,600	42.3	.671	.77	A.
September	275	97	145	8,630	− 5,600	3,030	51.0	.810	.90	B.
October	97	78	86.9	5,340	− 805	4,540	73.9	1.17	1.35	B.
The year	1,020	45	221	160,000	− 745	159,000	220	3.49	47.47	

a Estimate revised from original data.

Estimated monthly discharge of Kachess River below outlet of Kachess Lake, near Easton, Wash., 1903–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1909–10.										
November	1,790	81	674	40,100	+19,700	59,800	1,000	15.9	17.74	A.
December	1,580	244	618	38,000	−15,600	22,400	364	5.78	6.66	A.
January	258	131	192	11,800	− 105	11,700	191	3.03	3.49	A.
February	266	181	206	11,400	− 490	10,900	197	3.13	3.26	A.
March	806	294	497	30,600	+ 4,690	35,300	574	9.11	10.50	A.
April	1,080	436	614	36,500	+ 4,720	41,200	693	11.0	12.27	A.
May	1,070	698	855	52,600	− 2,980	49,600	807	12.8	14.76	A.
June	723	10	294	17,500	+ 2,450	20,000	336	5.33	5.94	A.
July	350	9	80.0	4,920	+ 1,260	6,180	100	1.59	1.83	A.
August	598	80	248	15,200	−13,400	1,800	29.3	.465	.54	A.
September	74	4	30.7	1,890	− 350	1,540	25.9	.411	.46	A.
October	395	5	193	11,900	+ 4,550	16,400	267	4.24	4.89	A.
The year	1,790	4	376	272,000	+ 4,440	277,000	383	6.08	82.34	
1910–11.										
November	1,120	25	467	27,800	+ 4,270	32,100	540	8.57	9.56	A.
December	550	181	277	17,000	− 5,700	11,300	184	2.92	3.37	A.
January	225	160	194	11,900	− 980	10,900	177	2.81	3.24	A.
February	158	94	122	6,780	− 1,470	5,310	95.6	1.52	1.58	A.
March	238	84	125	7,690	+ 3,150	10,800	176	2.79	3.22	A.
April	410	238	284	16,900	+ 2,620	19,500	328	5.21	5.81	A.
May	900	112	516	31,700	+ 3,640	35,300	574	9.11	10.50	A.
June	862	25	432	25,700	+ 7,500	33,200	558	8.86	9.88	A.
July	410	13	219	13,500	− 4,140	9,400	153	2.43	2.80	A.
August	442	12	211	13,000	−11,000	2,000	32.6	.518	.60	A.
September	608	0	467	27,800	−21,200	6,600	111	1.76	1.96	A.
October	0	0	0	0	+ 3,000	3,000	48.8	.775	.89	A.
The year	1,120	0	276	200,000	−20,300	179,000	247	3.92	53.41	
1911–12.										
November	950	0	201	12,000	+25,800	37,800	635	10.1	11.27	B.
December	830	421	620	38,100	−16,800	21,300	346	5.49	6.33	B.
January	539	182	340	20,900	0	20,900	340	5.40	6.23	B.
February	539	507	530	30,500	− 9,450	21,000	365	5.79	6.24	B.
March	640	0	399	24,500	−12,200	12,300	200	3.17	3.66	B.
April	432	419	428	25,500	− 2,100	23,400	393	6.24	6.96	B.
May	422	0	239	14,700	+37,100	51,800	842	13.4	15.45	B.
June	776	0	562	33,400	+ 1,080	34,500	580	9.21	10.28	B.
July	972	3.2	203	12,500	− 3,700	8,800	143	2.27	2.62	B.
August	1,040	4.0	465	28,600	−26,600	2,000	32.5	.516	.59	B.
September	658	0	186	11,100	− 8,310	2,790	46.9	.744	.83	B.
October	406	0	123	7,560	− 3,630	3,930	63.9	1.01	1.16	B.
The year	1,040	0	358	259,000	−18,800	241,000	332	5.28	71.62	

CLEALUM RIVER AT OUTLET OF CLEALUM LAKE, NEAR ROSLYN, WASH.

Location.—In sec. 10, T. 20 N., R. 14 E., 500 feet below the dam at outlet of Clealum Lake, 2½ miles northwest of Roslyn and about 4½ miles northwest of Clealum.

Records available.—October 10, 1903, to October 31, 1912.

Drainage area.—202 square miles.[1]

Gage.—Inclined staff on left bank.

Channel.—Gravel and bowlders; practically permanent.

Discharge measurements.—Made from cable or by wading near gage.

Winter flow.—Not affected by ice.

Regulation.—Flow is partly controlled by operation of dam at Clealum reservoir. Records corrected for storage since January, 1906.

Accuracy.—Records good.

[1] Revised measurement.

Estimated monthly discharge of Clealum River at outlet of Clealum Lake, near Roslyn, Wash., 1903–1912.

[Drainage area, 202 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1903–4.							
November	1,630	478	746	3.69	44,400	4.12	A.
December	3,900	425	1,020	5.05	62,800	5.82	B.
January	900	375	567	2.81	34,900	3.24	B.
February	565	240	367	1.82	21,100	1.96	B.
March	512	270	367	1.82	22,600	2.10	A.
April	3,900	285	1,970	9.75	117,000	10.88	B.
May	4,520	1,240	2,630	13.0	162,000	14.99	B.
June	4,140	1,670	2,680	13.3	159,000	14.84	B.
July	2,890	725	1,510	7.48	93,000	8.62	A.
August	705	330	517	2.56	31,800	2.95	A.
September	330	190	250	1.24	14,900	1.38	A.
October	285	165	234	1.16	14,400	1.34	A.
The year	4,520	165	1,070	5.30	778,000	72.24	
1904–5.							
November	725	190	391	1.94	23,300	2.16	B.
December	685	360	527	2.61	32,400	3.01	B.
January	408	215	269	1.33	16,500	1.53	B.
February	478	140	211	1.04	11,700	1.08	B.
March	1,590	495	1,160	5.74	71,000	6.62	B.
April	2,740	255	1,010	5.00	60,200	5.58	B.
May	2,490	965	1,450	7.18	89,200	8.28	B.
June	2,990	1,100	1,840	9.11	110,000	10.16	B.
July	1,080	548	733	3.63	45,100	4.18	B.
August	548	330	438	2.17	26,900	2.50	B.
September	453	270	314	1.55	18,700	1.73	B.
October	1,670	442	887	4.39	54,500	5.06	B.
The year	2,990	140	773	3.83	560,000	51.89	

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.[a]	Without storage.	Mean.	Mean per square mile.		
1905–6.										
November	665	360	452	26,900	....	26.900	452	2.24	2.50	B.
December	442	300	352	21,600	....	21,600	352	1.74	2.01	B.
January	785	296	401	24,700	+ 1,930	26,600	433	2.14	2.47	B.
February	885	460	644	35,800	− 980	34,800	627	3.10	3.23	B.
March	995	328	494	30,400	+ 2,590	33,000	537	2.66	3.07	B.
April	3,320	1,170	1,800	107,000	+ 2,990	110,000	1,850	9.16	10.22	B.
May	3,320	1,170	2,020	124,000	− 2,150	122,000	1,980	9.80	11.30	B.
June	1,970	....	1,230	73,200	− 1,850	71,400	1,200	5.94	6.63	B.
July	....	392	675	41,500	− 2,910	38,600	628	3.11	3.58	B.
August	392	130	318	19,600	− 950	18,600	302	1.50	1.73	B.
September	360	265	289	17,200	+ 760	18,000	302	1.50	1.67	B.
October	4,040	296	831	51,100	+ 3,300	54,400	885	4.38	5.05	B.
The year	4,040	130	791	573,000	+ 2,730	576,000	795	3.94	53.46	

[a] Storage table published in Water-Supply Paper 252 has been revised and corrections have been made accordingly. (See Water-Supply Paper 272, p. 177.)

Estimated monthly discharge of Clealum River at outlet of Clealum Lake, near Roslyn, Wash., 1903–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1906–7.										
November	17,700	650	2,650	158,000	− 1,400	157,000	2,640	13.1	14.62	B.
December	650	460	522	32,100	− 570	31,500	512	2.53	2.92	A.
January	530	328	426	26,200	− 570	25,600	416	2.06	2.38	B.
February	1,360	....	726	40,300	+ 570	40,900	736	3.64	3.79	B.
March	695	392	509	31,300	− 1,900	29,400	478	2.37	2.73	A.
April	1,800	392	1,070	63,700	+ 6,360	70,100	1,180	5.84	6.52	A.
May	4,400	1,500	3,210	197,000	+ 3,070	200,000	3,250	16.1	18.56	A.
June	4,280	1,110	1,880	112,000	− 4,540	107,000	1,800	8.91	9.94	A.
July	1,300	392	766	47,100	− 1,220	45,900	746	3.69	4.25	A.
August	460	296	349	21,500	0	21,500	349	1.73	1.99	C.
September	328	236	292	17,400	0	17,400	292	1.45	1.62	C.
October	236	106	170	10,500	− 1,390	9,110	148	.733	.85	B.
The year	17,700	106	1,050	757,000	− 1,590	755,000	1,040	5.15	70.17	
1907–8.										
November	425	130	228	13,600	+ 2,400	16,000	269	1.33	1.48	B.
December	650	360	489	30,100	+ 630	30,700	499	2.47	2.85	A.
January	460	265	351	21,600	− 2,240	19,400	315	1.56	1.80	B.
February	236	208	216	12,400	0	12,400	216	1.07	1.15	B.
March	1,360	208	605	37,200	+21,600	58,800	956	4.73	5.45	A.
April	3,440	530	1,430	85,100	+ 1,680	86,800	1,460	7.23	8.07	A.
May	2,980	1,570	2,240	138,000	+ 960	139,000	2,260	11.2	12.91	A.
June	5,380	1,430	2,810	167,000	+ 240	167,000	2,810	13.9	15.51	A.
July	3,200	650	1,750	108,000	− 2,640	105,000	1,710	8.47	9.76	A.
August	940	392	544	33,400	− 5,520	27,900	454	2.25	2.59	A.
September	885	208	379	22,600	− 8,340	14,300	240	1.19	1.33	B.
October	425	84	232	14,300	− 1,330	13,000	211	1.04	1.20	B.
The year	5,380	84	941	683,000	+ 7,440	690,000	951	4.71	64.10	
1908–9.										
November	835	236	374	22,300	+14,000	36,300	610	3.02	3.37	B.
December	425	236	319	19,600	− 240	19,400	316	1.56	1.80	B.
January	320	200	248	15,200	− 240	15,000	244	1.21	1.40	B.
February	290	175	224	12,400	− 240	12,200	220	1.09	1.14	B.
March	730	175	321	19,700	+ 1,440	21,100	343	1.70	1.96	B.
April	1,570	565	938	55,800	+ 960	56,800	954	4.72	5.27	B.
May	3,450	1,130	2,000	123,000	+ 2,400	125,000	2,030	10.0	11.53	A.
June	5,380	1,330	2,740	163,000	− 2,880	160,000	2,690	13.3	14.84	A.
July	1,460	645	1,020	62,700	− 5,950	56,800	924	4.57	5.27	A.
August	862	296	556	34,200	−17,000	17,200	280	1.39	1.60	B.
September	302	203	270	16,100	− 80	16,000	269	1.33	1.48	B.
October	320	224	267	16,400	− 728	15,700	256	1.27	1.46	B.
The year	5,380	175	773	560,000	− 8,560	552,000	762	3.77	51.12	
1909–10.										
November	9,940	245	2,160	129,000	+50,600	180,000	3,020	15.0	16.74	A.
December	6,220	613	1,230	75,600	−13,400	62,200	1,010	5.00	5.76	A.
January	790	412	553	34,000	− 6,030	28,000	455	2.25	2.59	A.
February	478	385	436	24,200	+ 330	24,500	441	2.18	2.27	A.
March	3,090	419	1,220	75,000	+13,800	88,800	1,440	7.13	8.22	A.
April	5,650	922	2,060	123,000	+ 1,800	125,000	2,100	10.4	11.60	A.
May	4,960	1,670	2,700	166,000	+ 240	166,000	2,700	13.4	15.45	A.
June	2,480	910	1,410	83,900	− 2,040	81,900	1,380	6.83	7.62	A.
July	976	422	735	45,200	− 1,200	44,000	716	3.54	4.08	A.
August	916	347	610	37,500	−21,400	16,100	262	1.30	1.50	A.
September	374	158	206	12,300	− 1,040	11,300	190	.941	1.05	B.
October	1,260	70	753	46,300	+14,300	60,600	986	4.88	5.63	B.
The year	9,940	70	1,180	852,000	+36,000	888,000	1,230	6.09	82.51	

Estimated monthly discharge of Clealum River at outlet of Clealum Lake, near Roslyn, Wash., 1903–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.[a]	Without storage.	Mean.	Mean per square mile.		
1910–11.										
November	4,540	670	1,440	85,700	+ 5,120	90,800	1,530	7.57	8.45	A.
December	1,030	474	702	43,200	−16,000	27,200	442	2.19	2.52	A.
January	492	160	238	14,600	+10,100	24,700	402	1.99	2.29	A.
February	188	125	157	8,720	+ 2,880	11,600	209	1.03	1.07	A.
March	1,150	145	385	23,700	+ 7,140	30,800	501	2.48	2.86	A.
April	2,020	710	1,100	65,500	+ 1,440	66,900	1,120	5.54	6.18	A.
May	2,720	1,270	1,640	101,000	+ 1,680	103,000	1,680	8.32	9.59	A.
June	3,870	1,090	2,130	127,000	− 2,760	124,000	2,080	10.3	11.49	A.
July	1,150	615	851	52,300	− 8,300	44,000	716	3.54	4.08	A.
August	810	200	484	29,800	−13,400	16,400	267	1.32	1.52	A.
September	474	77	127	7,560	+14,700	22,300	375	1.86	2.08	B.
October	530	177	417	25,600	−16,800	8,800	143	.708	.82	A.
The year	4,540	77	807	585,000	−14,200	570,000	788	3.90	52.95	
1911–12.										
November	1,680	152	671	39,900	+19,600	59,500	1,000	4.95	5.52	A.
December	570	354	467	28,700	+ 2,160	30,900	503	2.49	2.87	A.
January	810	270	471	29,000	+ 960	30,000	488	2.42	2.79	B.
February	630	325	469	27,000	− 1,200	25,800	449	2.22	2.39	B.
March	684	225	304	18,700	+ 1,440	20,100	327	1.62	1.81	B.
April	1,630	745	1,090	64,900	+ 1,560	66,500	1,120	5.54	6.18	B.
May	4,950	1,340	2,850	175,000	+ 600	176,000	2,860	14.2	16.37	B.
June	3,360	1,210	2,210	132,000	− 1,560	130,000	2,180	10.8	12.05	B.
July	1,090	425	737	45,300	− 2,280	43,000	699	3.46	3.99	B.
August	516	355	454	27,900	− 7,740	20,200	329	1.63	1.88	B.
September	720	220	453	27,000	−13,200	13,800	232	1.15	1.28	B.
October	238	68	166	10,200	+ 5,580	15,800	257	1.27	1.46	B.
The year	4,950	68	862	626,000	+ 5,920	632,000	870	4.31	58.59	

NACHES RIVER AT ANDERSON'S RANCH, NEAR NILE, WASH.

Location.—In sec. 35, T. 17 N., R. 14 E., half a mile below Lost Creek, 1 mile below Gold Creek, 7 miles below Bumping River, 9 miles above Rattlesnake Creek, 10 miles above Nile, and 24 miles above Naches.

Records available.—April 24, 1909, to October 31, 1912.

Drainage area.—394 square miles.[1]

Gage.—Vertical staff on left bank.

Channel.—Gravel and cobblestones; shifting in floods.

Discharge measurements.—Made from cable 500 feet above gage, or by wading near gage.

Winter flow.—Seriously affected by ice; then estimated by comparison with records at adjacent stations.

Regulations.—Flow partly regulated by operation of dam at Bumping Lake reservoir. Records corrected for storage since November, 1910.

Diversions.—Above all important diversions. A small amount of water diverted above station by Anderson ditch.

Accuracy.—Results good.

[1] Revised measurement.

Estimated monthly discharge of Naches River at Anderson's ranch, near Nile, Wash., 1909–1912.

[Drainage area, 394 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1909.							
April 24–30	1,500	1,120	1,320	3.35	18,300	0.87	A.
May	3,500	1,340	2,040	5.18	125,000	5.97	A.
June	5,350	1,500	2,880	7.31	171,000	8.16	A.
July	1,850	508	1,050	2.66	64,600	3.07	A.
August	508	246	320	.812	19,700	.94	A.
September	267	189	209	.530	12,400	.59	B.
October	216	167	189	.480	11,600	.55	A.
The period (191 days)					423,000		
1909–10.							
November [a]	9,500	212	2,160	5.48	133,000	6.11	B.
December [a]	5,460	800	1,430	3.63	85,100	4.18	B.
January	2,330	400	660	1.68	40,600	1.94	C.
February	860	275	530	1.35	29,400	1.41	B.
March	6,450	385	2,430	6.17	149,000	7.11	B.
April	7,050	1,410	2,920	7.41	174,000	8.27	B.
May	6,600	2,450	3,410	8.65	210,000	9.97	B.
June	3,300	910	1,780	4.52	106,000	5.04	B.
July	1,020	310	718	1.82	44,100	2.10	A.
August	345	160	233	.591	14,300	.68	A.
September	215	160	188	.477	11,200	.53	A.
October	700	190	409	1.04	25,100	1.20	A.
The year	9,500	160	1,410	3.58	1,020,000	48.54	

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1910–11.										
November	4,350	275	1,190	70,800	+ 3,000	73,800	1,240	3.15	3.51	A.
December	1,140	425	666	41,000	− 3,800	37,200	605	1.54	1.78	A.
January	615	345	459	28,200	+ 18	28,200	459	1.17	1.35	B.
February	415	165	269	14,900	− 10	14,900	268	.685	.71	B.
March	1,260	192	571	35,100	+ 196	35,300	574	1.47	1.70	A.
April	2,480	870	1,340	79,700	+ 1,260	81,000	1,360	3.48	3.88	A.
May	2,720	1,640	2,170	133,000	+ 1,940	135,000	2,200	5.63	6.49	A.
June	4,020	1,190	2,290	136,000	+24,100	160,000	2,690	6.88	7.68	A.
July	1,190	280	797	49,000	+ 3,780	52,800	859	2.20	2.54	A.
August	760	280	610	37,500	−19,100	18,400	299	.765	.88	B.
September	760	192	473	28,100	−10,300	17,800	299	.765	.85	A.
October	490	120	165	10,100	+ 1,320	11,400	185	.473	.55	A.
The year	4,350	120	918	663,000	+ 2,400	666,000	920	2.34	31.92	
1911–12.										
November	1,880	280	596	35,500	− 1,190	34,300	576	1.47	1.64	A.
December	615	280	413	25,400	− 1,960	23,400	381	.974	1.12	A.
January	1,300	160	545	33,500	+ 590	34,100	555	1.41	1.63	C.
February	660	312	528	30,400	− 415	30,000	522	1.32	1.42	A.
March	760	220	358	22,000	− 308	21,700	353	.896	1.03	A.
April	1,880	870	1,310	78,000	+ 833	78,800	1,320	3.35	3.74	A.
May	4,290	1,560	2,680	165,000	+16,100	181,000	2,940	7.46	8.60	A.
June	2,720	1,260	2,060	123,000	+14,900	138,000	2,320	5.89	6.57	A.
July	1,720	345	707	43,500	− 1,040	42,500	691	1.75	2.02	B.
August	562	312	400	24,600	− 7,620	17,000	276	.700	.81	B.
September	651	359	522	31,100	−16,600	14,500	244	.619	.69	B.
October	415	165	274	16,800	− 5,690	11,100	181	.459	.53	B.
The year	4,290	160	866	629,000	− 2,400	626,000	862	2.19	29.80	

[a] The discharge estimate has been computed from the original data.

NACHES RIVER AT OAK FLAT, NEAR NILE, WASH.

Location.—In sec. 34, T. 15 N., R. 16 E., just above Oak Flat, half a mile above intake of Selah Valley canal, 2 miles above Tieton River, 7 miles northwest of Naches, and 9 miles below Rattlesnake Creek.

Records available.—June 25, 1904, to October 31, 1912.

Drainage area.—640 square miles (revised value).

Gage.—Since April 13, 1909, cantilever chain gage (Pl. IV, *A*) to which a Barrett-Lawrence automatic gage has been referred since September 20, 1911. Prior to April 13, 1909, an inclined staff 800 feet below present site.

Channel.—Gravel and small cobblestones; shifting in floods.

Discharge measurements.—Made from cable 50 feet below gage, or by wading near gage.

Winter flow.—Occasionally affected by anchor ice.

Regulation.—Flow partly regulated by operation of dam at Bumping Lake reservoir. Results corrected for storage since November, 1910.

Diversions.—Above all important diversions.

Accuracy.—Results good. Gage-height record doubtful for some periods.

Estimated monthly discharge of Naches River at Oak Flat, near Nile, Wash, 1904–1912.

[Drainage area 640 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.[a]
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1904.							
June 25–30	3,000	2,250	2,560	4.00	30,500	0.89	C.
July	3,180	760	1,660	2.59	102,000	2.99	C.
August	664	274	390	.609	24,000	.70	C.
September	274	[a]139	[a]173	.270	10,300	.30	D.
October	366	[a]181	[a]234	.366	14,400	.42	D.
The period (129 days)					181,000		
1904–5.[b]							
November	2,430	208	713	1.11	42,400	1.24	C.
December	975	425	553	.864	34,000	1.00	C.
January	576	316	421	.658	25,900	.76	B.
February	760	208	364	.569	20,200	.59	B.
March	2,430	975	1,730	2.70	106,000	3.11	B.
April	3,000	864	1,470	2.30	87,500	2.57	B.
May	2,250	1,090	1,550	2.42	95,300	2.79	B.
June	4,310	1,530	2,360	3.69	140,000	4.12	B.
July	1,690	600	899	1.40	55,300	1.61	B.
August	680	390	487	.761	29,900	.88	B.
September	460	320	371	.580	22,100	.65	B.
October	1,690	390	778	1.22	47,800	1.41	B.
The year	4,310	208	978	1.53	706,000	20.73	
1905–6.							
November	630	390	467	.730	27,800	.81	B.
December	540	330	422	.659	26,000	.76	B.
January	840	390	513	.802	31,500	.92	B.
February	2,020	585	1,010	1.58	56,100	1.64	B.
March	2,380	730	996	1.56	61,200	1.80	B.
April	4,740	2,020	3,250	5.08	193,000	5.67	B.
May	4,220	1,690	2,810	4.39	173,000	5.06	B.
June	2,200	1,090	1,530	2.39	91,000	2.67	A.
July	1,090	390	676	1.06	41,600	1.22	A.
August	330	235	289	.452	17,800	.52	A.
September	330	235	267	.418	15,900	.47	A.
October	1,090	235	458	.716	28,200	.83	A.
The year	4,740	235	1,060	1.66	763,000	22.37	

[a] The records for 1904 are subject to great uncertainty on account of unreliable gage-height observations. The discharge estimates for 1904, as based on the observer's gage heights, indicate by far the most severe minimum flow obtaining during the period from June 25, 1904, to Oct. 31, 1912. The minimum flow for September is thought to have been more nearly 180 second-feet than 139 second-feet as derived from the questionable gage heights.

[b] The discharge estimate has been revised from Jan. 1 to Oct. 6, 1905.

Estimated monthly discharge of Naches River at Oak Flat, near Nile, Wash., 1904–1912—Continued.

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1906–7.							
November	21,100	460	3,620	5.66	215,000	6.32	B.
December	2,010	468	962	1.50	59,200	1.73	B.
January	801	372	569	.889	35,000	1.02	B.
February	2,280	635	1,420	2.22	78,900	2.31	B.
March	1,490	725	997	1.56	61,300	1.80	B.
April	3,440	772	2,020	3.16	120,000	3.53	B.
May	5,440	2,520	4,050	6.33	249,000	7.30	A.
June	4,970	1,750	2,660	4.16	158,000	4.64	A.
July	1,750	555	1,060	1.66	65,200	1.91	A.
August	555	330	419	.655	25,800	.76	A.
September	400	265	325	.508	19,300	.57	A.
October	265	185	220	.344	13,500	.40	A.
The year	21,100	185	1,520	2.38	1,100,000	32.29	
1907–8.							
November	1,130	210	325	.508	19,300	.57	A.
December	1,020	330	592	.925	36,400	1.07	A.
January	555	265	438	.684	26,900	.79	B.
February	475	265	337	.527	19,400	.57	B.
March	3,440	330	1,110	1.73	68,200	1.99	B.
April	6,060	662	2,350	3.67	140,000	4.10	A.
May	3,700	2,150	2,850	4.45	175,000	5.13	A.
June	6,340	2,150	3,720	5.81	221,000	6.48	A.
July	4,450	1,020	2,570	4.02	158,000	4.64	A.
August	894	398	568	.888	34,900	1.02	A.
September	398	224	294	.459	17,500	.51	B.
October	474	224	277	.433	17,000	.50	B.
The year	6,340	210	1,290	2.02	934,000	27.37	
1908–9.							
November	1,160	332	642	1.00	38,200	1.12	A.
December	562	274	411	.642	25,300	.74	A.
January	1,170	*a* 202	576	.900	35,400	1.04	B.
February	650	371	476	.744	26,400	.77	B.
March	1,060	338	595	.930	36,600	1.07	A.
April	1,740	850	1,250	1.95	74,400	2.18	A.
May	3,200	1,470	2,240	3.50	138,000	4.04	A.
June	5,640	2,030	3,520	5.50	209,000	6.14	A.
July	2,340	640	1,400	2.19	86,100	2.52	A.
August	575	270	370	.578	22,800	.67	A.
September	270	195	228	.356	13,600	.40	A.
October	270	195	229	.358	14,100	.41	A.
The year	5,640	195	995	1.55	720,000	21.10	
1909–10.							
November	10,100	270	2,620	4.09	156,000	4.56	A.
December	6,160	640	1,650	2.58	101,000	2.97	A.
January	1,700	443	716	1.12	44,000	1.29	B.
February	864	443	558	.872	31,000	.91	B.
March	7,470	944	3,190	4.98	196,000	5.74	B.
April	8,100	1,840	3,600	5.62	214,000	6.27	B.
May	7,470	3,010	4,320	6.75	266,000	7.78	B.
June	3,840	1,230	2,320	3.62	138,000	4.04	B.
July	1,340	490	919	1.44	56,500	1.66	B.
August	443	268	346	.541	21,300	.62	B.
September	295	244	261	.408	15,500	.46	B.
October	864	244	522	.816	32,100	.94	B.
The year	10,100	244	1,760	2.75	1,270,000	37.24	

a The discharge as indicated by the gage heights for the period Jan. 1–16 was decreased by 10 per cent to allow for ice conditions. The minimum for the month occurred during this interval.

Estimated monthly discharge of Naches River at Oak Flat, near Nile, Wash., 1904–1912—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1910–11.										
November	3,210	363	1,360	80,900	+ 3,000	83,900	1,410	2.20	2.46	A.
December	1,340	540	784	48,200	− 3,800	44,400	722	1.13	1.30	A.
January	515	325	401	24,700	+ 18	24,700	401	.631	.73	A.
February	325	190	269	14,900	− 10	14,900	269	.423	.44	A.
March	1,620	190	683	42,000	+ 196	42,200	686	1.08	1.24	A.
April	2,940	950	1,580	94,000	+ 1,260	95,300	1,600	2.52	2.81	A.
May	3,360	2,200	2,570	158,000	+ 1,940	160,000	2,600	4.09	4.72	A.
June	5,090	1,420	3,040	181,000	+24,100	205,000	3,450	5.42	6.05	A.
July	1,370	325	879	54,000	+ 3,780	57,800	940	1.48	1.71	A.
August	710	325	575	35,400	−19,100	16,300	265	.417	.48	A.
September	740	220	481	28,600	−10,300	18,300	308	.484	.54	A.
October	582	154	226	13,900	+ 1,320	15,200	247	.388	.45	A.
The year	5,090	154	1,070	776,000	+ 2,400	778,000	1,070	1.67	22.93	
1911–12.										
November	2,120	287	662	39,400	− 1,190	38,200	642	1.01	1.13	A.
December	640	270	417	25,600	− 1,960	23,600	384	.604	.70	A.
January	1,360	163	585	36,000	+ 590	36,600	595	.930	1.07	A.
February	856	466	628	36,100	− 415	35,700	621	.970	1.05	A.
March	967	308	432	26,600	− 308	26,300	428	.669	.77	A.
April	2,620	1,080	1,710	102,000	+ 833	103,000	1,730	2.70	3.01	A.
May	5,870	2,080	3,890	239,000	+16,100	255,000	4,150	6.48	7.47	A.
June	3,530	1,480	2,730	162,000	+14,900	177,000	2,980	4.66	5.20	A.
July	1,470	416	797	49,000	− 1,040	48,000	781	1.22	1.41	A.
August	640	328	436	26,800	− 7,620	19,200	312	.488	.56	A.
September	640	393	542	32,300	−16,600	15,700	264	.412	.46	A.
October	370	253	317	19,500	− 5,690	13,800	224	.350	.40	A.
The year	5,870	163	1,090	794,000	− 2,400	792,000	1,090	1.70	23.23	

NACHES RIVER BELOW TIETON RIVER, NEAR NACHES, WASH.

Location.—In sec. 35, T. 15 N., R. 16 E., about 600 feet below Tieton River, 500 feet above Naches (Wapatox) power canal intake, and 5 miles northwest of Naches.

Records available.—August 4 to October 28, 1905; March 16, 1909, to October 31, 1912.

Drainage area.—942 square miles.[1]

Gage.—Staff in two sections; lower section inclined, upper vertical.

Channel.—Gravel and large cobblestones; shifting in floods.

Discharge measurements.—Made from cable at gage.

Winter flow.—Not seriously affected by ice.

Regulation.—Flow partly regulated by operation of dam at Bumping Lake reservoir. Results corrected for storage since November, 1910.

Diversions.—Above all important diversions except Selah Valley and Tieton canals. Records corrected for diversions.

Accuracy.—Results fair. Gage-height record doubtful for some periods.

[1] Revised measurement.

Estimated monthly natural discharge of Naches River below Tieton River, near Naches, Wash., 1908–1912.

[Drainage area, 942 square miles.]

Month.	Discharge of river in second-feet.			Run-off in acre-feet.				Natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Diverted.[a]	Stored.	Natural.	Mean.	Mean per square mile.		
1908–9.											
November			[b]1,040	61,900			61,900	[b]1,040	1.10	1.23	C.[c]
December			[b]655	40,300			40,300	[b]655	.695	.80	C.[c]
January			[b]945	58,100			58,100	[b]945	1.00	1.15	C.[c]
February			[b]765	42,500			42,500	[b]765	.812	.85	C.[c]
March			[b]1,000	61,500			61,500	[b]1,000	1.06	1.22	C.[c]
April	2,610	1,430	1,950	116,000			116,000	1,950	2.07	2.31	C.[c]
May	5,600	2,300	3,580	220,000	[d]6,000		226,000	3,680	3.91	4.51	C.[c]
June	9,180	2,960	5,840	348,000	[d]6,500		354,000	5,950	6.32	7.05	C.[c]
July	3,150	1,110	2,060	127,000	6,580		134,000	2,180	2.31	2.66	C.[c]
August	1,110	518	700	43,000	6,520		49,500	805	.855	.99	C.[c]
September	518	410	476	28,300	5,410		33,700	566	.601	.67	C.[c]
October	460	360	406	25,000	[d]4,000		29,000	472	.501	.58	C.[c]
The year		360	1,620	1,170,000	35,000		1,210,000	1,680	1.78	24.02	
1909–10.											
November	18,800	460	4,620	275,000			275,000	4,620	4.90	5.47	C.[e]
December	10,200	850	2,580	159,000			159,000	2,580	2.74	3.16	C.[e]
January	2,420	680	1,090	67,000			67,000	1,090	1.16	1.34	C.[e]
February	1,570	740	983	54,600			54,600	983	1.04	1.08	C.[e]
March	10,200	1,140	4,880	300,000			300,000	4,880	5.18	5.97	C.[e]
April	9,000	2,670	4,780	284,000	[f]1,580		286,000	4,810	5.11	5.70	C.[e]
May	9,600	4,110	5,670	349,000	[f]7,810		357,000	5,810	6.17	7.11	C.[e]
June	5,870	1,830	3,280	195,000	[f]9,160		204,000	3,430	3.64	4.06	C.[e]
July	1,830	740	1,370	84,200	[f]9,590		93,800	1,530	1.62	1.87	C.[e]
August	680	418	537	33,000	[f]8,630		41,600	677	.719	.83	C.[e]
September	465	360	404	24,000	[f]6,720		30,700	533	.566	.63	C.[e]
October	1,830	465	883	54,300	[f]4,100		58,400	950	1.01	1.16	C.[e]
The year	18,800	360	2,600	1,880,000	47,600		1,930,000	2,670	2.83	38.38	

Month.	Discharge of river in second-feet.			Run-off in acre-feet.				Natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Diverted.[f]	Stored.[g]	Without storage.	Mean.	Mean per square mile.		
1910–11.											
November	6,000	565	2,630	156,000		+ 2,900	159,000	2,670	2.83	3.16	C.
December	2,420	815	1,200	73,800		− 3,690	70,100	1,140	1.21	1.40	C.
January	870	545	642	39,500		+ 3	39,500	642	.682	.79	C.
February	495	410	456	25,300		− 31	25,300	456	.484	.50	C.
March	2,260	410	1,040	64,000		+ 221	64,200	1,040	1.10	1.27	C.
April	3,110	1,350	1,960	117,000	4,840	+ 1,320	123,000	2,070	2.20	2.46	C.
May	4,940	2,740	3,270	201,000	9,590	+ 2,910	213,000	3,460	3.67	4.23	B.
June	7,500	1,830	4,180	249,000	12,500	+23,300	285,000	4,790	5.08	5.67	B.
July	1,830	545	1,200	73,800	15,200	+ 3,670	92,700	1,510	1.60	1.84	B.
August	1,350	495	801	49,300	14,200	−20,000	43,500	707	.751	.87	B.
September	1,350	410	693	41,200	8,910	− 9,960	40,100	674	.715	.80	B.
October	600	320	363	22,300	3,190	+ 1,560	27,000	439	.466	.54	B.
The year	7,500	320	1,540	1,110,000	68,400	+ 2,200	1,180,000	1,630	1.73	23.53	

[a] The Selah Valley canal diverts water past the station during the irrigation season.
[b] Estimated from combined flow of Naches River at Oak Flat and of Tieton River at Cobb's ranch.
[c] The rating is well defined, but the gage height observations are somewhat doubtful.
[d] Estimated on basis of 1910 diversion.
[e] Several shifts in the channel occurred during the climatic year of 1909–10 and the gage-height observations are somewhat doubtful.
[f] The Selah Valley and Tieton canals divert water past the station during the irrigation season.
[g] Storage in Bumping Lake reservoir.

Estimated monthly natural discharge of Naches River below Tieton River, near Naches, Wash., 1908–1912—Continued.

Month.	Discharge of river in second-feet.			Run-off in acre-feet.				Natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Diverted.[a]	Stored.[b]	Without storage.	Mean.	Mean per square mile.		
1911–12.											
November	4,940	450	1,020	60,700	1,270	− 1,190	60,800	1,020	1.08	1.20	B.
December	870	450	638	39,200	563	− 1,960	37,800	615	.653	.75	B.
January	2,280	350	963	59,200	....	+ 590	59,800	973	1.03	1.19	D.
February	1,450	730	1,060	61,000	....	− 415	60,600	1,050	1.11	1.20	B.
March	1,570	555	757	46,500	....	− 308	46,200	751	.797	.92	B.
April	3,640	1,690	2,380	142,000	1,680	+ 833	145,000	2,440	2.59	2.89	B.
May	7,960	2,580	5,030	309,000	14,100	+16,100	339,000	5,510	5.85	6.74	B.
June	5,650	1,760	3,860	230,000	18,000	+14,900	263,000	4,420	4.69	5.23	B.
July	2,580	505	1,120	68,900	17,200	− 1,040	85,100	1,380	1.46	1.68	B.
August	682	402	536	33,000	18,400	− 7,620	43,800	712	.756	.87	B.
September	918	515	630	37,500	11,600	−16,600	32,500	546	.580	.65	B.
October	530	344	435	26,700	5,260	− 5,690	26,300	428	.454	.52	B.
The year	7,960	344	1,530	1,110,000	88,200	− 2,400	1,200,000	1,650	1.75	23.84	

[a] The Selah Valley and Tieton canals divert water past the station during the irrigation season.
[b] Storage in Bumping Lake reservoir.

NACHES RIVER NEAR MOUTH, NEAR NORTH YAKIMA, WASH.

Location.—In sec. 12, T. 13 N., R. 18 E., half a mile above the mouth of the river and 2 miles northwest of North Yakima.

Records available.—August 14, 1893, to February 20, 1897, fragmentary; March 1, 1898, to October 31, 1912.

Drainage area.—1,120 square miles.

Gage.—Cantilever chain on right bank. Prior to June 18, 1908, 10 different gages at approximately the same location.

Channel.—Gravel and cobblestones; shifting.

Discharge measurements.—Made from cable 50 feet below gage.

Winter flow.—Occasionally seriously affected by ice jams; then estimated by comparison with records at other stations on same stream.

Regulation.—Flow partly regulated by operation of dam at Bumping Lake reservoir.

Diversions.—Below all diversions. The North Yakima Milling Co. and North Yakima Power Co. divert water around the station and waste directly into Yakima River. The combined flow of these wastes must be added to that of the river to obtain the total contribution of the Naches basin to Yakima River.

Accuracy.—Results poor.

Estimated monthly discharge of Naches River near mouth, near North Yakima, Wash., 1898–1909.

[Drainage area, 1,120 square miles.]

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1898.					
January[a]	....	....	500	30,700	D.
February[a]	....	....	3,000	167,000	D.
March	2,130	913	1,510	92,700	C.
April	5,800	1,020	3,160	188,000	C.
May	7,480	4,120	5,190	319,000	C.
June	6,640	2,480	4,500	268,000	C.
July	2,870	1,020	1,800	111,000	C.
August	1,020	385	594	36,500	C.
September	607	325	362	21,500	C.
October	811	325	445	27,400	C.
The period	....	....	....	1,260,000	

[a] Approximate.

Estimated monthly discharge of Naches River near mouth, near North Yakima, Wash., 1898–1909—Continued.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1898–99.					
November	709	385	510	30,300	C.
December	2,870	225	580	35,700	C.
January [a]	3,700	445	1,420	87,300	C.
February [a]	2,130	1,020	1,400	77,800	C.
March [a]	1,130	709	841	51,700	C.
April [a]	2,480	913	1,760	105,000	C.
May [a]	5,590	1,970	3,860	237,000	C.
June [a]	7,070	4,750	6,070	361,000	C.
July [a]	5,970	2,580	4,570	281,000	C.
August [a]	2,370	920	1,440	88,600	C.
September [a]	920	570	703	41,800	C.
October [a]	1,350	498	748	46,000	C.
The year	7,070	225	1,990	1,440,000	
1899–1900.					
November [a]	7,470	735	2,490	148,000	C.
December [a]	5,650	1,120	2,760	170,000	C.
January [a]	9,710	1,470	2,900	178,000	C.
February [a]	1,600	1,020	1,240	68,900	C.
March [a]	4,090	1,120	2,650	163,000	C.
April [a]	5,010	1,730	2,890	172,000	C.
May [a]	5,010	1,600	3,080	189,000	C.
June [a]	2,950	1,120	1,840	109,000	C.
July [a]	1,020	425	616	37,900	C.
August [a]	498	250	346	21,300	C.
September [a]	570	300	386	23,000	C.
October [a]	2,010	300	684	42,100	C.
The year	9,710	250	1,820	1,320,000	
1900–1901.					
November [a]	1,470	920	1,240	73,800	C.
December [a]	5,650	1,350	2,670	164,000	C.
January [a]	3,810	920	1,590	97,800	C.
February [a]	4,370	828	1,610	89,400	C.
March [a]	9,070	1,730	3,380	208,000	C.
April [a]	2,760	1,600	2,220	132,000	C.
May [a]	8,750	3,160	5,440	334,000	C.
June [a]	6,560	2,670	3,940	234,000	C.
July [a]	2,760	1,120	1,960	121,000	C.
August [a]	1,120	362	662	40,700	C.
September [a]	394	300	322	19,200	C.
October [a]	362	250	271	16,700	C.
The year	9,070	250	2,110	1,530,000	
1901–2.					
November [a]	6,290	362	1,090	64,900	C.
December [a]	3,810	735	1,600	98,400	C.
January	5,650	735	1,940	119,000	C.
February	2,150	650	1,210	67,200	C.
March	1,470	1,020	1,210	74,500	C.
April	5,010	1,120	2,640	157,000	C.
May	8,750	2,310	5,280	325,000	C.
June	5,010	2,760	3,780	225,000	C.
July	2,760	1,120	1,840	113,000	C.
August	1,120	300	589	36,200	C.
September	495	200	263	15,600	C.
October	495	300	390	23,900	C.
The year	8,750	200	1,820	1,320,000	

[a] Estimate revised from original data.

Estimated monthly discharge of Naches River near mouth, near North Yakima, Wash., 1898-1909—Continued.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1902-3.					
November	1,350	495	820	48,800	C.
December	1,600	650	975	60,000	C.
January	7,470	1,240	2,350	145,000	C.
February	1,470	920	1,080	60,200	C.
March	3,580	920	1,360	83,300	C.
April	4,050	1,860	2,620	156,000	C.
May	8,750	3,150	5,700	351,000	C.
June	11,300	5,330	8,460	503,000	C.
July	4,050	1,120	2,490	153,000	C.
August	1,020	300	585	36,000	C.
September	495	200	296	17,600	C.
October	2,760	250	1,670	103,000	C.
The year	11,300	200	2,380	1,720,000	
1903-4.					
November	3,810	1,350	1,970	117,000	C.
December	6,290	1,020	2,240	138,000	C.
January [a]	2,010	874	1,160	71,300	C.
February [a]	828	652	719	41,400	C.
March [a]	1,600	570	977	60,100	C.
April [a]	[b] 11,700	1,020	6,360	378,000	C.
May [a]	9,710	2,950	5,480	337,000	B.
June [a]	6,560	2,150	4,160	248,000	B.
July [a]	4,090	780	2,060	127,000	B.
August	780	210	436	26,800	B.
September [c]	260	160	189	11,200	B.
October	560	200	284	17,500	B.
The year	11,700	160	2,160	1,570,000	
1904-5. [d]					
November	2,260	230	832	49,500	D.
December	1,440	670	816	50,200	D.
January	820	478	577	35,500	D.
February	1,100	380	537	29,800	D.
March	2,520	1,170	1,980	122,000	D.
April	2,650	698	1,370	81,600	D.
May	2,260	1,170	1,520	93,300	D.
June	3,370	1,640	2,280	135,000	D.
July	1,760	478	882	54,200	D.
August	530	100	268	16,500	D.
September	380	100	184	11,000	D.
October	1,540	237	730	44,900	D.
The year	3,370	100	1,000	724,000	

[a] Estimate revised from the original data.
[b] Maximum obtained by extending 1902 rating table.
[c] Measurements of the North Yakima Power waste on Sept. 12 and 14 showed a discharge of 134 and 128 second-feet, respectively.
[d] There is considerable discrepancy between the flow measured at this station and the flow as determined by a summation of the run-off on Tieton River at Cobb's ranch and Naches River at Oak Flat. It is probable that the values are more accurate at the two upper stations than for this station on account of undefined channel conditions.

Estimated monthly discharge of Naches River near mouth, near North Yakima, Wash., 1898–1909—Continued.

Month.	Discharge in second-feet.			Run-off in acre-feet.	Accuracy.
	Maximum.	Minimum.	Mean.		
1905–6. [a]					
November	584	334	432	25,700	D.
December	478	254	350	21,500	D.
January	800	285	395	24,300	D.
February	2,190	525	1,030	57,200	D.
March	2,340	720	982	60,400	D.
April	4,500	1,900	3,120	186,000	D.
May	4,890	1,470	3,040	187,000	D.
June	2,630	910	1,550	92,200	D.
July	1,210	185	646	39,700	D.
August	150	30	67.6	4,160	D.
September	185	30	74.8	4,450	D.
October	1,570	45	386	23,700	D.
The year	4,890	30	1,010	726,000	
1906–7.					
November	21,900	525	4,290	255,000	C.
December	4,700	1,600	2,440	150,000	B.
January [b]			950	58,400	C.
February [b]			2,520	140,000	C.
March	2,540	1,180	1,680	103,000	B.
April	6,050	1,280	3,490	208,000	B.
May	8,620	3,680	6,100	375,000	B.
June	8,100	1,820	3,600	214,000	B.
July	1,820	375	830	51,000	B.
August	400	90	224	13,800	B.
September	280	105	184	10,900	B.
October	140	90	105	6,460	B.
The year	21,900	90	2,200	1,590,000	
1907–8.					
November	940	120	231	13,700	C.
December	2,190	425	840	51,600	C.
January	810	475	620	38,100	C.
February	600	450	527	30,300	B.
March	4,730	565	2,100	129,000	B.
April	9,770	1,520	4,090	243,000	B.
May	6,200	3,460	4,570	281,000	B.
June	8,500	2,900	4,970	296,000	B.
July	5,280	860	3,230	199,000	B.
August	860	248	492	30,300	B.
September	248	178	219	13,000	B.
October	805	148	268	16,500	B.
The year	9,770	120	1,710	1,240,000	
1908–9.					
November	1,760	348	762	45,300	C.
December	560	120	366	22,500	D.
January	2,070	348	880	54,100	C.
February	780	390	547	30,400	B.
March	1,540	455	799	49,100	B.
April	2,230	1,160	1,640	97,600	B.
May	4,880	1,910	3,160	194,000	B.
June	9,760	2,530	4,940	294,000	B.
July	2,710	645	1,540	94,700	B.
August	605	118	249	15,300	B.
September	485	93	146	8,690	B.
October	448	142	279	17,200	B.
The year	9,760	93	1,490	1,080,000	

[a] There is considerable discrepancy between the flow measured at this station and the flow as determined by a summation of the run-off on Tieton River at Cobb's ranch and Naches River at Oak Flat. It is probable that the values are more accurate at the two upper stations than for this station on account of undefined channel conditions.

[b] Discharge for January and February estimated from other stations in the vicinity. Ice present in the stream during these months.

NOTE.—Estimates do not include 80 to 200 second-feet of water diverted around the gaging station by the North Yakima Power canal.

Estimated monthly contribution of Naches River basin to Yakima River, 1909–1912.

Month.	Observed mean discharge in second-feet.			Contribution to Yakima River (in second-feet).	Contribution to Yakima River (in acre-feet).	Accuracy.
	Naches River at North Yakima.	North Yakima power waste.	North Yakima mill waste.			
1909–10.						
November	4,790	98	71	4,960	295,000	B.
December	2,360	80	54	2,490	153,000	B.
January	1,000	77	34	1,110	68,200	B.
February	783	92	71	946	52,500	B.
March	4,750	97	75	4,920	303,000	B.
April	4,570	78	62	4,710	280,000	B.
May	5,110	67	48	5,220	321,000	B.
June	2,550	66	57	2,670	159,000	B.
July	961	62	40	1,060	65,200	B.
August	234	61	34	329	20,200	A.
September	102	88	54	244	14,500	A.
October	693	94	68	855	52,600	B.
The year				2,460	1,780,000	
1910–11.						
November	1,810	113	51	1,970	117,000	B.
December	927	106	55	1,090	67,000	B.
January	652	111	61	824	50,700	B.
February	458	65	76	599	33,300	B.
March	1,020	50	47	1,120	68,900	B.
April	1,710	93	51	1,850	110,000	B.
May	2,690	103	55	2,850	175,000	B.
June	3,580	88	52	3,720	221,000	C.
July	952	61	43	1,060	65,200	B.
August	370	82	48	500	30,700	B.
September	533	121	68	722	43,000	C.
October	223	111	72	406	25,000	B.
The year				1,400	1,010,000	
1911–12.						
November	826	109	78.0	1,010	60,100	B.
December	556	102	58.8	717	44,100	B.
January	965	103	37.5	1,110	68,200	C.
February	1,010	103	69.0	1,180	67,900	B.
March	724	56.7	71.5	852	52,400	B.
April	2,150	95.4	61.6	2,310	138,000	B.
May	4,470	92.0	48.6	4,610	283,000	B.
June	3,470	90.6	46.7	3,610	215,000	B.
July	834	62.0	38.7	935	57,500	B.
August	171	74.5	49.0	294	18,100	B.
September	342	79.6	56.3	478	28,400	B.
October	322	91.0	67.9	481	29,600	B.
The year				1,460	1,060,000	

BUMPING RIVER AT OUTLET OF BUMPING LAKE, NEAR NILE, WASH.

Location.—At outlet of Bumping Lake, 150 feet below spillway of Bumping Lake dam and 1,000 feet below outlet conduit of Bumping Lake reservoir, about 20 miles west of Nile, and 46 miles northwest of Naches.

Records available.—June 13 to July 31, 1906; April 27, 1909, to October 31, 1912.

Drainage area.—68 square miles.

Gage.—Vertical staff in two sections on opposite banks. In 1906 gage was situated at dam site and April 27 to July 3, 1909, at a point 450 feet below the dam.

Channel.—Bowlders and cobblestones, shifting slightly in floods.

Discharge measurements.—Made from cable or by wading near gage.

Winter flow.—Not affected by ice.

Regulation.—Flow partly regulated by operation of dam at Bumping Lake reservoir. Results corrected for storage since November, 1910.

Accuracy.—Results good.

Monthly discharge of Bumping River at outlet of Bumping Lake, near Nile, Wash., 1906, 1909–1912.

[Drainage area, 68 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1906.							
June 13–30	417	266	318	4.68	11,400	3.13	A.
July	314	122	195	2.87	12,000	3.31	A.
The period					23,400		
1909.							
May	1,070	332	581	8.54	35,700	9.85	A.
June	1,980	578	1,090	16.0	64,900	17.85	A.
July	729	178	408	6.0	25,100	6.92	A.
August	171	68	102	1.50	6,270	1.73	A.
September	82	53	63.6	.935	3,780	1.04	B.
October	75	49	62.2	.915	3,820	1.05	B.
The period (184 days)					140,000		
1909–10.							
November	3,100	78	719	10.6	42,800	11.83	B.
December	1,460	178	390	5.74	24,000	6.62	B.
January	485	159	247	3.63	15,200	4.18	A.
February	254	[a] 0	154	2.26	8,550	2.35	A.
March	810	[a] 0	414	6.09	25,500	7.02	A.
April	1,550	269	579	8.51	34,500	9.50	A.
May	2,170	534	1,040	15.3	64,000	17.64	A.
June	1,460	300	675	9.93	40,200	11.08	A.
July	400	137	268	3.94	16,500	4.54	A.
August	137	50	88.0	1.29	5,410	1.49	A.
September	96	39	59.9	.881	3,560	.98	A.
October	300	64	202	2.96	12,400	3.41	A.
The year	3,100	[a] 0	405	5.96	293,000	80.64	

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1910–11.										
November	908	79	462	27,500	+ 3,000	30,500	513	7.54	8.41	A.
December	383	127	252	15,500	− 3,800	11,700	190	2.79	3.22	A.
January	151	121	137	8,420	+ 18	8,440	137	2.01	2.32	A.
February	144	129	138	7,660	− 10	7,650	138	2.03	2.11	A.
March	242	103	152	9,350	+ 196	9,550	155	2.28	2.63	A.
April	474	188	299	17,800	+ 1,260	19,100	321	4.72	5.27	A.
May	545	412	479	29,500	+ 1,940	31,400	511	7.51	8.66	A.
June	830	242	435	25,900	+24,100	50,000	840	12.40	13.83	A.
July	338	0	181	11,100	+ 3,780	14,900	242	3.56	4.10	A.
August	545	37	410	25,200	−19,100	6,100	99.2	1.46	1.68	A.
September	600	0	332	19,800	−10,300	9,500	160	2.35	2.62	D.
October	339	0	34.5	2,120	+ 1,320	3,440	55.9	.822	.95	C.
The year	908	0	276	200,000	+ 2,400	202,000	279	4.10	55.80	

[a] The river was dammed by a snowslide from Feb. 27 to Mar. 1.

Monthly discharge of Bumping River at outlet of Bumping Lake, near Nile, Wash.—Continued.

Month.	Observed discharge in second-feet.			Run-off in acre-feet.			Discharge in second-feet (without storage).		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	Observed.	Stored.	Without storage.	Mean.	Mean per square mile.		
1911-12.										
November	273	123	219	13,000	− 1,190	11,800	198	2.91	3.25	B.
December	273	123	182	11,200	− 1,960	9,240	150	2.21	2.55	B.
January	273	105	189	11,600	+ 590	12,200	198	2.91	3.36	B.
February	243	189	216	12,400	− 415	12,000	209	3.07	3.31	B.
March	177	105	126	7,750	− 308	7,440	121	1.78	2.05	B.
April	267	143	215	12,800	+ 833	13,600	229	3.37	3.76	B.
May	771	154	534	32,800	+16,100	48,900	795	11.7	13.49	B.
June	1,290	165	657	39,100	+14,900	54,000	908	13.4	14.95	C.
July	660	143	368	22,600	− 1,040	21,600	351	5.16	5.95	C.
August	322	177	239	14,700	− 7,620	7,080	115	1.69	1.95	B.
September	501	258	402	23,900	−16,600	7,300	123	1.81	2.02	B.
October	305	23	189	11,600	− 5,690	5,910	96.1	1.41	1.63	B.
The year	1,290	23	293	213,000	− 2,400	211,000	291	4.28	58.27	

AMERICAN RIVER AT MOUTH, NEAR NILE, WASH.

Location.—At a highway bridge three-fourths of a mile above the mouth of the river, about 17 miles northwest of Nile, and below all tributaries.

Records available.—April 25 to November 1, 1909; May 26 to November 15, 1910; May 18 to September 30, 1911.

Drainage area.—81 square miles.[1]

Gage.—Vertical staff on right abutment of highway bridge.

Channel.—Gravel and heavy bowlders; shifting slightly at high stages.

Discharge measurements.—Made from highway bridge.

Accuracy.—Results fair.

Estimated monthly discharge of American River at mouth, near Nile, Wash., 1909 and 1910–11.

[Drainage area, 81 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1909.							
April 25-30	444	334	378	4.67	4,500	1.04	A.
May	956	377	603	7.44	37,100	8.58	A.
June	1,580	520	980	12.1	58,300	13.50	A.
July	777	233	485	5.99	29,800	6.91	A.
August	215	74	117	1.44	7,190	1.66	A.
September	66	52	56.3	.695	3,350	.78	B.
October	66	45	53.2	.657	3,270	.76	B.
The period (190 days)					144,000		
1910.							
May 26-31	955	736	826	10.20	9,830	2.28	B.
June	969	344	541	6.68	32,200	7.45	B.
July	446	130	272	3.36	16,700	3.87	B.
August	130	75	99.4	1.23	6,110	1.42	B.
September	75	56	62.5	.772	3,720	.86	B.
October	374	60	170	2.10	10,500	2.42	B.
The period (159 days)					79,100		
1910-11.							
November 1-15	1,180	82	330	4.07	9,820	2.27	B.
May 18-31	800	432	518	6.40	14,400	3.33	B.
June	1,400	432	792	9.78	47,100	10.91	B.
July	540	118	280	3.46	17,200	3.99	B.
August	111	57	80.2	.990	4,930	1.14	B.
September	91	57	84.6	1.04	5,030	1.16	B.
The period (151 days)					98,500		

[1] Revised measurement.

TIETON RIVER AT MCALLISTER MEADOWS, NEAR NACHES, WASH.

Location.—About 800 feet above the McAllister Meadow dam site, half a mile above Wildcat Creek, 1½ miles below the junction of the forks of the river, 9 miles above the headworks of Tieton canal, and about 30 miles southwest of Naches.

Records available.—August 25, 1908, to October 31, 1912; fragmentary.

Drainage area.—187 square miles.

Gage.—Vertical staff on left bank.

Channel.—Gravel; fairly permanent.

Discharge measurements.—Made from cable 100 feet below gage or by wading near gage.

Winter flow.—Not affected by ice.

Accuracy.—Results fair.

Estimated monthly discharge of Tieton River at McAllister Meadows, near Naches, Wash., 1908–1912.

[Drainage area, 187 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches of the drainage area.	
1908.							
September	362	205	287	1.53	17,100	1.71	B.
October	446	198	239	1.28	14,700	1.48	B.
The period (61 days)					31,800		
1908–9.							
November [a]			349	1.87	20,800	2.09	B.
December [b]			190	1.02	11,700	1.18	B.
January [b]			300	1.60	18,400	1.84	B.
February [b]			230	1.23	12,800	1.28	B.
March [b]			350	1.87	21,500	2.16	B.
April	680	375	471	2.52	28,000	2.81	B.
May	1,240	515	788	4.21	48,500	4.85	B.
June	1,930	750	1,170	6.26	69,600	6.98	B.
July	860	402	570	3.05	35,000	3.52	A.
August	402	197	304	1.63	18,700	1.88	A.
September [c]	305	162	229	1.22	13,600	1.36	A.
October [a]	302	138	184	.984	11,300	1.13	A
The year			429	2.29	310,000	31.08	
1909–10.							
November	4,200	174	1,190	6.36	70,800	7.10	B.
December	1,820	238	611	3.27	37,500	3.77	A.
January [c]	1,140	127	326	1.74	20,000	2.01	B.
February [d]	430	210	281	1.50	15,600	1.56	C.
March [d]	2,260	500	1,050	5.61	64,600	6.46	C.
April	2,190	614	1,070	5.72	63,700	6.38	A.
May	2,370	917	1,340	7.17	82,400	8.27	A.
June	1,610	620	904	4.83	53,800	5.39	A.
July	748	360	523	2.80	32,200	3.23	A.
August	400	196	292	1.56	18,000	1.80	B.
September	282	206	235	1.26	14,000	1.41	B.
October	1,210	229	391	2.09	24,000	2.41	A.
The year	4,200	127	687	3.67	497,000	49.79	

[a] Partly estimated from other stations.
[b] Estimated from other stations.
[c] Discharge estimate revised from original data.
[d] Feb. 20 to Mar. 12 estimated by comparison with other stations.

Estimated monthly discharge of Tieton River at McAllister Meadows, near Naches, Wash., 1908–1912—Continued.

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches of the drainage area.	
1910–11.							
November	2,410	205	576	3.08	34,300	3.44	A.
December	390	229	282	1.51	17,300	1.74	B.
January	300	160	227	1.21	14,000	1.40	B.
February			[a]180	.963	10,000	1.00	C.
March	520	162	258	1.38	15,900	1.59	B.
April	760	308	461	2.47	27,400	2.76	B.
May	1,220	560	708	3.79	43,500	4.37	B.
June	2,210	650	1,180	6.31	70,200	7.04	B.
July	845	400	591	3.16	36,300	3.64	B.
August	405	250	305	1.63	18,800	1.88	B.
September	878	190	306	1.64	18,200	1.83	B.
October	190	157	175	.936	10,800	1.08	B.
The year	2,410	157	438	2.34	317,000	31.77	
1911–12.							
November	878	157	336	1.80	20,000	2.01	B.
December	282	176	211	1.13	13,000	1.30	B.
January	1,100	177	399	2.13	24,500	2.46	B.
February	455	263	355	1.90	20,400	2.05	B.
March	304	192	234	1.25	14,400	1.44	B.
April	787	362	508	2.72	30,200	3.04	B.
May	1,770	560	1,130	6.04	69,500	6.96	B.
June	1,570	840	1,220	6.52	72,600	7.27	B.
July	740	430	579	3.10	35,600	3.57	B.
August	662	244	367	1.96	22,600	2.26	B.
September	541	200	268	1.43	15,900	1.60	B.
October	208	174	185	.989	11,400	1.14	B.
The year	1,770	157	482	2.58	350,000	35.10	

[a] Estimated by comparison with Tieton at headworks.

NOTE.—A considerable part of the discharge data has been based on gage readings taken from 2 to 7 days apart. The discharge for periods during which gage heights are lacking has been estimated from the records of Tieton River at headworks of Tieton canal. The accuracy is also affected by diurnal fluctuations during the summer months.

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

Location.—In sec. 30, T. 14 N., R. 15 E. (unsurveyed), 500 feet below intake of Tieton canal, 15 miles above mouth of river, and 21 miles southwest of Naches.

Records available.—April 17 to July 24, 1906, fragmentary; June 26, 1907, to October 31, 1912.

Drainage area.—240 square miles.[1]

Gage.—Vertical staff on right bank, to which a Friez automatic gage has been referred since July 18, 1911. Bristol automatic gage was used July 28, 1909, to July 17, 1911; April 17 to July 24, 1906, a vertical staff 1½ miles below present location.

Channel.—Gravel and cobblestones; shifting in floods.

Discharge measurements.—Made from cable near gage or by wading.

Winter flow.—Occasionally seriously affected by anchor ice; then estimated by comparison with records at other stations on the river.

Accuracy.—Results good.

[1] Revised measurement.

Estimated monthly discharge of Tieton River at headworks of Tieton canal, near Naches, Wash., 1907–1912.

[Drainage area, 240 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches of the drainage area.	
1907.							
July	955	492	652	2.72	40,100	3.14	A.
August	562	268	366	1.52	22,500	1.75	A.
September	370	210	289	1.20	17,200	1.34	A.
October	281	203	243	1.01	14,900	1.16	A.
The period (123 days)					94,700		
1907–8.							
November	610	146	223	0.929	13,300	1.04	B.
December	910	180	334	1.39	20,500	1.60	A.
January	634	152	259	1.08	15,900	1.24	A.
February	292	162	228	.950	13,100	1.02	A.
March	3,170	203	764	3.18	47,000	3.67	A.
April	2,460	510	965	4.02	57,400	4.48	A.
May	1,310	845	1,040	4.33	64,000	4.99	A.
June	2,640	910	1,500	6.25	89,300	6.97	A.
July	1,920	600	1,250	5.21	76,900	6.01	B.
August	680	334	496	2.07	30,500	2.39	A.
September	386	224	320	1.33	19,000	1.48	A.
October	510	227	279	1.16	17,200	1.34	A.
The year	3,170	146	640	2.67	464,000	36.23	
1908–9.							
November	1,120	206	372	1.55	22,100	1.73	A.
December	295	150	224	.933	13,800	1.08	B.
January	850	230	339	1.41	20,800	1.63	B.
February	372	230	265	1.10	14,700	1.14	B.
March	652	224	380	1.58	23,400	1.82	B.
April	910	470	595	2.48	35,400	2.77	A.
May	1,400	735	929	3.87	57,100	4.46	A.
June	2,450	840	1,360	5.67	80,900	6.33	A.
July	902	515	685	2.85	42,100	3.29	A.
August	510	273	358	1.49	22,000	1.72	B.
September	382	204	283	1.18	16,800	1.32	B.
October	305	152	204	.850	12,500	.98	B.
The year	2,450	150	500	2.08	362,000	28.27	

Month.	Discharge of river in second-feet.			Run-off in acre-feet.			Natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Tieton Canal.	Natural.	Mean.	Mean per square mile.		
1909–10.										
November	4,970	191	1,320	78,600		78,600	1,320	5.50	6.14	B.
December	1,780	404	670	41,200		41,200	670	2.79	3.22	B.
January	1,070	200	361	22,200		22,200	361	1.50	1.73	C.
February	458	251	325	18,000		18,000	325	1.35	1.41	A.
March	2,710	789	1,350	83,000		83,000	1,350	5.62	6.48	B.
April	2,280	772	1,190	70,800		70,800	1,190	4.96	5.53	A.
May	2,350	1,010	1,380	84,800	1,700	86,500	1,410	5.88	6.78	A.
June	1,550	669	919	54,700	2,570	57,300	963	4.01	4.47	A.
July	723	352	567	34,900	2,540	37,400	608	2.53	2.92	A.
August	397	258	330	20,300	1,090	21,400	348	1.45	1.67	A.
September	319	213	256	15,200		15,200	256	1.07	1.19	A.
October	828	246	400	24,600		24,600	400	1.67	1.92	A.
The year	4,970	191	757	548,000	7,900	556,000	769	3.20	43.46	

Estimated monthly discharge of Tieton River at headworks of Tieton canal, near Naches, Wash., 1907–1912—Continued.

Month.	Discharge of river in second-feet.			Run-off in acre-feet.			Natural discharge in second-feet.		Run-off (depth in inches on drainage area).	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Tieton Canal.	Natural.	Mean.	Mean per square mile.		
1910–11.										
November	1,790	225	583	34,700	....	34,700	583	2.43	2.71	A.
December	467	265	331	20,400	....	20,400	331	1.38	1.59	A.
January	338	180	251	15,400	....	15,400	251	1.05	1.21	A.
February	227	175	198	11,000	....	11,000	198	.825	.86	A.
March	650	177	341	21,000	....	21,000	341	1.42	1.64	A.
April	862	388	548	32,600	1,360	34,000	571	2.38	2.66	A.
May	1,240	585	745	45,800	2,770	48,600	790	3.29	3.79	A.
June	2,160	645	1,190	70,800	6,070	76,900	1,290	5.38	6.00	A.
July	814	300	512	31,500	7,690	39,200	638	2.66	3.07	A.
August	304	208	252	15,500	6,270	21,800	355	1.48	1.71	A.
September	570	130	276	16,400	2,960	19,400	326	1.36	1.52	A.
October	224	175	201	12,400	117	12,500	203	.846	.98	A.
The year	2,160	130	453	328,000	27,200	355,000	491	2.05	27.74	
1911–12.										
November	880	175	328	19,500	1,270	20,800	350	1.46	1.63	A.
December	300	186	239	14,700	563	15,300	249	1.04	1.20	A.
January	998	185	439	27,000	....	27,000	439	1.83	2.11	B.
February	616	331	464	26,700	....	26,700	464	1.93	2.08	A.
March	491	243	314	19,300	....	19,300	314	1.31	1.51	A.
April	970	563	663	39,500	628	40,100	674	2.81	3.14	A.
May	1,760	654	1,180	72,600	8,670	81,300	1,320	5.50	6.34	B.
June	1,760	429	1,060	63,100	11,600	74,700	1,260	5.25	5.86	B.
July	662	188	424	26,100	10,200	36,300	590	2.46	2.84	A.
August	439	109	193	11,900	11,300	23,200	377	1.57	1.81	A.
September	336	119	189	11,200	5,220	16,400	276	1.15	1.28	A.
October	255	168	190	11,700	....	11,700	190	.792	.91	A.
The year	1,760	109	472	343,000	49,500	393,000	541	2.25	30.71	

TIETON RIVER NEAR MOUTH, NEAR NACHES, WASH.

Location.—In sec. 3, T. 14 N., R. 16 E., 200 feet below Oak Creek, 1½ miles above the mouth of the river, and 8 miles northwest of Naches.

Records available.—April 24, 1902, to July 10, 1907; April 21, 1909, to October 31, 1912.

Drainage area.—297 square miles[1] below Oak Creek and 264 square miles above Oak Creek.

Gage.—Cantilever chain on left bank since March 5, 1910. April 21, 1909, to March 4, 1910, an inclined staff at same location and datum. Prior to April 21, 1909, staff gages were located at various places as follows: April 24, 1902, to March 7, 1906, below the mouth of Oak Creek; March 7, 1906, to March 22, 1907, above the mouth of Oak Creek, which has a drainage area of 33 square miles; March 23, 1907, to April 20, 1909, at United States Reclamation Service camp 1, about 1 mile above Oak Creek, where an unmeasured but considerable part of the flow was diverted past the gage and measuring section and used to develop power in connection with the construction of the Tieton canal; April 21, 1909, to October 31, 1912, below Oak Creek.

Channel.—Rocks and gravel; shifting in floods.

Discharge measurements.—Made from cable near gage.

Winter flow.—Not seriously affected by ice.

Diversions.—Tieton canal has diverted past the station since the irrigation season of 1910.

Accuracy.—Fair. Flow prior to July 1, 1902, uncertain on account of shifting channel.

[1] Revised measurement.

Estimated monthly discharge of Tieton River below Oak Creek, at Cobb's ranch, near Naches, Wash., 1902–1912.

[Drainage area, 297 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1902.							
July [a]	985	568	783	2.64	48,100	3.04	B.
August [a]	671	342	470	1.58	28,900	1.82	B.
September [a]	406	260	328	1.10	19,500	1.23	B.
October [a]	312	240	261	.879	16,000	1.01	B.
The period (123 days)					112,000		
1902–3.							
November [b]	462	240	323	1.09	19,200	1.22	B.
December [b]	725	238	386	1.30	23,700	1.50	B.
January [b]	2,890	462	857	2.89	52,700	3.33	B
February [b]	490	350	398	1.34	22,100	1.40	B.
March [b]	1,070	330	486	1.64	29,900	1.89	B.
April [b]	1,100	587	768	2.59	45,700	2.89	B.
May [b]	2,070	919	1,300	4.38	79,900	5.05	B.
June [b]	4,850	1,180	2,200	7.41	131,000	8.27	B.
July [b]	1,440	528	818	2.75	50,300	3.17	B.
August [b]	548	376	452	1.52	27,800	1.75	A.
September [b]	482	297	362	1.22	21,500	1.36	A.
October [b]	912	281	422	1.42	25,900	1.64	A.
The year	4,850	238	734	2.47	530,000	33.47	
1903–4.							
November [b]	1,060	330	552	1.86	32,800	2.08	B.
December [b]	1,240	319	510	1.72	31,400	1.98	B.
January	500	308	360	1.21	22,100	1.40	B.
February	330	258	293	.987	16,800	1.06	B.
March	447	277	337	1.13	20,700	1.30	B.
April	3,140	330	1,580	5.32	94,100	5.94	B.
May	2,880	1,030	1,610	5.42	99,200	6.25	B.
June	2,200	1,000	1,460	4.92	86,600	5.49	B.
July	1,670	540	961	3.24	59,100	3.74	A.
August	602	353	458	1.54	28,200	1.78	A.
September	388	287	329	1.11	19,600	1.24	A.
October	500	233	278	.936	17,100	1.08	A.
The year	3,140	233	729	2.45	528,000	33.34	
1904–5.							
November	1,210	220	413	1.39	24,600	1.55	B.
December	540	287	357	1.20	22,000	1.38	A.
January [b]	381	233	293	.987	18,000	1.14	A.
February [b]	493	208	283	.953	15,700	.99	B.
March [b]	1,000	447	747	2.52	45,900	2.90	B.
April [b]	1,050	430	564	1.90	33,600	2.12	B.
May [b]	988	493	617	2.08	37,900	2.40	B.
June [b]	1,670	602	895	3.01	53,300	3.36	B.
July [b]	695	415	524	1.76	32,200	2.03	A.
August [b]	437	263	369	1.24	22,700	1.43	A.
September [b]	358	249	305	1.03	18,100	1.15	A.
October [b]	775	246	359	1.21	22,100	1.40	A.
The year	1,670	208	479	1.61	346,000	21.85	

[a] Discharge estimate revised from original data. The station was established Apr. 24, 1902, but a reliable estimate of discharge, prior to July 1, 1902, is impossible on account of shifting channel conditions.
[b] The discharge estimate has been revised from the original data.

Estimated monthly discharge of Tieton River above Oak Creek,[a] near Naches, Wash., 1905–1912.

[Drainage area, 264 square miles.[a]]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1905–6.							
November [b]	267	200	236	0.795	14,000	0.89	B.
December [b]	233	196	220	.741	13,500	.85	B.
January [b]	335	207	232	.781	14,300	.90	B.
February [b]	885	258	367	1.24	20,400	1.29	B.
March [a] [b]	940	285	381	1.44	23,400	1.66	B.
April [a]	1,370	696	1,000	3.79	59,500	4.23	B.
May [a]	1,370	593	956	3.62	58,800	4.17	B.
June [a]	961	452	616	2.33	36,700	2.60	A.
July [a]	802	398	560	2.12	34,400	2.44	A.
August [a]	420	228	350	1.33	21,500	1.53	A.
September [a]	389	168	250	.947	14,900	1.06	A.
October [a]	975	188	289	1.09	17,800	1.26	A.
The year	1,370	168	456	1.73	329,000	22.88	
1906–7.							
November	14,100	212	2,220	8.41	132,000	9.38	B.
December	2,280	536	921	3.49	56,600	4.02	B.
January	596	315	408	1.55	25,100	1.79	B.
February	1,280	315	786	2.98	43,700	3.10	B.
March	735	358	511	1.94	31,400	2.24	A.
April	1,200	410	887	3.36	52,800	3.75	A.
May	1,930	990	1,470	5.57	90,400	6.42	A.
June	2,060	840	1,220	4.62	72,600	5.16	A.
July			[c] 680	2.58	41,800	2.97	C.
August			[c] 375	1.42	23,100	1.64	C.
September			[c] 295	1.12	17,600	1.25	C.
October			[c] 250	.947	15,400	1.09	C.
The year			833	3.16	602,000	42.81	

[a] The location of the station was changed from below Oak Creek to above Oak Creek Mar. 7, 1906. The discharge values determined are applicable to 297 square miles of drainage area Nov. 1 to Mar. 6. For the remainder of the climatic year the discharge is contributed from 264 square miles of drainage area.
[b] Estimate revised from original data.
[c] Estimated by comparison with the records at the headworks of Tieton canal.

Estimated monthly discharge of Tieton River below Oak Creek, at Cobb's ranch, near Naches, Wash., 1902–1912.

[Drainage area, 297 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Acre-feet.	Depth in inches on drainage area.	
1908–9.							
November			[a] 380	1.28	22,600	1.43	C.
December			[a] 230	.774	14,100	.89	C.
January			[a] 350	1.18	21,500	1.36	C.
February			[a] 275	.926	15,300	.96	C.
March			[a] 390	1.31	24,000	1.51	C.
April			[a] 625	2.10	37,200	2.34	C.
May	1,420	705	1,030	3.47	63,300	4.00	A.
June	2,640	705	1,560	5.25	92,800	5.86	A.
July	970	475	678	2.28	41,700	2.63	C.
August	[a] 500	300	384	1.29	23,600	1.49	B.
September	385	205	285	.960	17,000	1.07	A.
October	260	156	207	.697	12,700	.80	A.
The year			534	1.80	386,000	24.34	

[a] Estimated by comparison with the records at the headworks of Tieton canal.

Estimated monthly discharge of Tieton River below Oak Creek, at Cobb's ranch, near Naches, Wash., 1902–1912—Continued.

Month.	Discharge of river in second-feet.			Run-off in acre-feet.			Natural discharge second-feet.		Depth in inches on drainage area.	Accuracy.
	Maximum.	Minimum.	Mean.	River.	Tieton canal.[a]	Natural.	Mean.	Mean per square mile.		
1909–10.										
November	7,290	180	1,580	94,000		94,000	1,580	5.32	5.94	B.
December	1,870	210	648	39,800		39,800	648	2.18	2.51	B.
January			370	22,800		22,800	[b] 370	1.25	1.44	B.
February			335	18,600		18,600	[b] 335	1.13	1.18	B.
March	3,380	870	1,640	101,000		101,000	1,640	5.52	6.36	B.
April	2,990	840	1,390	82,700		82,700	1,390	4.68	5.22	B.
May	2,530	1,060	1,480	91,000	1,700	92,700	1,510	5.08	5.86	B.
June	1,800	630	976	58,100	2,570	60,700	1,020	3.43	3.83	B.
July	780	360	583	35,800	2,540	38,300	623	2.10	2.42	B.
August	402	240	320	19,700	1,090	20,800	338	1.14	1.31	B.
September			260	15,500		15,500	[b] 260	.875	.98	B.
October			410	25,200		25,200	[b] 410	1.38	1.59	B.
The year			838	604,000	7,900	612,000	848	2.86	38.64	
1910–11.										
November			[b] 600	35,700		35,700	[b] 600	2.02	2.25	C.
December			[b] 340	20,900		20,900	[b] 340	1.14	1.31	C.
January			[b] 260	16,000		16,000	[b] 260	.875	1.01	C.
February			[b] 205	11,400		11,400	[b] 205	.690	.72	C.
March			[b] 350	21,500		21,500	[b] 350	1.18	1.36	C.
April	870	380	563	33,500	1,360	34,900	587	1.97	2.20	A.
May	1,200	630	785	48,300	2,770	51,100	831	2.80	3.23	B.
June	1,600	630	1,060	63,100	6,070	69,200	1,160	3.91	4.36	B.
July	690	305	550	33,800	7,690	41,500	675	2.27	2.62	A.
August	340	192	249	15,300	6,270	21,600	351	1.18	1.36	A.
September			[c] 276	16,400	2,960	19,400	326	1.10	1.23	B.
October			[c] 201	12,400	117	12,500	203	.684	.79	B.
The year			454	328,000	27,200	355,000	492	1.66	22.44	
1911–12.										
November	930	172	327	19,500	[d] 1,270	20,800	350	1.18	1.32	B.
December	288	172	227	14,000	[d] 563	14,600	237	.798	.92	A.
January	1,190	150	444	27,300		27,300	444	1.49	1.72	B.
February	660	339	436	25,100		25,100	436	1.47	1.58	B.
March	543	235	306	18,800		18,800	306	1.03	1.19	B.
April	1,150	570	740	44,000	628	44,600	750	2.53	2.82	B.
May	2,150	720	1,390	85,500	8,670	94,200	1,530	5.15	5.94	B.
June	1,950	570	1,170	69,600	11,600	81,200	1,360	4.58	5.11	B.
July	690	168	406	25,000	10,200	35,200	572	1.93	2.22	B.
August	570	120	186	11,400	11,300	22,700	369	1.24	1.43	B.
September	339	134	190	11,300	5,220	16,500	277	.933	1.04	A.
October	213	168	183	11,300		11,300	183	.616	.71	A.
The year	2,150	120	500	363,000	49,500	412,000	567	1.91	26.00	

[a] The Tieton canal diverts water past the station during the irrigation season.
[b] Estimated by comparison with the records at the headworks of Tieton canal.
[c] The gage heights as observed appear to be unreliable for September and October. The monthly means for Tieton River at headworks of Tieton canal have been used instead of the mean values computed from the gage heights of the lower station.
[d] Tieton canal diverted a small amount in November and December for construction purposes.

SMALL TRIBUTARIES OF UPPER YAKIMA RIVER.

Stream-flow records have been obtained on several of the minor tributaries of Yakima River since 1908. The estimated monthly discharge of the climatic years 1908–9, 1909–10, and 1910–11 of the streams tributary to the upper Yakima River is shown in the subjoined table.[1]

[1] Stations have also been maintained on Big, Wenas, and Naneum creeks, but the gage records and rating curves are not reliable. Further data in regard to the run-off of Teanaway River, Cabin, Swauk, Taneum, and Manastash creeks, as well as information in regard to the run-off of Satus, Toppenish, Simcoe, and Atanum creeks, may be found in Water-Supply Papers 252, 272, 292, 312, and 332.

The gaging station on Cabin Creek is situated about half a mile above the mouth, and the discharge represents the natural run-off of the basin of the creek.

The station on Teanaway River is situated about half a mile above the mouth of the stream and that on Swauk Creek about 2½ miles above the mouth. Diversions for irrigation materially decrease the natural flow during the irrigation season at both stations.

The stations on Taneum and Manastash creeks are situated above the mouths of the canyons from which these streams enter Kittitas Valley. The estimates of discharge at both stations represent very nearly the natural flow prior to November, 1910. At that time the gage on Taneum Creek was relocated below the head gates of an irrigation ditch.

Estimated monthly discharge, in second-feet, of small tributaries of Yakima River, 1909–1911.

Month.	Cabin Creek (drainage area, 31.7 square miles).	Teanaway River (drainage area, 205 square miles [a]).[b]	Swauk Creek (drainage area, 88 square miles [a]).[b]	Taneum Creek (drainage area, 76 square miles).	Manastash Creek (drainage area, 76 square miles).
1909.					
April	....	646	76.3	54.6	68.7
May	....	857	48.6	95.5	94.1
June	272	547	17.3	101	94.3
July	47.1	96.6	4.9	24.9	27.1
August	12.6	8.8	2.0	7.6	14.0
September	8.8	8.3	1.3	6.9	13.2
October	20.1	40.1	6.7	14.3	10.2
1909–10.					
November	190	865	68.0	84.5	48.8
December	132	306	67.1	63.6	38.3
January	39.5	[c] 150	[c] 80	[c] 40	43.1
February	21.3	[c] 120	[c] 70	[c] 30	30.2
March	622	1,470	564	245	277
April	414	1,350	278	297	254
May	343	974	89.4	167	234
June	64.8	329	18.1	50.8	79.8
July	15.3	62.4	2.2	14.5	27.5
August	8.6	8.2	.9	6.8	15.3
September	5.7	7.8	1.8	8.9	13.8
October	41.9	141	11.7	18.0	14.2
The year	158	482	104	85.5	89.7
1910–11.					
November	[d] 261	439	43.8	[b] [d] 20	21
December	[d] 66	239	24.7	[b] [d] 20	17.2
January	[d] 85	179	26.9	[b] [d] 21	17.2
February	[d] 34	112	19.7	[b] [d] 19	10.8
March	[d] 45	598	98.5	[b] [d] 36	52.1
April	[d] 65	955	117	[b] [d] 83	74.7
May	[d] 207	697	81.1	[b] [d] 112	101
June	[d] 169	420	37.2	[b] [d] 104	114
July	[d] 48	46	5.6	[b] [d] 16	32.9
August	[d] 10	13	3.1	[b] [d] 8	14.4
September	[d] 31	32	4.0	[b] [d] 11	14.7
October	[d] 19	24	10.3	[b] [d] 11	11.3
The year	86.7	313	39.3	38.4	40.1

[a] Revised measurement.
[b] The estimate of discharge is affected by diversions above the gaging station during the irrigation season.
[c] Values approximate. Discharge estimated by comparison with observations at other stations in the vicinity, which were not affected by ice.
[d] Approximate.

SUMMARY OF ESTIMATED NATURAL DISCHARGE.

A summary of the estimated natural discharge by years has been prepared to condense the essential details of the monthly estimates. The following table indicates the variation in flow from year to year at the different stations, and makes possible a comparison of flow at different stations at a glance. It should be borne in mind that many of the estimates have been corrected for storage regulation, so that they represent "flow without storage" instead of natural flow. However, such estimates constitute the natural flow as closely as it is possible to derive it.

Summary of estimated natural discharge, by climatic years, for Yakima River and tributaries.

Stream and location.	Climatic year.[a]	Minimum month.		Mean discharge for year.	Discharge per square mile.		Run-off in acre-feet.	Run-off in inches on drainage area.
		Discharge.	Month.		Minimum for month.	Mean for year.		
		Sec.-ft.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		
Yakima River at outlet of Keechelus Lake near Martin	1903–4	58.6	September		1.07			
Do	1904–5	79.7	August	307	1.45	5.58	223,000	75.89
Do	1905–6	57.5	do	280	1.05	5.09	203,000	69.19
Do	1906–7	74.0	October	389	1.35	7.07	282,000	96.15
Do	1907–8	72.2	September	357	1.31	6.49	259,000	88.26
Do	1908–9	106	August	285	1.93	5.18	206,000	70.13
Do	1909–10	39.2	do	429	.713	7.80	310,000	105.80
Do	1910–11	55.9	do	276	1.02	5.02	200,000	67.99
Do	1911–12	99.7	do	330	1.81	6.00	239,000	81.39
Mean		71.4		332	1.30	6.03	240,000	72.36
Yakima River at Easton.	1903–4	257	October		1.40			
Do	1909–10	114	August		.620			
Do	1910–11	179	October	663	.973	3.60	479,000	48.77
Do	1911–12	225	September	883	1.22	4.79	640,000	65.14
Mean		194		773	1.05	4.20	560,000	56.96
Yakima River at Clealum.	1905–6	442	September		.884			
Do	1906–7	260	October	2,200	.520	4.40	1,590,000	59.44
Do	1907–8	397	September	2,040	.794	4.08	1,480,000	55.32
Do	1908–9	468	October	1,550	.936	3.10	1,120,000	42.01
Do	1909–10	381	August	2,640	.762	5.28	1,910,000	71.83
Do	1910–11	343	October	1,670	.686	3.36	1,210,000	45.30
Do	1911–12	464	do	1,950	.928	3.91	1,410,000	53.07
Mean		394		2,010	.788	4.02	1,450,000	54.50
Yakima River at Union Gap.	1895–96	879	October		.248			
Do	1896–97	830	do	5,580	.234	1.57	4,040,000	21.30
Do	1897–98	1,140	September	5,190	.321	1.46	3,760,000	19.85
Do	1898–99	1,970	November	5,250	.555	1.48	3,800,000	20.04
Do	1899–1900	1,430	September	4,960	.403	1.40	3,590,000	18.96
Do	1900–1901	1,090	October	5,320	.307	1.50	3,850,000	20.34
Do	1901–2	1,220	do	4,900	.344	1.38	3,550,000	18.79
Do	1902–3	1,780	September	6,000	.501	1.69	4,340,000	22.91
Do	1903–4	1,060	October	5,940	.299	1.67	4,310,000	22.79
Do	1904–5	1,280	September	3,800	.361	1.07	2,750,000	14.48
Do	1905–6	1,060	do	3,700	.299	1.04	2,680,000	14.17
Do	1906–7	[b] 727	October	5,800	.205	1.63	4,200,000	22.19
Do	1907–8	1,180	do	4,500	.332	1.27	3,270,000	17.24
Do	1908–9	1,110	do	3,510	.313	.989	2,540,000	13.39
Do	1909–10	1,180	September	6,490	.332	1.83	4,700,000	24.81
Do	1910–11	1,080	October	3,890	.304	1.10	2,820,000	14.91
Do	1911–12	1,080	do	4,390	.304	1.24	3,190,000	16.84
Mean		1,180		4,950	.332	1.39	3,590,000	18.94

[a] Nov. 1 to Oct. 1.
[b] The sum of the discharges of the Yakima at Clealum, Naches at Oak Flat, and Tieton at headworks, amounted to 723 second-feet during October, 1907. On this basis the natural flow of Yakima River at Union Gap must have amounted to at least 800 second-feet. The records on Yakima River at Union Gap are unreliable for low water periods in 1907. (Water-Supply Paper 252, 1910, p. 147.)

Summary of estimated natural discharge, by climatic years, for Yakima River and tributaries—Continued.

Stream and location.	Climatic year.	Minimum month.		Mean discharge for year.	Discharge per square mile.		Run-off in acre-feet.	Run-off in inches on drainage area.
		Discharge.	Month.		Minimum for month.	Mean for year.		
		Sec.-ft.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		
Cabin Creek near Easton.	1908-9	8.8	September..	....	0.274	....	....	....
Do..............	1909-10	5.7	.....do.......	158	.178	4.94	115,000	67.41
Do..............	1910-11	10.0	August......	86.7	.312	2.71	62,800	36.84
Mean.........	....	8.2	....	122	.255	3.82	88,900	52.12
Kachess River at outlet of Kachess Lake.	[a] 1903-4	113	August......	329	1.79	5.22	239,000	71.12
Do..............	[a] 1904-5	98.9	February...	257	1.57	4.08	186,000	55.36
Do..............	1905-6	23.6	August......	235	.375	3.73	170,000	50.74
Do..............	1906-7	33.0	.....do.......	303	.524	4.81	219,000	65.18
Do..............	1907-8	35.0	September..	289	.556	4.59	209,000	62.18
Do..............	1908-9	42.3	August......	220	.671	3.49	159,000	47.47
Do..............	1909-10	25.9	September..	383	.411	6.08	277,000	82.34
Do..............	1910-11	48.8	October.....	247	.775	3.92	179,000	53.41
Do..............	1911-12	32.5	August......	332	.516	5.28	241,000	71.62
Mean.........	....	[b] 34.4	....	288	.546	4.58	209,000	62.16
Clealum River at outlet of Clealum Lake.	1903-4	234	October.....	1,070	1.16	5.30	778,000	72.24
Do..............	1904-5	211	February...	773	1.04	3.83	560,000	51.89
Do..............	1905-6	302	September..	795	1.50	3.94	576,000	53.46
Do..............	1906-7	148	October.....	1,040	.733	5.15	755,000	70.17
Do..............	1907-8	211	.....do.......	951	1.04	4.71	690,000	64.10
Do..............	1908-9	220	February...	762	1.09	3.77	552,000	51.12
Do..............	1909-10	190	September..	1,230	.941	6.09	888,000	82.51
Do..............	1910-11	143	October.....	788	.708	3.90	570,000	52.95
Do..............	1911-12	232	September..	870	1.15	4.31	632,000	58.59
Mean.........	....	210	....	920	1.04	4.56	667,000	61.89
Taneum Creek near Thorp.	1908-9	6.9	October.....	....	.090	....	....	....
Do..............	1909-10	6.8	August......	....	.089	....	....	....
Mean.........	....	6.8	....	....	.089	....	....	....
Manastash Creek near Ellensburg.	1908-9	10.2	October.....	....	.138	....	....	....
Do..............	1909-10	13.8	September..	90.1	.186	1.22	65,200	16.51
Do..............	1910-11	10.8	February...	40.2	.146	.543	29,100	7.37
Mean.........	....	11.6	....	65.2	.157	.882	47,200	11.94
Naches River at Anderson's ranch.	1908-9	189	October.....	....	.480	....	....	....
Do..............	1909-10	188	September..	1,410	.477	3.58	1,020,000	48.54
Do..............	1910-11	190	October.....	921	.482	2.34	665,000	31.66
Do..............	1911-12	181	.....do.......	862	.459	2.19	626,000	29.80
Mean.........	....	187	....	1,060	.474	2.69	770,000	36.67
Naches River at Oak Flat.	1904-5	364	February...	978	.569	1.53	706,000	20.73
Do..............	1905-6	267	September..	1,060	.418	1.66	763,000	22.37
Do..............	1906-7	220	October.....	1,520	.344	2.38	1,100,000	32.29
Do..............	1907-8	277	.....do.......	1,290	.433	2.02	934,000	27.37
Do..............	1908-9	228	September..	995	.356	1.55	720,000	21.10
Do..............	1909-10	261	.....do.......	1,760	.408	2.75	1,270,000	37.24
Do..............	1910-11	250	August......	1,080	.391	1.69	778,000	22.79
Do..............	1911-12	224	October.....	1,090	.350	1.70	794,000	23.23
Mean.........	....	261	....	1,220	.409	1.91	883,000	25.89

[a] Values for minimum month for this year are subject to correction for storage in Lake Kachess. No records of stage were obtained on the lake and the data can not be corrected.
[b] Mean discharge of the minimum months for the years 1903-4, 1904-5, have been disregarded.

Summary of estimated natural discharge, by climatic years, for Yakima River and tributaries—Continued.

Stream and location.	Climatic year.	Minimum month.		Mean discharge for year.	Discharge per square mile.		Run-off in acre-feet.	Run-off in inches on drainage area.
		Discharge.	Month.		Minimum for month.	Mean for year.		
		Sec.-ft.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		
Naches River below Tieton River.	1908–9	472	October.....	1,680	0.501	1.78	1,210,000	24.02
Do.............	1909–10	533	September..	2,670	.566	2.83	1,930,000	38.38
Do.............	1910–11	439	October.....	1,630	.466	1.73	1,180,000	23.53
Do.............	1911–12	428	.....do.......	1,650	.454	1.75	1,200,000	23.84
Mean..........	....	468	....	1,910	.497	2.02	1,380,000	27.44
Bumping River at outlet of Bumping Lake.	1908–9	62.2	October.....	....	.915	....	....	....
Do.............	1909–10	59.9	September..	405	.881	5.96	293,000	80.64
Do.............	1910–11	55.9	October.....	279	.822	4.10	202,000	55.80
Do.............	1911–12	96.1	.....do.......	291	1.41	4.28	213,000	58.27
Mean..........	....	68.5	....	325	1.01	4.78	236,000	64.90
American River at mouth.	1908–9	53.2	October.....	....	.657	....	....	....
Do.............	1909–10	62.5	September..	....	.772	....	....	....
Mean..........	....	57.8	....	....	.714	....	....	....
Tieton River at McAllister's meadows.	1908–9	184	October.....	429	.984	2.29	310,000	31.08
Do.............	1909–10	235	September..	687	1.26	3.67	497,000	49.79
Do.............	1910–11	175	October.....	438	.936	2.34	317,000	31.77
Do.............	1911–12	185	.....do......	482	.989	2.58	350,000	35.10
Mean..........	....	195	....	509	1.04	2.72	368,000	36.94
Tieton River at headworks of Tieton Canal.	1906–7	243	October.....	....	1.01	....	....	....
Do.............	1907–8	223	November..	640	.929	2.67	464,000	36.23
Do.............	1908–9	204	October.....	500	.850	2.08	362,000	28.27
Do.............	1909–10	256	September..	769	1.07	3.20	556,000	43.46
Do.............	1910–11	198	February...	491	.825	2.05	355,000	27.73
Do.............	1911–12	190	October.....	541	.792	2.25	393,000	30.71
Mean..........	....	219	....	588	.913	2.45	426,000	33.28
Tieton River below Oak Creek.	1901–2	261	October.....	....	.879	....	....	....
Do.............	1902–3	323	November..	734	1.09	2.47	530,000	33.47
Do.............	1903–4	278	October.....	729	.936	2.45	528,000	33.34
Do.............	1904–5	283	February...	479	.953	1.61	346,000	21.85
Tieton River above Oak Creek.[a]	1905–6	220	December...	456	.741	1.73	329,000	22.88
Do.............	1906–7	250	October.....	833	.947	3.16	602,000	42.81
Tieton River below Oak Creek.	1908–9	207	.....do.......	534	.697	1.80	386,000	24.34
Do.............	1909–10	260	September..	848	.875	2.86	612,000	38.64
Do.............	1910–11	203	October.....	492	.684	1.66	355,000	22.42
Do.............	1911–12	183	.....do.......	567	.616	1.91	412,000	26.00
Mean below Oak Creek.	....	246	....	626	.830	2.11	453,000	28.58
Mean above Oak Creek.	....	250	....	644	.947	2.44	466,000	32.84
Mean for period.....	....	247	....	630	....	....	456,000	....

[a] The location of the station was changed from below Oak Creek to above Oak Creek Mar. 7, 1906. The estimates given on p. 83 represent the discharge above Oak Creek Mar. 7, 1906, to Oct. 31, 1907.

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements, showing low-water conditions of natural run-off, have been made in the Yakima basin in the years 1893 to 1912. Other miscellaneous measurements made in the valley are recorded in the annual progress reports of the Geological Survey.

Miscellaneous measurements in Yakima River drainage basin.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Sept. 21, 1904	Yakima River	Columbia River	Clealum	442	500	0.884
Aug. 14, 1893	do	do	Union Gap	2,960		
Sept. 26, 1893	do	do	do	1,190		
Nov. 25, 1894	do	do	do	5,030		
Aug. 19, 1895	do	do	do	1,070		
Nov. 18, 1895	do	do	do	1,890		
Aug. 21, 1906	Boulder Creek	Lake Keechelus	Entrance to canyon.	2.5	2.2	1.14
Sept. 8, 1910	do	do	do	1.9	2.2	.864
Aug. 21, 1906	Gold Creek	do	do	[a] 25	13.4	1.86
Sept. 8, 1910	do	do	do	11.4	13.4	.851
Aug. 21, 1906	Roaring Creek [b]	do	do	36	5.7	6.32
Sept. 8, 1910	do [b]	do	do	26.4	5.7	4.63
Aug. 21, 1906	Meadow Creek	do	do	3.6	8.3	.434
Sept. 8, 1910	do	do	do	3.2	8.3	.386
Sept. 21, 1904	Cabin Creek	Yakima River	Mouth	6.9	31.7	.218
Aug. 8, 1907	do	do	do	2.5	31.7	.079
Aug. 16, 1893	Kachess River	do	do	211	63	3.35
Aug. 23, 1906	Box Canyon Creek.	Lake Kachess	Entrance to canyon.	14.0	12.4	1.13
Sept. 9, 1910	do	do	do	5.8	12.4	.468
Aug. 23, 1906	Gale Creek	do	do	[c] .8	6.7	
Sept. 8, 1910	do	do	do	1.3	6.7	.194
Sept. 15, 1910	Silver Creek	Yakima River	do	.9	8	.112
Do	Tucker Creek	do	do	.4		
July 23, 1909	Big Creek	do	do	18.3	26.2	.699
Oct. 4, 1909	do	do	do	12.5	26.2	.477
July 26, 1910	do	do	do	19.1	26.2	.729
Aug. 30, 1910	do	do	do	11.0	26.2	.420
Sept. 15, 1910	do	do	do	9.5	26.2	.363
Oct. 3, 1911	do	do	do	12.7	26.2	.485
Oct. 13, 1911	North Fork of Clealum River.	Clealum River	Above Camp Creek	31	37.9	.816
Sept. 10, 1910	Clealum River	Yakima River	Above West Fork.	95.9	112	.85
Sept. 22, 1904	do	do	Below Forks	206	152	1.36
Aug. 24, 1906	do	do	do	189	152	1.24
Sept. 10, 1910	do	do	do	136	152	.894
Do	Middle Fork of Clealum River.	Clealum River	Mouth	50	53	.943
Do	West Fork of Clealum River.	do	1½ miles above mouth.	40	39.7	1.01
July 8, 1911	do	do	do	227	39.7	5.72
Oct. 13, 1911	do	do	do	36.5	39.7	.919
Oct. 17, 1911	North Fork of Manastash Creek.	Manastash Creek	Mouth	.7	20.8	.033
Oct. 18, 1911	Wilson Creek	Yakima River	Entrance to canyon.	1.5	13	.115
Do	Naneum Creek	Wilson Creek	Above city intake.	25	73	.342
July 19, 1912	do	do	do	40	73	.548
Sept. 2, 1912	do	do	do	28.3	73	.388
Oct. 16, 1911	Coleman Creek	do	Entrance to canyon.	.9	18	.050
Do	Caribou Creek	do	do	.23		
Oct. 22, 1911	Naches River	Yakima River	Above Crow Creek	25	104	.240
Aug. 19, 1912	do	do	Above Bumping River.	52	145	.359
Oct. 22, 1911	Crow Creek	Naches River	Mouth	17	40.7	.418
Aug. 26, 1897	Bumping River	do	Below Bumping Lake.	83	68	1.22

[a] This measurement made by floats.
[b] This stream is outlet of Lost Lake.
[c] This measurement affected by underflow through the gravel.

Miscellaneous measurements in Yakima River drainage basin—Continued.

Date.	Stream.	Tributary to—	Locality.	Discharge.	Drainage area.	Discharge per square mile.
				Sec.-ft.	*Sq. miles.*	*Sec.-ft.*
Aug. 26, 1904	Bumping River	Naches River	Below Bumping Lake.	116	68	1.71
Aug. 29, 1907	do	do	do	73	68	1.07
Aug. 19, 1912	American River	Bumping River	Pleasant Valley	76	71	1.07
Aug. 27, 1904	do	do	Mouth	108	81	1.33
Aug. 30, 1907	do	do	do	62	81	.765
Aug. 18, 1912	do	do	do	83	81	1.02
Sept. 30, 1910	Gold Creek	Naches River	do	.75	8.0	.094
Do	Rock Creek	do	do	1.4	17.9	.078
Aug. 29, 1911	do	do	do	2.0	17.9	.112
Aug. 30, 1911	Nile Creek	do	Entrance to canyon.	*a* 1.5	32.1	.047
Aug. 29, 1904	Rattlesnake Creek.	do	Mouth	55	133	.413
Sept. 30, 1910	do	do	do	27	133	.203
Oct. 21, 1911	do	do	do	34	133	.256
Aug. 29, 1911	Little Rattlesnake Creek.	Rattlesnake Creek.	do	7.2	24.7	.292
Aug. 21, 1907	Oak Creek	Tieton River	do	1.5	32.6	.04

a Estimated.

STORAGE RESERVOIRS.

SITES INVESTIGATED.

Eventually storage reservoirs capable of regulating the entire flow of Yakima River will be constructed on many of the head streams and the impounded water will be used for irrigating arid lands. This regulation will result in greatly increasing the summer flow and appreciably reducing the flow from November 1 to March 31.

A number of possible storage sites have been investigated by the Reclamation Service.[1] Several other sites have been studied in more or less detail by the Indian Office and by private persons. (See pp. 93–94.)

The following table summarizes the essential features of the sites—classified as "approved" and "secondary" reservoir sites—investigated by the Reclamation Service above Union Gap. The information tabulated for approved sites is based on detailed surveys and estimates; that given for secondary sites has been derived from field reconnaissance of the Reclamation Service and surveys of reservoir sites by the Geological Survey, results of which are shown on Plates XIII, XVI, and XVII (at end of volume).

[1] The scheme of development and utilization of stored water in the Yakima project of the Reclamation Service is discussed by Charles H. Swigart on p. 162.

Reservoir sites above Union Gap investigated by the United States Reclamation Service.

Reservoir.	Location of dam site.	Height of dam.	Length of dam.	Kind of dam.	Volume of dam.	Storage.	Area of reservoir when full.
APPROVED SITES.		*Feet.*	*Feet.*		*Cu. yds.*	*Acre-feet.*	*Acres.*
Keechelus Lake (under construction).	At outlet of Keechelus Lake.	93	6,400	Earth fill..	480,000	152,000	2,500
Kachess Lake (constructed.)	At outlet of Kachess Lake.	75	1,400	...do......	250,000	210,000	4,800
Clealum Lake..........	At outlet of Clealum Lake.	181	1,150	...do......	660,000	490,000	4,980
Bumping Lake (constructed).	At outlet of Bumping Lake.	46	3,500	...do......	234,000	34,000	1,350
McAllister Meadows....	1.3 miles below mouth of South Fork of Tieton River.	196	950	Rock fill..	450,000	183,000	2,000
						1,069,000	
SECONDARY SITES.							
Fish Lake *a* *b*...........	Below Scatter Creek, North Fork of Clealum River.	85	1,700	Earth fill..	....	29,000	660
Waptus Lake *a*.........	Below outlet of Waptus Lake.	120	280	Masonry ..	....	45,600	850
Cooper Lake *a*	At outlet of Cooper Lake.	*c* 55	*c* 870	Earth fill..	....	23,700	750
Naches Meadows.......	1 mile above mouth of Sand Creek.	80	850	Rock fill ..	....	9,200	370
Pleasant Valley........	5.1 miles from mouth of American River.	150	1,050	...do......	....	44,800	1,040
Conrad Meadows *d*	15 miles above mouth of South Fork of Tieton River.	120	800	...do......	....	6,300	....
						158,600	

a Flow of Clealum River at outlet of Clealum Lake will be controlled by Clealum Lake reservoir. Hence storage for irrigation is not warranted in these reservoirs.
b This site was not investigated by the United States Reclamation Service. The details given are estimated from a reservoir survey by United States Geological Survey shown on Plate XIII (at end of volume).
c A dam 80 feet high and about 1,300 feet long on top would store approximately 42,000 acre-feet of water.
d The flow of Tieton River below South Fork will be controlled by the McAllister Meadows reservoir. Hence storage for irrigation is not warranted at Conrad Meadows.

Two of the storage units indicated in the foregoing table have been constructed and the third, Keechelus Lake (Pls. II and VII), is under construction. The following brief descriptions of the completed reservoirs at Kachess Lake and at Bumping Lake (Pls. VI and VII, at the end of this volume) have been abstracted from the annual reports of the United States Reclamation Service.

KACHESS LAKE.

Surveys to indicate the feasibility of impounding water by building a dam at the outlet of Lake Kachess were made by the Northern Pacific, Yakima & Kittitas Irrigation Co., but no construction work was undertaken. The Cascade Canal Co. began construction of a temporary timber crib dam at the mouth of the lake May 30, 1903, and the work was completed June 1, 1904. On April 1, 1907, the

Reclamation Service perfected an agreement with the Cascade Canal Co. and assumed control of the temporary dam. A plan of Kachess reservoir site is shown in Plate VII (at end of volume).

Authority was given by the Secretary of the Interior to begin the construction of the Kachess storage unit February 14, 1910. A camp was established in April, 1910, and 22 per cent of the work was completed at the end of the fiscal year 1910–11. The work was 75 per cent completed at the end of the fiscal year 1911–12, and the project was pushed to completion during the fall of 1912. All work was done by Government force account.

The Kachess Lake reservoir is formed by an earth and gravel fill dam located about 1,700 feet below the most southerly point of Lake Kachess. The dam is 1,400 feet long, with a crest elevation about 42 feet higher than the normal lake level. It has a volume of 250,000 cubic yards and is provided with a concrete core wall to avoid the possibility of excessive seepage through and under the dam. One of the noteworthy features of this storage unit is the scheme used to gain storage in the lake by increasing the normal lake level 32 feet and also drawing the water surface 33 feet below the original lake surface. Hence, the dam and auxiliary structures permit a range of stage of 65 feet which will make available 210,000 acre-feet of storage. The elevation of the top of the dam is 2,268 feet above sea level, that of the natural water surface is 2,226 feet, and the gate sill 2,193 feet.

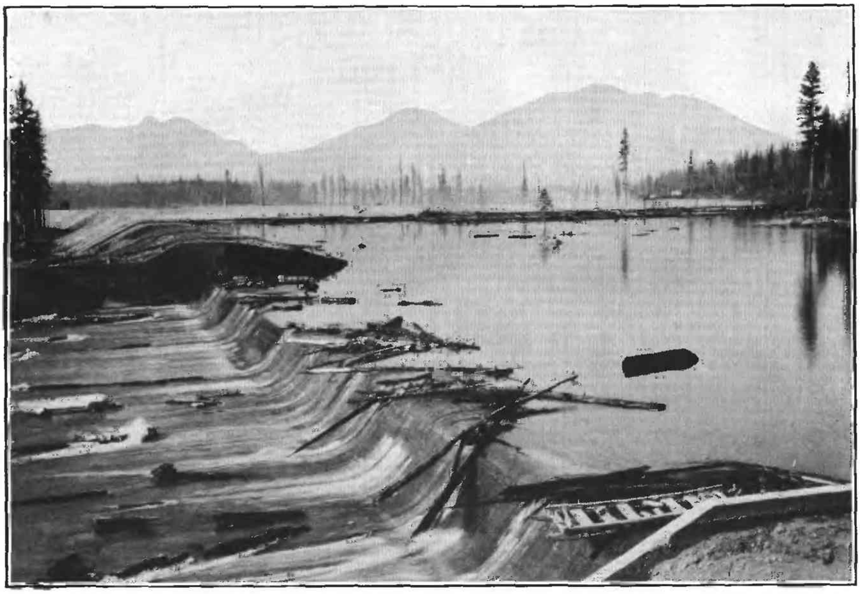
A dredged channel 1,100 feet long, a concrete approach conduit 1,400 feet long, and an open approach channel 265 feet long serve to carry the water from the lake to the outlet conduit extending through the dam. The concrete outlet conduit is horseshoe shaped in cross section and is 12 feet wide, 12 feet high, and 300 feet long. Two sets of three gates, 4 feet wide and 10 feet high, are operated from a concrete gate tower placed at the upper end of the outlet conduit. Below the dam the water flows through an open, paved channel for a distance of 700 feet, where it joins the original river channel.

The spillway for the reservoir is situated in a low place in the ridge extending toward the left side of the river and is about 3,000 feet east of the dam. The concrete crest of the spillway, which is 8 feet high and 250 feet long between abutments, is 10 feet lower than the top of the dam. A concrete apron is provided below the crest for a distance of 50 feet to prevent a displacement of the spillway foundations through channel changes.

BUMPING LAKE.

The first attempt to obtain storage by providing a dam at the outlet of Bumping Lake was made by the Northern Pacific, Yakima & Kittitas Irrigation Co. in 1894. Timber for the construction of a crib dam was cut, but lack of funds prevented further development.

A. TIETON VALLEY AND TIETON CANAL.



B. BUMPING LAKE STORAGE RESERVOIR, WITH SPILLWAY IN THE FOREGROUND.

Later, the possibilities of storage were investigated by the United States Reclamation Service, and during 1906 and 1907 two sets of specifications were submitted for proposals but no bids were received. The provision of transportation facilities from Naches City to the dam site constituted a very important item in the Bumping Lake storage unit. Assistance was rendered by Yakima County and by the State in constructing a road to the dam site, but the work was done for the most part by Government force account. The road was completed December 10, 1908, and a camp was established shortly afterward. Construction work on the dam was started May 17, 1909, and 40 per cent of the dam and accessory structures was completed at the end of the fiscal year June 30, 1910. The project was completed and put into operation in November, 1910.

A plan of the reservoir site is shown in Plate VI (at end of volume).

The Bumping Lake reservoir is formed by an earth dam (Pl. III, *B*), which is 3,500 feet long and 46 feet high at greatest depth of cross section and contains 233,800 cubic yards of material. The alignment of the dam was curved to reduce the necessary embankment. The embankment was constructed by a combined dumping and sluicing process. The material was excavated by a steam shovel, conveyed by wagons to the outer edges of the embankment, which were kept considerably higher than the center of the dam. Water, under pressure and directed by a nozzle, was then used to sluice the silt and fine sand toward a settling basin extending along the center line of the structure to form the puddled core wall.

The outlet works consist of a circular reinforced-concrete conduit with an inside diameter of 7 feet and a concrete gate tower near the upper toe of the dam, from which two sets of gates are operated. The tower is connected with the crest of the dam by a steel footbridge.

The spillway (Pl. III, *B*), which is located at the left or north end of the dam, consists of a broad-crested weir 235 feet long and 7 feet lower than the top of the dam. A concrete channel about 500 feet long, which narrows from the length of the weir to a width of 42 feet within about 100 feet below the spillway crest, is provided for carrying the flood water past the dam and into a wooden flume which delivers it to the river channel below the dam.

OTHER RESERVOIR SITES.

The more important reservoir sites investigated by the United States Indian Office and private parties are described in the following paragraphs:

The Sherman site on Wenas Creek, developed by the Yakima Highlands Irrigation & Land Co., is reported to be capable of furnishing 12,800 acre-feet of storage by a dam 125 feet high, 100 feet long on the bottom, and 500 feet long on the top. The dam site is located in sec. 3, T. 15 N., R. 17 E., Willamette meridian, and the construction consists of an earth and rock fill dam with a concrete core.

The development of a number of small storage sites that have been studied in the upper Atanum Creek basin, would be very expensive. In the plan proposed by the Atanum Water Users' Association about 1,200 acre-feet of storage is to be provided by three small dams.

The possibilities of storage in the basins of Toppenish and Satus creeks were investigated by the United States Indian Service. The only favorable sites found in Toppenish basin were on Simcoe Creek. One of the dam sites is situated 3 miles north and 2 miles east of Fort Simcoe in sec. 34, T. 11 N., R. 16 E. At this site a dam 120 feet high, 600 feet long on the bottom, and about 1,500 feet long on top would impound 46,000 acre-feet of water. A large acreage of land, worth from $75 to $100 per acre, would be flooded. As Simcoe Creek could supply only about 10,000 acre-feet of water per year, it would be necessary to fill the reservoir by diversion from Toppenish Creek.

Three reservoir sites were discovered on Satus Creek. The upper dam site is just below the mouth of Logy Creek, in sec. 6, T. 8 N., R. 19 E., where a dam 85 feet high and 300 feet long on top would impound 30,000 acre-feet of water. By far the most favorable storage site on this stream is located in sec. 24, T. 9 N., R. 19 E., a short distance below the mouth of Dry Creek, where a dam 130 feet high and 1,300 feet long on top would impound 64,000 acre-feet of water. At the lower dam site, which is situated in secs. 16 and 21, T. 9 N., R. 20 E., a storage capacity of 20,000 acre-feet can be obtained by a dam 100 feet high and 850 feet long on top. The total capacity of these reservoir sites is 114,000 acre-feet, or more than enough to regulate fully the flow of the stream.

WATER POWERS.

DEVELOPED WATER POWERS.

RATED CAPACITY.

Hydraulic power developments in the Yakima basin are unimportant when compared with the total water power developed in the State of Washington. The rated capacity of power machinery installed or in course of construction in the State in 1913 has been estimated at approximately 400,000 horsepower. Of this amount about 190,000 horsepower may be credited to the section of the State west of the Cascade Range and about 170,000 horsepower to the Spokane River developments. Only about 14,000 horsepower, or 3.5 per cent of the total in the State, is developed in the Yakima Valley. The following table, summarizing present developments in the basin, has been compiled from data furnished by the operators. For many of the plants listed the water supply is insufficient and few of them succeed in developing the rated horsepower.

Summary of water-power plants in Yakima Valley.

Name.	Location.	Head.	Water wheel.	Rated horsepower of wheels.
		Feet.		
J. L. Mills & Son, sawmill [a]	Thorp	11	48-inch Double Eclipse	[b] 53
Thorp flour mill [a]	do	11	48-inch Moore & Parker	40
Ellensburg city light plant	Ellensburg	51.5	29-inch Morgan Smith	1,000
			15-inch Victor	330
			do	330
Ellensburg Mill & Feed Co	do	22	17-inch Leffel	20
			30-inch Leffel	[c] 61
Tjossem flour mill	Holmes	10	35-inch Flenniken	19
			30-inch Trump	64
Gilson pumping plant	Pomona	11	17-inch Samson	16
Prosser power plant [c]	Prosser	17	56-inch Samson Vertical	400
			48-inch Special Victor	330
Prosser flour mills [c]	do	9	Leffel	100
Naches (Wapatox) power plant	Naches	151.4	52-inch Pelton Francis	5,000
			36-inch Victor	3,500
			Pelton	1,500
Fruitvale (North Yakima) power plant	North Yakima	38	Little Giant	500
			American	250
North Yakima Milling Co	do	16	30-inch New American	98
Total				13,611

[a] J. L. Mills & Son and Thorp flour mill are parts of one system.
[b] Horsepower of wheels computed from manufacturers' tables published in Water Supply Paper 180.
[c] Prosser power plant and Prosser flour mills are part of one development.

The Pacific Power & Light Co. operates the Naches, Fruitvale, and Prosser power plants, which have an aggregate rated capacity of 11,500 horsepower. These plants, together with the developments on Columbia River at Priest Rapids and Walla Walla River near Milton, Oreg., having an aggregate rated capacity of about 6,000 horsepower, are interconnected by 390 miles of 66,000-volt transmission line. The total length of this line in the Yakima Valley is 111 miles, extending from Naches to Kennewick. All the generators deliver 3-phase 60-cycle current, which is stepped up to 66,000 volts by transformers for long-distance transmission. Smaller voltages are used for transmission over short distances at North Yakima and at Walla Walla. An aggregate steam auxiliary of 4,500 horsepower is installed to insure continuity of service and to meet peak loads. The power plants of this company located in Yakima Valley produced over 18,000,000 kilowatt-hours in 1913. About 75 per cent of this was generated at the Naches hydroelectric plant. This percentage is lower than the usual proportional output of the Naches plant owing to the fact that little power was generated during the spring months when new equipment was being installed. The following table shows the total output for 1913 of the Pacific Power & Light Co.'s developments in Yakima Valley:

Total production of Pacific Power & Light Co.'s plants in Yakima Valley, 1913.

[Includes power generated at Naches, Fruitvale, and Prosser hydroelectric plants and at the Naches steam plant.]

	Kilowatt-hours.		Kilowatt-hours.
January	1,366,464	August	2,270,788
February	1,203,488	September	2,334,902
March	913,052	October	1,259,858
April	895,730	November	1,243,536
May	1,460,080	December	1,563,446
June	2,023,154		
July	2,111,290	The year	18,645,788

The only other corporation distributing electrical energy in the basin is the city of Ellensburg, which operates a municipal plant having a capacity of 1,660 horsepower.

NACHES (WAPATOX) POWER PLANT.

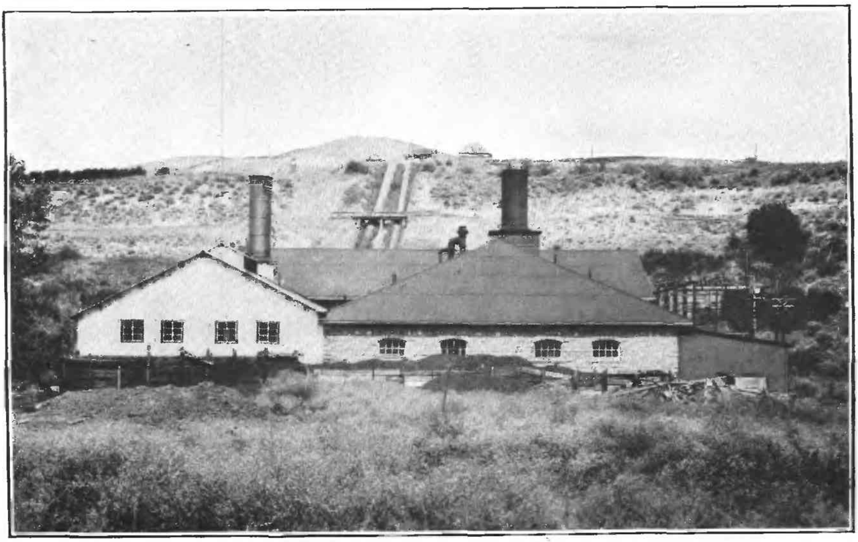
The largest power plant (Pl. IV, *B*) in the valley is situated on Naches River and was constructed in 1906. It is owned and operated by the Pacific Power & Light Co. and distributes electric energy to all parts of the valley below Selah. When the development was undertaken the headworks and conduit of Wapatox irrigating canal were enlarged to serve for both irrigation and power. The increasing power demand in the valley made it advisable to increase the capacity of the plant by 5,000 horsepower in 1913, and this installation made necessary an enlargement of the conduit. The canal was relocated at a smaller gradient, lined with concrete, and materially shortened. The head realized by the new construction, 53 feet, will eventually be used in a separate development of 1,400 kilowatts capacity. The new canal is 8.1 miles long, is substantially constructed, and is lined with concrete throughout. In addition to supplying water for the power development the canal delivers water to the old Wapatox irrigating canal, extending below the power-plant fore bay, and for the city water supply of North Yakima.

The water is diverted on the left side of Naches River, one-half mile below the mouth of Tieton River, and is conducted by the canal to a point about 3½ miles below Naches, where the plant is located.

Three wood-stave pressure pipes, each about 500 feet long, connect the fore bay at the end of the canal with separate power units operating under a static head of 151 feet. The largest of these is 92 inches in diameter and serves the unit installed in 1913, which is a 52-inch turbine with a capacity of 5,000 horsepower operating at 300 revolutions a minute. The new turbine is direct-connected to a 3,750-kilovolt-ampere alternating-current generator. A 72-inch pressure pipe delivers water to a 3,500-horsepower turbine which operates at 514

A. NACHES RIVER ABOVE TIETON RIVER AND BELOW HORSESHOE BEND.

Gage at Oak Flat gaging station in left foreground.



B. NACHES POWER PLANT.

revolutions per minute. This turbine was designed for a capacity of 5,000 horsepower at a head of 200 feet. It is now being rebuilt after a design more suited to the available head. It is direct-connected to an alternating-current generator with a capacity of 3,000 kilowatts. The smallest hydraulic unit is supplied with water from a 48-inch pressure pipe. It consists of a 1,500-horsepower Pelton impulse wheel, provided with three runners and two nozzles to each runner, operating

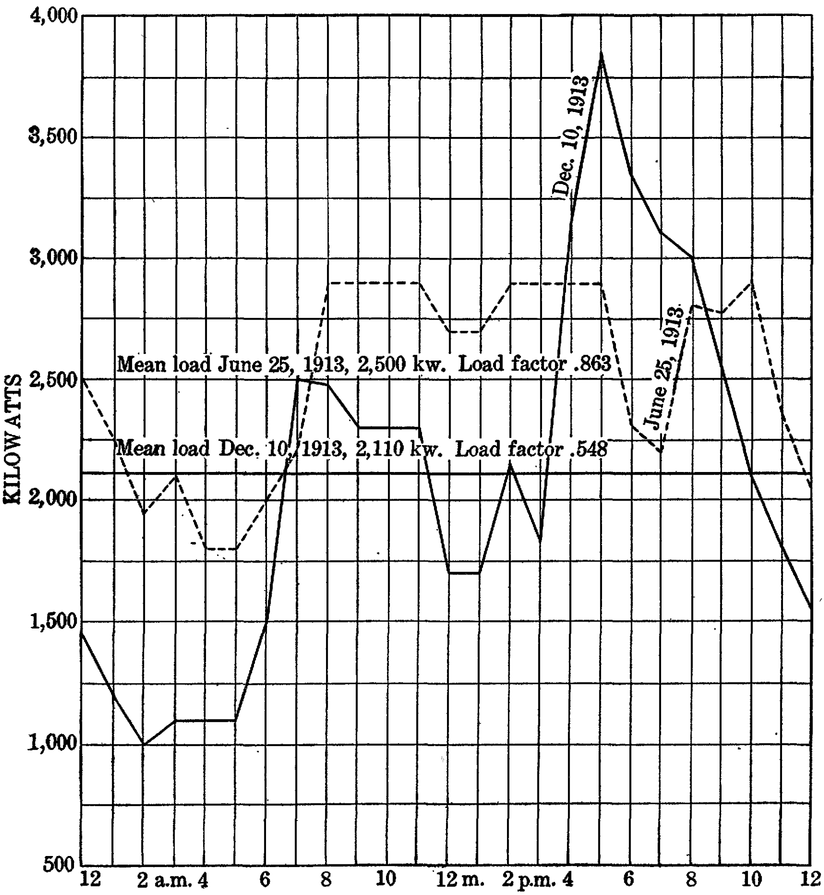


FIGURE 4.—Typical load curves of Naches power plant for summer and winter demand.

at 150 revolutions a minute. A 750-kilowatt alternating-current generator is direct-connected to the Pelton wheel.

Auxiliary steam power is provided for use in emergency and for carrying peak loads. A total boiler capacity of about 1,600 horsepower is available for running two generators. An 800-horsepower McEwen tandem compound reciprocating engine can be direct-connected to the generator in the Pelton wheel unit described above. The principal auxiliary unit consists of a Curtis steam-condensing turbine, operating at 1,800 revolutions a minute and direct-connected to an alternating-current generator of 2,000 kilowatts capacity.

All the electric equipment was manufactured by the General Electric Co.

The exciter equipment is composed of five direct-current units, operating at a voltage of 125 and having a total capacity of 150 kilowatts. Two of these are not in service and one is disconnected, so that the capacity of the units in use is 81 kilowatts.

Two sets of transformers are used to step up the current for the transmission lines. One set consists of seven 1,500-kilowatt oil-insulated water-cooled transformers in groups of three, with one spare. This set increases the voltage from 2,300 to 66,000. The other set consists of three 400-kilovolt-ampere transformers which increase the voltage to 23,000 for use in operating the street-railway system of North Yakima.

Load curves for days typical of the winter and summer demand are shown in figure 4. It should be noted that the load on June 25, 1913, was carried on the 3,000-kilowatt and 750-kilowatt generators, whereas the load on December 10, 1913, was carried on the new 3,750-kilowatt generator. It should also be noted that the Fruitvale and Prosser plants contribute a practically constant increment of about 600 kilowatts to the system at all times. The effect of the pumping load in increasing the load factor is very marked in comparing the demands of winter and summer.

PROSSER POWER PLANT.

The power plant at Prosser was constructed in 1894 in connection with the pumping development of the area now supplied by the Prosser siphon and included in the Sunnyside project (pp. 136–138). When the lands were provided with water under the gravity system the pumping machinery was abandoned. The plant is operated by the Pacific Power & Light Co. The average head of 17 feet is realized by means of a concrete dam 6 feet above bedrock and 350 feet long at the head of Prosser Falls and a wooden flume 10 feet high, 12 feet wide, and about 700 feet long, leading to the power house. At present two units are used for delivering hydroelectric energy. One consists of a 400-horsepower Sampson vertical turbine belted to a 400-kilowatt 2,300-volt generator. The other unit is composed of a 330-horsepower Victor turbine geared to a 200-kilowatt 2,300-volt generator. A turbine which is the exact duplicate of the Victor power unit is installed and in good condition, but owing to lack of water is not operated. In addition to the power developed for electric service there is a 100-horsepower installation owned by the Prosser

Flour Mills and operated by water taken from the flume under a 9-foot head.

FRUITVALE POWER PLANT.

The Fruitvale plant, which was constructed in 1890, is situated at North Yakima and is operated by the Pacific Power & Light Co. The water is diverted from Naches River a short distance below Cowiche Creek and carried on the right side of the valley through a canal about 2 miles long to the power house, where a head of 38 feet is realized.

The principal power unit consists of a 500-horsepower double-runner turbine, built by William Dowling & Co., which is direct-connected to a 350-kilowatt 2,300-volt General Electric generator. An American single-runner 250-horsepower turbine is connected by a shaft and belts to several pumps supplying water to North Yakima. In addition to the machinery for pumping water supplied with power by the small unit, there is a 30-kilowatt 3-phase induction motor provided for operating a centrifugal pump for increasing the pressure in the city mains in the Nob Hill district. The power house also furnishes space for the North Yakima main substation. The waste water from this plant is used by the North Yakima Milling Co., which develops 98 horsepower under a 16-foot head.

ELLENSBURG MUNICIPAL POWER PLANT.

The hydroelectric plant of the Ellensburg city light department is the most important power development on Yakima River proper. It supplies chiefly a lighting load in the city of Ellensburg and surrounding rural district.

The intake of the power canal is situated on the outside of a bend in the river on the right bank and no permanent diversion dam is provided. At low stages a log boom is swung part way across the stream and bags of sand are piled on top to form a temporary wing dam. New concrete headgates were constructed in 1912, and the banks of the river above and below were protected by piling. Below the intake a canal of 750 second-feet capacity extends through an earth channel for a distance of 3.6 miles and discharges into a wooden flume 200 feet long leading to the fore bay of the power plant. Provision is made in the fore bay to furnish water to three units under a head of 51.5 feet. The largest unit is a 1,000-horsepower turbine with two runners manufactured by the Morgan Smith Co. It is direct-connected to a 550-kilowatt 3-phase 60-cycle 6,600-volt Allis-Chalmers generator. The two smaller units are provided with Victor turbines having double runners and capacities of 330 horsepower each. They were manufactured by the Platt Iron Works. One of these turbines is direct-connected to a 200-kilowatt Fort Wayne generator with same phase, cycle, and voltage as the larger generator. The other small turbine is not in use.

One transmission line, about 3 miles long, connects the power house with the city of Ellensburg, and another, 5 miles long, is being constructed to the city waterworks. Both lines consist of three No. 0 copper wires strung on cedar poles. The current is transmitted directly from the generators without recourse to transformers for increasing the line voltage.

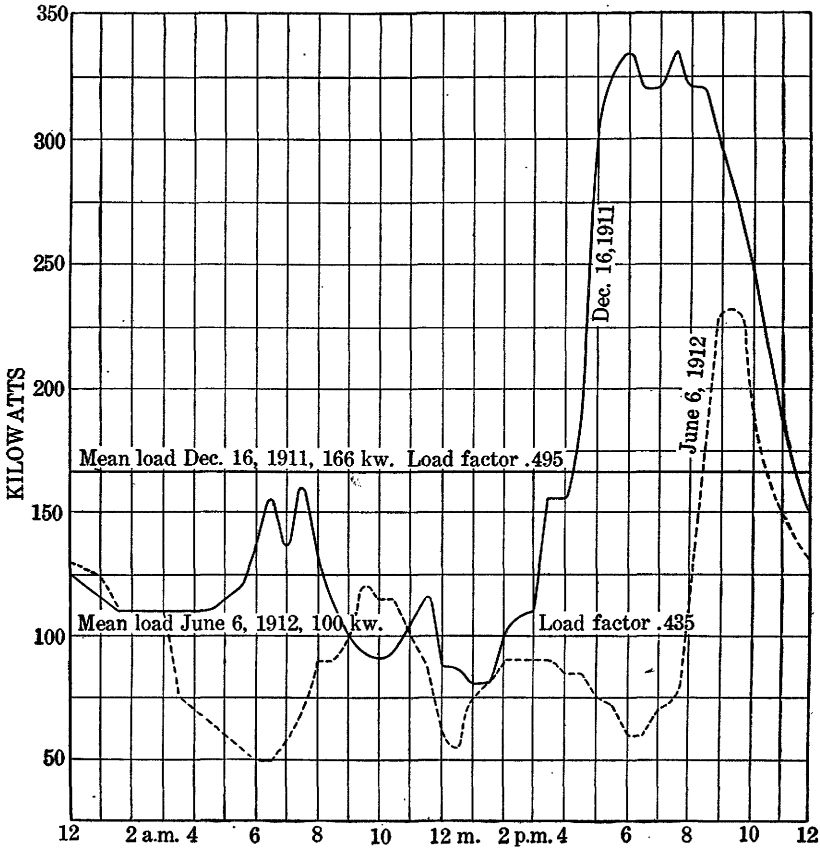


FIGURE 5.—Typical load curves of Ellensburg city light plant for summer and winter demand.

Recently the city of Ellensburg has filed for power purposes on 600 second-feet of water in Yakima River in addition to the former filing of 150 second-feet. The total claims of the city are now considerably greater than the low-water flow of the river at the intake, even when irrigation rights are disregarded. The power canal has been enlarged to a capacity of 750 second-feet, and it is proposed to use the additional water to meet future demands for electric service.

The present power requirements at this plant are governed principally by the lighting demand. The current used for industrial purposes is not a very prominent factor. The pumps will have a capacity of 4,000,000 gallons a day and will be operated, for the most part, during off-peak periods. Load curves for typical days of maximum and minimum lighting demand are shown in figure 5.

UNDEVELOPED POWER SITES.

SCOPE OF DISCUSSION.

The waters of the Yakima basin are admittedly of greater economic importance for irrigation than for power development. Consideration of power resources might therefore seem unwarranted, but a study of the scheme of control under which the water will be utilized to irrigate the greatest possible area of land indicates that three parts of the river system will offer favorable opportunities for power development:

1. Yakima River between Clealum River and Union Gap: Power can not be developed continuously in this section, but in some stretches of the river a large flow may be available during the irrigation season for use in pumping water to irrigate land that can not be reached by the present gravity systems.
2. Clealum River and tributaries above Clealum Lake: The flow will not be affected by regulation for irrigation and considerable storage may be utilized for increasing the yield during periods of deficiency.
3. Naches River and tributaries: The flow need not be greatly affected by the demands for irrigation, and if storage is regulated to meet the requirements of both irrigation and power the yield will be materially increased. The opportunities for development in this part of the river system are far more favorable than those found in any other part of the basin.

Conditions under which the flow will be regulated differ so widely that the power sites in each of the three parts are discussed separately.

METHOD OF ANALYSIS.

The determination of the available power in the sections indicated makes necessary the assumption that certain stretches of the rivers form logical development units. In some places the limits of a power development are unmistakably indicated by the natural conditions; in others they can be determined only by systematic study, and even then engineers working independently may differ as to details. The units selected for this report are based on general considerations of water supply, stream gradient, topography, and other physical features that demand attention in such a study. It is not claimed that the units selected are certainly the best; others may be as good or better; but they are well adapted to show the relative limits of good, bad, and indifferent power sites. Final location and selection are the work of the engineer in private practice and beyond the province of a report of this kind.

The fall and water supply are also essential factors to be determined. The fall in each development section chosen has been taken from plan and profile surveys of the United States Geological Survey and from surveys made by the United States Reclamation Service. (Pls. VIII to XX, at end of volume.) The water supply has been computed from the records of stream flow presented elsewhere and from a consideration of the probable regulations of storage for the complete development contemplated in the Yakima project of the United States Reclamation Service. The mass diagram has been used in studying the effect of storage regulation. This method is commonly employed by engineers and has been described by Barrows [1] in a report on Kennebec River, and by Barrows and Babb [2] in a similar report on Penobscot River.

The computations of horsepower are estimated at 70 per cent of the theoretical horsepower to compensate for losses in water wheels and for the necessity of sacrificing in conduit locations a part of the gross fall in each section.

SITES ON YAKIMA RIVER.

GENERAL CONDITIONS.

The ultimate control and utilization of a greater part of the yearly run-off of Yakima River for irrigation render the possibilities of continuous power development on the river distinctly unfavorable. The reservoirs at Clealum, Kachess, and Keechelus lakes (Pls. VI and VII, at end of volume), when completed, will control all the principal catchment areas above the Naches except Teanaway River. The river channels below the reservoirs will carry little water from November 1 to April 1, and during that period the sole source of water will be relatively low-lying drainage areas. The discharge records that have been obtained at Clealum and Umtanum, when corrected on the assumption that the three reservoirs will be storing all the available supply, indicate that this winter run-off will at times become very small, and that the available continuous power is of little importance. It should be borne in mind, however, that the river will not be completely controlled for a number of years.

[1] Barrows, H. K., Water resources of the Kennebec River basin: U. S. Geol. Survey Water-Supply Paper 198, pp. 150–162, 1907.

[2] Barrows, H. K., and Babb, C. C., Water resources of the Penobscot River basin, Maine: U. S. Geol. Survey Water-Supply Paper 279, pp. 194–202, 1912.

The most advantageous use to which the available fall in the river can be put is the development of power during the irrigation season, but the amount of water available for this purpose is also limited. The unstorable spring run-off of the Naches basin can be used most advantageously to supply canals below Union Gap, and during years of normal flow it will not be necessary to release stored water from the upper Yakima reservoirs for use in these canals until about the middle of July. The unstorable spring run-off of the basin above Selah Gap will be insufficient to supply the projects now in operation or contemplated in that section of the river and must be supplemented by water released from the upper Yakima reservoirs; economy of operation will make it desirable to release only enough to satisfy the requirements of irrigation above Selah Gap. It is evident that it would not be feasible to install power machinery with a capacity in excess of the water available during June and the early part of July. The summer power could be made available throughout the year by using steam auxiliaries during the nonirrigating season, a method that would be especially advantageous in the section of the river that lies above Ellensburg and in close proximity to the Kittitas County coal fields.

No power estimates have been submitted for the section of the river above the mouth of Clealum River. Economical operation of the three lake reservoirs will require manipulation as a single unit, so that it is impossible to forecast the regimen of the stream above Clealum River. It is thought also that it would not prove feasible to release water in such a manner as to accommodate the requirements of power development in that section.

In the section between the mouth of Naches River and Union Gap the amount of water that could be used to provide power throughout the entire year is probably sufficient to warrant development, and the requirements of irrigation insure the delivery of a large summer flow which could be used for pumping. This section of the river proper has the additional advantage of nearness to a possible market at North Yakima and to a considerable area of arid land that can readily be irrigated by pumping.

The power summaries have been computed without considering the rights of power plants now in operation, although it is evident that it will be necessary to sacrifice some stored water during the winter to satisfy existing power requirements.

The plan and profile of Yakima River are shown in Plates VIII to X (at end of volume).

FLOW AVAILABLE.

Power estimates for Yakima River between Clealum River and Union Gap have been made for two conditions of flow, under the assumption that all the reservoirs of the Yakima project except

Bumping reservoir (which is of small capacity) will be operated solely for irrigation—(1) the flow for the calendar month of minimum mean flow, this minimum representing the water that can be used to develop power throughout the year; and (2) flow for a critical month during the irrigation season, representing the flow that can be used for supplying energy to pump water during the irrigation season.

The methods employed in determining the water supply of development units for each of the two conditions of flow are described in the following paragraphs:

Minimum flow with storage for one calendar month.—During years of small run-off Keechelus, Kachess, Clealum, and McAllister Meadows reservoirs will store all water contributed above them from November to March, so that the flow available for continuous power development will amount to the yield of the drainage area which is not tributary to the reservoir sites. This flow has been computed at three points along the Yakima River, as follows: Clealum, Umtanum, and below Naches River.

The flow at Clealum has been determined by deducting the sum of the monthly discharge at the outlet of Keechelus, Kachess, and Clealum lakes, corrected for storage, from the flow of Yakima River at Clealum. The minimum flow for the winter months (November to March) from November, 1906, to March, 1912, thus determined, occurred November, 1907, and was 25 second-feet. The winter season of lowest flow was November, 1908, to March, 1909. The average flow during this period was 163 second-feet.

The flow at Umtanum has been determined in the same manner, using the discharge estimates at the gaging station on Yakima River at Umtanum as a basis. The minimum flow for one calendar month from November, 1906, to March, 1912, occurred November, 1907, and was 182 second-feet. The winter season of lowest flow was November, 1908, to March, 1909. The average flow during this period was 411 second-feet.

The flow below Naches River has been obtained by adding to the minimum flow derived for Yakima River at Umtanum for November, 1907 (182 second-feet) the mean discharge of Naches River at Oak Flat for the same month (325 second-feet) and an additional estimated discharge of 13 second-feet to represent the contribution of the low-lying drainage areas below the McAllister Meadows dam site and below Umtanum. The flow of Yakima River below Naches River for November, 1907, estimated in this manner, amounts to 520 second-feet.

The flow estimated for these three points on Yakima River has been used in determining the flow available for each development unit chosen for the power summaries by adding the approximate flow of minor tributaries in accordance with the location of the unit. The discharge of these tributaries for November, 1907, has been estimated as follows: Teanaway River, 63 second-feet; Swauk Creek, 12 second-feet; Taneum Creek, 10 second-feet.

Below the proposed intake of the Yakima High-Line canal and above Naches River the minimum flow can not be estimated from the unstorable flow for November, 1907. Economical operation of the storage system will involve utilizing as fully as possible the unstorable water supply of Naches basin, and will result in releasing only enough water to satisfy the demands of irrigation above Naches River, so that Yakima River will be practically dry above Naches River during June of a season of low water. The amount of water required from Yakima River for irrigation under the Selah-Moxee and Taylor canals is 78 and 23 second-feet, respectively, as defined by agreed diversion. (See p. 145.) Hence only 101 second-feet could be depended upon above the intake of Selah-Moxee canal during a season of low water.

Flow for a critical month during the irrigation season.—The utilization of the full capacities of the reservoirs for irrigation will require that the needs of irrigation below Naches River be supplied as far as possible from the unstorable waters of the Naches basin. Only sufficient water would be released from Keechelus, Kachess, and Clealum reservoirs to supply the present and prospective irrigation demands above Naches River prior to about July 15. It would not be feasible to install more machinery in pumping plants than could be supplied with energy during June. Hence June is the critical month in determining the flow of Yakima River above Naches River for pumping water during the irrigation season. A study of water supply and ultimate requirements for June, 1908, indicates that stored water would have to be released from the reservoirs above Clealum, so that the requirements of the various canals have been used in determining the flow available during June. These requirements are shown in the following table:

Requirements (in second-feet) of present and proposed canals diverting water from Yakima River between Clealum and Naches rivers.

Canal.	Water required.	Canal.	Water required.
Cascade	[a] 97	Pomona Heights (p. 158)	[b] 70
West Kittitas	[a] 80	Selah-Moxee	[a] 78
Ellensburg Water Co.	[a] 125	Taylor	[a] 23
Olson	[a] 24		
Bull	[b] 35		1,622
Proposed Yakima high line	[b] 1,090		

[a] Agreed diversion (p. 145). [b] Estimated.

It has been estimated that the total contribution of tributaries to Yakima River between Clealum and Umtanum amounted to 470 second-feet in June, 1908, and that of this amount Teanaway River contributed 330 second-feet, Swauk Creek 45 second-feet, and Wilson Creek 95 second-feet. The flow of Taneum and Manastash creeks was probably completely used for spring irrigation during the same month. Under these conditions the flow of Yakima River below Clealum River should have been about 1,150 second-feet in June, 1908, to supply the irrigation requirements listed in the foregoing table. The flow available for the development sections chosen for the power summary has been computed from requirements of canals and contributions of tributaries set forth above in accordance with the location of the section.

A different basis has been used in determining the flow on Yakima River below Naches River. The average flow during the irrigation season (April to October) required for meeting present and prospective irrigation demands below Union Gap has been considered the criterion for computing the flow that can be used to supply energy for an irrigation pumping load. The requirements of the present and proposed developments have been estimated by the United States Reclamation Service and are shown in the following table:

Average required delivery of water, in second-feet, at Union Gap.

Wapato unit	1,230
Sunnyside unit	1,080
Benton unit	520
All other requirements	100
	2,930

A part of the water diverted for the Wapato and Sunnyside units of the Yakima project of the Reclamation Service will return to the river during the irrigation season and will be available for use at points below. It is estimated by engineers of the United States Reclamation Service that this seepage return and 100 second-feet listed in the table for all other requirements will meet the irrigation demands in the lower valley not included in the table.

SUMMARY OF UNDEVELOPED POWER.

The following table summarizes the data for each development section and indicates the amount of power that may be developed for the two conditions of flow:

Summary of undeveloped power on Yakima River.

Section No.	Location on Yakima River.	Distance above Union Gap. Upper end of section.	Distance above Union Gap. Lower end of section.	Elevation above mean sea level. Upper end of section.	Elevation above mean sea level. Lower end of section.	Total fall in section.	Minimum flow at diversion point with storage. For one calendar month.	Minimum flow at diversion point with storage. Critical month irrigation season.	Horsepower (70 per cent efficiency). Continuous.	Horsepower (70 per cent efficiency). During irrigation season.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*		
1	Between Clealum and Teanaway rivers	77.6	68.0	1,950	1,810	140	25	1,150	278	12,800
2	Between Teanaway River and intake of Cascade canal	68.0	60.2	1,810	1,715	95	88	1,480	665	11,200
3	Between intakes of Cascade and Ellensburg Water Co.'s canals	60.2	53.3	1,715	1,610	105	100	1,350	835	11,300
4	Between intake of Ellensburg Water Co.'s canal and tailrace of Ellensburg city light plant	53.3	47.8	1,610	[a]1,535	[a]75	110	1,200	656	7,160
5	Between tailrace of Ellensburg city light plant and Wilson Creek	47.8	38.8	[a]1,535	1,415	[a]120	110	1,160	1,050	11,100
6	Between Wilson and Umptanum creeks	38.8	32.0	1,415	1,320	95	182	1,260	1,370	9,520
7	Between Umptanum Creek and proposed intake of Yakima high-line canal	32.0	21.5	1,320	1,205	115	182	1,260	1,660	11,500
8	Between proposed intake of Yakima high-line canal and intake of Selah-Moxee canal	21.5	16.4	1,205	1,140	65	101	101	522	522
9	Between intake of Selah-Moxee canal and Naches River	16.4	9.0	1,140	1,060	80	0	0	0	0
10	Between Naches River and Union Gap	9.0	0	1,060	930	130	[b]520	2,930	[b]5,370	30,300
									12,400	105,000

[a] Approximate.
[b] Manipulation of storage in Naches Meadows, Pleasant Valley, and Bumping Lake for power and irrigation development on Naches River would increase this figure to 775 second-feet and make 8,010 continuous horsepower available in this section.

CONSTRUCTION FEATURES.

Section 1. Yakima River between Clealum and Teanaway rivers.—The power indicated in the power summary could be developed by means of a diversion conduit along the south side of the valley, where construction would not be very difficult.

Section 2. Yakima River between Teanaway River and the intake of Cascade canal.—The second section lies almost wholly in Dudley Canyon and could be developed only by constructing somewhat expensive conduits along the steep hillsides.

Section 3. Yakima River between the intakes of the Cascade and Ellensburg Water Co.'s canals.—Development of the third section would require an expensive flume along the steep rocky hillsides on the north side of the valley and considerable tunneling.

Section 4. Yakima River between the intake of the Ellensburg Water Co.'s canal and the tailrace of the Ellensburg city light plant.—The Ellensburg city light plant utilizes 51.5 feet of the total head indicated in the power summary for the fourth section (pp. 99–101).

Section 5. Yakima River between the tailrace of the Ellensburg city light plant and Wilson Creek.—The total head indicated in the power summary could probably best be utilized by means of two or more units. The construction of diversion conduits would be relatively easy and inexpensive. Part of the power indicated in the power summary is developed by a flour mill at Ellensburg. (p. 95).

Section 6. Yakima River between Wilson and Umptanum creeks.—Section 6 lies wholly in Yakima Canyon, and the position of the Northern Pacific Railway tracks will prohibit development by dams. A diversion conduit would be very expensive on account of the tunneling required and the necessity of lining canals to prevent losses by seepage.

Section 7. Yakima River between Umptanum Creek and the proposed intake of the Yakima high-line canal.—Section 7 is similar to section 6; development would be affected by the same conditions.

Section 8. Yakima River between the proposed intake of the Yakima high-line canal and the intake of the Selah-Moxee canal.—Conditions to be considered in developing power in section 8 are similar to those in sections 6 and 7. The plan of the Yakima Canal Co. for development of summer power in a part of this section has been mentioned (p. 158), but it is probable that economical operation of the storage system would make it impossible to supply the necessary water for this project when the proposed gravity irrigation canals have been completed.

Section 9. Yakima River between intake of Selah-Moxee canal and Naches River.—The development of power in this section for use in North Yakima has been considered. The scheme proposes the enlargement of the Selah-Moxee canal from the intake to a point near Selah Gap, so that the flow not needed for irrigation could be used for power and for filling an equalizing reservoir at the power-house fore bay.

Section 10. Yakima River between Naches River and Union Gap.—The minimum water supply of this section, with economical storage regulation in effect, is probably sufficient to warrant development for power. The section is situated near considerable areas of first-class irrigable land which can readily be watered by pumping, and continuous power should find a favorable market at North Yakima. The most feasible scheme of development would be by a canal heading just below Naches River and passing around the eastern end of Moxee Valley. The canal would be about 12 miles long and could be constructed cheaply except for the lower 2 miles, where permanent impervious conduits would be required along the steep north hillside of Rattlesnake Ridge.

SITES ON CLEALUM RIVER.

GENERAL CONDITIONS.

The proposed Clealum Lake reservoir of the Yakima project (Pl. VI) has a capacity greater than any other reservoir in the Yakima basin. At this site the entire flow of the river during years of normal precipitation can be regulated to meet the requirements of irrigation, and any surplus from a wet year may be held over for use in a dry year, so that it will be advantageous to allow a greater storage period than for Keechelus and Kachess reservoirs. With such operation the river channel below the Clealum reservoir will be practically dry from about November 1 of one year to July 1 of the succeeding year, and no power development will be feasible below the reservoir. Hence, the estimate of power available on Clealum River has been limited to the parts of the stream above Clealum reservoir.

The importance of upper Clealum River as a power stream is greatly enhanced by the three reservoir sites afforded by Fish, Waptus, and Cooper lakes. These sites are thought to be of sufficient capacity to regulate the flow of contributing drainage areas during critical years, but the cost will doubtless be high. The storage can be regulated exclusively for power and not interfere with the availability of the water for irrigation.

The use of power developed on Clealum River to pump water for irrigation extensions is not probable on account of long transmission lines that would be required. A larger field of use will be opened if the two transcontinental lines crossing the Cascade Range at the headwaters of Yakima River are electrified. The exploitation of the mineralized belts in the surrounding mountainous region and the adoption of electric ore-reduction processes may also offer a profitable market for the power.

The plan and profile of Clealum River are shown in Plates XI to XIII (at end of volume).

FLOW AVAILABLE.

MASS-CURVE ESTIMATES.

The discharge of Clealum River below Clealum Lake has been determined accurately by continuous stream-flow records since October 10, 1903 (p. 62), but no reliable records have been obtained on the upper branches of the river. Estimates of discharge for North, Middle, and West forks have been based principally on miscellaneous measurements compared with the records below the lake. Their use is not warranted for detailed plans and estimates, but in the absence of actual records they have been used for a preliminary study of the power resources. The assumptions used for deriving the flow have been so chosen that the estimates are thought to be conservative.

Estimates of the discharge of North Fork above Camp Creek are based on a measurement of 31 second-feet made October 13, 1911. October, 1911, has been the month of lowest flow on record at the gaging station below Clealum Lake, and a comparison of daily discharge of Foss River and Swauk and Manastash creeks for this month apparently indicates that the discharge of those streams was slightly lower October 13 than the mean flow for the month. Hence it seems conservative to assume that for October, 1911, the mean flow of North Fork above Camp Creek was 31 second-feet (1,910 acre-feet), which is 22 per cent of the flow below Clealum Lake. The following table shows the results of mass-curve computations and estimates of run-off obtained from this comparison on the assumption that during the cold months the run-off from the high areas would reach a minimum lower than that of the entire basin. In order that the period considered might represent critical conditions two storage years extending from April of one year to March of the succeeding year have been chosen and are assumed to follow each other consecutively. The first, April, 1908, to March, 1909, contains the period of greatest deficiency; the second, April, 1911, to March, 1912, is the year of minimum yield.

Estimated run-off, in acre-feet, and mass-curve computations of North Fork above Camp Creek for April, 1908, to March, 1909, and April, 1911, to March, 1912.

[Drainage area, 37.9 square miles.]

Month.	Ratio.[a]	1908-9			1911-12		
		Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 150 second-feet.	Summation.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 150 second-feet.	Summation.
April	0.22	19,100	+10,200	10,200	14,700	+ 5,770	40,900
May	.21	30,600	+21,400	31,600	22,700	+13,500	54,400
June	.20	36,700	+27,800	59,400	27,300	+18,400	72,800
July	.20	23,100	+13,900	73,300	9,700	+ 480	73,300
August	.21	6,140	− 3,080	70,200	3,610	− 5,610	67,600
September	.22	3,150	− 5,780	64,400	4,900	− 4,030	63,600
October	.22	2,860	− 6,360	58,100	1,910	− 7,310	56,300
November	.22	8,000	− 930	57,100	13,100	+ 4,170	60,500
December	.22	4,080	− 5,140	52,000	6,500	− 2,720	57,800
January	.22	3,000	− 6,220	45,800	6,000	− 3,220	54,500
February	.22	2,440	− 5,890	39,900	5,160	− 3,470	51,100
March	.22	4,430	− 4,790	35,100	4,220	− 5,000	46,100
	....	144,000	+35,100	....	120,000	+11,000	....

[a] Assumed ratio of North Fork above Camp Creek to Clealum River below Clealum Lake.

A mass diagram (fig. 6) has been constructed from the data in the table to show the requirements of storage above Camp Creek for the two years selected. The average flow during the year April, 1911, to March, 1912, was 165 second-feet; about 35,000 acre-feet of storage would have been necessary to maintain this flow continuously. The period of deficiency during the year April, 1908, to March, 1909, was more severe, although the total run-off for the year was greater. A storage draft of about 45,000 acre-feet would have been required to maintain a continuous flow of 165 second-feet.

The discharge of West Fork at its mouth was obtained by similar methods. The approximate discharge for July, 1911—195 second-feet (12,000 acre-feet)—was computed from four gage heights at a temporary station near the mouth and a hydrograph comparison with the records on Foss River and East Fork of Foss River, which drain areas on the west side of the Cascade Range opposite Clealum basin; and a measurement giving 36.5 second-feet was made October

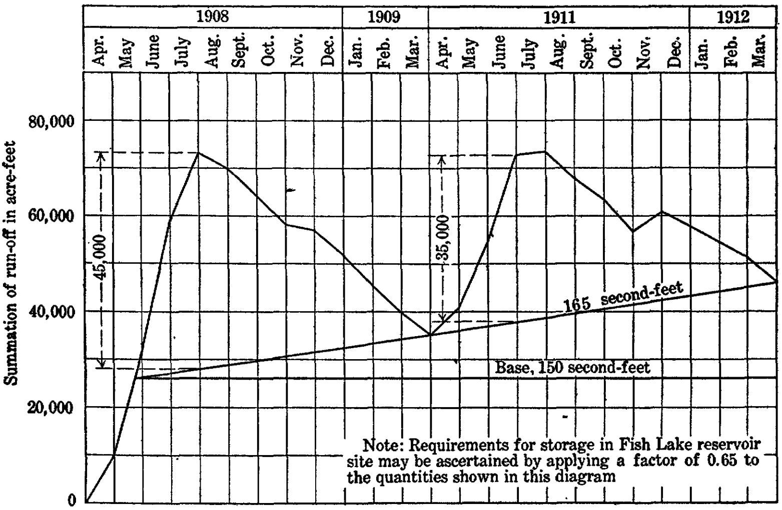


FIGURE 6.—Mass diagram for North Fork above Camp Creek.

13, 1911. The mean flow of West Fork at its mouth for October, 1911, has therefore been assumed as 37 second-feet (2,280 acre-feet). The ratio of the mean flow of West Fork at its mouth to the mean flow of Clealum River below Clealum Lake is 0.27 for July and 0.26 for October. The following table shows the results of estimates of run-off and mass-diagram computations obtained by use of these ratios and the assumption of lower minimum flow for the higher drainage areas during the cold months. As on the North Fork, two storage years have been selected, extending from April of one year to March of the succeeding year, the first, April, 1908, to March, 1909, being critical with respect to the period of greatest deficiency and the second, April, 1911, to March, 1912, with respect to water available.

Estimated run-off, in acre-feet, and mass-curve computations, of West Fork at its mouth for April, 1908, to March, 1909, and April, 1911, to March, 1912.

[Drainage area, 39.7 square miles.]

Month.	Ratio.[a]	1908–9			1911–12		
		Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 190 second-feet.	Summation.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 190 second-feet.	Summation.
April	0.27	23,400	+12,100	12,100	18,100	+ 6,800	45,200
May	.27	37,500	+25,800	37,900	27,800	+16,100	61,300
June	.27	45,100	+33,800	71,700	33,500	+22,200	83,500
July	.27	28,400	+16,700	88,400	12,000	+ 300	83,800
August	.27	7,530	− 4,150	84,200	4,430	− 7,250	76,500
September	.27	3,860	− 7,450	76,800	6,020	− 5,290	71,200
October	.26	3,380	− 8,300	68,500	2,280	− 9,400	61,800
November	.26	9,440	− 1,870	66,600	15,500	+ 4,200	66,000
December	.26	5,040	− 6,640	60,000	8,030	− 3,650	62,400
January	.25	3,750	− 7,930	52,100	7,500	− 4,180	58,200
February	.25	3,050	− 7,500	44,600	6,450	− 4,480	53,700
March	.26	5,490	− 6,190	38,400	5,230	− 6,450	47,300
	....	176,000	+38,400	....	147,000	+ 8,900	....

[a] Assumed ratio of West Fork at mouth to Clealum River below Clealum Lake.

A mass diagram (fig. 7) constructed from the data in the table shows the requirements of storage of West Fork at its mouth for the

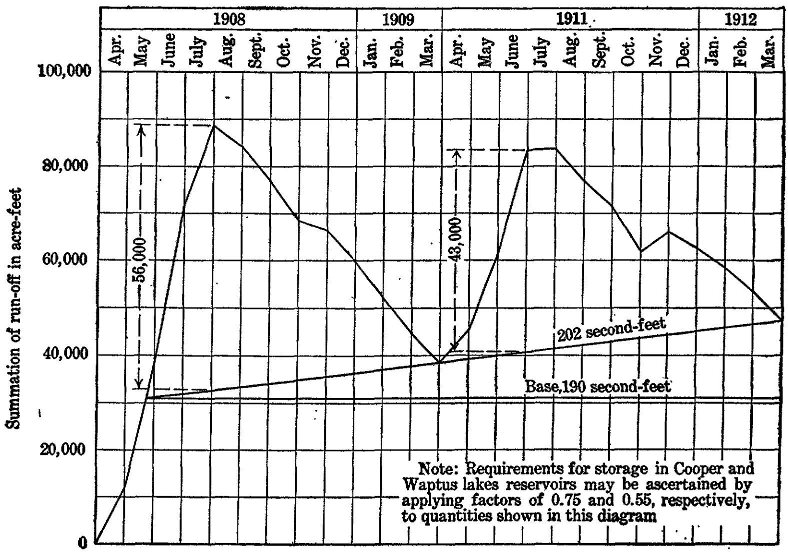


FIGURE 7.—Mass diagram for West Fork at its mouth.

two years. A storage capacity of about 43,000 acre-feet would have been necessary to maintain the average flow of 202 second-feet, April, 1911, to March, 1912. The mean flow during the year April, 1908, to March, 1909, was greater, but the period of deficiency was more severe, so that 56,000 acre-feet would have been required to maintain a continuous flow of 202 second-feet.

The run-off of Middle Fork at its mouth was estimated from a measurement of 50 second-feet made September 10, 1910. Comparison of the discharge with the mean flow for that month of Naches, American, and Bumping rivers and Manastash Creek apparently indicates that the mean flow for the month was slightly less than the discharge September 10. It has therefore been assumed that the mean flow of the Middle Fork for September, 1910, was about 49 second-feet, which bears a ratio of 0.26 to the mean flow for the month below Clealum Lake. The two comparisons of flow on West Fork at its mouth gave ratios of 0.26 and 0.27, so that it has been assumed that the water supply of Middle Fork at its mouth is the same as that already estimated for West Fork at its mouth.

CONDITIONS OF FLOW CHOSEN.

The undeveloped power in Clealum basin has been computed (1) for minimum flow, without storage, for one calendar month; and (2) for minimum flow, with storage, for critical years. The estimates based on the first assumption are used chiefly for the purpose of comparing the possible water powers of Clealum River with those of other rivers in the State; those based on the second assume that sufficient storage will be available in Fish, Cooper, and Waptus reservoirs to regulate the flow for power development during critical years.

For the first assumed condition the flow for each development unit is determined from the recorded or estimated flow for October, 1911 (the calendar month of minimum recorded flow below Clealum Lake) and factors derived from comparisons of drainage area. The factors chosen are slightly greater than those indicated by differences in drainage areas because the higher areas yield more run-off than the lower.

For determining the water supply and storage requirements of sections directly below Fish, Cooper, and Waptus Lake reservoirs, mass-curve estimates and the factors chosen for estimating the minimum flow, without storage, for one calendar month, furnish a basis. A uniform release of stored water from these reservoirs will maintain a flow at each reservoir greater than the minimum flow, without storage, for one calendar month. It has been assumed that the amount of increase at the reservoirs will result in an equal increase in the minimum flow without storage for one calendar year at points below the reservoirs.

SUMMARY OF UNDEVELOPED POWER.

The following table summarizes the data for each development section and indicates the amount of power that may be developed under the two conditions assumed:

Summary of undeveloped power in Clealum River basin.

Section No.	Stream and location.	Drainage area at diversion point.	Distance above mouth of stream.		Elevation above mean sea level.		Total fall in section.	Minimum flow at diversion point.		Continuous horsepower (70 per cent efficiency).	
			Upper end of section.	Lower end of section.	Upper end of section.	Lower end of section.		Without storage.[a]	With storage.[b]	Without storage.[a]	With storage.[b]
		Sq. miles.	*Miles.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Sec.-feet.*	*Sec.-feet.*		
1	North Fork between Scatter Creek and elevation 2,545 feet	22.8	30.8	23.9	3,310	[c]2,545	765	20	107	1,220	6,520
2	Middle Fork between the NE. ¼ sec. 30, T. 23 N., R. 14 E., and elevation 2,545 feet	[d]42.2	4.0	.8	2,835	[c]2,545	290	[e]31	[e]122	720	2,810
3	West Fork between dam site below Cooper Lake and elevation 2,545 feet	28.5	4.4	2.4	2,789	[c]2,545	244	28	151	540	2,930
4	Clealum River between elevation 2,545 feet and Big Salmon La Sac	[f]131	23.9	22.0	2,545	2,390	155	98	399	1,210	4,920
5	Clealum River between Big Salmon La Sac and the NE. ¼ sec. 32, T. 22 N., R. 14 E.	131	22.0	18.4	2,390	2,252	138	98	399	1,080	4,380
										4,770	21,560

[a] For one calendar month.
[b] For critical years.
[c] Backwater from possible dam above Big Salmon La Sac in section 4.
[d] The drainage area at dam site below Waptus Lake is 26.6 square miles.
[e] Including 11 second-feet assumed to have been contributed by drainage area between dam site and diversion point.
[f] Including drainage area at point of diversion on West Fork, section 3.

CONSTRUCTION FEATURES.

Section 1. North Fork between Scatter Creek and elevation 2,545 feet.—A storage capacity of about 29,000 acre-feet in Fish Lake would be necessary to supply a continuous flow of 107 second-feet for the critical years chosen in the mass diagram. (See fig. 6, p. 111.) A dam approximately 1,700 feet long on top would impound the required quantity at an elevation of about 3,390 feet. The dam would be expensive on account of its inaccessible location. It has been assumed that the water would be diverted below the dam site and carried to a power plant situated above backwater of a possible dam above Big Salmon La Sac in section 4.

Section 2. Middle Fork between the NE. ¼ sec. 30, T 23 N., R. 14 E., and elevation 2,545 feet.—A storage capacity of about 31,000 acre-feet in Waptus Lake would be necessary to supply a continuous flow of 111 second-feet for the critical years chosen in the mass diagram. See fig. 7, p. 112.)

A dam approximately 250 feet long on top would impound the required quantity at an elevation of about 3,012 feet. This is the best dam site of the three in the upper Clealum basin, and if transportation facilities were favorable it could be built cheaply. It has been assumed that the water would be diverted about 3½ miles below the dam site and carried to a power plant situated above backwater of a possible dam above Big Salmon La Sac in section 4. The fall between the dam site and the point of diversion indicated is less than 30 feet per mile, so that the cost of constructing a conduit along the rocky slopes of the creek to gain this head would probably not be warranted.

Section 3. West Fork between dam site below Cooper Lake and elevation 2,545 feet.—A storage capacity of about 42,000 acre-feet in Cooper Lake would be necessary to supply a continuous flow of 151 second-feet for the critical years chosen in the mass diagram. (See fig. 7, p. 112.) A dam approximately 1,300 feet long on top would impound the required quantity at an elevation of about 2,863 feet. A detailed survey of the reservoir and examination of the dam site might indicate that a storage of 42,000 acre-feet would not be warranted. It has been assumed that the water would be diverted below the dam site and carried along the left side of the creek to a power plant located above a possible dam above Big Salmon La Sac in section 4.

Section 4. Clealum River between elevation 2,545 feet and Big Salmon La Sac.—This development unit includes a project of the Kittitas Railway & Power Co. Preliminary investigations have resulted in locating a dam site one-half mile above Big Salmon La Sac, at a water surface elevation of about 2,425 feet. A concrete arch dam 120 feet high and a conduit located on the left side of the valley leading to a power house at Big Salmon La Sac are proposed. The plans for future development include diverting West Fork through a separate power unit delivering water above the proposed dam as indicated in section 3.

Section 5. Clealum River between Big Salmon La Sac and the NE. ¼ sec. 32, T. 22 N., R. 14 E.—The lower limit of this development unit is governed by the elevation to which it is proposed to impound water in Clealum Lake reservoir.

SITES ON NACHES RIVER.

GENERAL CONDITIONS.

Because of its steep gradient and well-sustained flow Naches River affords opportunities for power development that can be utilized with less sacrifice of the requirements of irrigation than any other stream of the Yakima basin except upper Clealum River, which is rather inaccessible. Moreover, the situation of the power sites with respect to the present and future market requirements, together with favorable physical conditions, render this basin of chief importance in the province of hydroelectric development.

The proposed reservoir site at McAllister Meadows on Tieton River, contemplated in the plans of the Reclamation Service for the Yakima project, and the Pleasant Valley reservoir site will control for irrigation during critical years practically all run-off of the drainage area tributary to them. The Bumping and Naches Meadows reservoir sites are small and can control only a small part of the annual flow. The ultimate regulation for irrigation will have less effect on the natural flow of Naches River above Tieton River than it will have on Yakima River proper, and it may even prove advantageous to regulate available storage in such a manner that benefits will accrue for both power and irrigation. Whether or not such procedure will be warranted can not now be definitely determined.

Plans and profiles of Naches, Bumping, American, and Tieton rivers are shown in Plates XIV–XX (at end of volume).

FLOW AVAILABLE.

MASS-CURVE ESTIMATES.

Mass diagrams have been used to determine the effect of storage at or near the four reservoir sites in Naches basin.

Stream-flow records on American River at its mouth during the summer months of 1909, 1910, and 1911 (p. 77) form a fair basis for estimating the probable run-off for the other months of those years. A comparison of mean monthly run-off for the periods covered by records with that for Bumping River at the outlet of Bumping Lake for the same periods seems to indicate that a factor of 0.96 should be applied to the run-off at Bumping Lake to determine the run-off for American River at its mouth. The monthly estimates so derived and computations for mass diagram are given in the following table. The estimates are grouped in storage years extending from April of one year to March of the succeeding year.

Estimated run-off, in acre-feet, and mass-curve computations, of American River at its mouth for April, 1909, to March, 1912.

[Drainage area, 81 square miles.]

Month.	1909–10			1910–11			1911–12		
	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 240 second-feet.	Summation.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 240 second-feet.	Summation.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 240 second-feet.	Summation.
April	[a]20,200	+ 5,900	5,900	33,000	+18,700	115,500	18,300	+ 4,000	155,800
May	37,100	+22,300	28,200	61,500	+46,700	162,200	30,100	+15,300	171,100
June	58,300	+44,000	72,200	32,200	+17,900	180,100	47,100	+32,800	203,900
July	29,800	+15,000	87,200	16,700	+ 1,940	182,000	17,200	+ 2,440	206,300
August	7,190	− 7,570	79,600	6,110	− 8,650	173,400	4,930	− 9,830	196,500
September	3,350	−10,900	68,700	3,720	−10,600	162,800	5,030	− 9,250	187,200
October	3,270	−11,500	57,200	10,500	− 4,260	158,500	3,320	−11,400	175,800
November	41,100	+26,800	84,000	29,300	+15,000	173,500	11,300	− 3,000	172,800
December	23,100	+ 8,300	92,300	11,200	− 3,560	170,000	8,850	− 5,910	166,900
January	14,600	− 160	92,200	8,120	− 6,640	163,300	11,700	− 3,060	163,900
February	8,220	− 5,110	87,100	7,330	− 6,000	157,300	11,600	− 2,200	161,700
March	24,500	+ 9,740	96,800	9,220	− 5,540	151,800	7,130	− 7,630	154,000
	271,000	+96,800	....	229,000	+55,000	....	177,000	+ 2,260	....

[a] Estimated as 27 per cent of run-off of Naches River at Oak Flat.

A mass diagram (fig. 8) constructed from this table indicates that the flow in the storage year 1911–12 was considerably lower than in the two preceding years. A continuous flow of 295 second-feet could have been maintained throughout the three years with 96,000 acre-feet of storage, but it is not thought that a storage capacity in excess of that required during a critical year is warranted. The mean flow during the year April, 1911, to March, 1912, was 243 second-feet. This flow could have been maintained with 54,000 acre-feet of storage, and 23,000 acre-feet would have been released after the irrigation

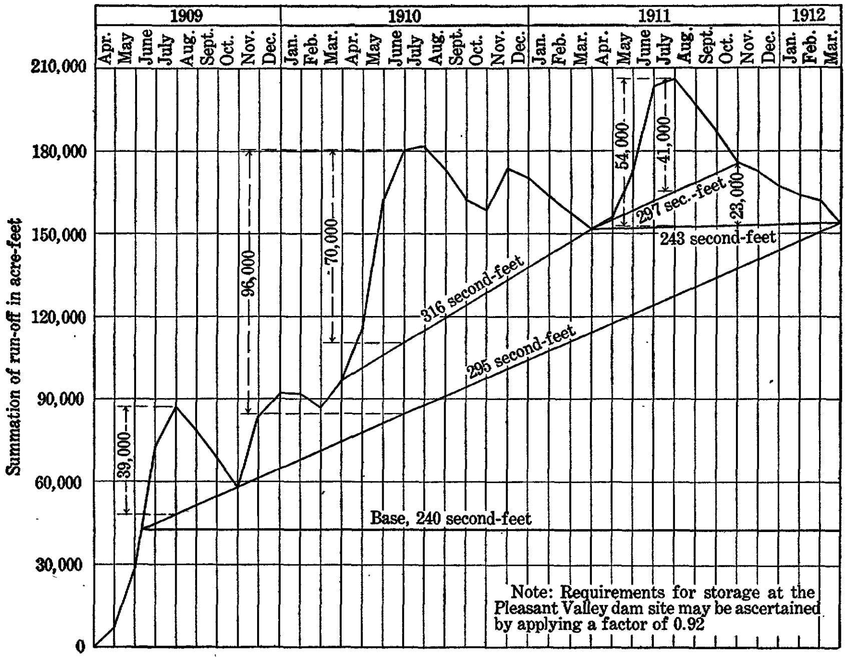


FIGURE 8.—Mass diagram for American River at its mouth.

season ending October 31. A storage capacity of 41,000 acre-feet would have been necessary to equalize the mean flow of 297 second-feet during the irrigation season.

The run-off and storage requirements at Pleasant Valley reservoir site have been computed by applying a factor of 0.92 to the values derived from the mass curve for American River at the mouth. This factor has been determined from a comparison of low-water measurements (p. 90) at the mouth and at the lower end of Pleasant Valley, and, as would be expected, is slightly greater than the ratio of drainage areas.

No stream-flow records have been obtained on Naches River above Bumping River. The flow of American River at its mouth is thought to be representative of conditions of run-off at the Naches Meadows reservoir site and has been used as a basis for the run-off estimates. The storage year, April, 1911, to March, 1912, was found to be the critical period in considering storage operations for American River at its mouth. Hence the same year has been chosen for the mass diagram of Naches River at Naches Meadows dam site. The run-off has been estimated by applying a factor of 0.28 to the quantities estimated for American River at its mouth. This factor has been determined by

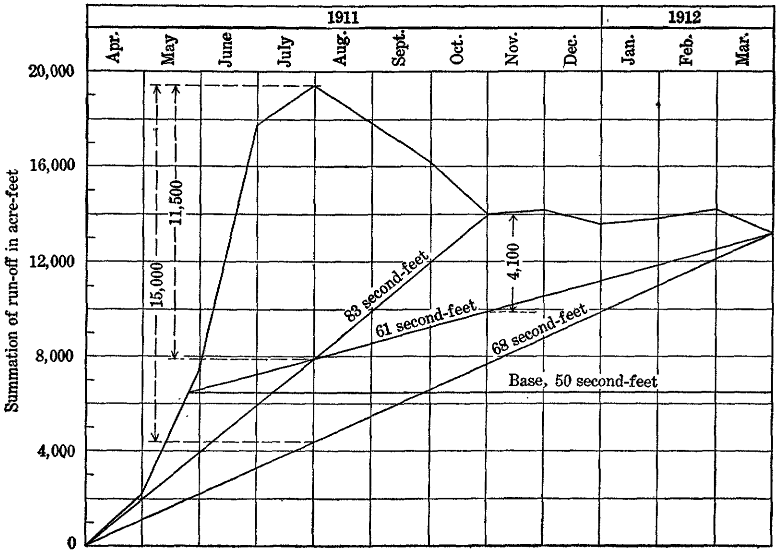


FIGURE 9.—Mass diagram for Naches River at Naches Meadows dam site.

a comparison of low-water measurements (p. 89) of upper Naches and American rivers, together with a consideration of differences in drainage areas and probable conditions of run-off. The estimates and mass-diagram computations are shown in the following table:

Estimated run-off, in acre-feet, and mass-curve computations of Naches River at Naches Meadows dam site, for April, 1911, to March, 1912.

[Drainage area, 63.7 square miles.]

Month.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 50 second-feet.	Summation.	Month.	Estimated run-off.	Excess (+) or deficiency (−) for mean flow of 50 second-feet.	Summation.
April	5,120	+ 2,140	2,140	November	3,160	+ 180	14,200
May	8,430	+ 5,360	7,500	December	2,480	− 590	13,600
June	13,200	+10,200	17,700	January	3,280	+ 210	13,800
July	4,820	+ 1,750	19,400	February	3,250	+ 370	14,200
August	1,380	− 1,690	17,800	March	2,000	− 1,070	13,200
September	1,410	− 1,570	16,200				
October	930	− 2,140	14,000		49,500	+13,200	....

A mass diagram (fig. 9) constructed from this table indicates that 15,000 acre-feet of storage would have been required to maintain the mean flow of 68 second-feet for the year. It is doubtful, however, whether a storage capacity of 15,000 acre-feet is feasible. The mean flow of 83 second-feet during the irrigation season, April to October, could have been maintained by 11,500 acre-feet of storage, and it is thought that this capacity might prove feasible. If 11,500 acre-feet of storage had been utilized to supplement the run-off during the low-water months, a flow of 61 second-feet would have been assured throughout the year and 4,100 acre-feet would have been released after the irrigation season ending October 31.

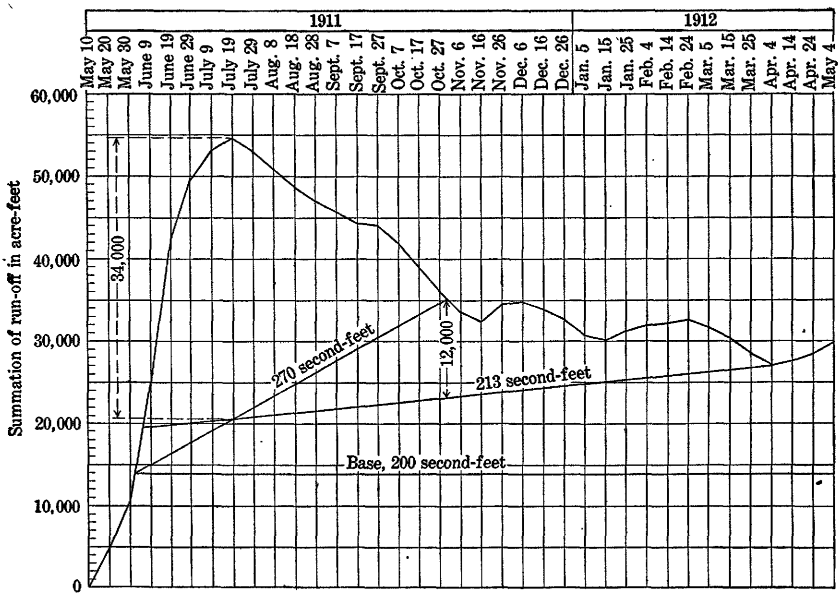


FIGURE 10.—Mass diagram for Bumping River at outlet of Bumping Lake.

The capacity of Bumping Lake reservoir, 34,000 acre-feet, is small in comparison to the run-off from the contributing drainage, so that the low-water interval is critical for storage operation. The stream-flow records below Bumping Lake indicate that the fall and winter months of 1911–12 included the critical period between April 27, 1909, and October 31, 1912. A summation of run-off, by 10-day intervals, based on a continuous flow of 200 second-feet and computed from the daily discharge of Bumping River at the outlet of Bumping Lake is shown in the following table. The summation has been corrected for storage in Bumping Lake.

Summation of run-off, based on a continuous flow of 200 second-feet, at outlet of Bumping Lake from May 10, 1911, to May 4, 1912.

[Drainage area, 68 square miles.]

Date at end of 10-day interval.	Summation in acre-feet.	Date at end of 10-day interval.	Summation in acre-feet.	Date at end of 10-day interval.	Summation in acre-feet.
May 20	4,830	Sept. 17	44,200	Jan. 15	30,100
30	10,400	27	44,000	25	31,200
June 9	24,600	Oct. 7	41,900	Feb. 4	31,900
19	42,400	17	39,000	14	32,100
29	49,400	27	36,100	24	32,500
July 9	53,100	Nov. 6	33,600	Mar. 5	31,800
19	54,600	16	32,300	15	30,300
29	53,000	26	34,500	25	28,400
Aug. 8	50,700	Dec. 6	34,700	Apr. 4	27,100
18	48,700	16	33,800	14	27,600
28	46,900	26	32,600	24	28,300
Sept. 7	45,800	Jan. 5	30,700	May 4	29,900

A mass diagram (fig. 10) constructed from this table indicates that a flow of 213 second-feet could have been maintained throughout the year with the storage available, and that 12,000 acre-feet would have been released after the close of the irrigation season. With 34,000 acre-feet of storage a flow of 270 second-feet would have been possible during the irrigation season ending October 31.

Records are available on Tieton River at McAllister Meadows dam site from August 25, 1908, to October 31, 1912. During this period the year ending October 31, 1911, appears to have been critical in respect to storage operation for irrigation. A summation of the natural run-off and required release for the Tieton unit during this year is shown in the following table:

Summation of run-off, in acre-feet, of Tieton River at McAllister Meadows dam site, and of release required for Tieton unit for November, 1910, to October, 1911.

Month.	1 Tieton River at McAllister Meadows dam site.	2 Increase in water supply between dam site and intake of Tieton canal.[a]	3 Requirement of the Tieton unit.	4 Release required at dam site for Tieton unit (3−2).	5 Run-off not needed for Tieton unit (1−4).
November	34,300				34,300
December	51,600				51,600
January	65,600				65,600
February	75,600				75,600
March	91,500				91,500
April	118,900				118,900
May	162,400	5,100	19,600	14,500	147,900
June	232,600	11,800	40,000	28,200	204,400
July	268,900	14,700	61,700	47,000	221,900
August	287,700	17,700	82,700	65,000	222,700
September	305,900	18,900	102,400	83,500	222,400
October	316,700	18,900	102,400	83,500	233,200

[a] Derived by comparison of monthly run-off of Tieton River at McAllister Meadows and Tieton River at headworks of Tieton canal.

A comparison of records on Tieton River at McAllister Meadows dam site with those near the mouth (above and below Oak Creek) indicates that for no year since records were begun at the lower point in 1902 would the water supply be insufficient for filling the reservoir with 183,000 acre-feet of stored water and supplying the requirements of Tieton canal prior to July 1. During the year ending October 31, 1906, which was least in total run-off, more than 20,000 acre-feet would have passed Tieton headworks prior to August 1 if the reservoir had been provided and the Tieton unit fully developed. It will prove advisable to empty the reservoir before the close of the irrigation season each year and fill it again as soon as possible in order that the unstorable run-off can be utilized during the irrigation season. Hence, the river will be practically dry from November 1 to the following June during years of low run-off.

A mass diagram (fig. 11) constructed from the foregoing table indicates that the reservoir would have been filled about June 20,

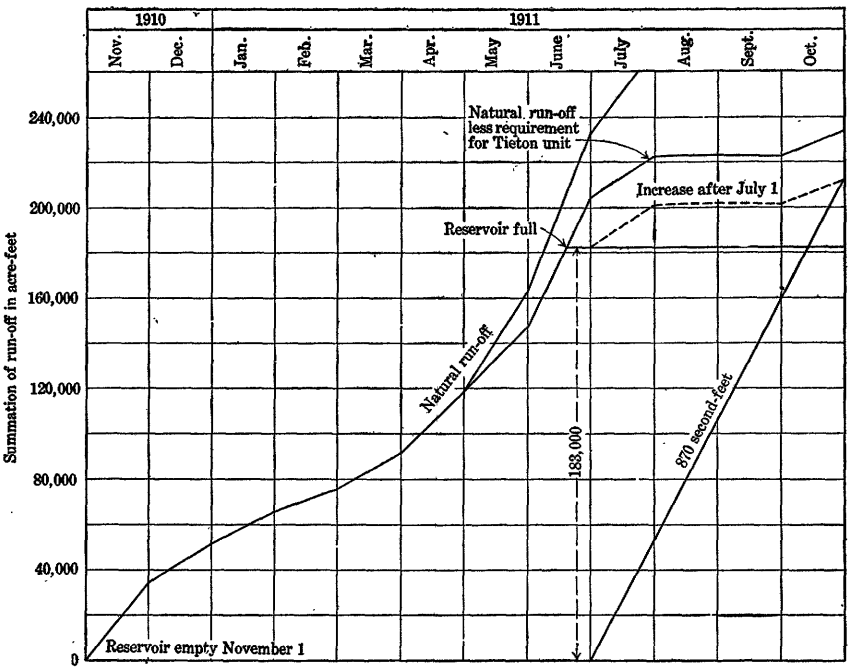


FIGURE 11.—Mass diagram for Tieton River at McAllister Meadows dam site.

1911, and that a continuous flow of 870 second-feet could have been maintained below the dam site from July 1 to the end of the irrigation season. The practical operation of reservoirs in Yakima basin will not permit a uniform release of storage from each reservoir, because it is essential that stored water from some may be emptied early in the season and from others reserved for later use. All must be operated more or less as a single unit to avoid waste. If stored water is released intermittently from McAllister Meadows reservoir the possible power on Naches River below Tieton River will be reduced materially on account of diversion for irrigation in that part of the stream. The maximum demand for irrigation from Naches River amounts to only about 500 second-feet and it seems probable that this demand can be supplied from McAllister Meadows reservoir after July 15, which, during normal years, is about the date that the unstorable water supply of Yakima basin will cease to meet the needs of irrigation. A large part of the stored water in McAllister Meadows reservoir would still be available for release in conjunction with that from upper Yakima reservoirs. With such regulation the flow of Naches River at the mouth from July 15 to October 31 each year will be the same as that for Naches River above Tieton River for the same period.

CONDITIONS OF FLOW CHOSEN.

The estimate of undeveloped power in Naches basin has been computed for three conditions of flow:

1. Minimum flow, without storage, for one calendar month. These estimates are useful chiefly for the purpose of comparing the possible water powers of Naches River with those of other rivers in the State.
2. Minimum flow, with storage, for a critical year. The estimates based on this condition assume that the water stored in Bumping, Pleasant Valley, and Naches Meadows reservoirs can be used to best advantage for both irrigation and power. Such operation would involve the release of stored water to maintain a uniform flow during the low-water periods and thereby utilize a part of the stored water after the close of the irrigation season. The value of this stored water for irrigation will depend on the price of land; its value for power will depend on the market price of energy. Present prices do not afford a fair basis for estimating values because the price of land will probably increase and that for energy decrease.
3. Mean flow with storage for the irrigation season. The estimates based on this condition assume the release of stored water from Bumping, Pleasant Valley, and Naches Meadows reservoirs to maintain a flow which would vary with the requirements of irrigation, so that power machinery could be installed for pumping water for irrigation. The use of stored water in this manner would involve no sacrifice of water for gravity irrigation, for the periods of high and low requirements of irrigation would coincide with those of power. The total storage in Bumping, Pleasant Valley, and Naches Meadows reservoir sites represents only a relatively small part of the total storage available in the Yakima basin, so that a uniform release of stored water from these reservoirs would not interfere greatly with operating all of the reservoirs as a single unit.

The methods employed in deriving the water-supply of development units for each of the three conditions of flow are described in the following paragraphs:

Minimum flow, without storage, for one calendar month.—Fortunately the water supply of Naches River and its principal tributaries has been accurately determined by stream-flow records. These records, estimates made for mass diagrams, and drainage-area factors have been used to compute the water supply for each development unit.

Minimum flow, with storage, for a critical year.—The mass-diagram estimates furnish the basis for computing the water supply of sections directly below Bumping, Pleasant Valley, and Naches Meadows reservoir sites. A uniform release of stored water from these reservoirs will maintain a flow at each reservoir greater than the minimum flow without storage for one calendar month. For estimating the water supply of sections above Tieton River it has been assumed that increase at the reservoirs will result in an equal increase in the minimum flow, without storage, for one calendar month at points below the reservoirs. If the minimum calendar month occurred synchronously throughout the valley, the assumption would be correct, but the records show that this condition does not obtain. A study of the records on Naches River at Anderson's ranch and at Oak Flat has been made to determine the effect of the aggregate storage capacity on the flow at those points. The results obtained were 5 to 8 per cent larger than those derived by the assumption indicated. Since it would be very difficult to operate the storage in the three reservoirs uniformly and without loss, the more conservative basis was chosen.

The operation of the McAllister Meadows reservoir will result in practically no flow in Tieton River below the dam site from November 1 each year until the reservoir is filled. Hence, Tieton River will not contribute an appreciable flow during the winter months, and the water supply for sections below Tieton River has been assumed to be the same as that directly above Tieton River.

Mean flow, with storage, for the irrigation season.—This flow is indicated in the mass-diagram estimates for development sections directly below Bumping, Pleasant Valley, and Naches Meadows reservoir sites. A uniform release of stored water from the three reservoirs will maintain a flow greater than the average flow without storage at the reservoirs for the period July 1 to October 31. Here also it has been assumed that increase at the reservoirs will result in equal increase in the average flow for the same period at points below the reservoirs. This assumption is subject to an uncertainty due to a lack of synchronous stages throughout the valley, but is thought to be sufficiently accurate for the purpose desired.

The method of deriving this condition of flow for Naches River at Anderson's ranch and at Oak Flat for the period July 1 to October 31, 1911, is shown in the following table:

Derivation of mean flow during the irrigation season of 1911 with storage at Bumping, Pleasant Valley, and Naches Meadows reservoir sites.

Record or estimate.	1 Mean flow during irrigation season with storage.	2 Mean flow without storage from July 1 to Oct. 31.	3 Increase due to storage (1—2).
	Second-feet.	*Second-feet.*	*Second-feet.*
Bumping River at outlet of Bumping Lake	270	139	131
American River at Pleasant Valley dam site	273	115	158
Naches River at Naches Meadows dam site	83	35	48
	626	289	337
	(2+3)		
Naches River at Anderson's ranch	750	413	337
Naches River at Oak Flat	779	442	337

The flow for development units on Naches River above Tieton River has been computed from values included in the table and a consideration of differences in drainage areas.

The flow for development units on Naches River below Tieton River has been based on the assumed release of stored water from McAllister Meadows reservoir site, described in the mass-diagram estimates. If water is released from the reservoir after July 15 to meet all requirements of irrigation from Naches River, the flow available for development units below Tieton River will be increased by the amount diverted for irrigation below those sections. The average amounts diverted during the irrigation season have been estimated as follows: Above Tieton River, 104 second-feet; below Tieton River and above Naches power canal, 81 second-feet; below Naches power plant and above North Yakima power canal, 156 second-feet; below North Yakima power canal, 99 second-feet.

The flow for development units on Tieton River has also been based on the mass-diagram estimates for Tieton River at McAllister Meadows dam site, which indicate that considerably more water will pass the proposed dam prior to July 15 than will be necessary to supply about 340 second-feet for the average irrigation requirement of the Tieton unit. After July 15 it has been assumed that water will be released for irrigation canals supplied from Naches River. Hence at all times during the irrigation season more than 340 second-feet will be available for power development between the dam site and the intake of Tieton canal. It has been assumed arbitrarily that a flow of 500 second-feet could be utilized. Under such conditions 160 second-feet could be used for power below the Tieton canal.

SUMMARY OF UNDEVELOPED POWER.

The following table summarizes the data for each development section and indicates the amount of power that may be developed for the three conditions of flow chosen:

Summary of undeveloped power in Naches River basin.

Section No.	Stream and location.	Distance above mouth of stream. Upper end of section.	Distance above mouth of stream. Lower end of section.	Elevation above mean sea level. Upper end of section.	Elevation above mean sea level. Lower end of section.	Total fall in section.	Minimum flow at diversion point. Without storage.a	Minimum flow at diversion point. With storage.b	Mean flow for irrigation season with storage.	Water released after irrigation season.c	Horsepower (70 per cent efficiency). Continuous. Without storage.a	Horsepower (70 per cent efficiency). Continuous. With storage.b	Horsepower (70 per cent efficiency). Mean for irrigation season with storage.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*			
1	Naches River between Naches Meadows and Bumping River	54.5	46.3	3,020	2,540	480	d 27	d 73	d 95	4,100	1,030	2,790	3,620
2	American River below Pleasant Valley	5.4	0	3,220	2,718	502	49	224	273	21,000	1,960	8,940	10,900
3	Bumping River between Bumping Lake and a point opposite Old Scab Mountain	16.2	12.1	e 3,389	3,165	224	56	213	270	12,000	997	3,790	4,810
4	Bumping River between Old Scab Mountain and American River	12.1	3.8	3,165	2,718	447	62	219	283	12,000	2,200	7,780	10,100
5	Bumping River below American River	3.8	0	2,718	2,540	178	120	452	569	33,000	1,700	6,400	8,050
6	Naches River between Bumping River and elevation 2,265 feet	46.3	38.5	2,540	2,265	275	181	559	750	37,000	3,960	12,200	16,400
7	Naches River between elevation 2,265 feet and Rattlesnake Creek	38.5	29.4	2,265	1,972	293	181	559	750	37,000	4,220	13,000	17,500
8	Naches River between Rattlesnake Creek and elevation 1,765 feet	29.4	23.7	1,972	1,765	207	220	598	779	37,000	3,620	9,850	12,800
9	Naches River between elevation 1,765 feet and intake of Selah Valley canal	23.7	19.3	1,765	1,620	145	220	598	779	37,000	2,540	6,900	8,980
10	Naches River between intakes of Selah Valley and Naches power canals	19.3	17.9	1,620	1,578	42	220	494	675	37,000	735	1,650	2,250
11	Tieton River between dam site below McAllister Meadows and intake of Tieton canal	22.4	15.0	f 2,744	2,303	441	175	0	500	....	6,140	0	17,500
12	Tieton River below Tieton canal	15.0	0	2,303	1,590	713	190	0	160	....	10,800	0	9,070
13	Naches River between intake and tailrace of Naches power plant	17.9	10.6	1,578	1,345	233	428	598	1,030	37,000	7,930	11,100	19,100
14	Naches River between tailrace of Naches power plant and intake of North Yakima power canal	10.6	3.0	1,345	1,120	g 225	428	598	878	37,000	7,660	10,700	15,700
15	Naches River below intake of North Yakima power canal	3.0	0	g 1,120	g 1,060	g 60	428	598	779	37,000	2,040	2,850	3,720
											57,530	97,950	160,500

a For one calendar month.
b For critical year.
c For minimum flow, with storage, for a critical year.
d Includes 12 second-feet from Crow Creek.
e Elevation of gate sill in outlet conduit of Bumping Lake reservoir.
f Elevation of gate sill in outlet conduit of proposed McAllister Meadows reservoir.
g Approximate.

CONSTRUCTION FEATURES.

Section 1. Naches River between Naches Meadows and Bumping River.—A storage capacity of 11,500 acre-feet has been assumed feasible in the mass-diagram estimates. A dam approximately 1,000 feet long on top would impound the assumed capacity at an elevation of about 3,097 feet. A conduit to utilize the head indicated in the power summary would prove very expensive on account of inaccessibility of the area and difficulty of construction. A conduit on the right side of the valley would be somewhat longer than one on the left side, but could obtain an additional supply of water from Crow Creek, and it has therefore been assumed as more feasible.

Section 2. American River below Pleasant Valley.—The mass-diagram estimates indicate that a storage capacity of about 50,000 acre-feet in the Pleasant Valley reservoir site would be necessary to maintain a mean flow of 224 second-feet during a critical year, and that a capacity of about 38,000 acre-feet would be necessary to maintain a mean flow of 273 second-feet during a critical irrigation season. The dam would impound 50,000 acre-feet at an elevation of about 3,365 feet and 38,000 acre-feet at an elevation of about 3,355 feet.

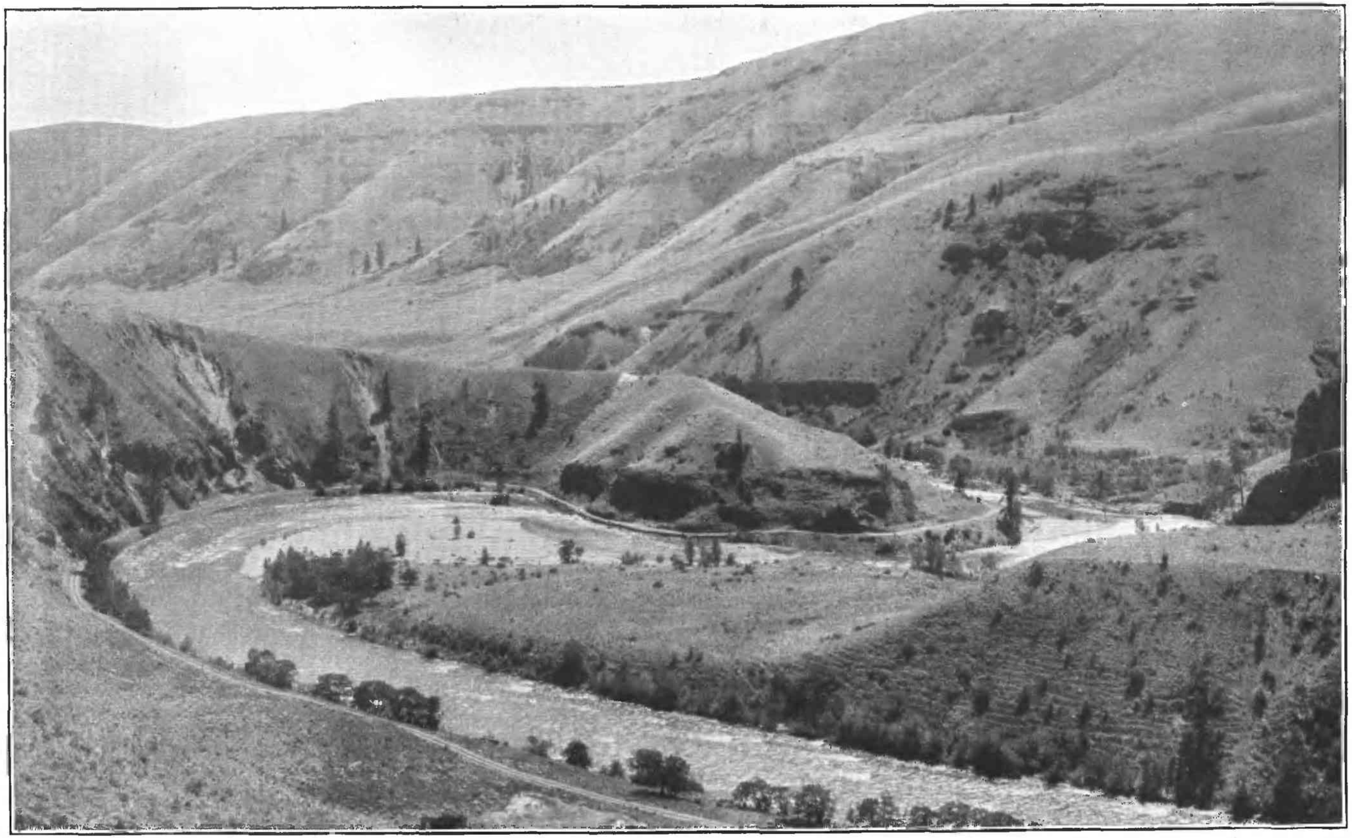
The Pleasant Valley reservoir site is probably more feasible than any other in the Yakima basin, exclusive of those contemplated in the Yakima project. The left side of the dam site is a lava and basalt wall which is very steep, and the right side is a long sloping hillside, fairly steep at the dam site. A roadway excavated along the right side discloses only soil and glacial bowlders and suggests that a suitable foundation may not be available. A dam 150 feet high would be approximately 1,100 feet long on top.

The slopes on the right side of the valley below the dam site are in general flatter than those on the left side, and there appears to be less columnar basalt on the right side. It is probable, therefore, that a conduit to utilize the head indicated in the power summary would be placed on the right side.

Section 3. Bumping River between Bumping Lake and a point opposite Old Scab Mountain.—The Bumping Lake reservoir constitutes one of the storage units of the Yakima project and is described fully elsewhere (p. 92).

A conduit to utilize the head indicated in the power summary would be longer if located on the left side of the valley than if located on the right side, but the supporting ground would be better on the left side. The construction of the lower end of the conduit would be difficult on account of shattered basalt slide rock.

Section 4. Bumping River between a point opposite Old Scab Mountain and American River.—The grade of Bumping River in this section is uniformly steep and there are few favorable dam sites, so that



NACHES RIVER AT HORSESHOE BEND.

diversion conduits will be required. Considerable tunneling through columnar basalt would be required for the conduits. The power indicated in the power summary for this section and for section 2 might be developed through separate units in the same power house.

Section 5. Bumping River below American River.—A conduit on the left side of the valley to utilize the head indicated in the power summary would offer few difficulties of construction in the upper half of the length required, but considerable tunneling would probably be necessary in the lower half.

Section 6. Naches River between Bumping River and elevation 2,265 feet.—The total head indicated in the power summary might be developed by means of several relatively low dams, but it is probable that a long diversion conduit would prove more feasible. Considerable tunneling through basalt would be required for permanency, and lined canals would prove advantageous to prevent excessive seepage losses.

Section 7. Naches River between elevation 2,265 feet and Rattlesnake Creek.—The power indicated in the summary could be developed by a dam 100 feet high and about 600 feet long on top at a favorable site 1.1 miles above Rock Creek and by a conduit on the left side of the valley. Both walls of the canyon at the dam site are composed of lava and basalt, so that considerable detailed investigation would be necessary to determine whether the foundations were suitable for intercepting the flow of the river.

Section 8. Naches River between Rattlesnake Creek and elevation 1,765 feet.—No favorable dam sites for gaining any considerable head exist in this section. Detailed surveys and estimates would be necessary to determine the most economical situation of a conduit for realizing the head indicated in the power summary.

Section 9. Naches River between elevation 1,765 feet and intake of Selah Valley canal.—Probably the best dam site on Naches River is at Horseshoe Bend (Pls. IV, *A*, and V), 3 miles above Tieton River. A dam 80 feet high at this point would be about 550 feet long. The sides of the canyon are columnar basalt, somewhat shattered on exposed surfaces, so that borings might indicate a lack of suitable foundations. Considerable pondage would be available for regulating diurnal fluctuation in load. A diversion conduit about 1½ miles long on the left side of the valley would be required to utilize the total head indicated in the summary.

Section 10. Naches River between the intakes of Selah Valley and Naches power canals.—The upper and lower limits of this section are determined by present hydraulic development which will probably be maintained permanently. The power indicated in the summary could be developed by enlarging Selah Valley canal and utilizing the water not required for irrigation in a power plant at the intake of the Naches power canal.

Section 11. Tieton River between dam site below McAllister Meadows and intake of Tieton canal.—Detailed surveys, plans, and estimates have been made by the United States Reclamation Service for a rock-fill dam 196 feet high and 950 feet long on top which will impound 183,000 acre-feet of water. The dam site is located below McAllister Meadows between Goose Egg Mountain on the right side of the valley and a steep slope on the left side. Dam sites for realizing any considerable head are lacking in the section, so that the total fall indicated in the power summary would be gained by diversion.

Section 12. Tieton River below Tieton canal.—The dam and concrete conduit built for diverting water to the Tieton unit of the Yakima project is described elsewhere (p. 138). If power development should prove feasible in this section, a large part of the fall indicated in the power summary could be realized by enlarging the Tieton unit conduit so that it would serve the interests of both irrigation and power.

Section 13. Naches River between intake and tailrace of Naches power plant.—The power in this section has been developed by the Pacific Power & Light Co. (pp. 96–97).

Section 14. Naches River between the tailrace of Naches power plant and the intake of the North Yakima power canal.—The power indicated in the summary could be developed by enlarging the intake and canal of the Naches Canal Co. and diverting water for both irrigation and power. This canal is longer than would be required along the escarpment south of Naches River, but the cost of construction and maintenance of a new conduit along this escarpment would probably be much greater than the cost of enlarging the canal of the Naches Canal Co.

Section 15. Naches River below the intake of the North Yakima power canal.—The power in this section has been developed by the Fruitvale power plant and the North Yakima Milling Co. (pp. 95, 99).

INDUSTRIAL DEVELOPMENT.

AGRICULTURE.

PRINCIPAL CROPS.

Yakima Valley is essentially an agricultural section. Stock raising is practiced on the open range, and cultivation ranges from the dry farming of large areas to the intensive cultivation of small irrigated tracts comprising 10 to 40 acres. The relative importance of intensive and diversified cultivation is, however, steadily increasing, and with the exception of some wheat raised by dry farming, all the agricultural products of the valley depend for successful yield on water from Yakima River and its tributaries.

The two leading agricultural crops of the region are forage and fruit. The census of 1910 showed for the three valley counties a total of 111,605 acres of hay land, about half of which was planted in alfalfa and about a third in timothy or in timothy and clover. Alfalfa is well adapted to the climate of the region except in some parts of the Kittitas Valley at a high elevation. The Yakima Indian Reservation is the main alfalfa district. A crop census of lands under the United States Indian Service ditches, made in June, 1912, showed 3 out of every 4 acres to be raising hay, and it is estimated that 90 per cent of this was alfalfa. A large amount of the cultivated land on the reservation is held on short-term leases, under which the holder lacks incentive to permanent improvements. This condition, together with the small amount of water available, has tended to keep the part of the reservation devoted to cultivation of hay much larger than it would be under more favorable circumstances.

Kittitas Valley is essentially a hay, dairy, and stock country, the principal hay crop here being timothy, although some alfalfa is raised.

The hay crop of the three counties in 1909 amounted to 340,000 tons, of which two-thirds was produced in Yakima County and nearly all the remainder in Kittitas County.

A large part of the forage is used in the valley for fattening stock and winter feeding of sheep. It is estimated that 150,000 sheep are owned in the Yakima basin, and although summer range is provided in the foothills of the Indian reservation and Rainier National Forest, winter feeding of alfalfa is necessary to supplement the bunch grass along the lower river. The census of 1910 credited the three valley counties with approximately 35,000 head of cattle. This figure includes the alfalfa-fed dairy stock.

The valley of the Yakima is most widely known as a fruit-growing and more particularly as an apple country. At the beginning of 1912 the orchards of the three Yakima counties comprised more than 60,000 acres, or over one-fourth of the orchard lands in the State.

The accompanying tables, compiled from the reports of the State commissioner of horticulture, indicate the growth of the fruit-growing industry in the last few years. The figures for 1906 must be regarded as approximate. They have been derived from the number of planted fruit trees, as given by the State report, allowing 55 apple trees to an acre and 106 trees of the other varieties to an acre. Three-fourths of the present orchards are planted in apples, although the acreage of peach and pear orchards is not insignificant.

Acreage of orchards in counties in Yakima Valley, 1906, 1909, and 1912.

	Benton County.[a]	Yakima County.	Kittitat County.	Total for three counties.
Apples:[b]				
1906	496	22,700	268	23,464
1909	1,622	27,938	898	30,458
1912	7,052	34,250	3,195	44,497
Pears:[c]				
1906	29	2,440	4	2,473
1909	296	5,719	60	6,075
1912	1,011	5,164	173	6,348
Peaches:[c]				
1906	440	380	1	820
1909	1,068	7,767	45	8,880
1912	1,719	6,369	26	8,114
Apricots:[c]				
1906	14	92	1	107
1909[d]				
1912[d]	88	210		298
Plums and prunes:[c]				
1906	6	200	3	209
1909	43	273	19	335
1912	136	423	23	582
Cherries:[c]				
1906	117	280	2	399
1909	481	2,398	53	2,932
1912	225	284	21	530
Total acreage:				
1906	1,102	26,092	279	27,472
1909	3,510	44,095	1,075	48,680
1912	10,231	46,700	3,438	60,369

[a] Benton County includes some orchards watered from Columbia River.
[b] These values have been computed from published figures of the number of trees, allowing 55 to an acre.
[c] These values have been computed from published figures of the number of trees, allowing 106 to an acre.
[d] The acreage is not available.

The Sunnyside Valley and the valleys centering about North Yakima, particularly the highly developed Nob Hill district immediately west of the city, constitute the principal fruit-raising sections. Commercial horticulture in the Kittitas Valley has not assumed large proportions. The greater number of the bearing orchards in that district are old and the fruits of noncommercial varieties. However, each year large hay ranches in Kittitas County are being divided into smaller tracts, to be planted for the most part in fruits. Even in Yakima County nearly two-thirds of the apple and over half the pear trees are not yet bearing. Only 2,900 acres of orchards had been planted in the Indian reservation up to 1912 on account of the system of leases in vogue there, although one of the largest nurseries in the section is located on the reservation.

Apples form the principal commercial fruit throughout the valley; peaches are raised chiefly in the lower parts of the Sunnyside district, centering around Prosser; and the lower altitude and early season has resulted in bringing the country around Kennewick and Richland into prominence in the production of berries and small fruit. Many orchards in this neighborhood are watered from Columbia River.

The production of fruit is increasing rapidly as the younger orchards come into bearing. The crop shipped in 1910 consisted of 3,000 carloads of apples and about 1,000 carloads of other fruit. In 1911 the production was small, but the shipments of the crop of 1912 had amounted to 7,000 carloads by the middle of November, and considerable fruit still remained in the hands of the growers. Estimates of the crop of 1912 place its total at about 5,000 cars of apples and half as many peaches, with several hundred carloads of miscellaneous fruit. In fact, the output of apples and peaches is increasing faster than the facilities for handling and marketing them would seem to warrant.

Of the various minor agricultural products, wheat, hops, and potatoes are probably among the most important. Hop raising is restricted almost entirely to the North Yakima and Sunnyside districts. Potatoes are more important in the Indian reservation and the Moxee Valley than elsewhere. Yakima County is estimated to have produced 3,000 carloads of potatoes and 23,050 bales of hops, weighing 180 pounds each, in 1912.

Wheat is generally raised by dry-farming methods, although some wheat and oats are raised on the partly irrigated areas in Kittitas County and the Indian reservation. Yakima County produced an average of 450,000 bushels of wheat a year during the decade from 1900 to 1909.

IRRIGATION BY GRAVITY SYSTEMS.

OWNERSHIP OF CANALS.

Many times the natural low-water flow of Yakima River and tributaries has been appropriated by filings for water rights. Indeed, at one time the water-appropriation filings in the valley called for sufficient water to supply the irrigation requirements of several States as large as Washington.[1] In 1912 the total acreage under canals leading from Yakima, Tieton, and Naches rivers is estimated at about 300,000 acres, of which not more than 225,000 is cultivated. In addition, about 40,000 acres receive a more or less uncertain supply from creeks and wells. The lands under these smaller tributaries receive a very deficient water supply, and after the 1st of July only a small part of the 40,000 acres receives any water. The scarcity of water resulting from overappropriation has led to much litigation and adjudication of water rights, and the water rights of the valley are in a condition of chaos, owing to the absence of a water code in the State of Washington, to conflicting claims of riparian owners and prior appropriators, and to the exorbitant filings made for many canals. The scarcity of water late in the summer has been very severely felt even on the main Yakima, and serious friction has been averted only by the mutual agreements entered into by the United States Reclamation Service and the private canal companies, limiting their rights to the natural low-water flow of the stream.

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[1] Waller, O. L., Report on irrigation conditions in Yakima Valley, Wash.: Washington State Agr. Coll. Bull. 61, pp. 19 et seq., 1904.

The greater number of the more important canal systems are cooperative enterprises, controlled by the water users under some form of organized cooperation, usually through a stock company. In many systems the ownership of the stock is appurtenant to the land, but this rule is not invariable. Similar to the cooperative projects, and not always readily distinguishable from them, are the enterprises controlled by individuals and informal partnerships of neighboring farmers. These are termed by the Bureau of the Census individual and private projects. A number of the projects are operated by commercial corporations, which supply water for a fixed charge to parties who own no interest in the distributing works. As a rule these companies have contracted to turn the operation of their systems over to associations of the water users after a term of years. This has been accomplished recently by the settlers supplied with water from Amon and Lower Yakima canals, which were formerly operated by the Benton Water Co.

Four of the largest canals in the basin are under the control of bureaus of the United States Government. Two of these are operated by the United States Indian Office for the irrigation of Yakima Indian lands and two are operated by the United States Reclamation Service under the reclamation act of 1902.

The acreage under irrigation in the three Yakima Valley counties and the character of ownership of canals was determined by the Bureau of the Census in 1910, and the results of the investigations are reproduced for comparison in the following table. A considerable part of the land under water in Benton County is supplied by pumping from Columbia River, especially by the pumping project at Hanford. No distinction is made by the Bureau of the Census between the well-watered land irrigated from the larger streams and areas receiving a more or less intermittent supply from the creeks and small tributaries. For this reason the values in the table are not strictly comparable with estimates made elsewhere in this report.

Acreage of irrigated lands in the Yakima Valley counties, April 15, 1910.

	Benton County.[a]		Yakima County.		Kittitas County.	
	Irrigated 1909.	Total in projects.[b]	Irrigated 1909.	Total in projects.[b]	Irrigated 1909.	Total in projects.[b]
United States Reclamation Service projects	5,777	10,955	46,223	122,141	....	....
United States Indian Service projects	....	....	35,000	100,000	....	....
Cooperative projects	152	312	37,436	54,055	29,730	31,140
Commercial projects	16,180	72,264	6,800	9,000	9,200	15,200
Individual and private projects	1,328	3,853	23,171	46,259	29,962	46,600
	23,437	87,384	148,630	331,455	68,892	92,940

[a] Acreage for Benton County includes considerable land watered from Columbia River.
[b] Includes acreage of all projects on which construction has been begun.

NOTE.—Benton Water Co. and Lower Yakima canals came under cooperative management after the irrigating season of 1911. Selah-Moxee canal came under commercial control at the same time.

PRESENT DEVELOPMENT.

GENERAL CONDITIONS.

In 1912, 23 canals, each of sufficient importance to constitute a separate project, were diverting water from Yakima, Naches, and Tieton rivers, in addition to the numerous small ditches used to irrigate areas ranging from 10 to several hundred acres. The following table shows the location and essential features of the principal canals of primary and secondary importance in the valley, but the absence of accurate data in regard to some of the canals casts considerable doubt on the value of the estimates:

Summary of principal irrigation canals in Yakima Valley.

Canal.	Diverts from—	Location of head gate.	Bank of river.	Date of construction.	Length of main canal.	Acreage.		Distribution of water.	Owner.
						Irrigated 1912.	Total in project.		
Irrigating Kittitas Valley.									
					Miles.				
Younger	Yakima River	Sec. 30, T. 20 N., R. 15 E.	Left			280			Individual.
Cascade	do	Sec. 28, T. 19 N., R. 17 E.	do	1903–4	43	a 11,000	a 15,000	Module	Cooperative.
West Kittitas	do	Sec. 33, T. 19 N., R. 17 E.	Right	1889	15	b 6,000	6,800	do	Do.
Ellensburg Water Co	do	Sec. 7, T. 18 N., R. 17 E.	Left	1887	30	b 10,000	10,000	do	Do.
Olson	do	Sec. 18, T. 18 N., R. 18 E.	do			b 960	1,200		Individual.
Bull	do	Sec. 11, T. 17 N., R. 18 E.	do	1885		1,460	1,460	Module	Cooperative.
Irrigating Selah and Moxee valleys.									
Selah-Moxee	Yakima River	Sec. 8, T. 14 N., R. 19 E.	Left	1900–1901	27	a 6,000	c 7,000	Module	Commercial.
Taylor	do	Sec. 19, T. 14 N., R. 19 E.	Right		4½	b 1,000	1,500		Individual.
Moxee d	do	Sec. 7, T. 13 N., R. 19 E.	Left		7	b 3,400	3,400	Weir	Commercial.
Fowler e	do	Sec. 18, T. 13 N., R. 19 E.	do	1884	31	b 5,000	5,000	do	Do.
Irrigating Reservation and Sunnyside.									
New Reservation	Yakima River	Sec. 17, T. 12 N., R. 19 E.	Right	1903		a 18,000	106,000	Cippoletti weir	Indian Service.
Old Reservation	do	Sec. 28, T. 12 N., R. 19 E.	do	1893	12½	a 14,000		do	Do.
Sunnyside	do	do	Left	1891–1893	61	a 61,500	102,000	do	Reclamation Service.
Gilbert	Wanita Slough		Right		7	b 4,500			Cooperative.
Piety Flat	Yakima River	Sec. 35, T. 12 N., R. 19 E.	Left						Individual.
Snipes & Allen	do	Sec. 17, T. 11 N., R. 20 E.	do						Do.
Diverting from lower Yakima River.									
Kiona	Yakima River	Sec. 10, T. 9 N., R. 26 E.	Left		9	b 2,400	f 3,000	Module	Commercial.
Kennewick	do	Sec. 3, T. 10 N., R. 27 E.	Right	g 1894, 1902	32	a 9,500	h 16,500	Cippoletti weir	Do.
Lower Yakima	do	do	Left	1904			i 17,000	do	Cooperative.
Benton Water Co. (Amon)	do		do	1905			3,000	do	Do.

Irrigating Naches Valley.

Selah Valley	Naches River	Sec. 35, T. 15 N., R. 16 E.	Left	1890	20	a 10,500		Module	Cooperative.
Wapatox j	do	Sec. 36, T. 15 N., R. 16 E.	do	1884	16	b 1,500	2,500	do	Do.
Clarke	do	Sec. 5, T. 14 N., R. 17 E.	do				340		Individual.
Upper Scott	do	Sec. 4, T. 14 N., R. 17 E.	Right			b 195	370		Do.
Lowery	do	Sec. 5, T. 14 N., R. 17 E.	Left			b 300	340		Do.
Kelly	do	do	do			b 340	400		Do.
Fortune	do	Sec. 9, T. 14 N., R. 17 E.	Right			b 210	300		Do.
Lower Scott	do	do	do			b 190	350		Do.
Basket Ford (Lasswell)	do	Sec. 14, T. 14 N., R. 17 E.	do			b 200	370		Do.
Naches Canal Co. (Gleed)	do	Sec. 24. T. 14 N., R. 17 E.	Left		10	b 1,800	2,000	Module	Cooperative.

Irrigating Atanum-Cowiche basin.

Tieton	Tieton River	Sec. 30, T. 14 N., R. 15 E.	Right	1907–1910	12	a 14,500	34,700	Cippoletti weir	Reclamation Service.
Yakima Valley (Congdon)	Naches River	Sec. 24, T. 14 N., R. 17 E.	do	1894	22	a 4,200	4,200	do	Cooperative.
Naches-Cowiche	do	Sec. 9, T. 13 N., R. 18 E.	do	1881	7	b 2,000	2,000	Module	Do.
Fruitvale, Schanno k	Power Canal l			1873–74		b 500	500	do	Do.
R. S. & C. k	do l			1873–74		b 500			Do.
New Schanno k	do l			1873–74	8	b 1,050	1,500	Module	Do.
Broadgage	do l			1885	3	b 800	800		Do.
Union Canal Co. m	Naches River	Sec. 11, T. 13 N., R. 18 E.	Right	1868	8½	b 3,700	3,750	Module	Do.
North Yakima Town	do	Sec. 12, T. 13 N., R. 18 E.	do						City of North Yakima.

a Estimate of acreage furnished by operating parties.
b Estimate of acreage, approximate; not based on surveys.
c Includes 1,700 acres under pumps.
d Includes the Moxee and Hubbard canals.
e Includes the Union Gap Irrigation Co. canal, constructed in 1906, and watering 3,500 acres above the Sunnyside canal.
f Includes 1,200 acres under pumps.
g Kennewick Canal was rebuilt throughout in 1902.
h Includes 2,500 acres under pumps.
i Includes 3,000 acres under Amon canal.
j Wapatox canal or Naches Power canal is also used to develop power.
k This canal is a part of the old Schanno canal.
l Old river headgate has been abandoned.
m Company owns the Old Union canal diverting from Naches River and Naches Avenue Union canal diverting from North Yakima power canal.

The development of irrigation in Yakima Valley prior to 1906 has been discussed in detail by Jayne[1] and Waller.[2] Therefore it has been deemed best to describe in this report only those projects which have been constructed since that date or which have been materially altered.

Very little construction work on new projects has been undertaken outside of that accomplished by the United States Reclamation Service. The only private project of importance completed since 1906 is the Lower Yakima canal, and this project is really an enlargement of the old Grosscup ditch heading at Horn Rapids. The diversion capacity was increased and a concrete lining was provided later to prevent seepage losses.

The information contained in the following paragraphs is given to supplement the descriptive matter embodied in the reports mentioned above.

SUNNYSIDE CANAL.

Sunnyside canal is the largest operating in the Yakima Valley, and some of the larger laterals compare in size and length with the largest of the private projects. The head gate is located in sec. 28, T. 12 N., R. 19 E., a short distance below Union Gap, and the canal roughly parallels the Yakima for a distance of 61 miles, supplying water to hundreds of laterals, the largest being the Snipes Mountain, Rocky Ford, Turner, Mabton siphon, and Prosser siphon. The United States Reclamation Service purchased the system in 1906 from the Washington Irrigation Co., which had 57 miles of main canal and 75 miles of laterals in operation.

At the head works the river flows close to bedrock, affording an excellent foundation for diversion dam and head gates. The original dam as constructed by the private company consisted of a series of steel-hinged brackets bedded in a concrete foundation. These were spaced 6 feet apart over the width of the river (360 feet) and were raised into place by chains during low water and flashboards were inserted. When in place, the dam extended 6 feet above the foundation. The difficulty and danger experienced in raising and lowering the brackets led the Reclamation Service to construct a concrete diversion dam. The new structure is an overflow weir of ogee type 8.5 feet high and 500 feet long between bulkheads. It is carried down to bedrock except for a short distance near one shore, where an indurated greenish clay furnishes a water-tight foundation. New concrete head works were also constructed and six 6-foot by 6-foot hand-operated cast-iron gates installed. Flashboard grooves have

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1 Jayne, S. O., Irrigation in the Yakima Valley, Wash.: U. S. Dept. Agr. Bull. 188, 1907.

2 Waller, O. L., Irrigation in the State of Washington: U. S. Dept. Agr. Bull. 214, 1909; Report on irrigation conditions in the Yakima Valley, Wash.: Washington State Agr. Coll. Bull. 61, 1904.

been provided, so that any gate may be cut off for repairs, and a set of wooden Tainter gates has been provided for emergencies.

Owing to a number of high laterals, it is often necessary to keep a much greater head of water in the first few miles of the canal than is required for irrigating purposes. This and the need of regulation for safe operation led to the construction of the Zillah wasteway—a concrete structure controlled by four 4-foot by 5-foot cast-iron gates and located at mile 17, at a point where the canal approaches within 2,200 feet of the river. The wasteway conduit for the upper 800 feet consists of a concrete trapezoidal section gradually decreasing in bottom width and increasing in gradient as it approaches the river. Operation has also made necessary a second regulating waste at Sulphur Creek crossing, near mile 37. The canal is 8 miles from the river at this point, and the need of a main drainage channel in the intervening territory had been felt long before Sulphur Creek was enlarged and deepened to a channel capacity of 515 second-feet. This channel serves not only as a regulating wasteway but also as a main drain to about 10,000 acres of swamped land. The first mile of the wasteway was lined with concrete to accommodate the high velocities, and 21 concrete drops were constructed between the Sunnyside canal and the main river.

The gradient of the upper 45 miles of canal is 1.25 feet per 5,000 feet. This has resulted in a velocity so great that a number of checks have been introduced to reduce the velocity to a safe limit. The old wooden checks built by the Washington Irrigation Co. have been replaced by structures of concrete and steel. The water is raised by flashboards fitting into channel beams slightly inclined from the vertical. These are made in five panels, each with a clear opening of 6 feet. The flashboards consist of 3-inch to 6-inch material, 6 feet 6 inches long, and are provided with iron loops, by means of which they can be withdrawn with a grapple.

Two main laterals of the Sunnyside system cross Yakima River by means of inverted siphons and irrigate lands on the south side of the valley.

The Mabton siphon diverts from the main canal at mile 50, passes through 1.5 miles of open canal and 3 miles of pressure pipe under a maximum head of about 170 feet, discharging into a small reservoir formed by damming a natural gully, and thence into the main lateral, which is 8 miles long and serves 9,000 acres. The pressure pipe consists of 3,100 feet of 54-inch concrete pipe 3.5 inches thick and reinforced by $\frac{5}{16}$-inch wire, 1,500 feet of 48-inch wood-stave pipe, and 11,100 feet of 55-inch wood-stave pipe. There is an 18-inch blow-off valve at the river crossing.

The Prosser siphon has a capacity of 26.6 second-feet and irrigates 2,181 acres on the south bank, of which 1,188 acres had partial water rights and were supplied formerly by the Prosser Falls Land & Power Co. pumping system. This lateral leaves the canal at mile 55 and crosses the river through 3,100 feet of 30.5-inch reinforced concrete pipe under a maximum head of 45 feet and 7,500 feet of 31-inch banded wood-stave pipe under 100 feet maximum head. The pipe is carried over the river by a 4-span steel truss 500 feet long.

The Sunnyside unit will include an aggregate of 102,000 acres. Water is distributed to the laterals and to the individual water users for the most part over Cippoletti weirs. Weir crests of galvanized iron, bent and soldered into shape and set into a weir board, were formerly used. Owing to velocity of approach and slight rounding in the weir crests causing incomplete contraction, they delivered more water than is indicated by formulas and have nearly all been replaced by sharp-crested steel weirs. Between the head gate and Zillah a number of laterals are provided with miner's inch modules. These consist of an orifice 2 inches high and provided with a slide by which its length may be varied. A long spillway leads from the canal to the module and purports to keep a head of 6 inches over the top of the orifice. This method of distribution, though crude, is required by contract with the water users under the old Kennewick ditch.

TIETON CANAL.

The Tieton canal (Pl. III, *A*), constructed by the United States Reclamation Service and serving 35,000 acres, mostly in Cowiche Valley and Wide Hollow, first delivered water during the season of 1910. It heads in the right bank of Tieton River in sec. 30, T. 14 N., R. 15 E. The entire low-water flow of Tieton River has been fully appropriated for some time, so that the amount of water diverted from the river in the Tieton canal is replaced by water released from storage in Bumping Lake reservoir on the headwaters of the Naches, pending the construction of a storage dam at McAllister Meadows at the forks of Tieton River.

The diversion dam is a spillway or rollway 3 feet high and 110 feet long. It is protected upstream by sheeting reaching down to impervious strata and backed by puddling. On the downstream side timber cribbing and sheeting extending down to the impervious strata, together with a filling of large bowlders, protect against back cutting. The head-gate structure is of reinforced concrete. There are three 4-foot by 5-foot gate openings controlled by cast-iron hand-operated sluice gates. Flashboard grooves are provided both above and below the gates so that one gate may be cut out of service and repaired without interfering with the others.

The canal follows the right side of Tieton Canyon for 12 miles, passes through a tunnel 3,810 feet long, and enters the valley of

Cowiche Creek. The Naches branch heads a short distance below the tunnel and diverts water to about 10,000 acres on the plateau between North Fork of Cowiche Creek and the Naches Canyon. The other two main laterals, about equal in size to the Naches branch, are the Cowiche-Yakima branch, watering the Cowiche Valley and the ridges south of Cowiche Creek, and the Wide Hollow branch, watering the south portion of the project from Cowiche Mountain to Atanum Creek.

The canal (Pl. III, *A*) consists of an open, reinforced concrete flume a little more than 8 feet in diameter. It is laid on a slope of 0.00165, and is designed to carry 5 feet 3 inches of water or about 300 second-feet. The flume is built in 24-inch sections which are 4 inches thick. Each section is reinforced longitudinally by nine quarter-inch square rods and circumferentially by six $\frac{3}{8}$-inch square rods, and is made rigid by reinforced concrete crossbars with a cross-sectional area of 4 by 4 inches, placed in the center of each section.

There are five tunnels above the Cowiche Valley with a total length of 10,960 feet. These were driven on tangents, with headings 7 feet 3 inches in diameter and lined with concrete to form a circular section 6 feet in diameter on a slope of 0.0045.

The canals are regulated by means of five automatic wasteways, located at 2-mile intervals along the canyon and controlled by floats connected with the operating mechanism by electric circuits.

The distribution of water on the project is greatly complicated by the uneven topography of the country. Concrete and wood-stave pressure pipes are numerous, and their use has prevented undue seepage losses and made possible service on many steep hillsides. A number of drops have been found necessary. They consist of open rock-paved channels in the larger laterals and cement pipes in the smaller conduits. Sublaterals are supplied from main laterals by means of turnouts built of cement pipe barrels with timber headwalls and gate. All turnouts are provided with weirs and water is delivered to each 40-acre tract through a measuring box consisting of a gate, baffle board, and Cippoletti weir, together with the necessary framing and bracing. The weir crests on this project are of sheet iron and designed to measure not over 2 second-feet.

The unit as a whole consists of 12 miles of main canal and 51 miles of main laterals.

SELAH VALLEY CANAL.

The Selah Valley canal, a cooperative project, owned by the Selah Development Co., heads in the left bank of Naches River in sec. 35, T. 15 N., R. 16 E., about a mile above the mouth of Tieton River. It follows the Naches Valley for several miles, watering considerable bench land on the way, and crosses the divide between Naches and

Yakima rivers to supply the bench lands of Selah Valley. The main canal is 19 miles long and at the lower end is divided into three main laterals, 3, 5, and 8 miles long. About 10,500 acres was irrigated in 1912, most of which was planted in fruit. The canal has no permanent headworks in the river and is therefore dependent upon a temporary wing dam, renewed yearly, to insure a low-water supply. Regulation is provided by the Stump wasteway, 1.5 miles below the head gate and the Naches City wasteway, several miles below.

Practically all the 19 miles of main canal is side-hill construction, much of which is in very porous material, so that seepage and evaporation losses have been extremely high. Only 66 second-feet of water is required to be delivered to the water users, but the agreed diversion is 105 second-feet, and this amount is frequently exceeded. During the last few years the company has taken measures to reduce the losses and also to replace some of the old wooden flumes with more permanent structures. Sixteen hundred linear feet of concrete lining was laid in 1911 to eliminate the high seepage losses in the first mile of the canal; 3,000 feet additional was laid in 1912; and 1,582 feet of steel flumes was built to replace long and leaky meanders caused by detours around gullies crossing the line of the canal. Creosoted wood was used to replace much of the older flume.

Two Lietz automatic gages have been installed, and the canal superintendent is supplied with a current meter for the purpose of making possible a more intelligent and satisfactory distribution of the water. The contract duty is 1 second-foot per 160 acres, but, unfortunately, the company still adheres to the old method of distribution through an orifice under pressure.

YAKIMA VALLEY OR CONGDON CANAL.

The Congdon canal supplies water for 4,200 acres on Nob Hill and Wide Hollow, just west of North Yakima, practically all of which is bearing fruit and is rated as the most valuable land in the Yakima Valley.

The canal heads in the right bank of Naches River in sec. 24, T. 14 N., R. 17 E., and the upper 6 miles of the conduit is located along a steep, rocky hillside which requires flumes. The canyon of Cowiche Creek is crossed by means of two inverted siphons under a maximum head of 90 feet. These are wood-stave pipes 32 inches in diameter, 900 feet long, and banded with half-inch rods.

In the last few years the canal has been enlarged and the wooden flume between the intake and Nob Hill has been replaced by concrete. Lining of the canal was started during the winter of 1910–11. Plain concrete lining with very little reinforcement and practically no definite design was used. A large part was lined only on the bottom and downhill side, the uphill side being left in rock. The results were not very satisfactory, for the lining cracked and heaved with the frost, so that it went to pieces in a short time. In the winter of 1911–12, 11,000 feet of monolithic reinforced concrete flume was laid above Cowiche Creek siphon. The section was 5 feet 9 inches wide and designed to carry 2.5 feet of water. Walls 4 inches thick were used, and the canal was built as a flume, both in cut and fill, no reliance being placed in the supporting qualities of the surrounding earth. The method has proved very satisfactory, since the flume not only withstands changes of temperature without checking, but also holds up well under rock and landslides. Another section of the canal was lined with 4 inches of reinforced concrete during the same winter.

The replacement of the old wooden flumes by monolithic concrete structures has been continued, and practically all wooden flumes from the intake to a point below Cowiche Creek siphon have been reconstructed. Several trestles, ranging in length from 20 to 200 feet, have been necessary, and at such places the reinforcement in the flume was strengthened to avoid the use of girders.

Water rights under the Yakima Valley canal call for the delivery of 0.000238 ($\frac{1}{4200}$) of the flow of the canal to each holder of one share. In practice, it is stated that an attempt is made to furnish one second-foot to approximately 107 acres, which amounts to a considerable increase over the amount of water supplied to the irrigators before the permanent construction outlined above was provided. Many of the water users find this amount much more than sufficient for the requirements of irrigation, although there is frequently a shortage of water near the lower end of the canal.

Water is distributed to the laterals over Cippoletti weirs and distribution is made to the water users through concrete and wood-stave pipes leading to the measuring boxes. Cippoletti weirs are in general used in measuring to the individual irrigator, and the system of distribution is far superior to the average in the valley. However, there is a lack of uniformity in the construction of the weirs. Many of them have rounded crests so that the measured volume is in excess of the theoretical discharge. In some laterals on Nob Hill containing several rights the water is fed into the bottom of a concrete basin or fountain and spilled out to the various users over Cippoletti weirs with lengths proportional to the number of shares owned by each. In a few laterals caps were fixed to the hydrants and rated to deliver to each water user a proper share of water when all hydrants were running. This system has been abandoned as unsatisfactory.

It is worthy of note that the Yakima Valley Canal Co. is the only cooperative organization in the valley which has adopted a system of measuring water over weirs in preference to distribution through an orifice.

OTHER IMPROVEMENTS.

Private enterprise has recently been directed chiefly to replacing temporary structures with those of a more permanent character and to the reduction of losses from seepage and evaporation.

The Schanno and Broadgage canals, which formerly carried water in separate, open channels, have been consolidated, and reinforced concrete pipe has been provided to carry the water along the west side of the city of North Yakima in order to eliminate seepage and consequent flooding of cellars in the city.

A concrete lining has been found to be necessary to reduce the enormous losses in the Lower Yakima canal.

Wooden flumes on the Selah-Moxee are being replaced by steel with the intention of saving seepage water and pumping it to lands above the canal. The Cascade Canal Co. is contemplating replacing a part, at least, of the many miles of unstable flume by tunneling, in order to save thousands of dollars expended yearly for repairs. These operations indicate the present trend of private construction toward permanence, economy, and the improvement of existing works.

Efforts have also been made to increase the supply of some of the smaller tributaries. Plans to divert water from Diamond Fork of the Klickitat into the Toppenish basin have been abandoned, and attempts to store water at Pleasant Valley on East Selah Creek have not yet proven successful. Certain water users on Manastash Creek have developed a few hundred acre-feet of storage, affording water for a late irrigation, and extensive works are being started on Atanum and Wenas creeks.

DRAINAGE.

The custom of using excessive quantities of water on the land has resulted in water-logging the soil of low-lying areas and thereby permitting the alkali to be precipitated on the surface in many parts of the valley. Thousands of acres have been rendered unfit for cultivation and in some places extensive drainage works have been necessary.

In the Yakima Indian Reservation a combination of causes led to swamping and bringing the alkali to the surface on about 30,000 acres of land along lower Toppenish Creek. Among these causes is the high loss due to seepage in the reservation canals and to a somewhat wasteful use of water during the spring months. The swamping has also been materially augmented by the large underflow through the gravel underlying the Wapato Valley. The United States Indian Service has constructed a system of drainage canals 40 miles long to drain this land. The system extends throughout the area lying south and west of Toppenish, much of which has been rendered nonproducing, and empties into Yakima River opposite Granger.

In other parts of the valley similar works have been necessary. The method of irrigation practiced on the Sunnyside canal for a period of 15 years resulted in raising the ground-water level 25 feet, so that a large area of the lower lands was water-logged. Sulphur Creek wasteway was deepened and improved by the United States Reclamation Service to serve as a drain for 10,000 acres of this land. There are 15 drainage districts in Yakima County which are capable of providing drainage facilities for an aggregate of about 25,000 acres.

Only a few years of irrigation by the Lower Yakima and Kennewick canals were necessary to flood much valuable land. The Richland district, comprising 8,000 acres lying under the Lower Yakima canal, and the Finley district, comprising 6,000 acres lying under the Kennewick canal, are the largest districts formed to remedy this condition.

Drainage systems are necessary wherever irrigation has been practiced on the bottom lands for a number of years. At least 10 per cent of the land under the Ellensburg Water Co. canal is affected by alkali. The lowlands of the Moxee Valley have required extensive works to prevent damage by too much water, and in all of the valleys it will be necessary eventually to provide means for aiding natural drainage. The only bottom lands that appear to have efficient natural drainage are those along the Naches. The fact that drainage systems are almost as essential to an efficient irrigation project as the diversion works is beginning to be realized and it is thought that future plans for projects will include adequate provision for maintaining a low ground-water level.

METHODS OF DISTRIBUTING WATER.

It was stated in 1907 that there was not a canal in the entire Yakima basin able to make an adequate approach to equitable division and distribution to the water user.[1] Though the conditions to-day are not nearly so serious, they are by no means satisfactory. The more progressive canal companies, following the lead of the Reclamation Service, measure the water to the consumer over Cippoletti weirs. This method, properly handled, would be reasonably accurate, but improper installation, resulting in a velocity of approach, incomplete contraction due to the slight rounding of the weir crests, and in some places submergence of weir crests, subjects the results obtained to great inaccuracies.

The usual method—that of measuring water to the user by the so-called miner's inch—consists of allowing the water to flow from an orifice under pressure. This method is not only crude and inaccurate, but frequently no provision is made to eliminate velocity of approach and no attempt to maintain the head on the orifice stipu-

[1] Jayne, S. O., Irrigation in the Yakima Valley: U. S. Dept. Agr. Bull. 188, p. 42, 1907.

lated in the contract. These devices, according to Jayne, "serve merely as rough guides for the ditch tenders, helping them to compare the discharges of individual deliveries from day to day, and also help the consumer to imagine he is getting his just portion of water." In many canals the water users are entitled, not to a definite specified flow, but to a certain proportion of the total flow of the canal, thus introducing another difficulty in distribution, especially during periods of low water. In the Moxee Valley very crudely constructed rectangular weirs have been used.

The growing necessity for more economical usage of water has led to a tendency to place the operation of the larger canals in charge of a competent engineer, and is resulting in better distribution to the consumer and in the introduction of more scientific methods of measurement. In many places, however, the engineers have been greatly hampered in attempted improvements by the strong prejudice of the water users against the Cippoletti weir, in favor of the orifice under pressure. The owners of at least one canal (the Selah Moxee) are contemplating replacing the old measuring boxes by special meters.

HYDROMETRIC WORK.

Hydrometric work on the canals of the Yakima Valley was begun by the United States Department of Agriculture in 1903. In the following year an estimate of discharge on all the leading canals was obtained by engineers of the United States Geological Survey. The work was continued in 1905, although no estimates of discharge were published. This work was discontinued during 1906–1908, except that estimates were obtained on Sunnyside, Old Reservation, and New Reservation canals for those years, and in 1908 on the Kiona canal. During the season of 1909 the records on all important diversion ditches were resumed by the United States Reclamation Service and they were continued during 1910 and 1911 by the United States Geological Survey. The United States Reclamation Service again assumed charge of the work in 1912.

The period of maximum requirement and the period of low supply both occur during the summer months. The river system supplies more than sufficient water for all existing canals prior to July 1 in normal years. Hence the critical period for meeting the demands of irrigation occurs during July, August, and September. The summary of hydrometric results which is inserted below has been prepared to indicate the mean diversion for the month during which the maximum amount of water was diverted throughout the valley. The limiting agreements entered into between the United States Reclamation Service and private canal companies in 1906 have also been included for purpose of comparison. The maximum mean diversions as shown in the summary are listed for the part of the irrigation season subsequent to July 1. Some of the canal systems have inadequate water rights, and under such circumstances the maximum diversion is practiced prior to July 1.

The data tabulated may be supplemented by more detailed information contained in the publications listed below.

1903. Washington State Agr. College Bull. 61, pp. 3–6; U. S. Dept. Agr. Bull. 188, pp. 19–20.
1904. U. S. Geol. Survey Water-Supply Paper 135, pp. 107–169.
1905. U. S. Geol. Survey Water-Supply Paper 178, pp. 52–78.
1906. U. S. Geol. Survey Water-Supply Paper 214, pp. 67–70.
1907–8. U. S. Geol. Survey Water-Supply Paper 252, pp. 192–204.
1909. U. S. Geol. Survey Water-Supply Paper 272, pp. 231–248.
1910. U. S. Geol. Survey Water-Supply Paper 292, pp. 229–286.
1911. U. S. Geol. Survey Water-Supply Paper 312, pp. 262–263.

Summary of mean diversions, in second-feet, by irrigating canals in Yakima basin for maximum month during the low-water period, July to September, 1903–4, 1909–1911.

Irrigating Kittitas Valley.

Name.	Agreed diversion.[a]	1903	1904	1909	1910	1911
Cascade canal	97.3	0	0	88	86	85
West Kittitas canal	80	46	55	96	109	98
Ellensburg Water Co. canal	125	140	127	125	135	114
Olson canal	24	....	....	25	[b] 96	29
Bull canal	....	....	....	38	....	....

Irrigating Selah and Moxee valleys.

Name.	Agreed diversion.[a]	1903	1904	1909	1910	1911
Selah-Moxee canal	78	55	78	69	72	70
Taylor canal	23	7	....	25	18	....
Moxee Co.[c]	38	38	[b] 73	35	32	33
Fowler canal [d]	51	22	33	38	52	66

Irrigating Reservation and Sunnyside.

Name.	Agreed diversion.[a]	1903	1904	1909	1910	1911
New Reservation canal [e]	[e] 147	0	86	288	277	353
Old Reservation canal	....	135	164	210	150	184
Sunnyside canal	[e] 650	685	610	685	719	834
Gilbert canal	....	55	48	....	....	....

Diverting from lower Yakima River.

Name.	Agreed diversion.[a]	1903	1904	1909	1910	1911
Kiona canal	[f] 23	8	21	27	25	28
Kennewick canal	[f] 175	42	126	....	203	189
Lower Yakima canal	....	0	0	....	140	118

[a] Maximum diversion as defined by mutual limiting agreements between the canal companies and United States Reclamation Service.
[b] A large part of this water was returned to the river.
[c] The Moxee Co. owns the Moxee and Hubbard canals.
[d] The Fowler canal includes the Union Gap Irrigation Co. canal.
[e] Values do not include rights to stored water.
[f] Agreement made in 1912.

Summary of mean diversions, in second-feet, by irrigating canals in Yakima basin for maximum month during the low-water period, July to September, 1903–4, 1909–1911—Continued.

Irrigating Naches Valley.

Name.	Agreed diversion.	1903	1904	1909	1910	1911
Selah Valley canal	105	65	87	107	123	133
Wapatox Canal Co.[a]	50	37	37	60	67	52
Upper Scott canal	6	....	....	14	14	12
Fortune canal	....	....	....	20	17	18
Lower Scott canal	4	....	....	....	11	20
Naches Canal Co. (Gleed)	67.25	54	69	62	61	66

Irrigating Atanum-Cowiche basin.

Name.	Agreed diversion.	1903	1904	1909	1910	1911
Tieton canal	[b] 0	0	0	0	41	125
Yakima Valley (Congdon) canal	62.5	64	78	52	54	49
Naches-Cowiche canal	40	39	54	32	38	31
Fruitvale Schanno canal	10	....	....	20	17	17
R. S. & C. canal	12	....	....	8	10	9
New Schanno canal	15	22	30	21	35	26
Broadgage canal	9.12	....	16	10	11	....
Union Canal Co.[c]	65	....	37	57	75	64
North Yakima Town canal	2	....	14	12	8	9

[a] Values do not include diversion for power.
[b] This does not include rights to stored and flood waters.
[c] Values include combined diversion of Old Union and Naches Avenue Union canals.

PROSPECTIVE DEVELOPMENT.

GENERAL CONDITIONS.

The extension of irrigation under gravity systems will require the storage of flood waters and the construction of long and comparatively expensive distribution systems to reach the better land. The United States Reclamation Service has completed two storage reservoirs with an aggregate capacity of 244,000 acre-feet, and another reservoir with a capacity of 152,000 acre-feet is under construction (p. 91). The total capacity of the five approved reservoir sites contemplated in the Yakima project is 1,069,000 acre-feet. The stored water may be sold to private or cooperative canal systems under perpetual contracts or it may be utilized by the Reclamation Service for supplying water to its own projects. The additional water supply gained by storage will be sufficient to irrigate approximately 350,000 acres of land which is not already provided with water, and will bring the total acreage irrigated by the Yakima and Naches rivers to about 650,000 acres. Eventually the acreage may be further increased by constructing minor storage units, the development of which is not to be expected in the immediate future. It is also probable that a more economical usage of water will make possible a large increase in acreage in the ultimate development of irrigation.

The construction of future irrigation systems will require organizations of considerable financial strength because of the high initial cost of bringing water to the irrigable lands not now provided with water. All the largest possibilities have been investigated in more or less detail by the United States Reclamation Service and have been included in their general plans for the development of the entire valley. The more favorable scheme of the proposed gravity developments in the valley are outlined in the following table:

Summary of proposed gravity irrigation developments in Yakima Valley.

Name of development.	Ownership.	Acreage.	Duty of water (gross acre-feet).	Source of water.	Point of diversion.	Requirement per annum (acre-feet).	Maximum diversion (second feet).
Kittitas Reclamation district.	Irrigation district.	[a] 93,000	3.00	Storage from Reclamation Service reservoirs.	S. 11, T. 20 N., R. 13 E.	246,000	871
Yakima high line..	Commercial.	100,000	3.75	.....do................	S. 28, T. 15 N., R. 19 E.	375,000	1,137
Wapato project	Indian Service.	[b] 120,000	4.29	.....do................	S. 17, T. 12 N., R. 19 E.	515,000	1,479
Benton project	Commercial.	90,000	4.29	.....do................	....	386,000	1,106
Yakima Highlands.	.....do......	7,500	......	Storage in Wenas Creek.	T. 15 N., R. 17 E.	....	......
Atanum project	Irrigation district.	[c] 11,000	......	Atanum Creek and shallow wells.	T. 12 N., R. 16 E.	....	90
Satus project.......	Indian Service.	[d] 36,000	......	Storage in Satus Creek.	....	....	......

[a] 18,000 acres partly irrigated at present.
[b] 36,000 acres partly irrigated at present; to be irrigated, 14,000 acres, by pumping.
[c] Partly irrigated.
[d] About 1,000 acres now irrigated.

A brief description of the essential features of the prospective developments is given in the following paragraphs:

KITTITAS RECLAMATION DISTRICT.

In September, 1911, the landowners in the proposed Kittitas unit of the United States Reclamation Service organized an irrigation district in accordance with State laws. Later it was voted to bond the lands included in the district to the extent of $5,000,000 for the construction of canals to irrigate land above the present systems in the Kittitas Valley. About 20,000 acres included in the project are now cultivated and partly irrigated from Manastash, Taneum, Naneum, and other smaller creeks. The waters of these streams will be wholly available for irrigating land lying above the canal when the development is completed.

The canal planned will head in the right side of Yakima River, 1 mile below the mouth of Kachess River, and will roughly parallel the river for 26 miles, supplying water to 13,000 acres en route. Near Dudley the canal will divide into two branches. The south branch will be 14 miles long and will water 18,000 acres above the West Kittitas canal, most of which is now partly irrigated from Manastash and Taneum creeks. The north branch, which will be 50 miles long, will cross Yakima River through an inverted siphon and irrigate 62,000 acres above the Cascade canal. A part of this acreage is now very inadequately supplied from several small creeks. The project includes a total of 93,000 acres, about 82,000 of which is irrigable.

A concrete gravity section diversion dam, about 50 feet high and 150 feet long, is proposed. The main canal leading from the dam will be the longest diversion conduit in the valley. Construction of the canal will involve 100,000 cubic yards of concrete and 3,500,000 cubic yards of excavation. Concrete lining will be required for a total length of 10 miles, and 5 miles more will consist of reinforced concrete flumes 14 feet wide and 10 feet high. There will be 16,000 linear feet of siphon and 1,200 linear feet of tunnel. The wooden flumes planned for some of the smaller stream crossings will be temporary structures which will eventually be replaced by concrete.

The most important engineering feature of the project will be the North Fork siphon across the river near Dudley. The plans call for a steel pipe, 8 feet in diameter and over a mile long, which will operate under a maximum head of 320 feet. The lowest part of the siphon across the river and the Northern Pacific Railway will be carried on a steel truss bridge of three spans, each of which will be 192 feet long.

A diversion duty of 3 acre-feet per acre at the intake has been planned and the designs are based on an allowance of 30 per cent of this amount for seepage losses. A possible extension of this development by pumping water for 20,000 acres is described elsewhere (p. 157).

WAPATO PROJECT.

Work on the Wapato project, which includes 106,000 acres of Yakima Indian lands to be watered by gravity and 14,000 acres to be supplied by pumping, may be said to have begun in 1903, when the New Reservation canal was built. It involves the construction of a concrete diversion dam 8 feet high and 500 feet long, a short distance below Union Gap; the extension of the New Reservation canal, and the delivery of stored water by the United States Reclamation Service. The system will require 65 miles of main canals and laterals and 200 miles of sublaterals. The lands irrigated in a somewhat wasteful manner by the Old Reservation canal, Gilbert and Hatch canals, and smaller diversions, will be included in the new project. Reference has been made elsewhere (p. 142) to the construction of 40 miles of drainage canals to drain 30,000 acres of swamped and alkalied lands in the southern part of the area to be served. The loose, gravelly subsoil has also given rise to considerable loss of water by seepage. Hence, the questions of seepage and drainage are of the utmost importance and will require careful plans to provide an economical system. The development as planned includes possible power developments and pumping plants which are discussed on page 156.

The Indian Service canals supply water to 32,000 acres of land, and 15,000 acres additional are irrigated from private ditches, from sloughs, and by subirrigation. None of this land receives sufficient water near the end of the irrigation season.

BENTON AND YAKIMA HIGH-LINE PROJECTS.

The Benton and Yakima high-line projects have never been carefully considered. Preliminary investigations have been made by the Reclamation Service, but it is probable that the enterprises will not be undertaken by that bureau. The information available seems to indicate that the most feasible manner of irrigating the lands affected would be to divert the water from the left side of Yakima River near Roza and to conduct it along the Yakima Canyon as far as Pomona Gap just above Selah Valley. It will serve only a small area north of the Rattlesnake Hills.

Two plans have been brought forth to water the Benton unit. One involves diversion from the left bank of the Yakima near Prosser and, in fact, the completion of the old Ledbetter canal. The other provides for an extension of the Yakima high-line canal, developing power for pumping at drops en route. Either plan will require an inverted siphon over the river below Kiona to reach 25,000 acres of irrigable land lying above the Kennewick canal. A part of the land originally included in the Benton unit has already been brought under water by pumping systems at Hanford and White Bluffs on Columbia River.

YAKIMA HIGHLANDS PROJECT.

The Yakima Highlands project involves the construction of storage reservoirs of 15,000 acre-feet capacity on Wenas Creek and the conservation of the flood flow. Wenas Creek was one of the first tributaries to be used for irrigation and the low-water flow has been over-appropriated to such an extent that considerable litigation has resulted. During the later part of the irrigation season only about one-eighth of the irrigated land receives water. Attempts have been made by some ranchers to augment the water supply by diverting the upper headwaters of Gold and Rock creeks in the Naches basin around Bald Mountain into the North Fork of Wenas Creek.

The Yakima Highland Irrigation & Land Co. has acquired many of the water rights on the creek and has obtained a release from the United States Reclamation Service of all claim to the flood waters of the stream. The immediate plans include, in addition to a storage reservoir of 13,000 acre-feet, the construction of 12 miles of canal to irrigate 7,500 acres.

The storage dam at present under construction by the company is located on the old Sherman ranch, in sec. 3, T. 15 N., R. 17 E. In 1913 construction had proceeded far enough to afford storage for the irrigation of 2,500 acres. The dam is to be completed in 1914 and at a later date supplemental storage will be supplied on the North Fork of Wenas Creek.

ATANUM WATER USERS' ASSOCIATION.

Atanum Creek, like all the other small tributaries of the Yakima, has been greatly overappropriated and, in addition to the usual litigation over prior and riparian rights, conditions have been complicated by claims of the Yakima Indians. An agreement between the United States Indian Office and the white water users has defined the rights of the Indians to one-fourth of the natural flow of the stream at The Narrows, the flow being described in the agreement as the sum of the measured flow at The Narrows and all diversions. On account of the difficulty of measuring all the small diversions above The Narrows, the division of water is based on the sum of the discharges of North and South forks of Atanum Creek as measured above diversions. The share of water belonging to the Water Users' Association is used to irrigate about 7,000 acres of land which is vested with prior water rights. An additional 4,000 acres in the vicinity of Tampico, vested with subsequent rights, is irrigated from Atanum Creek when the aggregate flow of the two forks is more than 90 second-feet. The discharge seldom exceeds 90 second-feet after the 1st of July.

The absence of adequate supervision of distribution and the large seepage losses which occur in the canal systems led to the organization of the Atanum Water Users' Association in 1911, for the purpose of realizing the full benefit of the water supply.

During 1911 and 1912 investigations and plans for an economic distribution were undertaken, and an effort was made to obtain an equitable partition of water among the water users. The organization of an irrigation district is contemplated, and it is proposed to issue bonds to the amount of $208,000 for improvements.

A diversion weir will be constructed just below The Narrows, and a main canal of 90 second-feet capacity will be provided. The canal will consist of a reinforced concrete flume about 20 miles long and will be built on a steep gradient in order to reduce the cross section necessary. The proposed canal will cross Atanum Creek at several points, and the plans call for the installation of pumps at such places for the recovery of seepage water from the creek bed. Shallow wells will also be sunk at convenient points and pumps provided to augment the low-water supply. The association plans to install 30 pumping plants, at an estimated cost of $30,000. The plants will be operated by 2-foot to 4-foot drops in the canal and plunger-type pumps directly connected to specially designed undershot water wheels will be installed. With a 4-foot drop a wheel 11 feet 9 inches in diameter will be used, operating at 20 revolutions per minute and capable of lifting 1.9 to 2.2 second-feet of water to a height of 16 feet at 30 per cent efficiency of the low-water flow. The average well lift will be about 16 feet and the lifts from the creek bed about 8 feet. It is estimated that the seepage and underflow recovered in this manner will amount to 50 to 75 per cent of the low-water supply, belonging to the association, which is available at The Narrows. Laterals of concrete and vitrified pipe will deliver the water to each 40-acre tract. It is also planned to construct small storage reservoirs on the North Fork of Atanum Creek and additional distributing systems to supply late irrigation for the lands near Tampico.

SATUS PROJECT.

South of Toppenish Ridge is an area comprising approximately 36,000 acres of reservation land susceptible of irrigation by stored flood waters of Satus Creek. Two good reservoir sites on this stream afford storage for the entire flow of the stream. At one site, just below the mouth of Dry Creek, approximately 64,000 acre-feet may be impounded by a masonry or rock fill dam 130 feet high and 1,300 feet long. The second site is situated just below the mouth of Logy Creek and has an estimated capacity of 30,000 acre-feet, requiring an 85-foot earth or masonry dam about 300 feet long.

It is probable that the run-off of Satus Creek will be insufficient to irrigate all the available land, so that a part of the lower area can best be covered by pumping, either from Yakima River or the drainage canals of the Indian Office. About 1,000 acres in this project is now under water from the natural flow of Satus Creek.

IRRIGATION BY PUMPING.

PRESENT DEVELOPMENT.

GENERAL CONDITIONS.

Future extension of the irrigated area in the Yakima basin under gravity systems can be effected economically only by the construction of projects which require large outlays of capital and many of which can not be considered feasible in the immediate future. Pumping systems have, therefore, been installed in some places to utilize water from the Yakima or the underground waters of the basin.

Pumped water has been used for irrigation in this section for many years. Crude current wheels, of low efficiency, operated either by the river itself or by canals, formerly numerous in the valley, have for the most part been superseded by more efficient devices, but are still used in various sections. It is probable that 22 feet is the maximum lift obtained with a current wheel in the Yakima basin.[1] Higher lifts have been undertaken with the use of the gasoline engine and electric motor-driven pumps. The following table, embodying statistics of lands irrigated by pumping in the three Yakima Valley counties at the

[1] Wright, A. E., Current wheels, their use in lifting water for irrigation: U. S. Dept. Agr. Bull. 146, 1904.

beginning of 1910, abstracted from the census reports, show the small extent of development at that time. Practically the whole acreage under water was served by the pumping projects at White Bluffs and Hanford, on Columbia River, and the project of the Prosser Falls Land & Power Co., subsequently abandoned. At present there are single plants in operation which irrigate more land than was watered by all existing plants in the Yakima Valley in 1910, if the acreage covered by the Prosser Falls plant is excluded.

Statistics of irrigation by pumping in counties in Yakima Valley, 1910.

	Benton.	Kittitas.	Yakima.
Acreage irrigated by pumping from streams	[a] [b] 4,849	355	[b] 434
Acreage irrigated by pumping from wells	636	....	265
Total acreage irrigated by pumping	5,485	355	699
Number of pumped wells	31	....	9
Capacity (gallons per minute)	10,158	....	1,382
Total number of pumping plants	84	3	18
Horsepower of pumping plants	5,894	207	270
Capacity (gallons per minute)	147,059	11,700	11,812

[a] The greater part of this area is irrigated by pumping from Columbia River.
[b] There are 1,300 acres in Yakima and Benton counties irrigated by the plant at Prosser Falls which has since been abandoned.

More than 6,000 acres of Yakima Valley land are now served by pumps with a motor installation of over 1,500 horsepower, and many small plants are operated by gasoline engines. Several of the projects are comparable, in acreage served, with many of the older gravity projects and contain less waste land, but the greater number of the pumping stations are small. The following table shows the essential features of the larger projects supplied with electric current. Nearly all the plants not listed in this table are small, with capacities ranging from 2 to 20 horsepower, and lifts for the most part are low.

Summary of principal pumping systems in Yakima Valley.

Name of project.	Location.	Acreage. Irrigated in 1912.	Acreage. Total in project.	Head pumped against (feet).	Capacity of pumps (gallons per minute).	Kind of pumps.	Horsepower of motors.	Duty (acres per second-foot).
Yakima Orchard Securities Co.	Moxee Valley.	400	700	160	2,000	Worthington turbine.	120	[b] 300
Central Washington Investment & Power Co.[a]	.....do........	440	1,000	170	3,200	.....do............	240	......
Morningside Irrigation Co.	.....do........	290	......	80	....	Deep-well pumps.	65	......
Grandridge Irrigation Association.	Sunnyside....	200	......	41	1,600	Turbine..........	20	......
Hillcrest Water Co....	.....do........	175	......	210	550	.....do............	75	......
Kiona-Benton Highlands.	Benton City..	600	1,200	213	1,700	Worthington turbine.	150	160
Benton City town site.	.....do........	300	......	198	....	Byron-Jackson....	100	......
Kennewick Highlands	Kennewick....	2,500	[b]6,000	137,170	12,000	Worthington turbine.	800	[c] 210
Horn Rapids Irrigation Co.	Richland......	200	......	20	....	Kingsford.........	50	......

[a] This project includes three plants, two of which are installed.
[b] This value is approximate.
[c] The contract duty is 2 acre-feet per year, which amounts to 1 second-foot per 210 acres for a seven-month irrigating season.

Water power has always been the principal source of energy for pumping water for irrigation. Current wheels make use of this energy directly by lifting the water to the lands. Turbines directly connected to pumps accomplish the same purpose more efficiently where the irrigable land lies near streams with feasible power sites. Recent improvements in the hydraulic ram may furnish another efficient means of lifting the water to the desired levels. A large part of land that can be irrigated advantageously by pumping is remote from feasible power sites, so that electric current transmitted from hydroelectric plants is employed to drive the pumps. The broadest field for irrigation by pumping is offered in the utility of this source of energy. When the storage and irrigation systems contemplated by the United States Reclamation Service are completed, the flow of Yakima and Naches rivers will be well sustained during the growing season, and the storage will be regulated in accordance with demands

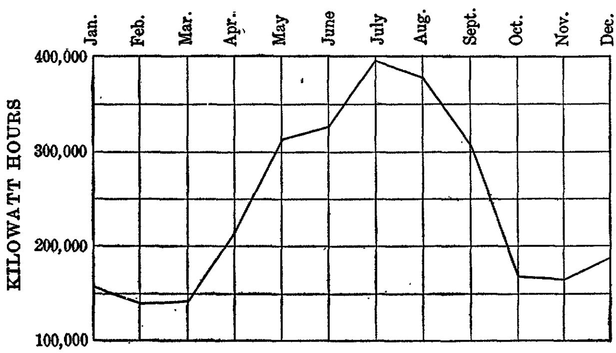


FIGURE 12.—Curve of electric energy distributed from Prosser, Sunnyside, and Toppenish substations of the Pacific Light & Power Co. in 1913, showing effect of pumping load.

of irrigation. This condition may make possible the installation of hydroelectric machinery for use only during the irrigation season.

The electric energy distributed during 1913 by the Pacific Power & Light Co. through three substations located at Prosser, Sunnyside, and Toppenish is diagrammatically shown in figure 12. The marked effect of the pumping load is evident in the increased demand during the months of April to September.

Few of the pumping stations operated in the Yakima basin are sufficiently important to merit special attention. None of them is comparable with the large systems in operation at Pasco, Burbank, and Hanford. A brief description of the more important systems is, however, presented in the following sections.

PROSSER FALLS LAND & WATER CO. SYSTEM.

The earliest important development of pumping for irrigation in the Yakima basin was at Prosser Falls, in Benton County, where water was supplied to 1,300 acres of land on the south bank of the stream. The project was taken over by the United States Reclamation Service in September, 1910, and the lands formerly irrigated by pumping are now supplied by gravity from the Sunnyside canal through the Prosser siphon.

The pumping plant consisted of two 25-inch duplex pumps with 24-inch stroke, driven by two 48-inch Samson turbines under 12-foot head. The water was forced through an 1,800-foot steel pressure pipe, 28 inches in diameter, into a fore bay from which it entered the gravity canal. The lift amounted to 100 feet.

PUMPING PROJECTS ABOVE SELAH-MOXEE CANAL.

Two allied companies—the Yakima Orchard Securities Co. and the Central Washington Investment & Power Co.—have installed pumping plants in the Moxee Valley to lift water from the Selah-Moxee canal to irrigate orchards lying above the canal.

The project of the Yakima Orchard Securities Co. comprises 700 acres, 400 of which have been planted in trees. Two 60-horsepower Wagner electric motors, each operating a single-stage 6-inch Worthington centrifugal pump of 1,000 gallons per minute capacity, have been installed. The pumps operate continuously against a head of 160 feet to an elevation of 145 feet above the canal into an underground system of pipes and hydrants. The project is noteworthy for the high duty attained, chiefly owing to the system of piping water in movable pipes to individual trees. The 400 acres of this orchard were irrigated in 1912 with a flow of only 1 to 1.5 second-feet.

The Central Washington Investment & Power Co. controls 1,000 acres under three pumping plants, all operating against a head of 170 feet to an elevation of 150 feet above the canal. Station No. 1 consists of two 5-inch 2-stage Worthington centrifugal pumps, each of 500 gallons per minute capacity, operated by two 40-horsepower Wagner electric motors. Station No. 2 consists of two similar pumps operated by two 50-horsepower motors with a capacity of 700 gallons per minute per pump. The third unit is being installed and will consist of two Union Iron Works 3-stage pumps, each of 400 gallons per minute capacity. Two 30-horsepower Wagner electric motors will furnish the power. The distribution system is similar to that of the Yakima Orchard Securities Co. About 440 acres were irrigated in 1912.

KIONA-BENTON HIGHLANDS PROJECT.

The irrigable area included in the Kiona-Benton Highlands project consists of 1,200 acres of land in T. 9, Rs. 26 and 27 E., just northeast of Benton City. The project was inaugurated in 1910 by the Kiona-Benton Land & Water Co. The company commenced to pump from the Kiona canal in 1911 and during the season of 1912 supplied water to over 600 acres, 400 acres of which is planted in orchards.

The installation consists of one 150-horsepower General Electric motor, connected to a 2-stage Worthington centrifugal pump of 1,700 gallons per minute capacity. The water is discharged into a wood-stave pressure pipe, 4,600 feet long, against a maximum head of 213 feet. About 70 per cent of the water is discharged into a flume under a lift of 155 feet and the remainder into a high-line ditch. The water is distributed by gravity to the lands from two canals which have a total length of over 19,000 feet. A duty of 1 second-foot to 160 acres for the irrigating season of April 1 to October 1, or 2.25 acre-feet per acre, obtains under this project.

KENNEWICK HIGHLANDS PROJECT.

The largest pumping project in the Yakima Valley is that of the Kennewick Highlands. In addition to the 2,500 acres under water at the present time, probably 3,000 to 4,000 acres could be profitably irrigated by pumping. However, the land will eventually be supplied by gravity from either the Yakima high-line or Benton unit so that further extensions of the pumping system await investigations as to the feasibility of the gravity project.

The water is pumped from the Kennewick canal in two lifts, one of 137 feet and one of 170 feet. Water is delivered into a sump at the upper end of the pressure pipes, and thence flows through concrete-lined canals to the water users. The duty is 2 acre-feet per acre, and most of the land is planted in young fruit trees.

The plant consists of two sets of pumps connected to separate pipe lines. Two Worthington 2-stage centrifugal pumps of 2,700 gallons per minute capacity each are direct-connected to 150-horsepower General Electric motors. The pumps operate against a head of 137 feet. Two similar pumps of 3,300 gallons per minute capacity, connected to 250-horsepower motors, pump against a head of 170 feet.

PROSPECTIVE DEVELOPMENT.

EXTENSION OF GRAVITY SYSTEMS BY PUMPING.

A large amount of land in the Yakima basin not capable of being economically covered by gravity systems will eventually be irrigated by pumping. The plans of the United States Reclamation Service and the United States Indian Office provide for the irrigation of at least 26,000 acres lying above the Sunnyside and Wapato canals and for the supply of 8,000 acres in the Pomona Heights project. All the remainder of the low-water flow of the river and stored water in proposed reservoirs will be supplied to various gravity canals constructed and projected.

A duty of water greater than that obtained in present usage will probably be gained by more economic methods and permanent irrigation works. This increase in duty will make it possible to extend gravity systems, and a considerable part of such extension will be undertaken by pumping water from the gravity canals. The development of storage in secondary reservoir sites (p. 91) may also increase the water supply available for this purpose. Another source of water for pumping is available in the ground waters of the valley. This subject has been fully treated in other publications of the Survey by Smith,[1] Calkins,[2] and Waring.[3] Artesian water in the eastern artesian basin has probably reached the fullest utility, but other artesian areas are unexploited. Four flowing wells, yielding a total of 5.5 second-feet, were sunk in the East Selah Valley above the Selah-Moxee canal in 1913, and artesian flows have been discovered in Wide Hollow and in the Indian reservation west of Wapato. Many of the nonflowing wells which are pumped for irrigation are simply sump holes fed by seepage from the river, but others are deep wells fed from the underground waters of the region.

PUMPING WATER FOR YAKIMA PROJECT OF UNITED STATES RECLAMATION SERVICE.

The gradient of the Sunnyside, Tieton, and Wapato canals is broken by a number of drops which were made necessary by topographic features. Plans for the development of power at many of these drops have been considered with a view of utilizing the energy for pumping water for irrigation. The following table outlines the essential features of these plans in connection with the gravity systems included in the Yakima project:

Summary of power sites on Government irrigation projects available for pumping water for irrigation.

Location of power site.	Head.	Discharge available for power (average).	Horse-power, 70 per cent efficiency.	Irrigable acreage.	Lift.	Quantity of water to be pumped.
Sunnyside project.	*Feet.*	*Sec.-feet.*			*Feet.*	*Sec.-feet.*
Outlook: Drop in Snipes Mountain lateral	45	140	501	4,500	100	31
Euclid:						
Drop in Mabton feeder	22	83	145	4,250	17	3.3
Drop in Rocky Ford lateral	75	25	149		48	13.5
					80	11.8
Drop at head South Branch Snipes Mountain lateral	65	71	367	1,574	166	8.4
Drop to sublateral from Mabton west lateral	44	30	105	1,800	53	12.3
Tieton project.						
S. 12, T. 14 N., R. 16 E., drop in main canal	114	250	2,260			
Wapato project.						
Drop 0, 3 miles below intake	24	1,110	2,120	14,000		
Drop 1, 6 miles below intake	40	928	2,950			
Drop 2, 9 miles below intake	32	694	1,765			
Drop 3, 13 miles below intake	34	398	1,075			
			11,437			

[1] Smith, G. O., Geology and water resources of a portion of Yakima County, Wash.: U. S. Geol. Survey Water-Supply Paper 55, 1901.

[2] Calkins, F. C., Geology and water resources of a portion of east-central Washington: U. S. Geol. Survey Water-Supply Paper 188, 1905.

[3] Waring, G. A., Geology and water resources of a portion of south-central Washington: U. S. Geol. Survey Water-Supply Paper 316, 1913.

No plans have been made by the United States Reclamation Service for the utilization of the power on the Tieton unit. The development, if undertaken, will be left to commercial enterprise. The lack of a sufficient water supply and the fact that there is very little land in the vicinity of the power plant irrigable by pumping will make it necessary to provide transmission lines to favorable tracts.

Tentative plans have been made to install four pumping plants on the Sunnyside unit which will be capable of irrigating approximately 12,200 acres of land with lifts varying from 17 to 166 feet.

The possibilities of summer power on the Wapato unit are far greater than on the other units. Nearly 8,000 horsepower at 70 per cent efficiency may be developed by utilizing the available head in four drops in the canal system. A large amount of this power could be used to pump water to excellent land in the reservation which can not be reached by gravity. It is proposed to use the first drop in the system to pump water to 14,000 acres lying immediately above the main canal and including some of the best land in the reservation. Power developed at the other drops will require transmission lines of considerable length to reach irrigable areas. There are 4,000 acres lying between Satus and Toppenish creeks which can not be reached by gravity flow but which may be very readily watered by a 30-foot lift. The 36,000 acres adjacent to Satus Creek is probably a larger area than can be irrigated by the run-off of that stream even if the total flow is regulated by storage. Therefore, it may prove advantageous to water the lower parts of the area by pumping from Yakima River. It is probable that power to operate pumping plants for such irrigation could economically be generated at drops in the Wapato canal.

Investigations in Kittitas Valley have shown that 32,000 acres above the Kittitas high-line canal can be covered by a maximum lift of 200 feet. It is estimated that 20,000 acres of this area is irrigable land. Plans to pump water to this acreage were at one time considered by the Kittitas irrigation district. The scheme proposed involved the construction of a power plant on Yakima River above Thorp. Although the plan was pronounced feasible, the difficulty of obtaining water rights led the district to abandon the proposition.

All plans considered for the construction of the Benton and Yakima high-line canals have contemplated the construction of power plants at various drops in the canals and the irrigation of considerable areas by pumping. Plans for the development of these projects are at present so indefinite that no estimate of the available power is possible.

PUMPED WATER FOR POMONA HEIGHTS.

Construction of the project of the Yakima Canal Co. for irrigating 8,000 acres in Selah Valley was begun several years ago, but has never been completed. The recent discovery of artesian waters within the area which it was proposed to water has further delayed development. A power canal 2 miles long, involving very difficult construction through the lower part of Yakima Canyon, was planned and in part constructed. The proposed location of the power plant is just above the Selah-Moxee intake, at which point it was planned to develop 3,000 horsepower with a fall of 35 feet. The turbines were to be directly connected to pumps operating against three separate heads of 100, 200, and 300 feet, respectively. The water supply was to be derived from stored water purchased from the Reclamation Service.

COMPARISON OF PUMPING AND GRAVITY SYSTEMS.

A large number of factors affect the feasibility of pumping projects in competition with possible gravity systems. The cost of developing a few of the more modern pumping systems seems to indicate that water can be supplied by pumping at considerably less initial cost than can be realized in constructing gravity systems in Yakima Valley in the future. However, the maintenance charges on pumping systems, with present power rates, will average about $5 an acre a year, whereas the maintenance charge on gravity systems of the better class ranges from $1 to $2 an acre a year. The difference between these charges is almost wholly due to the cost of energy for pumping, for the distribution costs are no larger and in some places are even smaller than for gravity systems. When the pumping load for irrigation becomes greater the power rates will doubtless be very materially lowered, so that the cost of maintenance will be greatly decreased. With the present schedule of rates in operation it appears that pumping can be practiced advantageously only in connection with the development of high-grade land with good market facilities.

In addition to the relative cost of maintenance, many other factors, of which the most important are outlined in the following paragraphs, should be studied in making a detailed comparison of the two systems.

1. Gravity projects feasible for future construction comprise large areas, and will realize the decided benefits accruing from large units, whereas pumping systems in the Yakima Valley are at present restricted to small areas.

2. Gravity systems are constructed to serve all irrigable lands included in projects, much of which is often second-grade land. Pumping systems may be limited to serve only high-grade land.

3. Gravity systems must be constructed at the outset to serve all irrigable land included in projects and will return small interest on capital invested until all the lands are placed in cultivation. Pumping projects may be limited at the outset to lands ready for immediate development and extended in units as warranted.

4. Gravity systems have benefited by nearly a half century of experience in construction and maintenance, whereas pumping systems are still in the experimental stage. Many small pumping plants have failed because of inefficient machinery.

5. The cost of power to operate pumps makes necessary a high duty of water. The distribution systems of the later pumping systems are of a higher grade than it has heretofore been found profitable to employ in gravity systems.

6. Pumping projects in general will serve land either naturally well drained or more easily artificially drained better than gravity systems.

PRODUCTION OF COAL.

By Edwin J. Saunders.

Consideration of the production of coal in an area is important in connection with hydroelectric development not only because of limitation in warranted cost imposed by competition with steam power in localities favored by large beds of coal that can be mined cheaply, but also because the economical development of streams lacking storage reservoirs makes necessary the installation of auxiliary steam plants to carry a portion of the demand for energy during periods of low water.

Coal has been found in a number of localities in Kittitas County,[1] but only the Roslyn field is economically important, though coal is being shipped from a small mine in the Manastash formation along Taneum Creek about 10 miles west of Thorp.

The Roslyn bed, which is the principal one being worked in the Roslyn field, has given Yakima Valley first rank among the coal-producing sections of the State. The northern boundary of the bed has been accurately traced from Clealum to Jonesville, and the east and west limits are fairly well defined in the workings at Clealum and Jonesville, but the southern boundary is known only approximately. The average thickness of the bed over the whole field is 4 feet 3 inches. From the proved area, the probable area, and the average thickness, an estimate has been made of the quantity of coal in the field and, with an estimate of future production, is shown in the following table. The estimate of future production was based on the percentage of coal mined in each part of the field in relation to the known coal of that section as shown by actual workings. A map on a scale of 400

[1] Smith, E. E., U. S. Geol. Survey Bull. 474, pp. 55-62, 129-152, 1911.

feet to the inch, furnished by the Northwestern Improvement Co. and prepared about June, 1910, was used for this work. From all the information at hand it appears that about 70 per cent of the coal in the proved areas had been recovered up to that time. Improved methods of laying out workings will return a conservative estimate of 75 per cent for proved areas now beginning to be worked, and a conservative estimate indicates that 80 per cent of the reserve coal may be recovered. It is possible that this percentage may be exceeded in actual practice.

Estimates of future production of coal from Roslyn bed.

	Area in acres.	Total original tonnage.[a]	Recovery.	
			Per cent.	Tons.
Probable area	2,221	16,524,240	80	13,218,202
Proved area unworked	4,153	30,898,320	75	23,173,740
Proved area worked	3,287	24,455,280	70	17,118,696
	9,661	71,877,840		53,510,638
Production reported by State mine inspectors, 1887-1911 [b]				[b] 19,455,947
Estimated future production				34,054,691

[a] 7,440 short tons per acre.
[b] This output is for the Roslyn bed alone. The output of all beds in Kittitas County is shown in the following table.

The following table shows the mine production for the years 1887 to 1912, inclusive, as reported by the United States Geological Survey. The total production of the Roslyn field has been about 30 per cent of the grand total for the State.

Annual production of coal in Kittitas County, 1887 to 1912.

	Short tons.		Short tons.		Short tons.
1887	104,782	1897	370,657	1907	1,524,887
1888	220,000	1898	566,396	1908	1,414,621
1889	294,701	1899	661,210	1909	1,550,539
1890	445,311	1900	873,751	1910	1,661,650
1891	348,018	1901	1,012,521	1911	1,256,745
1892	285,088	1902	1,250,920	1912	1,237,427
1893	253,467	1903	1,369,716		
1894	232,580	1904	1,340,400		21,526,331
1895	281,534	1905	1,280,845		
1896	265,953	1906	1,422,612		

The Big Dirty, a bed containing about 6 feet of good coal and lying about 200 feet above the Roslyn bed, is now being worked at Jonesville by the Roslyn Fuel Co. as mine No. 2.

The fields outside of Roslyn are not at present producing sufficient coal to enable steam to compete with water power. The extent of proved area, the total content of the coal-bearing beds, and the amount probably recoverable are indicated by the following table:

Proved area, probable recovery, and total content of coal-bearing beds in Kittitas County.

Field.	Proved area.	Total original content.	Probably recoverable.
	Acres.	*Tons.*	*Tons.*
Roslyn	9,661	87,680	25,600
Lower Taneum		768	60
Manastash		5,372	300
		93,820	25,960

MINERALS OTHER THAN COAL.

In the mountainous parts of the district considerable prospecting has been done for gold, copper, lead, iron, and cinnabar, deposits of which are known to exist. Placer mining has been practiced for years along Swauk Creek, and many prospects have been located and some development work has been done in the upper Clealum basin. Gold-bearing formations which have yielded very favorable prospects have been located at the head of American River, but development has been hampered by the high cost of transportation over roads and trails. Better transportation facilities will make mining practicable and open a local market for the water powers.

MANUFACTURING.

The principal manufacturing industries in the Yakima basin include milk products, lumber and flour mills. Practically all the products are used locally.

Pasturage is abundant and dairying and cattle raising have become profitable adjuncts of the extensive hay fields in Kittitas and Yakima counties. Milk and cream are collected at a dozen or more creameries in the vicinity of Ellensburg, North Yakima, and Sunnyside. The following table, abstracted from reports of the Census Bureau for the year 1909, serves to indicate the amount and value of dairy products in Kittitas, Yakima, and Benton counties:

Dairy products of the Yakima Valley counties during 1909.

Product.		Benton County.	Kittitas County.	Yakima County.	Total.
Milk:					
Produced	gallons	359,396	999,625	3,074,763	4,433,784
Sold	do	36,954	392,834	367,437	797,225
Cream: Sold	do	1,874	16,453	93,823	112,150
Butter:					
Produced	pounds	96,205	120,573	300,442	517,220
Sold	do	46,446	88,912	82,240	217,598
Cheese:					
Produced	do		4,200	1,240	5,440
Sold	do		3,870	1,140	5,010
Butter fat: Sold	do		125,000	518,515	643,515
Value of dairy products[a]		$38,294	$144,930	$403,472	$586,696
Receipts from sale of dairy products		$23,598	$134,474	$339,522	$497,594

[a] These values are exclusive of home use of milk and cream.

Lumbering has been an important factor in the growth of Yakima Valley, although less predominant than in many other parts of the State. The Cascade Lumber Co. is said to have cut from 25,000,000 to 30,000,000 board feet yearly for the last seven years. The logs have been collected chiefly from the Teanaway and upper Yakima basins and driven in the streams to the North Yakima mill, the capacity of which is about 200,000 board feet a day. Smaller mills are situated at Ellensburg, Clealum, and other places in the timbered region.

It is estimated that 58,000,000 board feet of lumber is standing on the flowage areas of the reservoir sites at Keechelus, Kachess, and Clealum lakes. Contracts have been let by the Reclamation Service for clearing these areas before 1919, and logging is now in progress on all three lakes.

Practically the entire amount of lumber produced at the mills is used in the valley, only a very small amount reaching points east of Pasco or west of Easton.

As early as 1875 a gristmill was operated on Wilson Creek north of Ellensburg, and the total present capacity of flour mills is about 800 barrels a day. The largest mill, located at North Yakima, has a daily capacity of 300 barrels. Nearly all the mills use hydraulic power for driving the machinery.

The utilization of waste and second-grade orchard products and the rapid extension of fruit-bearing areas are opening up large industrial fields. Canning factories and cold-storage plants are operated in the North Yakima and Sunnyside districts, and North Yakima has at present cold-storage facilities for 300 cars of fruit and other produce, but canning and refrigerating will not be industrially important at Ellensburg until commercial horticulture becomes more prominent in Kittitas Valley. It has been estimated that at the present rate of extension of orchard area, Yakima Valley will within a few years produce annually 50,000 carloads of fruit. When a production of this magnitude is considered, the need of evaporators, denatured-alcohol factories, and other establishments capable of utilizing waste orchard products becomes obvious.

SCHEME OF DEVELOPMENT AND UTILIZATION OF STORED WATER.

By Charles H. Swigart.

THE STORAGE SYSTEM.

The Yakima project storage unit comprises five approved and several secondary reservoir sites. Two of the principal reservoirs (Lake Kachess and Bumping Lake) have been completely developed by permanent dams and other works. At Lake Keechelus permanent construction is in progress. Lake Clealum has been partially developed by the construction of a crib dam, and at this point, as well as at the fifth site, McAllister Meadows, full surveys and investigations have been completed and preliminary plans and estimates made.

Three of the largest reservoir sites are situated on and control the run-off from the three principal catchment areas at the source of the Yakima. Two of the smaller sites are on tributaries of Naches River, the principal branch of the Yakima.

The conditions that determined the general storage scheme which has been adopted were:

1. The position of the feasible reservoir sites.
2. The position of the areas of irrigable land.
3. The relation of the amount of irrigable land to the available water supply.

A careful study of these conditions led to the following conclusions:

1. That the situation of these reservoir sites was such that water impounded in them could be used to supplement the flood flow of the entire drainage basin and irrigate the greatest area of land.
2. That these reservoirs comprise all of the larger sites on Yakima River that could be developed at a cost justified by the present value of the lands to be reclaimed.
3. That the stored water supply which could be made available by the largest economical development of these sites, if used to supplement the unstorable flow of the entire basin, would furnish an adequate supply of water for all of the irrigable lands whose present value would justify the expenditure necessary for distributary works.
4. That there was a considerable body of good land for which the cost of distributary works would be greater than would be justified by the present demand.

Careful investigation may prove the feasibility of some of the possible reservoir sites which have been classed as secondary, but it will not be possible to store sufficient water to adequately supply the irrigation needs of all the good lands of the valley.

The facts noted above have been given due weight in making plans for the development of each site, and each plan provides for the utilization of the greatest capacity consistent with safety, economy of construction, run-off of the tributary basins, and the possible use of the stored water in supplementing the unstorable flow of the river system.

THE IRRIGABLE LANDS.

The normal low-water flow of Yakima River was all appropriated and put to beneficial use by private parties before the Reclamation Service began investigations in the valley. Only a small part of the good irrigable land had been irrigated, but the reclamation of any more land would require storage works to make available an adequate supply of water during the low-water season. The total available water supply was not adequate for the reclamation of all of the remaining irrigable lands. To secure the highest ultimate efficiency in the use of the available water supply and consequently the largest possible development of irrigation, it was necessary to include all of the principal remaining areas of irrigable land and all of the principal feasible reservoir sites in one plan of development. The following table shows the units of the Yakima project above the confluence of Yakima River with the Columbia and the status of their development:

Irrigable lands of the Yakima project.

Units.	Total area.	Area dependent on storage.	Status of units.
	Acres.	*Acres.*	
Benton	90,000	90,000	Reconnaissance surveys only.
Sunnyside	102,000	31,600	Construction practically completed.
Wapato	120,000	105,600	Surveys completed.
Tieton (on Naches watershed)	34,700	34,700	Construction completed.
Undefined high-line and smaller projects.	108,000	108,000	Partial reconnaissance.
Kittitas	82,000	82,000	Surveys completed. Irrigation district organized under State law.
	536,700	451,900	

UTILIZATION PLAN.

During the nonirrigation season of normal years that part of the run-off into upper Yakima River which can not be stored will be sufficient to take care of power rights that had been acquired when the Reclamation Service began work on the Yakima project. The records indicate that during years of extremely low run-off it will be necessary to use some of the storable water from the reservoirs to supplement the unstorable flow in order to satisfy these rights. Any power that may be acquired on Yakima River in the future will, therefore, be satisfied at the expense of irrigation and will reduce the area reclaimable by irrigation by the amount of storable water required for such power rights during the low-water period of the nonirrigation season.

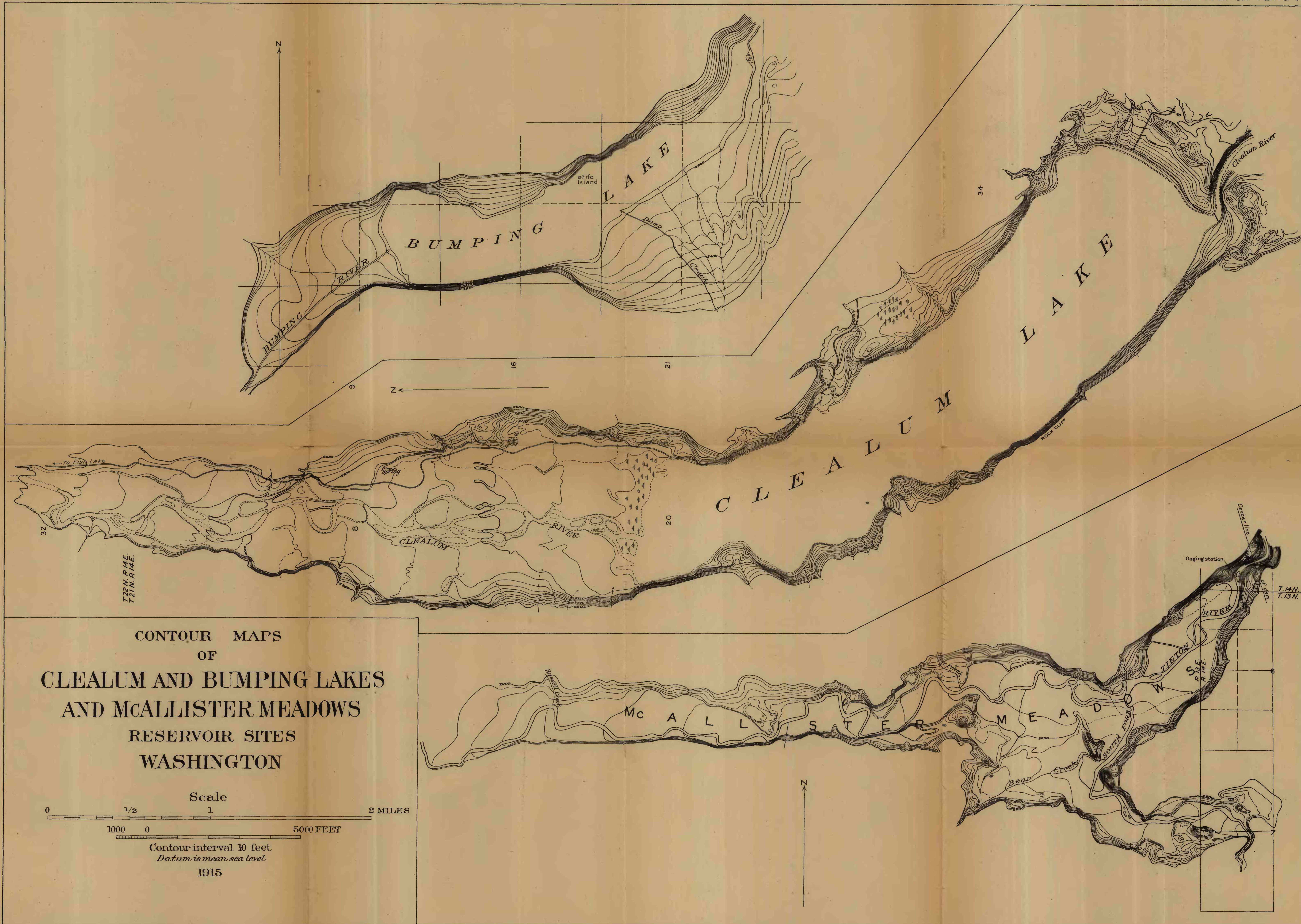
The records show a fairly uniform and well-sustained spring-flood flow from the Naches River basin, unstorable because of lack of suitable reservoir sites. The position of large areas—approximately half of the irrigable lands of the project—below the junction of Naches and Yakima rivers makes it possible to use the unstorable run-off from the Naches during the irrigation season, supplementing this, as necessary, by water stored in the reservoirs located on either stream.

As present plans contemplate the use of the entire storage system in this way, it would seem that highest efficiency could be attained only by having the operation of the reservoir system under one management.

The studies that have been made show that during the flood-flow period of the irrigation season the run-off from the basin of the upper Yakima, outside of the catchment areas of the three Yakima lakes, will not be sufficient to provide for the irrigation of those units taking their water supply from Yakima River above the mouth of the Naches. They also show that the storage capacity which can be economically developed at these lakes will be more than sufficient to impound all the storable run-off from their catchment areas during average years and that it is desirable to develop a certain amount of hold-over capacity which must be filled during the years of large run-off.

The future agricultural development of the Yakima Valley depends entirely on irrigation. As the water supply that can be made available for this purpose must depend on the construction of storage reservoirs, it follows that the largest economical development of storage is necessary for the highest use of the resources of the valley; therefore, all the water at present classed as storable should be held for use for irrigation, and rights inimical to that use should not be granted.

INDEX.



Surveyed by U.S. Reclamation Service

Subject to adjustment

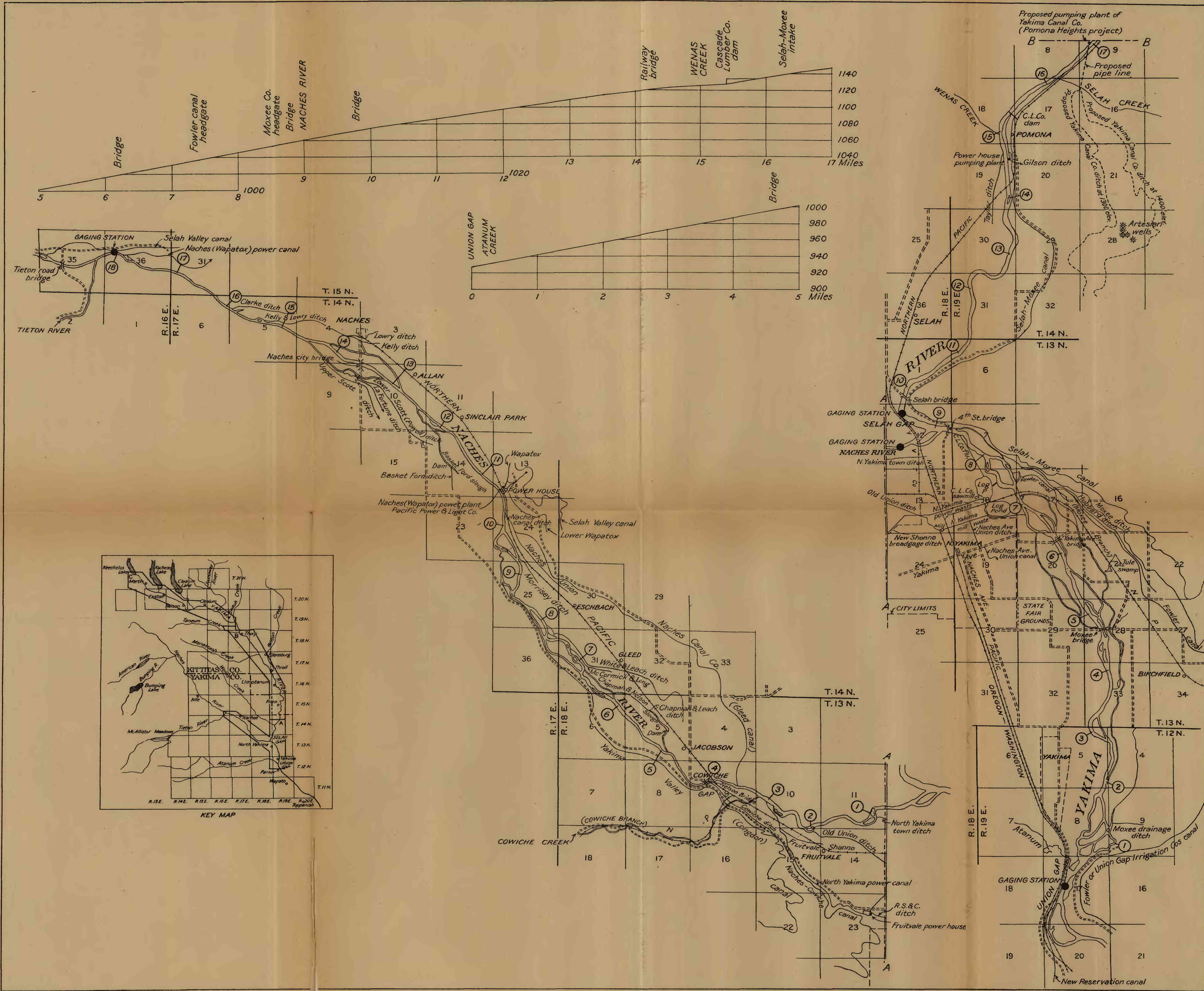
Surveyed by U.S. Reclamation Service

House Doc. 1087; 63d Cong., 2d Sess.

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PLAN AND PROFILE OF YAKIMA RIVER FROM UNION GAP TO KEECHELUS LAKE AND PLAN OF NACHES RIVER FROM TIETON RIVER TO YAKIMA RIVER

SHEET A



From surveys made by the U.S. Reclamation Service

Scale $\frac{1}{63,360}$

1 0 1 2 3 4 5 Miles

4,000 0 4,000 8,000 12,000 16,000 20,000 Feet

1 0 1 2 3 4 5 Kilometers

Vertical scale 1 inch = 80 feet
Datum is mean sea level
1915

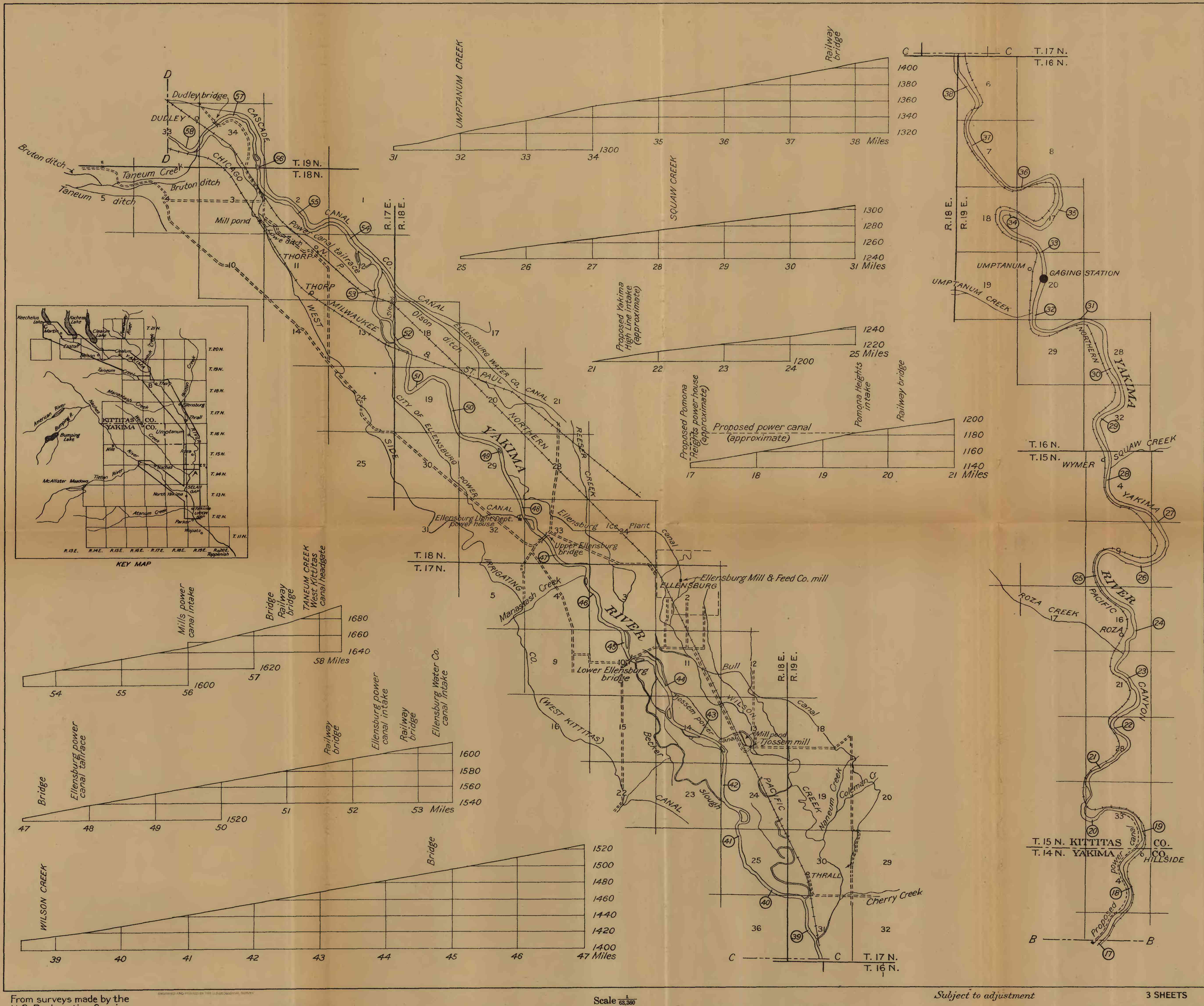
Subject to adjustment

3 SHEETS

House Doc. 1087; 63d Cong., 2d Sess.

PLAN AND PROFILE OF YAKIMA RIVER FROM UNION GAP TO KEECHELUS LAKE

SHEET B



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Subject to adjustment

3 SHEETS

DIAGRAM OF TOWNSHIP

Scale $\frac{1}{63,360}$

1 0 1 2 3 4 5 Miles

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Vertical scale 1 inch = 80 feet
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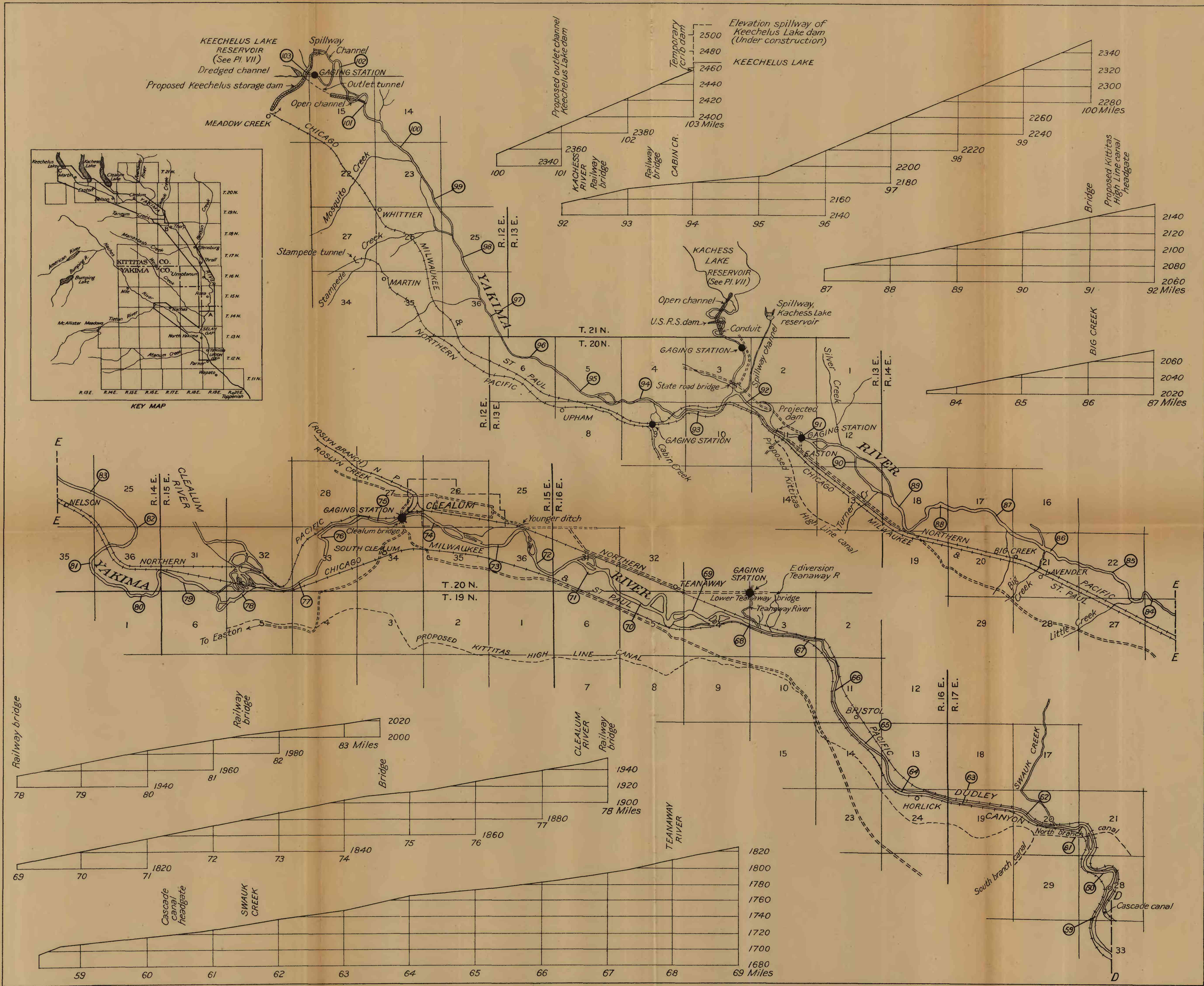
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PLAN AND PROFILE OF
YAKIMA RIVER
FROM UNION GAP TO KEECHELUS LAKE

SHEET C

WATER-SUPPLY PAPER 369 PLATE X



From surveys made by the U.S. Reclamation Service

DIAGRAM OF TOWNSHIP

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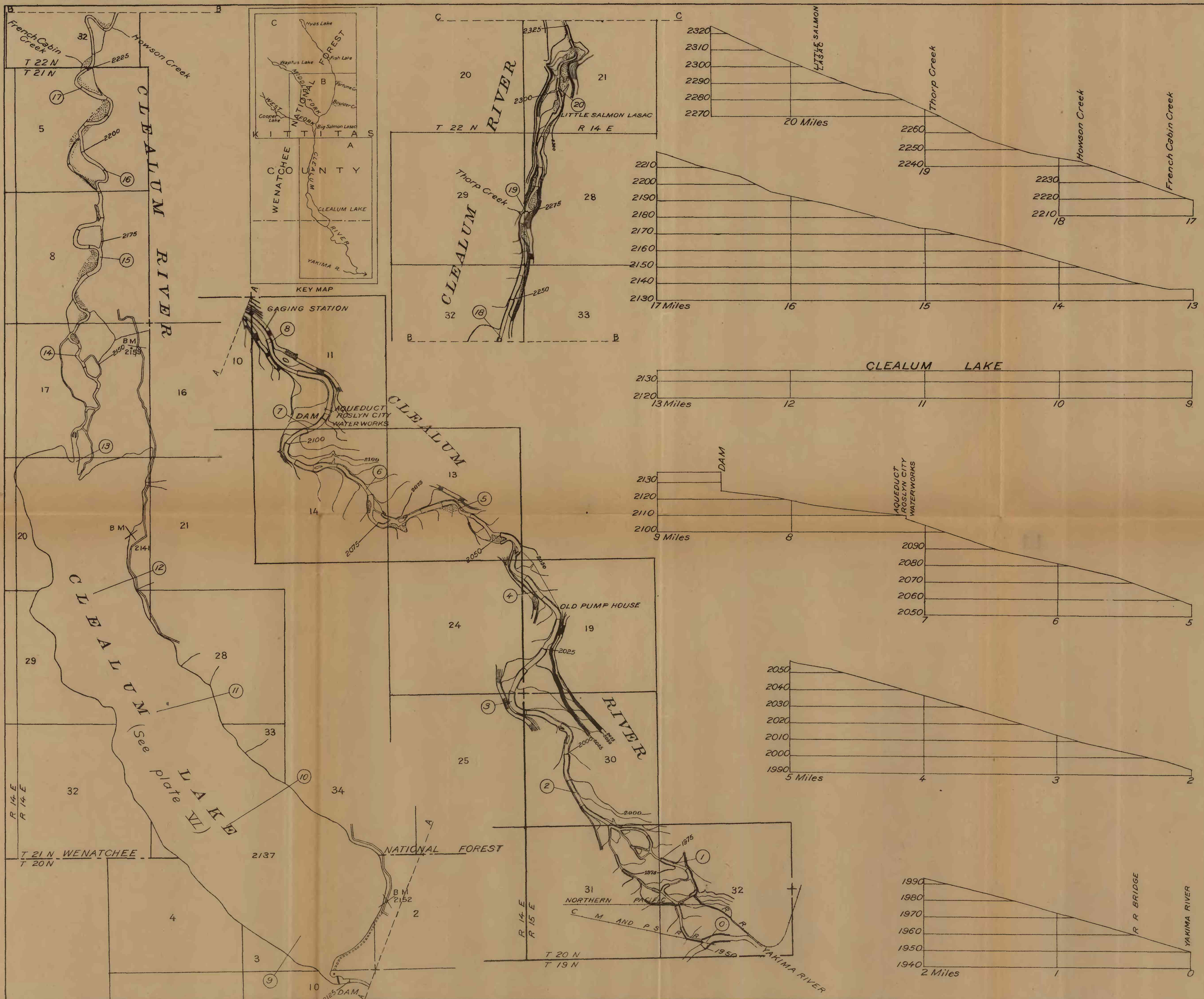
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR
STATE OF WASHINGTON
M. E. HAY, GOVERNOR
HENRY LANDES, STATE GEOLOGIST

PLAN AND PROFILE OF CLEALUM RIVER WASHINGTON

SHEET A



R. B. Marshall, Chief Geographer
T. G. Gerdine, Geographer in charge
Topography by T. H. Moncure
Surveyed in 1911
SURVEYED IN COOPERATION WITH THE STATE OF WASHINGTON

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Scale $\frac{1}{31,680}$

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1 0 1 2 Kilometers

Vertical scale 1 inch = 40 feet
Contour interval 5 feet
Datum is mean sea level
1915

TRUE NORTH — MAGNETIC NORTH 23°
APPROXIMATE MEAN DECLINATION 1911

Subject to adjustment

3 SHEETS

House Doc. ; 63d Cong., 2d Sess.

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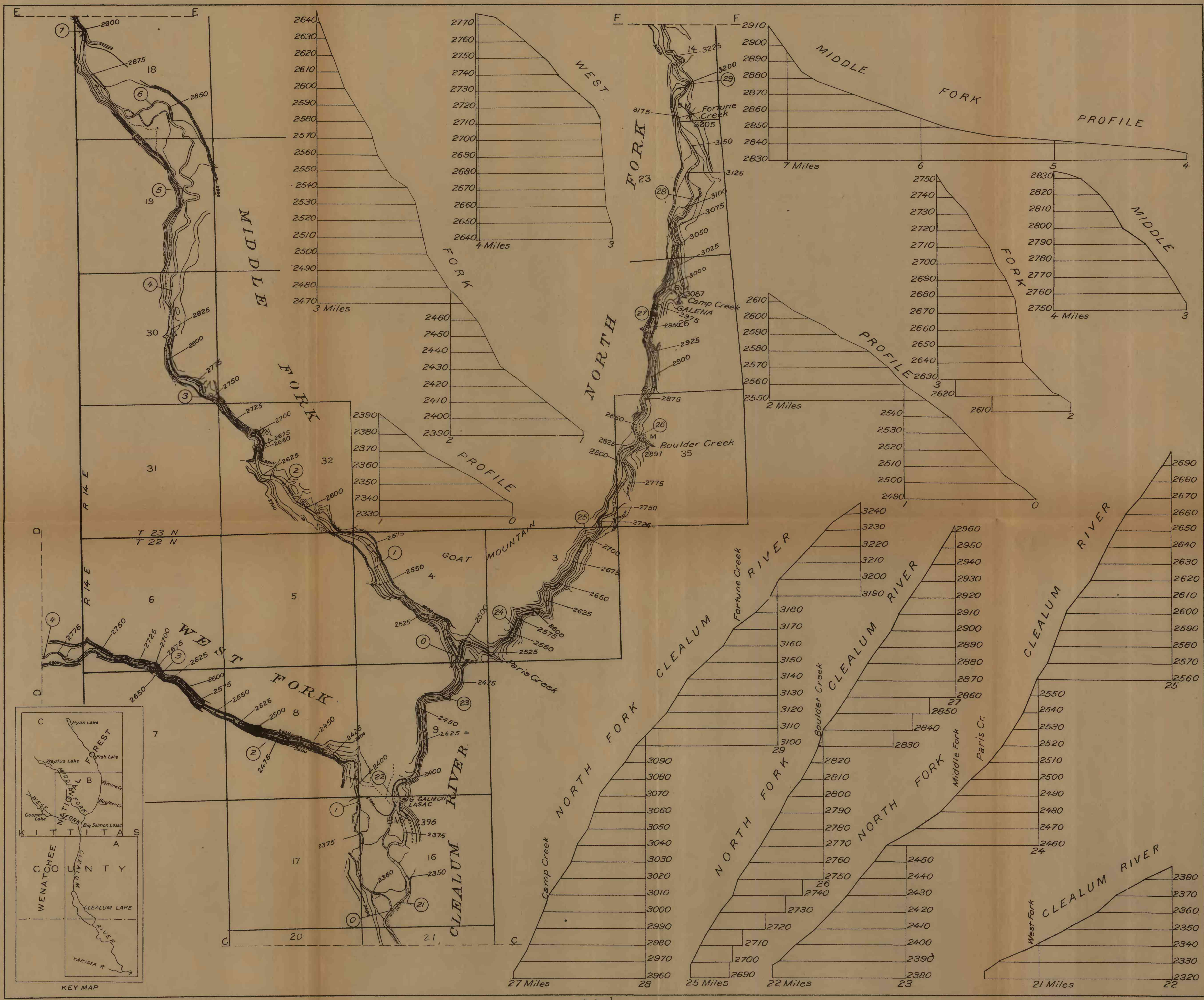
PLAN AND PROFILE OF CLEALUM RIVER WASHINGTON

SHEET B



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Scale $\frac{1}{31,680}$

1 0 1 2 Miles

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1 0 1 2 Kilometers

Vertical scale 1 inch = 40 feet
Contour interval on land 25 feet
Contour interval on river surface 5 feet
Datum is mean sea level
1915

TRUE NORTH
MAGNETIC NORTH
23°
APPROXIMATE MEAN DECLINATION 1911

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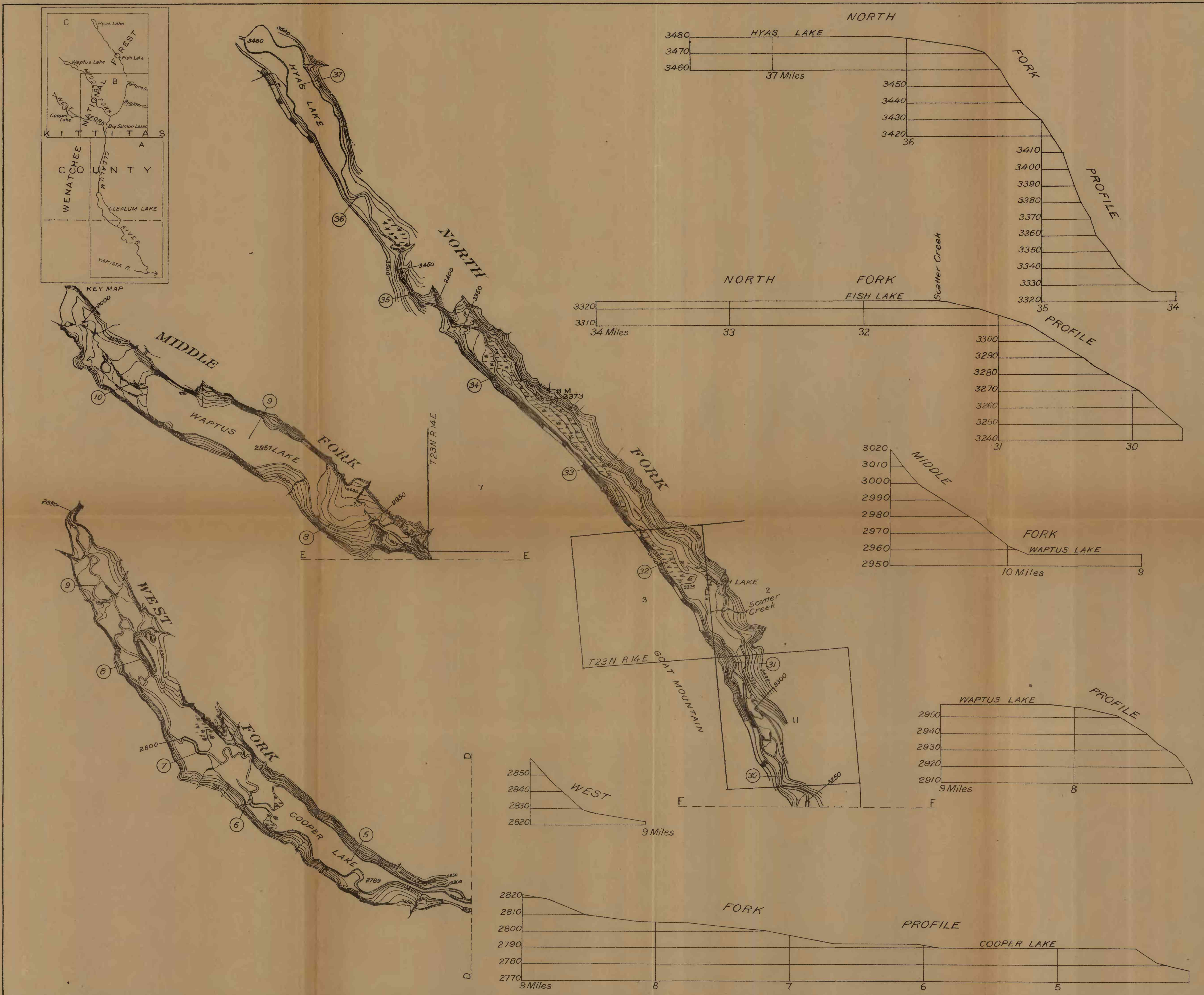
PLAN AND PROFILE OF CLEALUM RIVER WASHINGTON

SHEET C



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Scale $\frac{1}{31,680}$

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4,000 2,000 0 4,000 8,000 Feet

1 0 1 2 Kilometers

Vertical scale 1 inch = 40 feet
Contour interval 10 feet
Datum is mean sea level
1915

TRUE NORTH MAGNETIC NORTH 23°
APPROXIMATE MEAN DECLINATION 1911

Subject to adjustment

3 SHEETS

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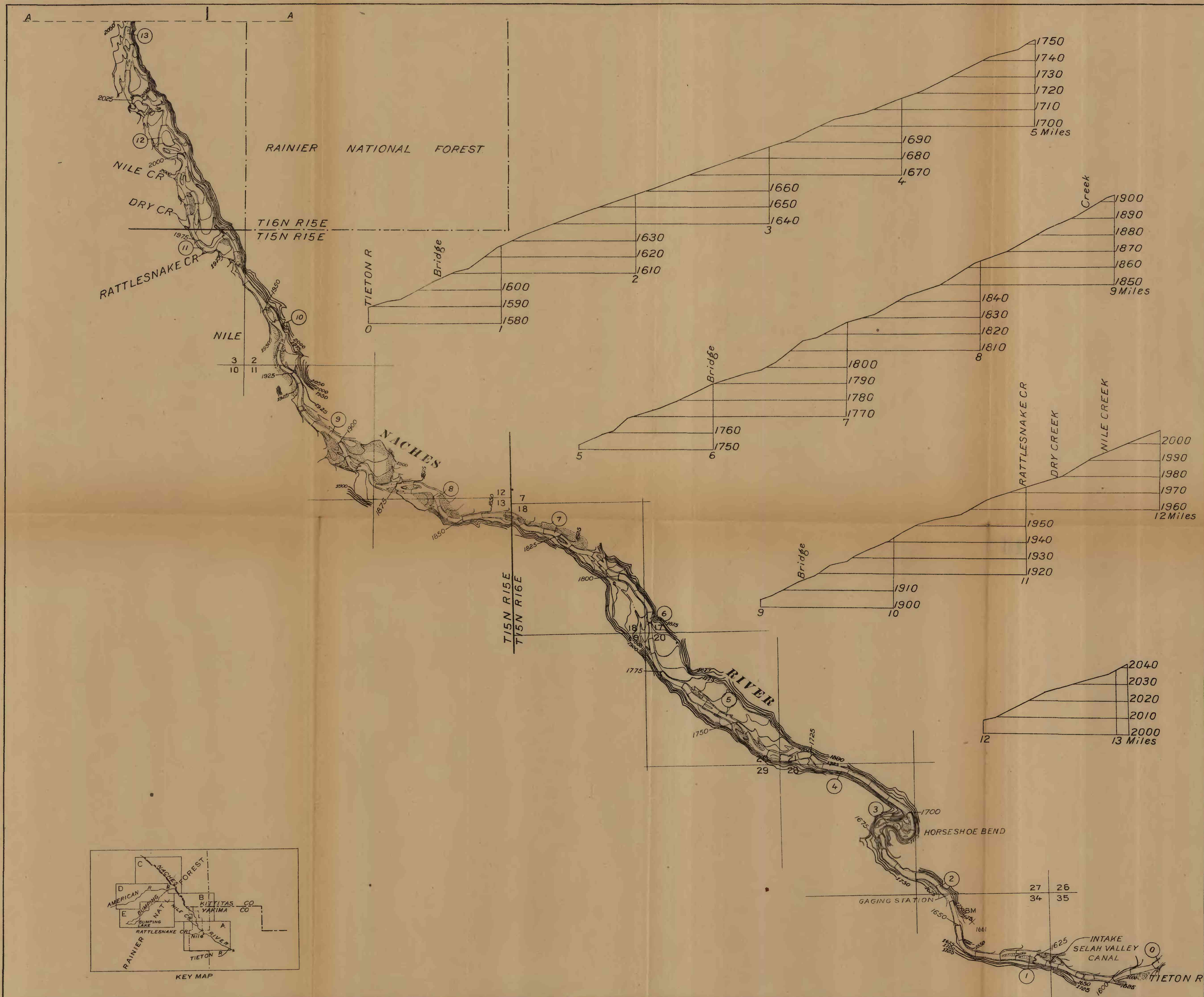
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR
STATE OF WASHINGTON
M. E. HAY, GOVERNOR
HENRY LANDES, STATE GEOLOGIST

PLAN AND PROFILE OF NACHES RIVER MOUTH OF TIETON TO HEADS OF AMERICAN AND BUMPING RIVERS, WASHINGTON

SHEET A



R. B. Marshall, Chief Geographer
T. G. Gerdine, Geographer in charge
Topography by W. B. Lewis
Surveyed in 1910
SURVEYED IN COOPERATION WITH THE STATE OF WASHINGTON

DIAGRAM OF TOWNSHIP

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Scale $\frac{1}{31,680}$

1 0 1 2 Miles

4,000 2,000 0 4,000 8,000 Feet

1 0 1 2 Kilometers

Vertical scale 1 inch = 40 feet
Contour interval 5 feet
Datum is mean sea level
1915

$22\frac{1}{2}°$
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1910

Subject to adjustment

5 SHEETS

House Doc. ; 63d Cong., 2d Sess.

U. S. GEOLOGICAL SURVEY
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STATE OF WASHINGTON
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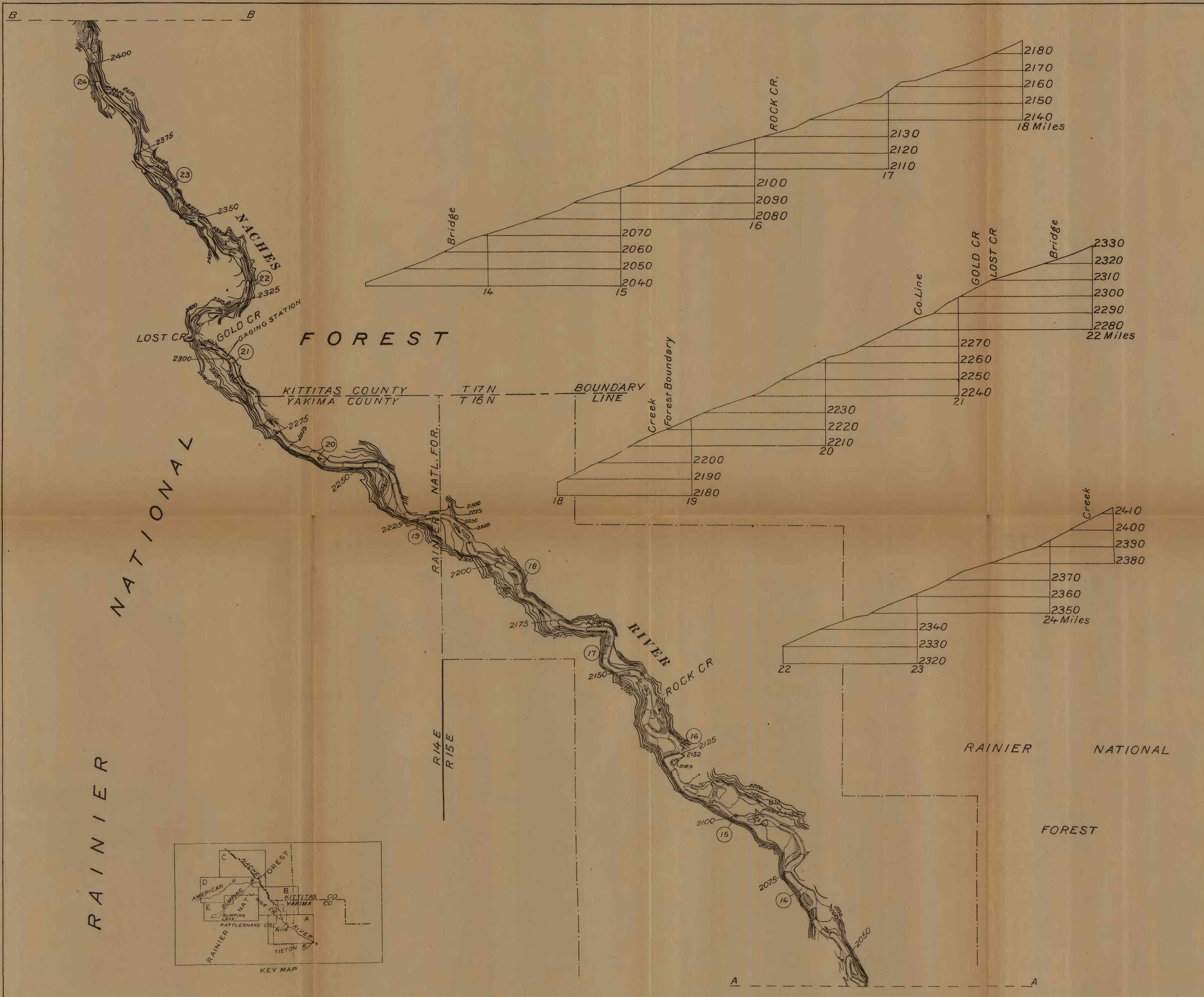
HENRY LANDES, STATE GEOLOGIST

PLAN AND PROFILE OF NACHES RIVER
MOUTH OF TIETON TO HEADS OF AMERICAN AND BUMPING RIVERS, WASHINGTON

SHEET B



R. B. Marshall, Chief Geographer
T. G. Gerdine, Geographer in charge
Topography by W. B. Lewis
Surveyed in 1910
SURVEYED IN COOPERATION WITH THE STATE OF WASHINGTON

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Scale $\frac{1}{31,680}$

1 0 1 2 Miles
4,000 2,000 0 4,000 8,000 Feet
1 0 1 2 Kilometers

Vertical scale 1 inch = 40 feet
Contour interval 5 feet
Datum is mean sea level
1915

22½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1911

Subject to adjustment

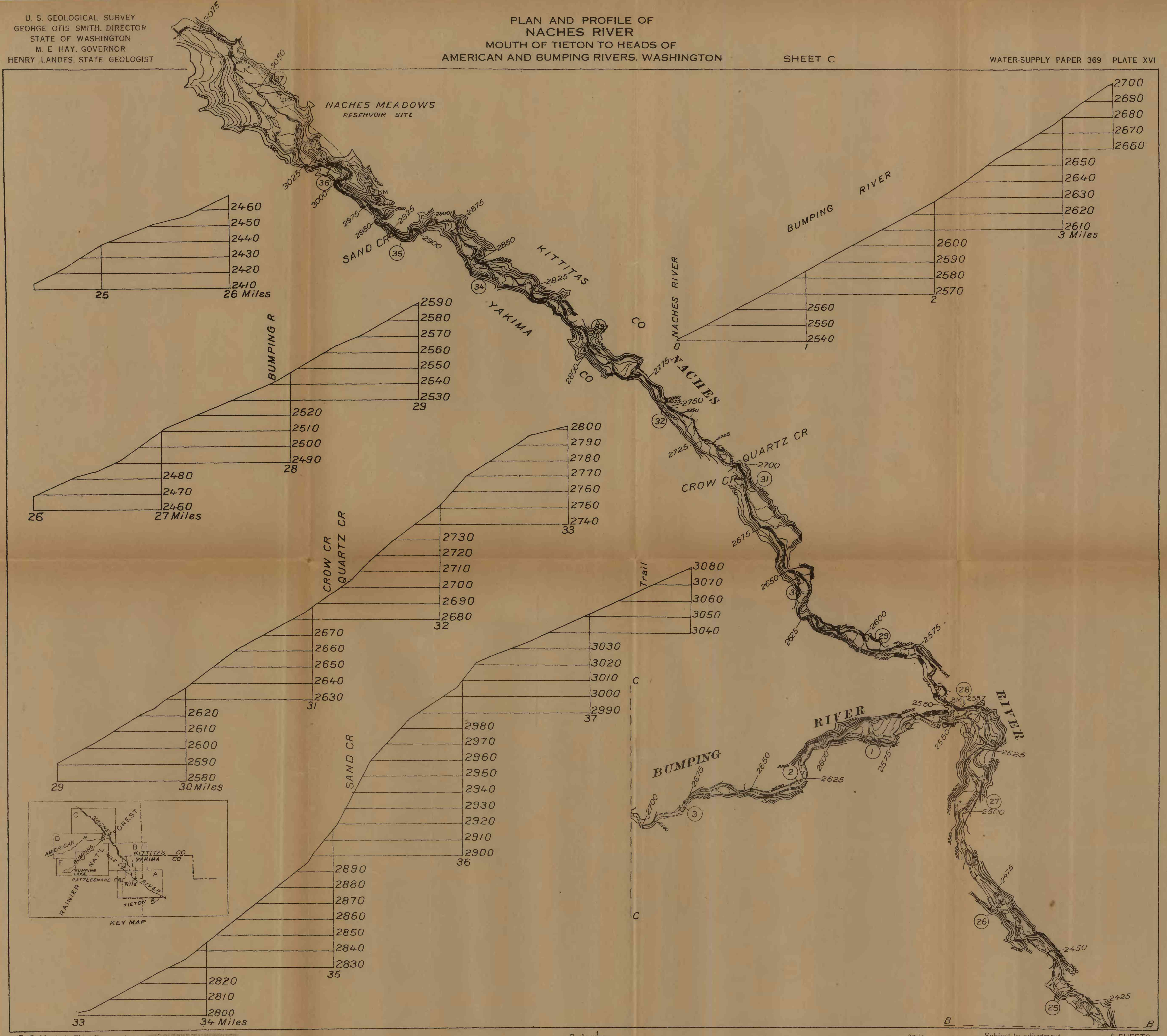
5 SHEETS

House Doc. ; 63d Cong., 2d Sess.

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR
STATE OF WASHINGTON
M. E. HAY, GOVERNOR
HENRY LANDES, STATE GEOLOGIST

PLAN AND PROFILE OF NACHES RIVER
MOUTH OF TIETON TO HEADS OF AMERICAN AND BUMPING RIVERS, WASHINGTON

SHEET C



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APPROXIMATE MEAN DECLINATION 1910

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PLAN AND PROFILE OF NACHES RIVER
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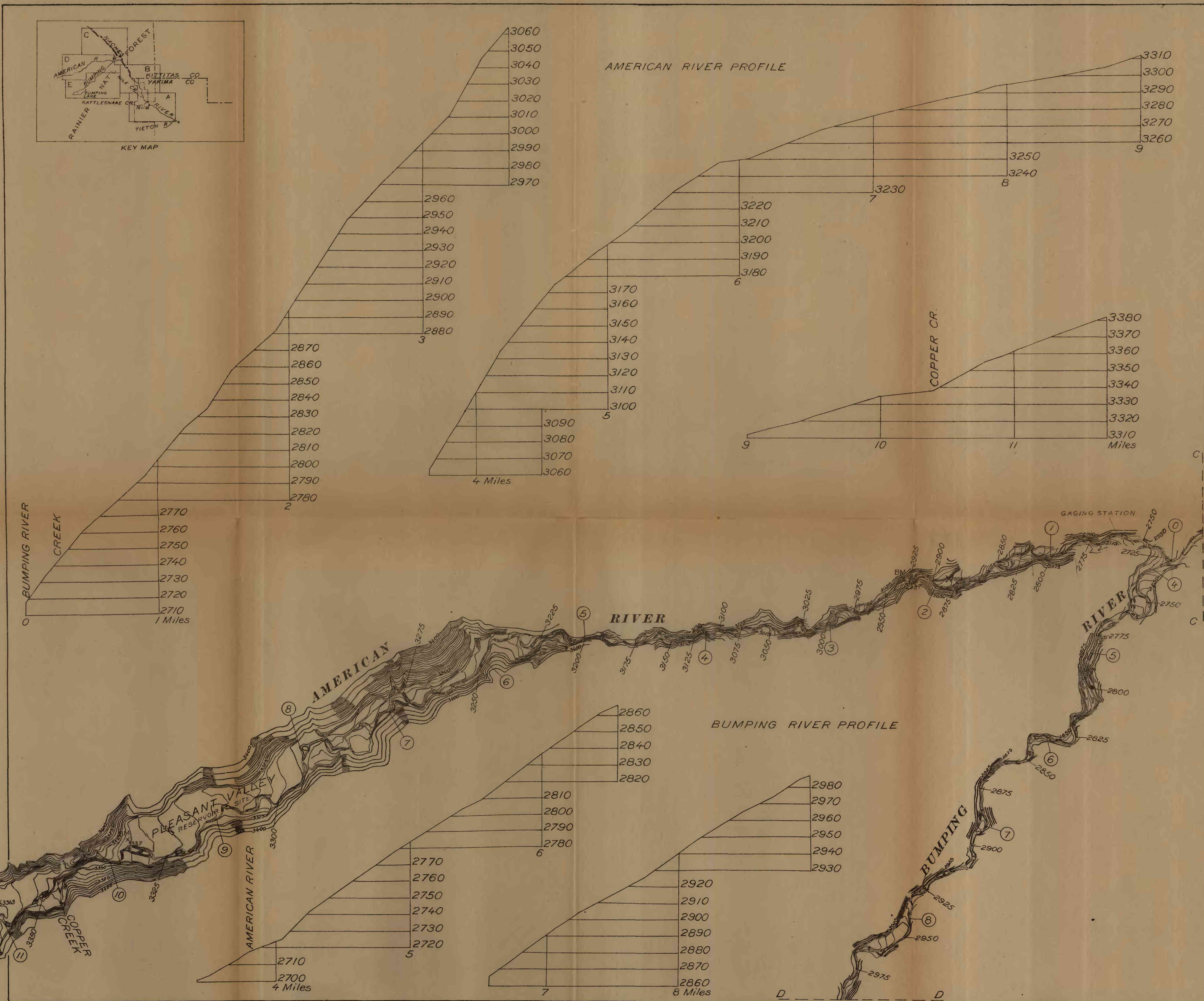
SHEET D



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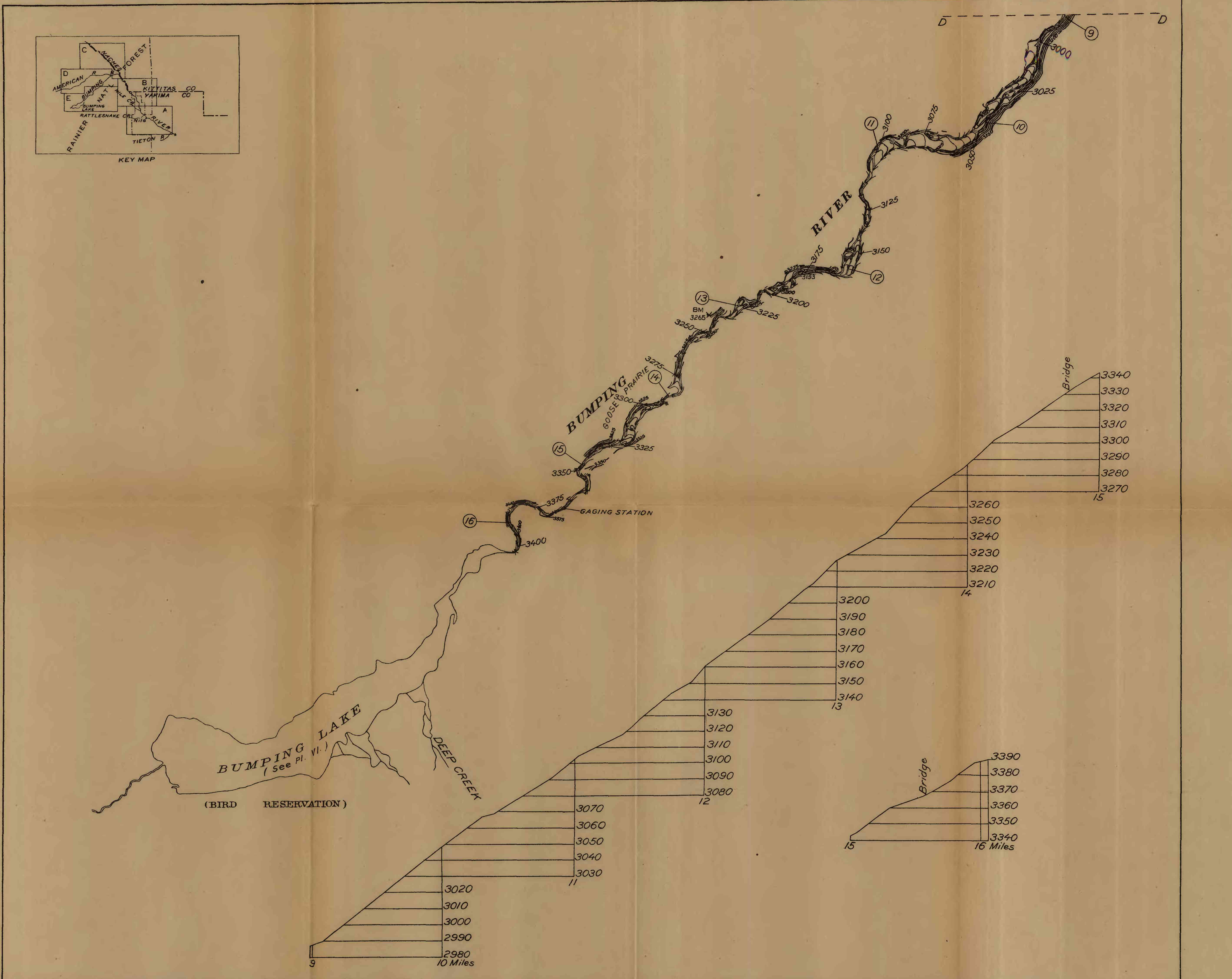
PLAN AND PROFILE OF NACHES RIVER
MOUTH OF TIETON TO HEADS OF AMERICAN AND BUMPING RIVERS, WASHINGTON

SHEET E



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APPROXIMATE MEAN DECLINATION 1911

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U. S. GEOLOGICAL SURVEY
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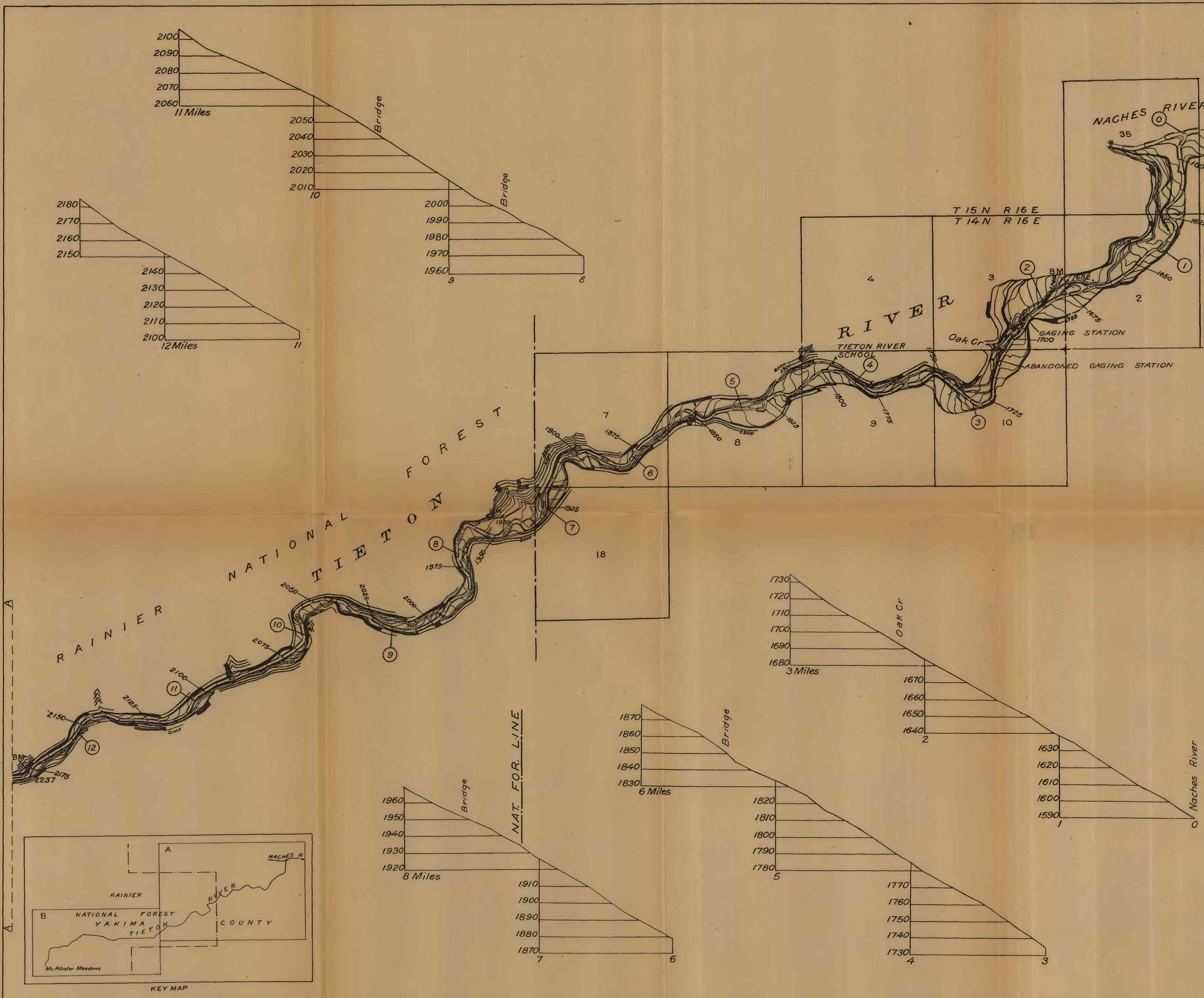
PLAN AND PROFILE OF TIETON RIVER
MOUTH TO McALLISTER MEADOWS, WASHINGTON

SHEET A



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MAGNETIC NORTH
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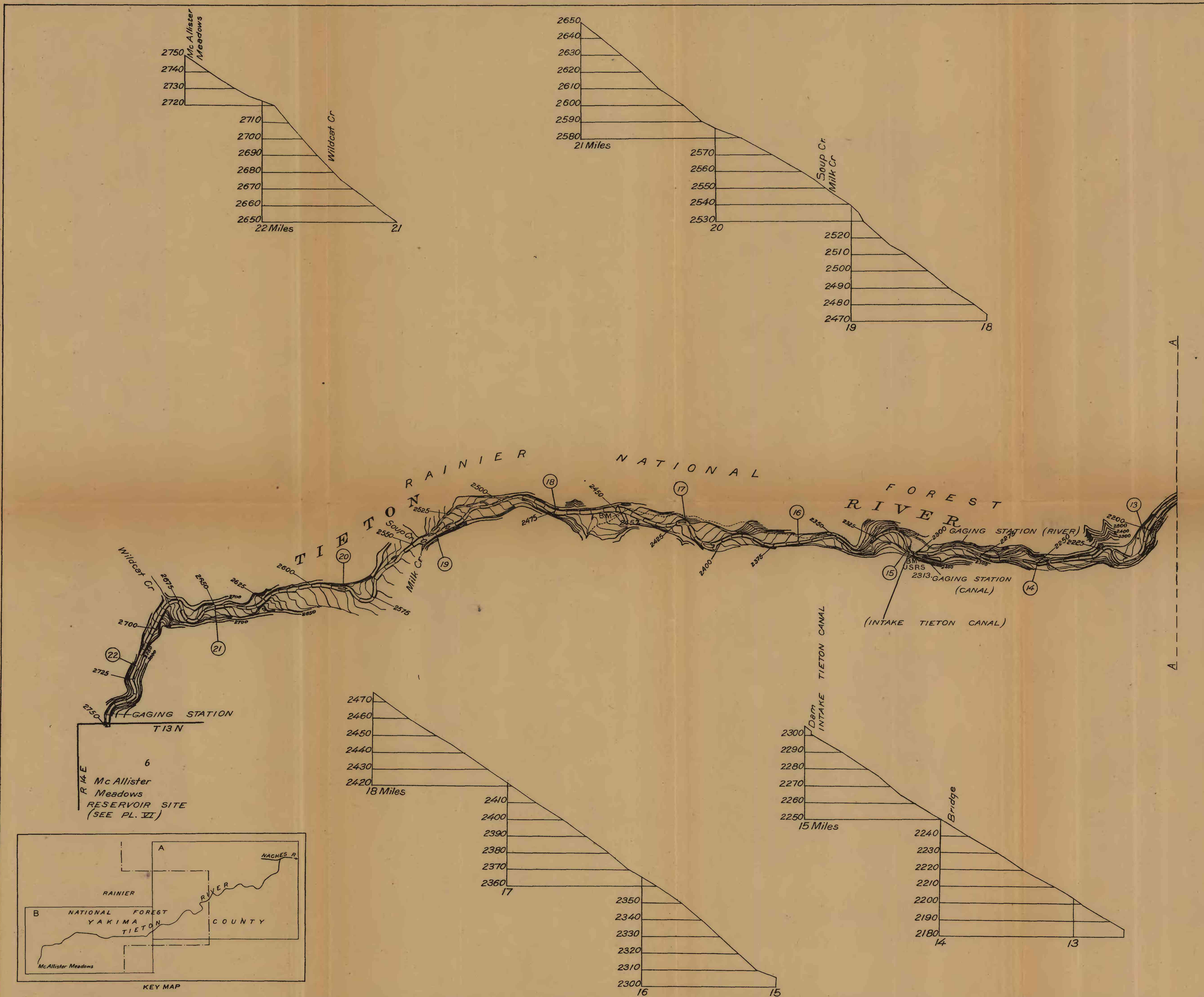
PLAN AND PROFILE OF TIETON RIVER
MOUTH TO Mc ALLISTER MEADOWS, WASHINGTON

SHEET B



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