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DESCHUTES RIVER, OREGON AND ITS UTILIZATION

BY

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AND E. J. McCAUSTLAND

Prepared in cooperation with
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DESCHUTES RIVER, OREGON, AND ITS UTILIZATION.

By F. F. Henshaw, John H. Lewis, and E. J. McCaustland.

INTRODUCTION.

By N. C. Grover.

In several respects Deschutes River is unique among rivers of the United States. Its natural flow is remarkably constant; its headwaters afford reservoir sites sufficiently large and so distributed that the total flow of the river may be utilized both for irrigation and for power; the irrigable lands in the valley, aggregating 300,000 to 500,000 acres, are so situated on a plateau in the upper part of the basin that the total flow of the upper river and its principal tributaries may be utilized for irrigation; and below the irrigable area the river flows in a deep canyon having a fair slope and affording excellent opportunities for power development, a reliable water supply being assured by the return waters from the irrigated areas above and by the lower tributaries of the river. The future use of this exceptional combination of abundant water supply, large area of irrigable land, and great water powers will transform the Deschutes Valley into a region whose agricultural importance will be enhanced by the many hydroelectric plants that will furnish power for local use or for transmission to distant power markets.

The Deschutes is tributary to the Columbia about 15 miles above The Dalles. (See map, Pl. I, p. 20.) The mouth of the river may be reached by boats which navigate the Columbia through the canals and locks at The Dalles and the Cascades. The main line of the Oregon-Washington Railroad & Navigation Co. crosses the Deschutes near its mouth, and the Oregon Trunk Railway (Spokane, Portland & Seattle Railway) and a branch line of the Oregon-Washington Railroad & Navigation Co. traverse the canyon and portions of the upper valley. Good transportation facilities are assured for the principal parts of the basin.

The mouth of the river is about 135 miles from Portland; the shortest distance from Deschutes Canyon to Portland is about 130 miles; and from Cline Falls, at the upper end of the canyon, to Portland the distance is about 180 miles. A power-transmission line 150 to 160

miles long therefore appears to be necessary to connect a power site on Deschutes River with Portland. The length of Deschutes River from Cline Falls to the mouth is about 160 miles, so that a transmission line of that length would connect all the power sites on the river.

The investigations made by Prof. McCaustland, who has prepared the part of this report that pertains to the possibilities of power development on Deschutes River, indicate that, after allowance is made for requirements of irrigation, a total of 600,000 horsepower may be developed. The utilization of the river for power has on one hand been facilitated by the building of the railroads through the canyon, and on the other hand has probably been made more expensive by the placing of the tracks at an elevation only a few feet above high stage of the river. Such construction has forced on the power developments of the future, throughout a large part of the canyon, the expense of relocating and reconstructing the railroads to permit the construction of high dams, or the necessity of designing plants consisting of low dams and conduits leading therefrom to the power houses—a type of development that in general is believed not to be feasible on the Deschutes, because of the narrow canyon, relatively small slope of the river, and the quantity of water to be utilized. Except for three power sites in the lower part of the canyon, which have been passed by the railroads at sufficient elevation to clear proposed dams and flowage, and a section of the upper canyon, which is not traversed by the railroads, the cost of future power developments on the river must include large items for the relocation and reconstruction of the railroads. To make the statement concrete, let us assume that the present roads, where they conflict with power development, cost $50,000 a mile and that they could have been built on the higher grade for $75,000 a mile. The increased cost to provide for power development would then have been $25,000 a mile. Under present conditions, however, power construction must be preceded by reconstruction of the lines at a cost of $75,000 a mile and the present lines must be abandoned. The economic loss is thus the cost of the present lines less the salvage of track. Even assuming that the central Oregon country needs two competing lines up Deschutes River and that no economic waste is involved in this duplication of construction, power development in these sections of the river must always bear this double burden.

The retardation of water-power development effected by this handicap can not be estimated. The railroads are built and in operation. Neither the railroads nor the Federal Government realized at the time the roads were projected the economic significance of water power. The relation of the railroads to Deschutes River can not now be corrected except at large cost, but the situation

presents a great object lesson of the necessity for the careful study of the relation of railroads to waterways and the adjustment of transportation and other economic interests in advance of large expenditures for construction.

A part of the irrigable land in the basin has already been reclaimed under the systems of the companies operating under the Carey Act. The settlement of the lands under these systems has, however, progressed slowly until the recent improvement in the transportation facilities afforded by the railroads rendered successful agriculture possible. The agricultural lands are situated at elevations ranging from 3,000 to more than 4,000 feet above sea level, and consequently the crops are limited in general to forage, hardy vegetables, grains, and small fruits. The soil is, however, good though shallow and in places broken by lava. An abundant water supply makes the prospects of irrigation attractive in spite of the limits imposed on agriculture by the climate. The United States Reclamation Service has joined the State in an investigation of the possibility of irrigating the undeveloped land and in a study of the whole problem of utilizing the river. In advance of this investigation it is of course unwise to estimate the acreage that may ultimately be irrigated by means of the water of the Deschutes.

This report has been prepared in cooperation with the State of Oregon, and the sections on economic distribution of water for power, irrigation, and domestic supplies and water rights and appropriations have been written by John H. Lewis, State engineer. These sections contain statements regarding the present status of laws relating to water-power development that represent Mr. Lewis's personal views on topics concerning which he is peculiarly fitted to speak with authority. His suggestions regarding the policy for future legislation indicate a loyalty to both State and Federal institutions but can not be regarded as representing in all respects the views of the officers of the Federal Government with whom Mr. Lewis is cooperating in this work.

GENERAL FEATURES OF DESCHUTES RIVER BASIN.[1]

THE RIVER.

The conspicuously arid and treeless portion of central Oregon merges on the west into a less arid region drained by Deschutes River, which carries to the Columbia the drainage of an area comprising more than 9,000 square miles, of which more than 6,000 square miles lie on the eastern slope of the Cascades. The annual rainfall in this area ranges from 10 inches along the main course of the stream to

[1] Abstracted in large part from Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, 1905.

100 inches in the summit of the Cascades near which the river has its source in a number of mountain lakes that lie just across the divide from the headwaters of Willamette River. The course of the river is in general northward to the Columbia, which it enters about 15 miles above The Dalles. (See map, Pl. I, p. 20.)

It is a swift-flowing stream of conspicuously clear, greenish-blue water, broken by many rapids and cascades, and is a delight to the beholder on account of its beautiful colors, refreshing coolness, and the picturesque and impressive scenery of its canyon walls. It is also an attraction to the angler, as its waters are abundantly stocked with trout. Salmon ascend its lower portion, but on account of the falls do not reach its upper course.

The flow of the river is more remarkably uniform than that of any other river in the United States comparable with it in size, and its economic value is almost incalculable. At the mouth of the stream the maximum discharge is only six times the minimum. Ocular evidence of this uniformity of flow is presented by the low grass-grown banks between which the river flows for much of its course. From the mouth of Crooked River upstream to Benham Falls, near Lava Butte, a distance of about 50 miles, the variation in the height of the river throughout the year is not more than 8 or perhaps 10 inches where the width is not abnormally restricted. Wooden bridges that cross the river in this part of its course are placed only 2 or 3 feet above its summer-stage surface, and even the amount of space thus afforded beneath their floors is determined by the height of the approaches and not by the fluctuations in the level of the water.

The uniform flow of the stream can not be attributed to forestation, for the only timbered portion of the drainage basin is found on the eastern slope of the Cascades, and the divide between Crooked River and the John Day basin is but sparsely timbered. Indeed the entire supply of timber could be removed without in the least affecting the flow of the river. The reason for the practically constant volume between Benham Falls and the mouth of Crooked River is mainly because the river is bordered throughout a part of its course in this section by cellular lava which receives the waters that would otherwise cause increase of stage.

Although the winter temperatures are low ice does not affect the flow of the streams, for the winter flow is derived largely from springs. The high stages usually occur in July and result from the melting of snows in the mountains, although occasionally floods are caused by chinooks in the early spring or late fall.

The area drained by the Deschutes is rough and mountainous. The agricultural lands consist largely of high table-lands cut by deep canyons, through which the rivers flow, and small areas of arable land that border the streams. The soil is a coarse, disintegrated lava.

The rocks of the entire area are volcanic and are so peculiarly porous that the basin has the effect of a huge sponge. Elevations within the upper basin of the Deschutes range from 3,600 feet above sea level near Bend to about 6,000 feet at the summit of the Cascade Mountains. Prineville is 2,868 feet above sea level, and Paulina, near the upper part of the Crooked River drainage basin, 3,684 feet.

THE TRIBUTARIES.

The principal tributaries of the Deschutes are White, Warm Springs, Metolius, and Crooked rivers and the West Fork of the Deschutes.

The tributaries of the Deschutes above the mouth of Crooked River come mainly from the west and drain the eastern slope of the Cascade Mountains. The most marked exception, in reference to direction of flow, is Paulina Creek, which has its source in Paulina Lake, situated in the summit of an old and deeply eroded volcanic mountain about 35 miles east of the crest of the Cascade Mountains. The Walker Mountains, also situated well to the east of the Cascades, send some tribute to the Deschutes. The streams just referred to, like the tributaries of the main river from the west, flow over a region deeply covered with pumice and are clear and cold.

Crooked River is formed by the outflow from a number of copious warm springs about 10 miles east of Hampton Butte and flows north and west among steep-sided mountains all the way to its junction with the Deschutes, a distance of about 115 miles. In its upper portion, just after leaving the alkaline marsh in which it rises, it receives copious contributions from springs and in its progress rapidly increases in volume, even in late summer, when there is no surface run-off. It is said to receive contributions from other springs at several localities along its course until it nears Prineville. Below that town it diminishes in volume, and in late summer its bed near Forest, about 12 miles below Prineville, is frequently dry. This marked decrease is now due largely to the use of the water of the stream for irrigation in the expanded portion of its canyon below Prineville, but the stream is known to have shown marked seasonal variations even under strictly natural conditions. When the volume of the stream diminishes below Prineville it exhibits the characteristics common to many streams that flow from the uplands of arid regions and suffer absorption and evaporation as they pass through the lower part of their courses where springs are absent. Owing to the absence of saturation at any but great depths, percolation is away from instead of toward the stream channels, and such flow as persists becomes tepid, more or less alkaline, and unwholesome. Another and still more remarkable change occurs down the channel of Crooked River about 10 miles northwest of Forest, where springs of great

volume appear in its bed and along its sides. One of these springs, conspicuous on account of its large volume, is known as Opal Spring, for the reason that in the sands it brings to the surface are kernels and grains of opal derived from the basaltic rock through which its supplying conduit passes. Other springs come in near at hand, and the river quickly becomes a rushing torrent of clear, cool water. This conspicuous instance of copious springs rising in the lower course of a river in an arid region finds its explanation in the depth and wide extent of the loose volcanic débris through which the river has cut its present canyon.

The warm springs feeding Crooked River are of interest not only on account of the use that is now being made of their waters but because they supplement other evidence pointing to the probability that artesian water can be had over a large part of the basin in which they are situated. The springs range in temperature from 60° to 87° F. and are scattered for about 2 miles along a narrow north-south belt. Where the waters of the springs are combined at the outlet of the valley, they make a creek of warm water, the volume of which, by a rough estimate, is between 20 and 25 second-feet. The temperature of the water indicates that it comes from a considerable depth, possibly 2,500 feet.

East of Prineville Crooked River flows westward through a rugged valley in which outcrops of soft material carrying fossils are reported to occur. About 6 miles before reaching the town it traverses a narrow canyon with vertical walls of basalt about 650 feet high. The basalt is in well-defined layers, with scoriaceous surfaces, and at least seven layers are exposed. The stream has not yet cut through the pile of basaltic sheets, although a few miles farther up its course the underlying rocks are exposed.

Less than a mile above Prineville the canyon of Crooked River becomes abruptly wider, and for 6 miles west of that town has a width of 4 or 5 miles, this abrupt increase being due to the presence of soft material beneath the basalt.

For several miles below the town the stream meanders in sweeping curves through the alluvial bottom lands and affords fine illustrations of the behavior of an aggrading stream.

Metolius River rises on the eastern slopes of the Cascade Mountains, in the western part of Cook County, flows northward 18 miles, then turns abruptly southeast and east to its junction with Deschutes River, 6 miles northwest of Haystack. Throughout its course the stream runs in a deep canyon, and its average fall from its headwaters to its confluence with the Deschutes is about 35 feet to the mile. Its flow is derived largely from springs and is well maintained throughout the year. Its water is clear, it carries practically no drift, and the formation of ice will probably never be a disturbing factor in the

operation of power plants along its course. It is quite unlike Deschutes River in its general character and in its possibilities of power development, for sites suitable for the construction of dams of greater height than 20 to 25 feet are found at only a few places along its entire course.

LAKES NEAR SOURCES OF DESCHUTES RIVER.

Near the sources of West Fork of Deschutes River and also at the head of the main stem of the river, sometimes designated the Middle Fork and also locally called Little River, there are beautiful lakes, still surrounded by primeval forests, which furnish instructive examples of water bodies held by dams built by glaciers or formed by lava flows.

On West Fork of Deschutes near its source is Davis Lake, which is retained by a dam of lava. Lieut. T. W. Symons, who visited it in 1878, describes it as follows:[1]

> This lake and valley were about 12 by 6 miles in size and took us completely by surprise, as they were evidently in the course of our West Fork and were not on any map. Reaching it we found at its southern end many acres of rich grass and bunches of tall willows. Following around the west shore to the north end we ascertained that there was no visible outlet. We saw the watermarks 20 feet above us on the lava bluffs of the northern and northwestern shores, and camping beside these in the night we heard strange rumblings in the vast pile.
>
> We found the next day that these lava beds formed an impassable barrier extending unbroken for about 4 miles to the north, and at their end were again surprised to find, foaming out from underneath the giant bowlders, the clear, cold river that we had seen lose itself in the lake 15 miles or more to the south.

On the east side of the Cascade Mountains, near their crest, is Odell Lake, a sheet of clear, cold water, which receives the water from the snow fields on Diamond Peak, the height of which is 8,807 feet.

Situated approximately 4 miles southwest of Odell Lake is Crescent Lake, which is larger and in nearly every way finer than its neighboring water body, and like it is surrounded by beautiful scenery and magnificent forests. This lake is about 4 miles long and 2 miles wide, and its area is not far from 7 square miles. It is retained by a strong, well-defined terminal moraine, which sweeps across the valley in a graceful curve, presenting its concave side to the west, the direction from which came the glacier that built it. The outlet of Crescent Lake is at the north end of the moraine that confines it, where the outflowing waters have cut a gorge of the same character as the one excavated by the stream flowing from Odell Lake.

The width of the stream is 89 feet, and its average depth on September 4, 1903, as shown by 15 measurements, was nine-tenths of a foot. This may safely be taken as its minimum depth during the year.

[1] U. S. Geog. Surveys W. 100th Mer. Ann. Rept., 1879, Appendix B, p. 218.

Crescent Lake, as reported by frontiersmen familiar with it, rises in March and April about 10 inches above its lowest stage, which occurs in September. These statements are in harmony with the evidence furnished by the beaches about the borders of the lake and by the downward limit of vegetation on its shores. Not only is Crescent Lake larger than Odell Lake, but the area of mountainous land draining to it is greater, while the rainfall is essentially the same, each lake receiving some of the precipitation falling on Diamond Peak, the highest elevation in the region.

STREAM FLOW.

By F. F. Henshaw.

DEFINITION OF TERMS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups: (1) Those which represent a rate of flow, as second-feet, gallons per minute, miner's inches, and discharge in second-feet per square mile; and (2) those which represent the actual quantity of water, as run-off in depth in inches, acre-feet, and millions of cubic feet. The units used in this report are second-foot, second-feet per square mile, run-off in inches, acre-foot, and millions of cubic feet. They may be defined as follows:

"Second-foot" is an abbreviation for "cubic foot per second" and is a unit for the rate of discharge of water flowing in a stream. A second-foot is the rate of discharge of water flowing in a channel of rectangular cross section 1 foot wide and 1 foot deep at an average velocity of 1 foot a second. It is generally used as a fundamental unit from which others are computed by the use of the factors given in the tables of convenient equivalents (pp. 17–18).

"Second-foot per square mile" is used as a measure of the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off (depth in inches)" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

An "acre-foot" is equivalent to 43,560 cubic feet and is the quantity that would be required to cover an acre to the depth of 1 foot. The term is commonly used in connection with storage for irrigation.

"Millions of cubic feet" is a unit used to express quantities of water stored in reservoirs, and is most frequently used in studies of flood control.

The following terms used in these reports are not in very common use and may be defined as follows:

"Control," "controlling section," and "point of control" are terms used to designate that cross section of the stream below the gage which controls or regulates the height of the water surface at the gage. It should be noted that the control may not be the same cross section at all stages.

"Discharge relation" is an abbreviation for the term "relation of gage height to discharge."

The "point of zero flow" for a given gaging station is that point on the gage—the gage height—to which the surface of the river would fall if there were no flow.

CONVENIENT EQUIVALENTS.

The following tables furnish convenient equivalents for use in hydraulic computations:

Table for converting discharge in second-feet per square mile into run-off in depth in inches over the area.

Discharge in second-feet per square mile.	Run-off in inches.				
	1 day.	28 days.	29 days.	30 days.	31 days.
1	0.03719	1.041	1.079	1.116	1.153
2	.07438	2.083	2.157	2.231	2.306
3	.11157	3.124	3.236	3.347	3.459
4	.14876	4.165	4.314	4.463	4.612
5	.18595	5.207	5.393	5.578	5.764
6	.22314	6.248	6.471	6.694	6.917
7	.26033	7.289	7.550	7.810	8.070
8	.29752	8.331	8.628	8.926	9.223
9	.33471	9.372	9.707	10.041	10.376

NOTE.—For part of a month multiply the values for one day by the number of days.

Table for converting discharge in second-feet into run-off in acre-feet.

Discharge in second-feet.	Run-off in acre-feet.				
	1 day.	28 days.	29 days.	30 days.	31 days.
1	1.983	55.54	57.52	59.50	61.49
2	3.967	111.1	115.0	119.0	123.0
3	5.950	166.6	172.6	178.5	184.5
4	7.934	222.1	230.1	238.0	246.0
5	9.917	277.7	287.6	297.5	307.4
6	11.90	333.2	345.1	357.0	368.9
7	13.88	388.8	402.6	416.5	430.4
8	15.87	444.3	460.2	476.0	491.9
9	17.85	499.8	517.7	535.5	553.4

NOTE.—For part of a month multiply the values for one day by the number of days.

Table for converting discharge in second-feet into run-off in millions of cubic feet.

Discharge in second-feet.	Run-off in millions of cubic feet.				
	1 day.	28 days.	29 days.	30 days.	31 days.
1	0.0864	2.419	2.506	2.592	2.678
2	.1728	4.838	5.012	5.184	5.356
3	.2592	7.257	7.518	7.776	8.034
4	.3456	9.676	10.024	10.368	10.712
5	.4320	12.095	12.530	12.960	13.390
6	.5184	14.514	15.036	15.552	16.068
7	.6048	16.933	17.542	18.144	18.746
8	.6912	19.352	20.048	20.736	21.424
9	.7776	21.771	22.554	23.328	24.102

NOTE.—For part of a month multiply the values for 1 day by the number of days.

1 second-foot equals 40 California miner's inches (law of March 23, 1901).

1 second-foot equals 38.4 Colorado miner's inches.

1 second-foot equals 40 Arizona miner's inches.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,317 gallons for one day.

1 second-foot for one year covers 1 square mile 1.131 feet or 13.572 inches deep.

1 second-foot for one year equals 31,536,000 cubic feet.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot for one day equals 86,400 cubic feet.

1,000,000,000 (1 United States billion) cubic feet equals 11,570 second-feet for one day.

1,000,000,000 cubic feet equals 414 second-feet for one 28-day month.

1,000,000,000 cubic feet equals 399 second-feet for one 29-day month.

1,000,000,000 cubic feet equals 386 second-feet for one 30-day month.

1,000,000,000 cubic feet equals 373 second-feet for one 31-day month.

100 California miner's inches equals 18.7 United States gallons per second.

100 California miner's inches for one day equals 4.96 acre-feet.

100 Colorado miner's inches equals 2.60 second-feet.

100 Colorado miner's inches equals 19.5 United States gallons per second.

100 Colorado miner's inches for one day equals 5.17 acre-feet.

100 United States gallons per minute equals 0.223 second-foot.

100 United States gallons per minute for one day equals 0.442 acre-foot.

1,000,000 United States gallons per day equals 1.55 second-feet.

1,000,000 United States gallons equals 3.07 acre-feet.

1,000,000 cubic feet equals 22.95 acre-feet.

1 acre-foot equals 325,850 gallons.

1 inch deep on 1 square mile equals 2,323,200 cubic feet.

1 inch deep on 1 square mile equals 0.0737 second-foot per year.

1 foot equals 0.3048 meter.

1 mile equals 1.60935 kilometers.

1 mile equals 5,280 feet.

1 acre equals 0.4047 hectare.

1 acre equals 43,560 square feet.

1 acre equals 209 feet square, nearly.

1 square mile equals 2.59 square kilometers.

1 cubic foot equals 0.0283 cubic meter.

1 cubic foot of water weighs 62.5 pounds.

1 cubic meter per minute equals 0.5886 second-foot.

1 horsepower equals 550 foot-pounds per second.

1 horsepower equals 76.0 kilogram-meters per second.

1 horsepower equals 746 watts.

1 horsepower equals 1 second-foot falling 8.80 feet.

1⅓ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11}$ = net horsepower on water wheel realizing 80 per cent of theoretical power.

ACCURACY AND RELIABILITY OF FIELD DATA AND COMPARATIVE RESULTS.

The accuracy of stream-flow data depends primarily on the natural conditions at the gaging station and on the methods and care with which the data are collected. Errors of the first group depend on the permanency of channel and on the permanency of the relation between discharge and stage. Errors of the second group are due, first, to errors in observation of stage; second, to errors in measurements of flow; and, third, to errors due to misinterpretation of stage and flow data.

The base data for the tables of monthly discharge presented in this report, unless otherwise stated in description of station, have been collected by the methods commonly used at current-meter gaging stations and described in standard textbooks.

In the table of monthly discharge the column headed "Maximum" gives the mean flow, as determined from the rating table, for the day when the mean gage height was highest. As the gage height is the mean for the day, it does not indicate correctly the stage when the water surface was at crest height and the corresponding discharge was consequently larger than given in the maximum column. Likewise, in the column of "Minimum," the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" is the average flow in cubic feet for each second during the month.

The accuracy column in the monthly discharge table does not apply to the maximum or minimum nor to any individual day, but to the monthly mean. It is based on the accuracy of the rating curve, the probable reliability of the observer, the number of gage readings per day, the range of the fluctuation in stage, and knowledge of local conditions. In this column, A indicates that the mean monthly flow is probably accurate within 5 per cent; B, within 10 per cent; C, within 15 per cent; D, within 25 per cent. Special conditions are covered by footnotes.

Even though the monthly means for any station may represent with a high degree of accuracy the quantity of water flowing past the gage, the figures showing discharge per square mile and depth of run-off in inches may be subject to gross errors which result from including in the measured drainage area large noncontributing districts, or omitting estimates of water diverted for irrigation or other use. On

this account the computations of "second-feet per square mile" and "run-off (depth in inches)" are not here published. All values of "second-feet per square mile" and "run-off (depth in inches)" previously published by the Survey should be used with caution.

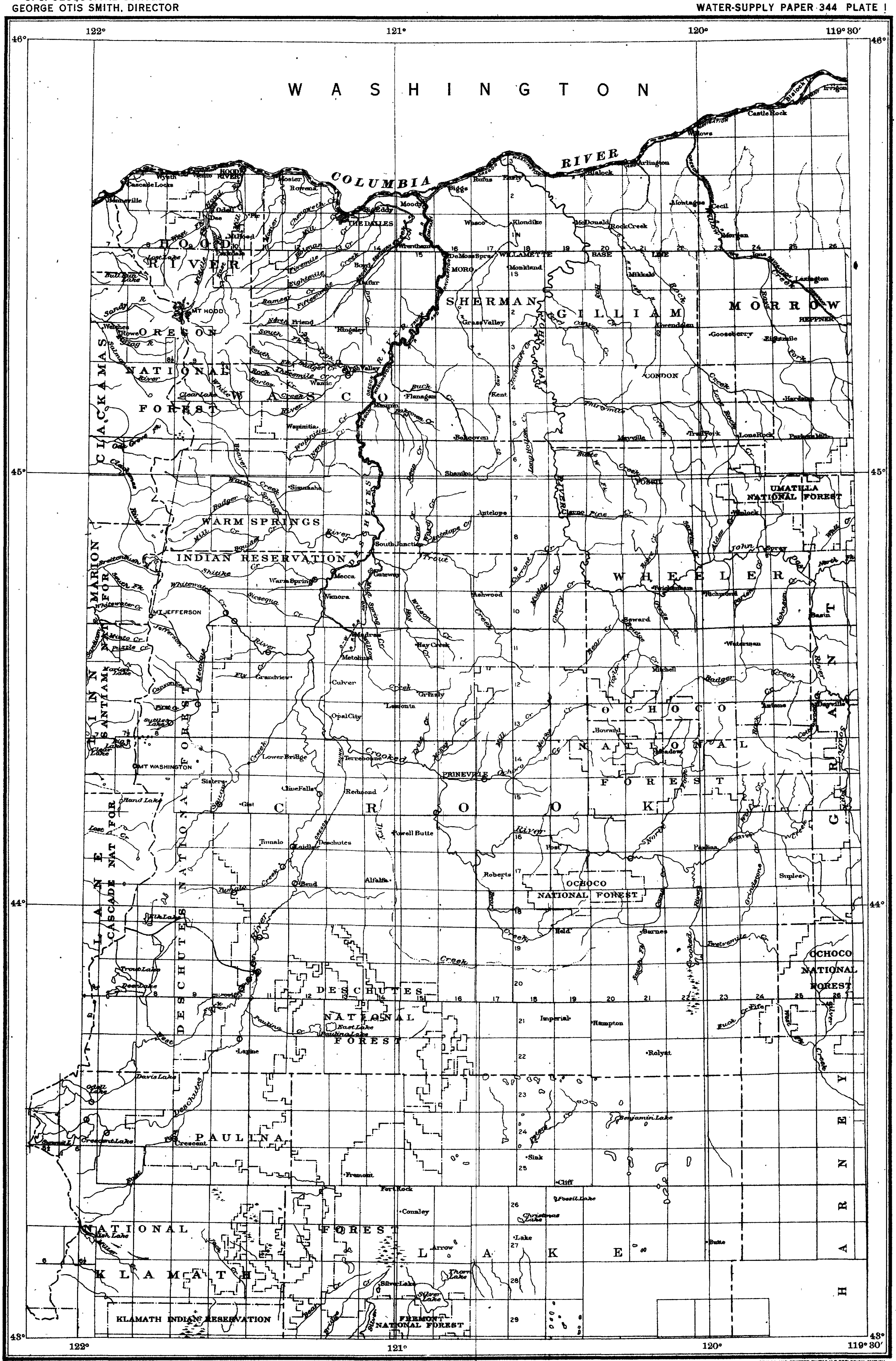
In general, the base data collected each year by the Survey engineers are published not only to comply with the law but also to afford any engineer the means of examining and adjusting to his own needs the results of the computations. The table of monthly discharge is so arranged as to give only a general idea of the flow at the station and should not be used for other than preliminary estimates. The determinations of daily discharge allow more detailed studies of the variation in flow by which the period of deficiency may be determined.

It should be borne in mind that the observations in each succeeding year may be expected to throw new light on data already collected and published, and the engineer who makes use of the figures presented in these papers should verify all ratings and make such adjustments for earlier years as may seem necessary.

GAGING STATIONS.

The following is a list of gaging stations that have been maintained in the Deschutes River basin by the United States Geological Survey and cooperating parties. The stations are arranged in downstream order, stations from source to mouth of the main stem of the river being first listed and then those on the tributaries from source to mouth, the streams in each tributary basin being listed before those of the next basin below. The positions of the gaging stations are indicated on the map, Plate I.

Big Marsh outlet near Crescent, 1912–
Deschutes River near Lapine, 1910–
Deschutes River at Allen's ranch, near Lava, 1905–
Deschutes River at West's ranch, near Lava, 1906–1909.
Deschutes River at Benham Falls, near Bend, 1909–
Deschutes River at Bend, 1904–
Deschutes River at Laidlaw, 1909–1912.
Deschutes River near Cline Falls, 1910–
Deschutes River at Mecca, 1911–
Deschutes River near Moro, 1897–1899.
Deschutes River at Moody (Biggs), 1906–
    Crescent Lake outlet near Crescent, 1912–
    East Fork of Deschutes River near Crescent, 1904–1908; 1910–
    West Fork of Deschutes River near Lapine, 1910–
    West Fork of Deschutes River near Lava, 1905–1907; 1909–
        Odell Lake outlet near Crescent, 1912–
    Tumalo Creek near Laidlaw, 1906–
    Tumalo Creek near Bend, 1906–
    Squaw Creek near Sisters, 1906–



MAP OF DESCHUTES RIVER BASIN, SHOWING POSITION OF GAGING STATIONS

Base from one-millionth scale map of United States now in preparation

o Gaging station

Scale $\frac{1}{1,000,000}$

10 5 0 10 20 30 Miles

10 5 0 10 20 30 Kilometers

1914

Crooked River near Post, 1908–1911.
Crooked River near Prineville, 1908–
Ochoco Creek near Prineville, 1908–1910.
Metolius River at Allingham ranger station, near Sisters, 1910–
Metolius River at Hubbard's ranch, near Grandview, 1910–
Metolius River at Riggs ranch, near Sisters, 1908–1912.
Lake Creek near Sisters, 1911–
Whitewater Creek near Sisters, 1911–
Shitike Creek at Warm Spring, 1911–
Warm Springs River near Warm Spring, 1911–
White River near Tygh Valley, 1911–
Tygh Creek at Tygh Valley, 1911–
Central Oregon canal near Bend, 1905–
Pilot Butte canal near Bend, 1905–
Wimer canal near Sisters, 1906–
Columbia Southern canal near Sisters, 1906–
McAllister's ditch near Sisters, 1909–

PUBLICATIONS.

The results of stream-measurement work in the Deschutes River basin have appeared in the following reports of the United States Geological Survey: Nineteenth Annual Report, Part IV; Twentieth Annual Report, Part IV; Twenty-first Annual Report, Part IV, Water-Supply Papers 16, 28, 38, 39, 51, 66, 75, 85, 100, 135, 178, 214, 252, 272, 292, 312,[1] 332,[1] 362.[1]

STATION RECORDS.

BIG MARSH OUTLET NEAR CRESCENT, OREG

Location.—At Hoey's (formerly Royce's) ranch, known as Dellcrest, one-fourth mile above junction with Crescent Lake outlet, 14 miles west of Crescent, Oreg., in NE. ¼ sec. 20, T. 24 S., R. 7 E.
Records available.—April 8 to December 31, 1912.
Drainage area.—50 square miles.
Gage.—Vertical staff driven into stream bed on right bank.
Channel.—Cemented gravel; permanent.
Discharge measurements.—Made from private wagon bridge or by wading.
Winter flow.—Materially affected by ice for several weeks.
Accuracy.—Results uncertain for high stage on account of missing gage readings and lack of flood measurements. Low-water estimates are excellent.

Monthly discharge of Big Marsh outlet, near Crescent, Oreg., for 1912.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
April	165	97	122	7,260	B.
May	297	170	246	15,100	B.
June	297	186	263	15,600	C.
July	180	50	94.2	5,790	B.
August	50	35	44.0	2,710	A.
September	50	35	38.4	2,280	A.
October	50	28	35.5	2,180	A.
November	99	35	68.3	4,060	A.
December	50	35	44.9	2,760	B.
The period				57,700	

[1] In preparation as this report goes to press.

DESCHUTES RIVER NEAR LAPINE, OREG.

Location.—At the Rosland ranger station, 1¼ miles below the wagon bridge at Rosland, in sec. 2, T. 22 S., R. 10 E.

Records available.—September 22, 1910, to December 31, 1912; incomplete.

Drainage area.—Not measured.

Gage.—Vertical staff. During 1910 a staff on highway bridge was read.

Channel.—Sand and clay; not likely to shift.

Discharge measurements.—Made from the downstream rail of the highway bridge at Rosland, 1¼ miles above the gage, or by wading.

Winter flow.—Materially affected by ice.

Accuracy.—Open-channel curve well defined.

Cooperation.—Gage readings have been furnished by the United States Forest Service.

Monthly discharge of Deschutes River, near Lapine, Oreg., for 1910–1912.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1910.					
September 22-30	131	112	118	2,110	A.
October	192	113	137	8,420	A.
November	330	114	184	10,900	A.
December	386	165	255	15,700	B.
1911.					
April	470	218	301	17,900	A.
August	158	114	130	7,990	A.
1912.					
March	232	156	185	11,400	A.
April	338	182	268	15,900	A.
May	700	356	540	33,200	B.
June	760	500	668	39,700	C.
July	480	222	339	20,800	C.
August	218	158	185	11,400	A.
September	194	138	157	9,340	A.
The period				142,000	

DESCHUTES RIVER AT ALLEN'S RANCH, NEAR LAVA, OREG.

Location.—In the SW. ¼ SW. ¼ sec. 8, T. 20 S., R. 11 E., on C. B. Allen's ranch, about 1 mile north of Lava, Oreg., and about half a mile above the mouth of West Fork of Deschutes River, 18 miles south of Bend.

Records available.—February 17, 1905, to January 4, 1908; March 1, 1908, to May 4, 1912.

Drainage area.—Indeterminate.

Gage.—Inclined staff on east bank of river; datum remained unchanged until 1912; readings for that year refer to a datum 0.10 foot higher than previously.

Channel.—Clay; considerable growth of weeds during summer months.

Discharge measurements.—Made from a cable about 50 feet below the gage.

Winter flow.—Gage heights are rather seriously affected by ice during the winter months.

Accuracy.—Records are not so accurate as they should be, owing to weeds that grow in the river in the vicinity of the station during the summer months, and to possible shifting of the channel.

Monthly discharge of Deschutes River at Allen's ranch, near Lava, Oreg., for 1905–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
February 17–28	368	262	306	7,280	B.
March	382	283	319	19,600	B.
April	317	242	274	16,300	B.
May	317	252	278	17,100	B.
June	294	205	241	14,300	B.
July	196	115	141	8,670	C.
August	125	93	107	6,580	C.
September	97	89	90.9	5,410	C.
The period				95,200	
1905–6.					
October	115	97	100	6,150	C.
November	102	79	90.6	5,390	B.
December	115	82	99.2	6,100	B.
January	223	120	166	10,200	D.
February	160	97	123	6,830	C.
March	180	106	136	8,360	C.
April	544	147	332	19,800	C.
May	559	329	445	27,400	B.
June	483	294	369	22,000	B.
July	294	141	220	13,500	C.
August	135	106	122	7,500	C.
September	120	102	108	6,430	C.
The year	559	79	193	140,000	
1906–7.					
October	115	97	103	6,330	C.
November	188	89	137	8,150	C.
December	205	115	144	8,850	B.
January	329	115	220	13,500	D.
February	1,890	329	793	44,000	C.
March	513	242	345	21,200	B.
April	770	294	570	33,900	B.
May	810	608	696	42,800	B.
June	676	410	558	33,200	C.
July	410	252	330	20,300	C.
August	252	205	227	14,000	D.
September	223	173	196	11,700	D.
The year	1,890	89	360	258,000	
1907–8.					
October	173	154	161	9,900	D.
November	188	141	157	9,340	D.
December	624	160	287	17,600	D.
January			[a] 300	18,400	D.
February			[a] 170	9,780	D.
March	485	154	271	16,700	B.
April	687	223	407	24,200	B.
May	592	283	416	25,600	B.
June	452	262	339	20,200	B.
July	294	180	254	15,600	C.
August	166	125	139	8,550	C.
September	242	120	141	8,390	C.
The year			254	184,000	
1908–9.					
October	340	115	174	10,700	B.
November	262	154	180	10,700	B.
December	214	160	180	11,100	C.
January			[a] 150	9,220	D.
February			[a] 200	11,100	D.
March	262	173	203	12,500	C.
April	498	205	355	21,100	C.
May	559	329	458	28,200	C.
June	575	355	488	29,000	C.
July	329	196	264	16,200	D.
August	188	141	160	9,840	D.
September	166	130	143	8,510	D.
The year			246	178,000	

[a] Estimated.

Monthly discharge of Deschutes River at Allen's ranch, near Lava, Oreg., for 1905–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1909–10.					
October	141	120	130	7,990	D.
November	2,150	115	556	33,100	C.
December	1,310	439	748	46,000	D.
January	.....	.....	[a] 350	21,500	D.
February	.....	.....	[a] 350	19,400	D.
March	1,030	528	712	43,800	C.
April	591	468	502	29,900	C.
May	658	382	516	31,700	C.
June	368	223	289	17,200	C.
July	223	160	185	11,400	D.
August	154	135	142	8,730	D.
September	147	125	132	7,860	D.
The year	.....	.....	384	279,000	
1910–11.					
October	173	115	138	8,480	C.
November	272	115	162	9,640	C.
December	468	135	229	14,100	C.
January	.....	.....	[b] 150	9,220	C.
February	.....	.....	[b] 170	9,440	D.
March	196	147	174	10,700	C.
April	410	188	256	15,200	C.
May	528	382	416	25,600	C.
June	559	355	487	29,000	C.
July	382	147	226	13,900	C.
August	141	106	125	7,690	D.
September	160	110	128	7,620	D.
The year	.....	.....	222	161,000	
1911–12.					
October	141	106	118	7,260	C.
November	223	97	143	8,510	C.
December	147	97	114	7,010	C.
January	355	108	240	14,800	C.
February	565	195	299	17,200	B.
March	245	152	179	11,000	B.
April	380	165	270	16,100	B.
The period	.....	.....	.....	81,900	

[a] Estimated.
[b] Estimated from measurement of Jan. 22 and studies of discharge at other stations.

NOTE.—Corrections have been made for effect of ice during the periods Jan. 1 to Feb. 28 and Dec. 23 to 26, 1909; Jan. 1 to Feb. 28 and Mar. 5, 1910; Jan. 1 to Mar. 13 and Dec. 22 to 31, 1911; Jan. 1 to Mar. 7, 1912. It is probable that there was considerable ice in 1905 to 1908, but no adequate notes were made as to its existence. The estimates for winter periods are very uncertain, and for the earlier years are undoubtedly too high.

DESCHUTES RIVER AT WEST'S RANCH AND AT BENHAM FALLS, NEAR BEND, OREG.

Location.—In the NE. ¼ sec. 16, T. 19 S., R. 11 E., about 250 yards above Benham Falls and 14 miles above Bend, above the more important irrigation diversions from Deschutes River, and just below the dam site of the proposed Benham Falls reservoir, since March 20, 1909.

Records available.—July 21, 1906, to December 31, 1912. As this record has been used as basis for all studies of the possibilities of power and irrigation development on Deschutes River between West Fork and Crooked and Metolius rivers, it has been extended by the aid of the records at Bend and West's ranch and made continuous from January 1, 1905, to December 31, 1912.

Drainage area.—Not measured.

Gage.—Vertical staff driven into edge of stream on right bank. Some uncertainty at times in regard to the maintenance of the gage datum. July 21, 1906, to February 20, 1909, vertical staff in the SW. ¼ sec. 31, T. 19 S., R. 11 E., at West's ranch, about 7 miles, by river, above Benham Falls.

Channel.—Sandy; may shift slightly. Considerable growth of weeds along the right bank.

Discharge measurements.—Made from standard car and cable.

Winter flow.—Not materially affected by ice.

Diversions.—The diversion of water by some small ditches that are taken out above this station has no appreciable effect on discharge.

Accuracy.—Rating curve well defined. Some uncertainty as to effect of weeds.

Cooperation.—Station maintained in cooperation with the Central Oregon Irrigation Co.

Monthly discharge of Deschutes River at Benham Falls, near Bend, Oreg., for 1904–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1904–5.					
October to December				360,000	D.
January	2,700	2,080	2,240	138,000	A.
February	2,380	1,920	2,160	120,000	A.
March	2,260	2,080	2,160	133,000	A.
April	2,260	1,920	2,070	123,000	B.
May	2,220	1,880	2,010	124,000	B.
June	1,890	1,730	1,810	108,000	A.
July	1,750	1,630	1,710	105,000	A.
August	1,740	1,490	1,620	99,600	A.
September	1,640	1,590	1,620	96,400	A.
The year				1,410,000	
1905–6.					
October	1,660	1,530	1,620	99,600	A.
November	1,620	1,470	1,560	92,800	B.
December	1,370	1,080	1,290	79,300	A.
January	1,450	1,200	1,360	83,600	A.
February	1,410	1,240	1,330	73,900	A.
March	1,550	1,250	1,360	83,600	A.
April	1,880	1,530	1,710	102,000	B.
May	1,920	1,700	1,840	113,000	B.
June	1,920	1,650	1,770	105,000	B.
July	1,680	1,430	1,560	95,900	B.
August	1,430	1,360	1,410	86,700	A.
September	1,400	1,360	1,370	81,500	A.
The year	1,920	1,080	1,520	1,100,000	
1906–7.					
October	1,360	1,290	1,320	81,200	A.
November	1,510	1,290	1,370	81,500	A.
December	1,510	1,320	1,390	85,500	A.
January	1,610	1,160	1,390	85,500	B.
February	4,000	1,520	2,300	128,000	B.
March	2,060	1,610	1,750	108,000	B.
April	2,500	1,680	2,170	129,000	B.
May	2,680	2,430	2,510	154,000	B.
June	2,540	2,120	2,350	140,000	B.
July	2,120	1,900	2,020	124,000	B.
August	1,900	1,800	1,860	114,000	B.
September	1,850	1,700	1,770	105,000	B.
The year	4,000	1,160	1,850	1,340,000	
1907–8.					
October	1,700	1,590	1,630	100,000	B.
November	1,700	1,520	1,580	94,000	B.
December	2,560	1,480	1,770	109,000	B.
January	2,060	1,390	1,700	105,000	B.
February	1,520	1,280	1,440	82,800	B.
March	1,960	1,350	1,600	98,400	B.
April	2,230	1,560	1,880	112,000	B.
May	2,120	1,850	2,030	125,000	B.
June	2,180	1,850	2,000	119,000	B.
July	2,010	1,750	1,890	116,000	B.
August	1,750	1,660	1,680	103,000	B.
September	1,660	1,560	1,620	96,400	B.
The year	2,560	1,280	1,740	1,260,000	

Monthly discharge of Deschutes River at Benham Falls, near Bend, Oreg., for 1904–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
October	1,900	1,560	1,660	102,000	B.
November	1,700	1,520	1,570	93,400	B.
December	1,520	1,170	1,430	87,900	B.
January	2,280	1,280	1,650	101,000	B.
February	1,750	1,520	1,620	90,000	B.
March	1,750	1,520	1,570	96,500	A.
April	1,800	1,590	1,720	102,000	A.
May	1,870	1,690	1,790	110,000	A.
June	1,870	1,690	1,790	107,000	A.
July	1,690	1,530	1,600	98,400	A.
August	1,560	1,510	1,530	94,100	A.
September	1,560	1,500	1,520	90,400	A.
The year	2,280	1,170	1,620	1,170,000	
1909–10.					
October	1,530	1,430	1,480	91,000	A.
November	4,760	1,400	2,040	121,000	B.
December	2,610	1,530	1,930	119,000	B.
January	1,740	1,330	1,530	94,100	A.
February	1,880	1,420	1,590	88,300	A.
March	2,380	1,950	2,090	129,000	A.
April	2,020	1,880	1,950	116,000	A.
May	2,090	1,840	1,980	122,000	A.
June	1,840	1,670	1,750	104,000	A.
July	1,670	1,570	1,610	99,000	A.
August	1,570	1,510	1,540	94,700	A.
September	1,510	1,480	1,500	89,300	A.
The year	4,760	1,330	1,750	1,270,000	
1910–11.					
October	1,540	1,420	1,470	90,400	A.
November	1,600	1,420	1,490	88,700	A.
December	1,780	1,420	1,560	95,900	A.
January	1,540	1,180	1,420	87,300	A.
February	1,420	1,240	1,360	75,500	B.
March	1,540	1,240	1,400	86,100	A.
April	1,670	1,480	1,570	93,400	A.
May	1,740	1,600	1,670	103,000	A.
June	1,740	1,600	1,710	102,000	A.
July	1,600	1,420	1,500	92,200	A.
August	1,420	1,360	1,380	84,800	B.
September	1,480	1,360	1,390	82,700	B.
The year	1,780	1,180	1,490	1,080,000	
1911–12.					
October	1,420	1,300	1,360	83,600	B.
November	1,480	1,300	1,380	82,100	B.
December	1,360	1,180	1,280	78,700	B.
January	1,500	1,000	1,380	84,800	B.
February	1,780	1,430	1,560	89,700	A.
March	1,500	1,360	1,430	87,900	A.
April	1,710	1,430	1,590	94,600	A.
May	2,100	1,710	1,890	116,000	A.
June	2,260	1,980	2,150	128,000	A.
July	1,940	1,710	1,800	111,000	A.
August	1,780	1,640	1,690	104,000	A.
September	1,710	1,640	1,670	99,400	A.
The year	2,260	1,000	1,600	1,160,000	
1912.					
October	1,640	1,570	1,590	97,800	A.
November	1,780	1,500	1,620	96,400	A.
December	1,570	1,360	1,500	92,200	A.

NOTE.—Monthly discharge for October, November, and December, 1904, estimated at 120,000 acre-feet per month. Monthly discharge, January, 1905, to July, 1906, and February and March, 1909, determined by adding the discharge of Central Oregon and Pilot Butte canals to that of Deschutes River at Bend.

DESCHUTES RIVER AT BEND, OREG.

Location.—In the NE. ¼ sec. 32, T. 17 S., R. 12 E., just below the power house of the Bend Electric Light & Power Co. at city pumping plant, Bend, Oreg., 1 mile above the diversion dam of the North canal of the Central Oregon Irrigation Co.

Records available.—December 22, 1904, to March 30, 1907, at Sizemore's bridge, in sec. 5, T. 18 S., R. 12 E.; April 23, 1907, to October 8, 1910, and April 11 to December 31, 1912, at gage below power house; October 1, 1910, to April 10, 1912, at gage above dam.

Drainage area.—Indeterminate.

Gage.—Vertical staff nailed to pier of bridge over pond, near right bank, above dam, zero level with crest; at pumping plant, vertical staff bolted to a bowlder; at Sizemore's bridge (prior to 1907), vertical staff spiked to bent.

Channel.—Broad crested weir, actual length 224.6 feet, broken by 19 piers; at pumping plant and cable, very rough and rocky but permanent; at Sizemore's bridge, wide and shallow, broken by pile bents.

Discharge measurements.—April, 1907, to February, 1912, from Staat's bridge, three-fourths mile above pumping station and Bend dam; conditions unfavorable. After August, 1912, from cable and car 40 feet above pumping plant gage. Prior to 1907 from Sizemore's bridge.

Winter flow.—Unaffected by ice.

Diversions.—The Pilot Butte and Central Oregon canals of the Central Oregon Irrigation Co. divert water 5 miles by river above the present gage and measuring section, and have been operated since 1905. Arnold canal, which takes out at the head of Lava Island Falls (Pl. VI, *B*, p. 80), 9 miles above, has been operated only during 1912. No other diversions of any consequence. No storage yet developed.

Accuracy.—The records covering the period January 1, 1905, to June 30, 1906, and January 1, 1909, to December 31, 1912, are good and at times excellent.

Cooperation.—Gage heights since 1907 have been furnished gratis by C. A. Stanburrough, engineer of the pumping plant.

Monthly discharge of Deschutes River at Bend, Oreg., for 1905–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
January	2,700	2,080	2,240	138,000	A.
February	2,380	1,920	2,160	120,000	A.
March	2,220	2,080	2,130	131,000	A.
April	2,220	1,920	2,060	123,000	A.
May	2,220	1,780	1,960	121,000	A.
June	1,780	1,630	1,720	102,000	A.
July	1,630	1,630	1,630	100,000	A.
August	1,630	1,490	1,530	94,100	A.
September	1,490	1,490	1,490	88,700	A.
The period				1,020,000	
1905–6.					
October	1,490	1,490	1,490	91,600	A.
November	1,490	1,350	1,430	85,100	B.
December	1,320	1,070	1,210	74,400	A.
January	1,450	1,190	1,310	80,600	A.
February	1,320	1,190	1,270	70,500	A.
March	1,450	1,190	1,320	81,200	A.
April	1,730	1,450	1,610	95,800	B.
May	1,740	1,600	1,700	105,000	B.
June	1,740	1,460	1,590	94,600	B.
The period				779,000	

Monthly discharge of Deschutes River at Bend, Oreg., for 1905–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1909.					
January	1,900	1,160	1,560	95,900	B.
February	1,720	1,400	1,550	86,100	B.
March	1,550	1,380	1,440	88,500	B.
April	1,570	1,420	1,510	89,800	B.
May	1,600	1,340	1,450	89,200	B.
June	1,640	1,260	1,420	84,500	B.
July	1,600	1,100	1,340	82,400	B.
August	1,230	1,040	1,090	67,000	B.
September	1,240	1,120	1,180	70,200	B.
The period				754,000	
1909–10.					
October	1,340	1,200	1,240	76,200	B.
November	4,760	1,330	2,070	123,000	B.
December	3,330	1,530	2,030	125,000	C.
January	1,810	1,330	1,640	101,000	A.
February	1,740	1,440	1,590	88,300	A.
March	2,650	2,020	2,290	141,000	A.
April	2,100	1,810	1,890	112,000	A.
May	2,020	1,490	1,720	106,000	A.
June	1,740	1,230	1,360	80,900	A.
July	1,230	1,050	1,130	69,500	A.
August	1,440	1,050	1,210	74,400	A.
September	1,330	1,050	1,160	69,000	A.
The year	4,760	1,050	1,610	1,170,000	
1910–11.					
October	1,240	1,160	1,200	73,800	A.
November	1,580	1,170	1,420	84,500	A.
December	1,660	1,360	1,470	90,400	A.
January	1,440	1,170	1,330	81,800	B.
February	1,440	1,240	1,330	73,900	A.
March	1,510	1,170	1,340	82,400	A.
April	1,510	1,240	1,360	80,900	A.
May	1,370	1,170	1,310	80,600	A.
June	1,730	1,170	1,270	75,600	A.
July	1,170	910	1,050	64,600	A.
August	1,370	850	918	56,400	A.
September	1,240	910	1,050	62,500	A.
The year	1,730	850	1,250	907,000	
1911–12.					
October	1,240	975	1,130	69,500	A.
November	1,510	1,040	1,310	78,000	A.
December	1,370	1,040	1,260	77,500	A.
January	1,660	1,150	1,380	84,800	B.
February	1,880	1,240	1,510	86,900	A.
March	1,510	1,170	1,360	83,600	A.
April	1,730	1,270	1,430	85,100	A.
May	1,940	1,420	1,580	97,200	A.
June	2,150	1,540	1,690	101,000	A.
July	1,730	1,190	1,310	80,600	A.
August	1,270	1,150	1,210	74,400	A.
September	1,470	1,250	1,400	83,300	A.
The year	2,150	975	1,380	1,000,000	
1912.					
October	1,480	1,290	1,390	85,500	A.
November	1,660	1,370	1,490	88,700	A.
December	1,730	1,370	1,570	96,500	A.

DESCHUTES RIVER AT LAIDLAW, OREG.

Location.—In the NE. ¼ sec. 31, T. 16 S., R. 12 E., at the highway bridge in Laidlaw, 9 miles by river below Bend, 3 miles below Tumalo Creek, and below all diversions of any consequence.

Records available.—January 1, 1909, to October 15, 1912. Records prior to July, 1910, are questionable.

Drainage area.—Indeterminate.

Gage.—Vertical staff at old highway bridge at Laidlaw.

Channel.—Gravel. Permanent control. There are two channels at the gage, about two-thirds of the flow passing in the right channel, in which the gage is placed. The channel divides about 200 feet above the bridge.

Discharge measurements.—From wagon bridge, 1½ miles above gage in the SE. ¼ sec. 6, T. 17 S., R. 12 E.

Winter flow.—Probably some ice effect in extremely cold weather.

Diversions.—In addition to the diversions above the Bend station, two small canals divert between Bend and Laidlaw; records not corrected for diversion.

Accuracy.—Fair; measuring conditions unsatisfactory; low-water estimates probably too high.

Monthly discharge of Deschutes River at Laidlaw, Oreg., for 1910–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1910.					
July 8–31	1,270	1,140	1,200	57,100	B.
August	1,440	1,100	1,260	77,500	B.
September	1,440	1,140	1,240	73,800	B.
The period				208,000	
1910–11.					
October	1,330	1,240	1,290	79,300	B.
November	1,760	1,270	1,550	92,200	B.
December	1,830	1,510	1,630	100,000	B.
January	1,580	1,440	1,500	92,200	B.
February	1,580	1,370	1,470	81,600	B.
March	1,730	1,300	1,490	91,600	B.
April	1,660	1,370	1,470	87,500	B.
May	1,510	1,330	1,420	87,300	B.
June	1,890	1,270	1,480	88,100	B.
July	1,370	930	1,140	69,500	B.
August	1,370	897	949	58,400	B.
September	1,170	930	1,080	64,300	B.
The year	1,890	897	1,370	992,000	
1911–12.					
October	1,300	1,140	1,180	72,600	B.
November	1,510	1,140	1,360	80,900	B.
December	1,510	1,240	1,390	85,500	B.
January	1,730	1,210	1,500	92,200	B.
Febraury	1,890	1,370	1,620	93,200	B.
March	1,580	1,300	1,470	90,400	B.
April	1,730	1,300	1,520	90,400	B.
May	1,890	1,580	1,690	104,000	B.
June	2,060	1,660	1,870	111,000	B.
July	1,730	1,240	1,410	86,700	B.
August	1,300	1,170	1,230	75,600	B.
September	1,440	1,270	1,360	80,900	B.
The year	2,060	1,660	1,470	1,060,000	
1912.					
October 1–15	1,330	1,300	1,300	38,700	B.

DESCHUTES RIVER NEAR CLINE FALLS, OREG.

Location.—In sec. 13, T. 15 S., R. 12 E., 12 miles below Laidlaw, about 4 miles west of Redmond, and 1½ miles southwest of Cline Falls.

Records available.—February 15, 1910, to March 4, 1911; February 20 to December 31, 1912.

Drainage area.—Indeterminate.

Gage.—Vertical staff on right bank.

Channel.—Sand, gravel, and bowlders; some moss grows on the bottom; practically permanent.

Winter flow.—Not materially affected by ice.

Discharge measurements.—Made from a boat which is operated on a taut wire stretched across the stream near the gage.

Diversions.—Same as Laidlaw station. Apparent decrease in discharge between the two stations may be due to seepage of water into the river bed or to inaccuracies in the Laidlaw record.

Accuracy.—A well-developed curve makes the results very reliable.

Monthly discharge of Deschutes River near Cline Falls, Oreg., for 1910–1912.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1910.					
February 15–28	1,600	1,460	1,580	43,900	A.
March	2,480	1,820	2,100	129,000	B.
April	1,820	1,670	1,740	104,000	A.
May	1,900	1,390	1,710	105,000	A.
June	1,820	1,160	1,310	78,000	A.
July	1,160	1,020	1,090	67,000	A.
August	1,270	974	1,110	68,200	A.
September	1,160	974	1,050	62,500	A.
The period				658,000	
1910–11.					
October	1,110	1,020	1,070	65,800	A.
November	1,530	1,060	1,350	80,300	A.
December	1,600	1,270	1,380	84,800	A.
January	1,330	1,160	1,250	76,900	A.
February	1,270	1,110	1,220	67,800	A.
March 1–4			1,190	9,440	A.
The period				385,000	
1912.					
February 19–29	1,670	1,270	1,440	31,300	A.
March	1,330	1,060	1,200	73,800	A.
April	1,460	1,060	1,270	75,600	A.
May	1,740	1,270	1,430	87,900	A.
June	1,820	1,530	1,670	99,400	A.
July	1,530	1,060	1,220	75,000	A.
August	1,160	1,040	1,090	67,000	A.
September	1,250	1,140	1,200	71,400	A.
The period				581,000	
1912.					
October	1,250	1,110	1,190	73,200	A.
November	1,500	1,220	1,330	79,100	A.
December	1,530	1,270	1,430	87,900	A.

DESCHUTES RIVER AT MECCA, OREG.

Location.—In the SW. ¼ sec. 20, T. 9 S., R. 13 E., at ferry at Mecca, 1½ miles below mouth of Shitike Creek, and 12 miles above mouth of Warm Springs River.

Records available.—June 7, 1911, to December 31, 1912.

Drainage area.—Not measured.

Gage.—Vertical staff fastened to tree on right bank, 100 yards above Government ferry.

Channel.—Rock and heavy gravel; practically permanent.

Discharge measurements.—Made from car on ferry cable.

Winter flow.—Not affected by ice.

Diversions.—The flow at this station is affected by same diversions from upper Deschutes River as the Laidlaw and Cline Falls stations. The summer flow of Crooked River is practically all diverted.

Accuracy.—Results are excellent.

Cooperation.—Station is maintained at expense of Office of Indian Affairs.

Monthly discharge of Deschutes River at Mecca, Oreg., for 1911–12.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
June 7–30	5,260	4,540	4,880	232,000	A.
July	4,720	4,040	4,360	268,000	A.
August	4,200	3,880	4,050	249,000	A.
September	4,200	4,040	4,150	247,000	A.
1911–12.					
October	4,200	3,880	4,090	251,000	A.
November	4,540	3,880	4,210	251,000	A.
December	4,370	4,200	4,300	264,000	A.
January	6,800	3,300	5,050	311,000	A.
February	8,490	4,900	5,940	342,000	A.
March	5,830	4,900	5,200	320,000	A.
April	7,410	5,830	6,460	384,000	A.
May	8,270	6,400	7,100	437,000	A.
June	6,800	5,450	6,020	358,000	A.
July	6,210	4,370	4,850	298,000	A.
August	5,080	4,370	4,550	280,000	A.
September	4,720	4,370	4,520	269,000	A.
The year	8,490	3,300	5,190	3,760,000	
1912.					
October	4,900	4,200	4,390	270,000	A.
November	5,260	4,370	4,770	284,000	A.
December	5,080	4,540	4,670	287,000	A.

DESCHUTES RIVER AT MOODY, NEAR BIGGS, OREG.

Location.—In the SE. ¼ sec. 26, T. 2 N., R. 15 E., 1 mile below Moody railroad station, 1¼ miles above the bridge of the Oregon-Washington Railroad & Navigation Co., about 5 miles southwest of Biggs, Oreg., and 1½ miles above the mouth of the river.

Records available.—Records for 1908 and 1910 somewhat fragmentary; July 7, 1906, to December 31, 1912; October 19, 1897, to December 31, 1899, for a station near Moro, 10 miles above the mouth of the river, in NE. ¼ sec. 5, T. 1 S., R. 16 E.

Drainage area.—About 9,180 square miles; south and east limits of basin poorly defined.

Gage.—Staff in two sections—the lower inclined, the upper vertical. At the Moro station the gage was an inclined staff.

Discharge measurements.—Made from a cable about 450 feet above the gage. At Moro station, made from the "free bridge," 3 miles below the gage.

Diversions.—The summer discharge at this station has been progressively reduced since about 1904 or 1905 by diversions from the upper river. Some of this water returns, but the net reduction during midsummer is now probably 10 or 15 per cent.

Accuracy.—An excellent rating curve has been developed; records are good except when the gage-height record is fragmentary. During such periods the discharge has been estimated from studies of the records.

Monthly discharge of Deschutes River at Moody, near Biggs, Oreg., for 1897–1899 and 1906–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1897–98.					
October 19–31	6,260	6,030	6,100	157,000	B.
November	8,880	6,030	6,900	411,000	B.
December	11,700	6,260	8,090	497,000	B.
January	8,320	6,260	6,830	420,000	B.
February	10,800	6,500	8,040	447,000	B.
March	8,320	6,030	7,130	438,000	B.
April	8,880	6,030	7,670	456,000	B.
May	7,780	6,740	7,240	445,000	B.
June	7,510	6,030	6,680	397,000	B.
July	6,740	5,350	5,740	353,000	B.
August	5,570	5,130	5,280	325,000	B.
September	5,350	4,920	5,170	308,000	B.
The period	.....	.....	.....	4,650,000	
1898–99.					
October	5,130	4,710	4,960	305,000	C.
November	7,250	4,920	5,680	338,000	B.
December	5,800	4,100	5,040	310,000	C.
January	11,700	4,300	6,390	393,000	C.
February	14,400	4,710	7,720	429,000	B.
March	16,000	6,740	8,090	497,000	B.
April	14,100	7,780	11,000	655,000	B.
May	12,600	8,880	10,600	652,000	B.
June	11,400	9,720	10,700	637,000	B.
July	9,720	7,250	8,700	535,000	B.
August	7,250	6,260	6,840	421,000	B.
September	7,250	5,800	6,500	387,000	B.
The year	16,000	4,100	7,680	5,560,000	
1899.					
October	8,880	5,800	6,460	397,000	B.
November	11,700	6,500	7,340	437,000	B.
December	11,700	8,880	10,000	615,000	B.
1906.					
July 22–31	5,360	5,360	5,360	106,000	A.
August	5,360	5,360	5,360	330,000	A.
September	5,080	5,080	5,080	302,000	A.
1906–7.					
October	5,850	5,080	5,180	319,000	A.
November	12,200	5,220	7,290	434,000	A.
December	9,420	5,820	6,720	413,000	A.
January	11,600	5,980	6,720	413,000	A.
February	30,600	7,040	13,900	772,000	A.
March	15,500	7,530	9,590	590,000	A.
April	14,200	8,050	11,900	708,000	A.
May	10,600	8,100	8,950	550,000	A.
June	8,000	6,680	7,250	431,000	A.
July	6,680	5,660	6,230	383,000	A.
August	5,820	5,660	5,670	349,000	A.
September	5,660	5,660	5,660	337,000	A.
The year	30,600	5,080	7,920	5,700,000	
1907–8.					
October	5,660	5,660	5,660	348,000	A.
November	7,800	5,660	5,980	356,000	A.
December	22,200	6,080	8,720	536,000	A.
January	8,000	6,150	7,420	456,000	A.
February	6,150	5,980	6,110	351,000	A.
March	15,800	6,000	8,600	529,000	B.
April	10,100	7,420	8,510	506,000	A.
May	8,420	6,790	7,340	451,000	A.
June	.....	.....	6,500	387,000	B.
July	.....	.....	6,000	369,000	B.
August	.....	.....	5,400	332,000	B.
September	.....	.....	5,300	315,000	B.
The year	.....	.....	6,800	4,940,000	

NOTE.—Discharges for March, 1908, and June to October, 1908, estimated from comparison with West's ranch.

Monthly discharge of Deschutes River at Moody, near Biggs, Oreg., for 1897–1899 and 1906–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
October	.....	.....	5,300	326,000	B.
November	.....	.....	5,970	355,000	B.
December	5,960	5,510	5,710	351,000	A.
January	14,200	5,660	7,470	459,000	B.
February	11,700	5,790	7,180	399,000	A.
March	10,300	6,680	7,520	462,000	A.
April	9,420	7,800	8,390	499,000	A.
May	8,000	6,320	7,040	433,000	A.
June	8,200	5,870	6,760	402,000	A.
July	5,880	5,360	5,580	343,000	A.
August	5,510	5,080	5,260	323,000	A.
September	5,510	5,080	5,360	319,000	A.
The year	.....	.....	6,460	4,670,000	
1909–10.					
October	5,570	5,510	5,540	341,000	A.
November	26,000	5,570	9,380	558,000	A.
December	12,700	8,200	8,710	536,000	A.
January	18,400	7,400	9,420	579,000	B.
February	15,000	7,040	8,110	450,000	B.
March	26,900	9,320	14,300	879,000	B.
April	.....	.....	8,740	520,000	B.
May	.....	.....	7,960	489,000	B.
June	.....	.....	6,320	376,000	B.
July	.....	.....	5,400	332,000	B.
August	.....	.....	5,180	319,000	B.
September	.....	.....	5,230	311,000	B.
The year	.....	.....	7,860	5,690,000	
1910–11.					
October	.....	.....	5,290	325,000	B.
November	.....	.....	6,300	375,000	B.
December	.....	.....	6,820	419,000	B.
January	7,800	5,360	6,350	390,000	C.
February	5,980	5,360	5,710	317,000	A.
March	10,300	5,360	7,210	443,000	A.
April	10,800	6,320	7,450	443,000	A.
May	7,420	6,320	6,810	419,000	A.
June	7,040	5,660	6,380	380,000	A.
July	5,660	4,820	5,260	323,000	A.
August	5,080	4,820	4,850	298,000	A.
September	5,080	4,820	4,930	293,000	A.
The year	.....	.....	6,110	4,420,000	
1911–12.					
October	5,080	4,820	4,990	307,000	A.
November	6,680	4,820	5,440	324,000	A.
December	5,660	5,080	5,340	328,000	A.
January	17,900	4,080	7,940	488,000	A.
February	15,200	7,420	9,720	559,000	A.
March	7,800	6,320	6,920	425,000	A.
April	11,700	7,800	9,550	568,000	A.
May	10,800	8,600	9,770	601,000	A.
June	10,300	5,660	7,980	475,000	A.
July	6,320	5,660	5,910	363,000	A.
August	5,660	5,360	5,390	331,000	A.
September	5,980	5,360	5,520	328,000	A.
The year	17,900	4,080	7,040	5,100,000	
1912.					
October	5,660	5,360	5,480	337,000	A.
November	7,040	5,660	6,030	359,000	A.
December	7,800	5,660	6,000	369,000	A.

NOTE.—The monthly means for April to December, 1910, were obtained from comparison with the discharges of upper Deschutes River and its tributaries. The results obtained in different ways are so consistent that they can not be much in error.

CRESCENT LAKE OUTLET NEAR CRESCENT, OREG.

Location.—At highway bridge about 3 miles below the lake and 3 miles above the Hoey ranch; until September 30, 1912, at lake outlet, sec. 11, T. 24 S., R. 6 E.

Records available.—August 2 to September 6, 1911; January 1 to December 31, 1912, weekly readings.

Drainage area.—55 square miles.

Gage.—Vertical staff at both points.

Channel.—Gravel; not likely to shift; some drift logs jammed at gage section at lake.

Discharge measurements.—Made by wading near the gage.

Winter flow.—Probably unaffected by ice.

Cooperation.—Station has been maintained in cooperation with Hunter Land Co.

Monthly discharge of Crescent Lake outlet near Crescent, Oreg., for 1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
January	78	45	60.6	3,730	C.
February	89	46	66.9	3,850	C.
March	.....	.....	35.0	2,150	C.
April	45	27	37.4	2,230	B.
May	124	45	67.6	4,160	C.
June	181	124	153	9,100	C.
July	149	120	134	8,240	B.
August	119	58	77.0	4,730	B.
September	73	54	62.1	3,700	B.
October	78	60	71.7	4,410	B,
November	.....	.....	78.0	4,640	B.
December	.....	.....	78.4	4,820	B.
The year	.....	.....	76.8	55,800	

EAST FORK OF DESCHUTES RIVER AT CRESCENT, OREG.

Location.—In the NE. ¼ SW. ¼ sec. 30, T. 24 S., R. 9 E. Willamette meridian, at the wagon bridge at Crescent, Oreg., 5 miles above mouth of East Fork.

Records available.—December 25, 1904, to March 31, 1908, and September 25, 1910, to December 31, 1912.

Drainage area.—179 square miles.

Gage.—Vertical staff spiked to a pile supporting the bridge on upstream side.

Channel.—Coarse gravel; practically permanent except at infrequent floods.

Discharge measurements.—Made by wading or from the wagon bridge to which the gage is nailed.

Winter flow.—Stage materially affected by ice.

Accuracy.—Results good except during periods of ice and extreme floods.

Cooperation.—Station maintained in cooperation with the United States Forest Service.

Monthly discharge of East Fork of Deschutes River at Crescent, Oreg., for 1905–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
January	131	60	76.6	4,710	C.
February	104	41	74.0	4,110	B.
March	92	60	64.7	3,980	A.
April	81	60	65.4	3,890	A.
May	92	70	74.7	4,590	A.
June	76	46	62.8	3,740	A.
July	76	19	35.1	2,160	A.
August	36	25	28.0	1,720	A.
September	31	25	25.5	1,520	A.
The period				30,400	
1905–6.					
October	41	28	31.9	1,960	A.
November	41	10	23.7	1,410	B.
December	41	10	23.6	1,450	C.
January	146	24	88.8	5,460	C.
February	146	72	97.3	5,400	C.
March	110	49	80.8	4,970	B.
April	140	49	89.3	5,310	B.
May	174	81	124	7,620	B.
June	146	90	111	6,600	B.
July	100	42	65.2	4,010	B.
August	49	30	37.1	2,280	B.
September	49	30	36.2	2,150	B.
The year	174	10	67.4	48,600	
1906–7.					
October	60	30	35.4	2,180	B.
November	76	30	52.1	3,100	B.
December	68	42	51.8	3,190	C.
January	174	64	89.7	5,520	C.
February	395	110	183	10,200	C.
March	174	90	104	6,400	B.
April	245	81	184	10,900	B.
May	245	146	195	12,000	C.
June	216	90	151	8,980	B.
July	110	49	76.5	4,700	B.
August	56	42	47.5	2,920	B.
September	42	42	42.0	2,500	B.
The year	395	30	101	72,600	
1907–8.					
October	42	33	35.5	2,180	B.
November	52	33	35.2	2,090	B.
December	160	33	68.9	4,240	C.
January	81	46	58.1	3,570	C.
February	100	52	70.8	4,070	B.
March	100	36	60.9	3,740	B.
The period				19,900	
1910–11.					
October	56	32	35.7	2,200	B.
November	121	32	50.5	3,000	B.
December	110	43	57.0	3,500	C.
January	76	40	51.0	3,140	C.
February	81	30	67.1	3,730	B.
March	121	56	87.1	5,360	B.
April	90	56	74.3	4,420	B.
May	133	81	105	6,460	B.
June	188	81	139	8,270	B.
July	81	37	54.2	3,330	B.
August	37	34	35.8	2,200	B.
September	40	32	34.4	2,050	B.
The year	188	30	65.9	47,700	
1911–12.					
October	37	34	35.5	2,180	B.
November	.....	.....	44.3	2,640	C.
December	.....	.....	35.3	2,170	C.
January	.....	.....	.....	.....	.....
February 11–29	122	54	75.6	2,850	C.
March	54	38	46.2	2,840	B.
April	127	54	81.3	4,840	B.

Monthly discharge of East Fork of Deschutes River at Crescent, Oreg., for 1905–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911–12.					
May	300	94	212	13,000	C.
June	320	152	248	14,800	C.
July	146	61	87.5	5,380	B.
August	61	47	51.8	3,190	B.
September	69	41	46.5	2,770	B.
The period				56,700	
1912.					
October	50	41	42.1	2,590	B.
November	69	41	47.4	2,820	B.
December	43	20	29.7	1,830	C.

WEST FORK OF DESCHUTES RIVER NEAR LAPINE, OREG.

Location.—At Forest Service bridge in the NW. ¼ sec. 26, T. 20 S., R. 10 E., 4 miles above mouth, and 11 miles north of Lapine, Oreg.

Records available.—September 21 to December 21, 1910; February 18 to November 30, 1912.

Drainage area.—About 495 square miles.

Gage.—Vertical staff nailed to bent of bridge.

Channel.—Gravel and sand; probably permanent; tortuous; gradient low.

Discharge measurements.—Made from upper side of bridge.

Winter flow.—Never affected by ice.

Accuracy.—Results excellent.

Cooperation.—Gage readings furnished by United States Forest Service.

Monthly discharge of West Fork of Deschutes River near Lapine, Oreg., for 1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
February 18–29	1,060	910	960	22,800	A.
March	910	890	894	55,000	A.
April	1,030	910	952	56,600	A.
May	1,150	965	1,060	65,200	A.
June	1,250	1,150	1,210	72,000	A.
July	1,200	1,150	1,170	71,900	B.
August			1,200	73,800	A.
September			1,220	72,600	A.
October	1,200	1,150	1,170	71,900	A.
November	1,200	1,100	1,140	67,800	A.
The period				630,000	

WEST FORK OF DESCHUTES RIVER NEAR LAVA, OREG.

Location.—In the NE. ¼ sec. 24, T. 20 S., R. 10 E., about 1½ miles west of the former post office of Lava, 1½ miles above the junction with Deschutes River, or Little River, as it is locally known above the mouth of West Fork.

Records available.—February 20, 1905, to April 14, 1907; April 23, 1909, to January 21, 1911; February 23 to May 3, 1912.

Drainage area.—About 500 square miles.

Gage.—Inclined staff on right bank.

Channel.—Gravel, with some vegetation at the edges; effect not appreciable. Practically permanent, but backwater from the Deschutes may extend up to gage when that river is relatively high.

Discharge measurements.—Made from cable and car 100 yards below the gage.

Winter flow.—Never any ice in this stream.

Accuracy.—Results are good, with only slight uncertainties due to effect of backwater.

Monthly discharge of West Fork of Deschutes River near Lava, Oreg., for 1905–1911.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
February 20–28	1,130	1,100	1,120	20,000	A.
March	1,150	1,080	1,120	68,900	A.
April	1,100	1,060	1,070	63,700	A.
May	1,080	1,060	1,060	65,200	A.
June	1,060	1,020	1,030	61,300	A.
July	1,010	974	988	60,800	A.
August	962	962	962	59,200	A.
September	974	916	934	55,600	A.
The period				455,000	
1905–6.					
October	962	916	934	57,400	A.
November	904	870	890	53,000	A.
December	916	836	862	53,000	A.
January	916	814	836	51,400	A.
February	847	803	812	45,100	A.
March	858	781	814	50,100	A.
April	916	870	895	53,300	B.
May	960	890	926	56,900	B.
June	996	910	956	56,900	B.
July	950	939	947	58,200	A.
August	950	928	943	58,000	A.
September	962	916	928	55,200	A.
The year	996	781	895	649,000	
1906–7.					
October	939	904	924	56,800	A.
November	939	893	908	54,000	A.
December	939	847	899	55,300	A.
January	1,060	870	946	58,200	A.
February	1,060	939	990	55,000	B.
March	1,100	920	970	59,600	A.
April	1,080	1,020	1,040	61,900	A.
The period				401,000	
1909.					
April 23–30	960	940	950	15,100	A.
May	1,050	956	985	60,600	A.
June	1,080	1,000	1,040	61,900	A.
July	1,090	1,040	1,060	65,200	A.
August	1,060	1,050	1,060	65,200	A.
September	1,070	1,030	1,050	62,500	A.
The period				330,000	
1909–10.					
October	1,030	1,010	1,020	62,700	A.
November	1,700	985	1,160	69,000	A.
December	1,430	1,000	1,140	70,100	A.
January			1,030	63,300	B.
February	1,060	1,010	1,020	56,600	B.
March	1,250	1,140	1,210	74,400	B.
April	1,220	1,160	1,180	70,200	B.
May	1,280	1,200	1,220	75,000	B.
June	1,200	1,140	1,160	69,000	A.
July	1,150	1,130	1,140	70,100	A.
August	1,130	1,100	1,110	68,200	A.
September	1,100	1,060	1,080	64,300	A.
The year			1,120	813,000	
1910–11.					
October	1,060	996	1,030	63,300	A.
November	1,080	985	1,020	60,700	A.
December	1,080	963	1,000	61,500	A.
January 1–21	962	939	941	39,200	A.

ODELL LAKE OUTLET NEAR CRESCENT, OREG.

Location.—In sec. 26, T. 23 S., R. 6 E., about 18 miles from Crescent and 6 miles from Hoey's ranch.

Records available.—August 5 to September 18, 1911; January 5 to September 28, 1912; occasional readings.

Drainage area.—48 square miles.

Gage.—Vertical staff 500 feet below outlet; datum poorly maintained at times.

Channel.—Clean gravel; practically permanent.

Discharge measurements.—Made by wading near the gage.

Winter flow.—Probably unaffected by ice.

Accuracy.—On account of few gage readings, lack of measurements at high stages, and uncertainties of gage datum, results are only approximate.

Cooperation.—Gage readings furnished by United States Forest Service.

Monthly discharge of Odell Lake outlet near Crescent, Oreg., for 1912.

Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).	Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).
January	120	7,380	July	110	6,760
February	160	9,200	August	56	3,440
March	70	4,300	September	70	4,170
April	70	4,170			
May	150	9,220	The period		62,900
June	240	14,300			

TUMALO CREEK NEAR LAIDLAW, OREG.

Location.—In sec. 3, T. 18 S., R. 10 E. Willamette meridian; 300 feet above intake of Wimer ditch, about 1½ miles above intake of Columbia Southern canal, and 15 miles from Laidlaw.

Records available.—May 15, 1906, to December 31, 1912, irrigating season only; records during winter kept at lower station near Bend.

Drainage area.—48 square miles.

Gage.—Vertical staff; present gage installed April 20, 1910. During 1906 and 1907 gage was located in sec. 2, half a mile above headgate of Columbia Southern canal and below Wimer canal.

Channel.—Gravel and large rocks; fairly permanent.

Discharge measurements.—Made from a foot log or by wading.

Winter flow.—Practically no records during winter period.

Diversions.—Present station is above all diversions; earlier station was below intake of Wimer canal, discharge of which has been added to give the total for the creek.

Accuracy.—Rating curve well defined; open-channel estimates close.

Cooperation.—Station maintained in cooperation with Columbia Southern Irrigation Co.

Monthly discharge of Tumalo Creek near Laidlaw, Oreg., for 1906–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1906.					
May 15–31	450	140	218	7,350	B.
June	393	136	244	14,500	B.
July	424	103	210	12,900	B.
August	91	78	82.0	5,040	C.
September	108	78	79.9	4,910	C.
The period	.....	.....	.....	44,700	
1906–7.					
October	237	80	102	6,270	B.
November	820	118	242	14,400	C.
December	182	109	145	8,920	B.
January	.....	109	120	7,380	C.
February	442	128	206	11,400	B.
March	182	128	151	9,280	B.
April	166	109	141	8,390	B.
May	438	166	271	16,700	A.
June	457	162	313	18,600	B.
July	386	151	265	16,300	B.
August	189	90	112	6,890	B.
September	111	88	98.4	5,860	B.
The year	.....	80	181	130,000	
1907–8.					
October	100	84	89.0	5,470	B.
November	86	62	74.5	4,430	B.
December	142	62	86.0	5,290	B.
January	152	78	90.1	5,540	C.
February	163	70	97.8	5,630	C.
March	132	62	88.5	5,440	B.
April	203	84	127	7,560	A.
May	192	118	156	9,590	A.
June	462	170	285	17,000	A.
July	400	118	264	16,200	A.
August	110	84	90.1	5,540	A.
September	84	84	84.0	5,000	A.
The year	462	62	128	92,700	
1908–9.					
October	180	84	94.6	5,820	A.
November	98	50	80.0	4,760	C.
December	78	62	69.7	4,290	C.
January	93	68	78.7	4,840	B.
February	83	75	77.2	4,290	B.
March	80	73	75.9	4,670	B.
April	.....	.....	91.1	5,420	C.
May	277	134	169	10,400	A.
June	440	184	265	15,800	A.
July	226	105	152	9,350	A.
August	108	82	90.8	5,580	A.
September	118	78	83.3	4,960	A.
The year	.....	.....	111	80,200	
1909–10.					
October	89	78	79.5	4,890	A.
November	.....	.....	240	14,300	C.
December	.....	.....	177	10,900	C.
January	.....	.....	115	7,070	C.
February	.....	.....	97.4	5,410	C.
March	.....	.....	148	9,100	C.
April	268	.....	188	11,200	B.
May	249	136	196	12,100	B.
June	249	111	161	9,580	B.
July	142	83	103	6,330	A.
August	81	76	79.0	4,860	A.
September	.....	.....	80.0	4,760	B.
The year	.....	.....	139	100,000	

Monthly discharge of Tumalo Creek near Laidlaw, Oreg., for 1906–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1910–11.					
October	.....	.....	92.3	5,680	C.
November	.....	.....	87.0	5,180	C.
December	.....	.....	111	6,820	C.
January	.....	.....	82.3	5,060	C.
February	.....	.....	90.7	5,040	C.
March	.....	.....	63.0	3,870	C.
April	130	79	95.3	5,670	A.
May	244	108	134	8,240	A.
June	396	171	267	15,900	B.
July	244	79	140	8,610	A.
August	98	64	72.0	4,430	A.
September	79	64	67.9	4,040	A.
The year	.....	.....	109	78,500	
1911–12.					
October	72	64	65.0	4,000	A.
November	.....	.....	62.0	3,690	B.
December	.....	.....	70.0	4,300	C.
January	.....	.....	91.9	5,650	C.
February	106	70	85.9	4,940	B.
March	88	61	67.3	4,140	A.
April	88	64	75.8	4,510	A.
May	298	79	165	10,100	A.
June	468	191	294	17,500	B.
July	244	130	174	10,700	A.
August	244	79	99.2	6,100	A.
September	119	83	90.3	5,370	A.
The year	.....	.....	112	81,000	
1912.					
October	.....	.....	73.3	4,510	B.
November	.....	.....	67.0	3,990	C.
December	209	.....	91.3	5,610	C.

TUMALO CREEK NEAR BEND, OREG.

Location.—In the SE. ¼ sec. 23, T. 17 S., R. 11 E. Willamette meridian, half a mile below highway bridge on Bend-Sisters road, 4 miles above mouth.

Records available.—October 6, 1906, to December 31, 1912 (fragmentary). This station is maintained in winter months only to insure a year-long record on the stream. The upper station is somewhat isolated and sometimes inaccessible in winter.

Drainage area.—57 square miles.

Gage.—Vertical staff, nailed to overhanging stump, since November, 1910; previous records at different site.

Channel.—Rocks and gravel; not liable to shift greatly.

Discharge measurements.—At ordinary stages, made by wading near the gage; at flood stages, made from the highway bridge, one-half mile above gage.

Winter flow.—Gage heights have been considerably affected by ice during extreme cold weather.

Diversions.—All the water of this stream diverted above station, making it dry, except for seepage return, during the irrigation season.

Accuracy.—An accurate open-channel curve has been developed, applicable except during extreme high stage.

Monthly discharge of Tumalo Creek near Bend, Oreg., for 1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January 28–31	70	70	70.0	555
February	106	70	85.9	4,940
March	116	53	70.2	4,320
April	56	6	24.0	1,430
May	209	17	84.6	5,200
June	346	70	166	9,880
July 1–8	68	56	62.5	992
December 18–31	209	70	110	3,050

NOTE.—These discharges are published to afford a comparison with Laidlaw station minus diversions. Monthly discharges for other periods are included with those for Tumalo Creek near Laidlaw.

SQUAW CREEK NEAR SISTERS, OREG.

Location.—In sec. 30, T. 15 S., R. 10 E. Willamette meridian, about 4 miles above Sisters and above all diversions except McAllister's ditch.

Records available.—July 1, 1906, to December 31, 1912.

Drainage area.—63 square miles.

Gage.—Vertical staff.

Channel.—Gravel and rock; practically permanent. Backwater from a changeable dam reaches the gage and introduces changes in the rating curve.

Discharge measurements.—Made from a foot log just above the gage.

Winter flow.—Ice tends to jam above the dam, and during extreme cold weather effect is very marked.

Diversions.—McAllister's ditch heads above this station and its flow is added to get the total. The low-water flow of the stream is all diverted by several irrigation ditches below the station.

Accuracy.—Records for 1910–1912 are good; those for previous years are subject to considerable error.

Monthly discharge of Squaw Creek near Sisters, Oreg., for 1906–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1906.					
July	458	136	251	15,400	B.
August	185	100	133	8,200	B.
September	207	72	97.9	5,830	B.
1906–7.					
October	185	67	88.3	5,400	B.
November	990	58	226	13,400	C.
December [a]			109	6,700	C.
January [a]			90.0	5,530	C.
February	940	90	220	12,200	C.
March	116	87	92.9	5,710	B.
April	132	87	114	6,780	B.
May [a]			217	13,300	C.
June	320	121	195	11,600	B.
July	290	165	208	12,800	B.
August	195	80	122	7,500	C.
September	130	59	80.4	4,780	C.
The year			147	106,000	

[a] Estimated from comparison with Tumalo Creek.

Monthly discharge of Squaw Creek near Sisters, Oreg., for 1906–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1907–8.					
October	86	59	69.0	4,240	C.
November [a]			78.2	4,650	C.
December [a]			64.5	3,970	C.
January [a]			67.6	4,160	C.
February	76	65	73.2	4,210	C.
March	335	66	104	6,400	B.
April [a]			102	6,070	C.
May [a]			125	7,690	C.
June	239	134	168	10,000	B.
July	297	152	213	13,100	B.
August	176	81	133	8,180	B.
September	122	68	90.3	5,370	B.
The year			107	78,000	
1908–9.					
October	378	66	86.2	5,300	B.
November	118	69	76.9	4,580	B.
December [a]	63		52.6	3,230	C.
January [a]			59.2	3,640	C.
February [a]			57.9	3,220	C.
March [a]			60.7	3,730	C.
April	98	74	78.4	4,670	B.
May	197	101	127	7,810	B.
June	272	173	216	12,900	B.
July	228	129	169	10,400	B.
August	173	99	129	7,930	B.
September	200	68	91.4	5,440	B.
The year			100	72,800	
1909–10.					
October	82	58	68.4	4,210	B.
November	1,960	69	255	15,200	C.
December	253	84	133	8,180	C.
January	155	68	86.3	5,310	C.
February	112	54	73.0	4,050	B.
March	253	84	118	7,260	A.
April	172	80	116	6,900	A.
May	310	112	183	11,300	A.
June	317	139	201	12,000	A.
July	226	146	178	10,900	A.
August	144	84	112	6,890	A.
September	188	66	95.0	5,650	A.
The year	1,960	54	135	97,800	
1910–11.					
October	250	57	81.2	4,990	A.
November	307	41	102	6,070	A.
December	115	62	81.6	5,020	B.
January	76	50	61.7	3,790	C.
February	76	47	52.5	2,920	C.
March	62	42	50.4	3,100	B.
April	97	49	68.5	4,080	A.
May	128	80	93.8	5,770	A.
June	313	144	237	14,100	B.
July	344	163	223	13,700	B.
August	194	97	124	7,620	A.
September	117	65	80.4	4,780	A.
The year	344	41	105	75,900	
1911–12.					
October	65	45	56.8	3,490	A.
November	65	46	58.3	3,470	A.
December	60	41	47.2	2,900	C.
January	186	49	68.8	4,230	C.
February	130	43	64.5	3,710	B.
March	56	32	45.7	2,810	A.
April	84	46	59.5	3,540	A.
May	261	60	131	8,060	A.
June	395	191	249	14,800	B.
July	261	158	202	12,400	B.
August	336	102	168	10,300	A.
September	152	72	90.2	5,370	A.
The year	395	32	103	75,100	
1912.					
October	102	44	64.7	3,980	B.
November	104	54	70.6	4,200	B.
December	66	50	55.1	3,390	C.

[a] Estimated from comparison with Tumalo Creek.

CROOKED RIVER NEAR POST, OREG.

Location.—In sec. 7, T. 17 S., R. 21 E., 12 miles above Post and half a mile below mouth of North Fork of Crooked River, at a point locally known as Stewarts Grade, just below dam site of proposed reservoir.

Records available.—November 9, 1908, to August 27, 1911.

Drainage area.—About 1,390 square miles.

Gage.—Combination vertical staff and inclined staff. Vertical staff read at low water; datum lowered 1 foot October 22, 1909; all gage heights for 1909 reduced to new datum.

Channel.—Rocks and bowlders; probably permanent.

Discharge measurements.—Made from cable and car at gage section; conditions very poor.

Winter flow.—Stream freezes and water sometimes flows over ice; gage height affected for two or three months each winter. Estimates of discharge during such periods have generally been made by comparison with records of the Prineville station.

Diversions.—A considerable and unknown amount of water diverted for irrigation above station.

Accuracy.—Results only fair on account of unfavorable conditions.

Monthly discharge of Crooked River near Post, Oreg., for 1908–1911.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
November 10–30	113	71	87.4	3,640	C.
December	94	64	80.2	4,930	C.
January	a 500	a 50	189	11,600	D.
February	1,300	156	395	21,900	C.
March	1,490	265	699	43,000	B.
April	1,440	520	954	56,800	B.
May	760	162	314	19,300	B.
June	191	27	73.9	4,400	B.
July	82	27	39.8	2,450	C.
August	41	9	18.9	1,160	D.
September	47	14	33.8	2,010	C.
The period				171,000	
1909–10.					
October	57	44	56.0	3,440	C.
November	2,740	60	431	25,600	B.
December			a 214	13,200	D.
January	2,040		351	21,600	C.
February	3,040	240	690	38,300	B.
March	4,540	800	1,900	117,000	C.
April	940	235	597	35,500	B.
May	415	36	152	9,350	B.
June	31	8	15.4	916	B.
July	41	13	17.3	1,060	B.
August	15	8	10.3	633	C.
September	46	10	27.9	1,660	B.
The year			372.1	268,000	
1910–11.					
October	57	36	46.2	2,840	B.
November		48	102	6,070	B.
December			274	16,800	C.
January			146	8,980	C.
February			174	9,660	C.
March	2,200	94	1,020	62,700	C.
April	2,000	385	770	45,800	B.
May	370	114	240	14,800	B.
June	100	19	42.8	2,550	B.
July	19	6	13.1	806	C.
August	19	6	12.4	762	C.
The period				172,000	

a Estimated.

CROOKED RIVER AT STEARNS RANCH, NEAR PRINEVILLE, OREG.

Location.—In sec. 36, T. 15 S., R. 15 E., about 5½ miles southeast of Prineville, near point from which diversion can be made to Agency Plains, north of lower Crooked River.

Records available.—October 31, 1908, to December 31, 1912.

Drainage area.—About 1,990 square miles.

Gage.—Vertical staff; datum unchanged.

Channel.—Sand; somewhat shifting.

Discharge measurements.—At ordinary and flood stages made from a flume; at low water, by wading above a riffle about half a mile above the gage.

Winter flow.—Probably affected by ice during extremely cold weather.

Diversion.—A large and undetermined amount of diversion above station for irrigation. No storage developed.

Accuracy.—Results good for total run-off, but somewhat uncertain for some low-water periods.

Monthly discharge of Crooked River near Prineville, Oreg., for 1908–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
October			40	2,460	C.
November			65	3,870	C.
December			65	4,000	C.
January	490	65	205	12,600	D.
February	2,350	131	421	23,400	A.
March	1,870	245	764	47,000	A.
April	2,130	625	1,150	68,000	A.
May	600	96	280	17,200	A.
June	160	32	68.8	4,090	A.
July	79	23	36.7	2,260	B.
August	36	20	26.0	1,600	C.
September	48	22	35.6	2,120	B.
The year			261	189,000	
1909–10.					
October	59	43	51.4	3,160	A.
November	4,630	53	530	31,500	C.
December	398	172	233	14,300	C.
January	2,510	108	369	22,700	D.
February	5,110	215	931	51,700	D.
March	9,080	813	3,260	200,000	D.
April	900	295	628	37,400	A.
May	450	38	187	11,500	A.
June	31	9.4	14.4	857	A.
July	18	6.6	8.91	548	A.
August	7.0	5.0	5.65	347	A.
September	41	5.0	18.6	1,110	A.
The year	9,080	5.0	519	375,000	
1910–11.					
October	60	35	45.9	2,820	A.
November	376	44	106	6,310	A.
December	813	120	298	18,300	A.
January	310	109	159	9,780	B.
February	412	79	189	10,500	A.
March	2,980	60	1,310	80,600	C.
April	2,980	449	884	52,600	B.
May	633	136	296	18,200	A.
June	125	12	44.6	2,650	A.
July	34	4	17.5	1,080	A.
August	12	7	9.3	572	A.
September	26	7	18.1	1,080	A.
The year	2,980	4	282	204,000	

Monthly discharge of Crooked River near Prineville, Oreg., for 1908–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911–12.					
October	103	34	50.8	3,120	A.
November	103	47	66.7	3,970	A.
December	227	40	80.6	4,960	A.
January	1,760	63	354	21,800	A.
February	2,320	250	682	39,200	A.
March	948	193	361	22,200	A.
April	3,000	930	1,600	95,200	B.
May	2,520	678	1,490	91,600	B.
June	870	34	299	17,800	A.
July	148	24	67.0	4,120	A.
August	60	20	33.2	2,040	A.
September	55	11	34.3	2,040	A.
The year	3,000	11	424	308,000	
1912.					
October	72	15	49.1	3,020	A.
November	103	63	85.5	5,090	A.
December	242	82	124	7,620	A.

OCHOCO CREEK AT ELLIOTT'S RANCH, NEAR PRINEVILLE, OREG.

Location.—In the NE. ¼ sec. 5, T. 15 S., R. 17 E., at Elliott's ranch, 6 miles east of Prineville, Oreg., on the dam site of a reservoir proposed in connection with the development of the Ochoco irrigation project by the United States Reclamation Service.

Records available.—October 29, 1908, to April 30, 1910.

Drainage area.—300 square miles.

Gage.—Vertical staff. No change in gage datum since July 15, 1909, when the gage was lowered 0.75 foot.

Channel.—Gravel.

Discharge measurements.—Made from a cable near the gage.

Diversions.—Elliott's ditch diverts water from the left bank of the creek about 1,000 feet above the gaging station. Records of the flow of the ditch are kept in order to determine the total flow of the creek. There are other diversions for irrigation farther up the creek.

Winter flow.—Gage heights not seriously affected by ice.

Accuracy.—Rating curve good. Records considered good.

Monthly discharge of Ochoco Creek near Prineville, Oreg., for 1908–1910.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
November	22	0	10.0	595	C.
December	32	.....	10.3	633	C.
January	306	6	107	6,580	C.
February	440	60	113	6,280	B.
March	276	45	135	8,300	B.
April	248	148	181	10,800	B.
May	170	45	97.5	6,000	B.
June	75	18	32.0	1,900	B.
July	17	0	5.4	332	C.
August	1.5	0	.87	53.5	C.
September	1.5	0	.45	26.8	D.
The period	.....	.....	.....	41,500	
1909–10.					
October	.5	0	.13	8.0	D.
November	1,050	0	109	6,490	C.
December	387	83	158	9,720	B.
January	422	38	143	8,790	B.
February	387	52	110	6,110	B.
March	608	262	431	26,500	B.
April	234	67	148	8,810	B.
The period	.....	.....	.....	66,400	

METOLIUS RIVER AT ALLINGHAM RANGER STATION, NEAR SISTERS, OREG.

Location.—In sec. 3, T. 13 S., R. 9 E., about 17 miles northwest of Sisters, at Allingham ranger station, 3 miles below head of river and 1½ miles below mouth of Lake Creek.

Records available.—September 15, 1910, to December 31, 1912.

Drainage area.—50 square miles.

Gage.—Vertical staff on left bank, 100 yards below ranger station.

Channel.—Rock and gravel; practically permanent.

Discharge measurements.—Made by wading a short distance below the gage.

Winter flow.—No effect of ice.

Diversions.—None.

Accuracy.—Records excellent.

Cooperation.—Station maintained in cooperation with the United States Forest Service.

Monthly discharge of Metolius River at Allingham ranger station, near Sisters, Oreg., for 1910–1912.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1910.					
September 15–30	356	347	350	11,100	A.
1910–11.					
October	361	352	356	21,900	A.
November	438	352	377	22,400	A.
December	465	381	415	25,500	A.
January	406	366	381	23,400	A.
February	381	361	370	20,500	A.
March	376	366	372	22,900	A.
April	.....	.....	391	23,300	B.
May	454	411	434	26,700	A.
June	427	371	406	24,200	A.
July	361	329	346	21,300	A.
August	333	324	329	20,200	A.
September	333	329	331	19,700	A.
The year	.....	.....	376	272,000	
1911–12.					
October	329	311	320	19,700	A.
November	347	318	337	20,100	A.
December	336	311	324	19,900	A.
January	449	307	392	24,100	A.
February	566	406	478	27,500	A.
March	462	381	407	25,000	A.
April	411	371	378	22,500	A.
May	471	396	426	26,200	A.
June	517	361	458	27,300	A.
July	361	329	338	20,800	A.
August	352	329	330	20,300	A.
September	352	324	330	19,600	A.
The year	.....	.....	376	273,000	
1912.					
October	352	324	333	20,500	A.

METOLIUS RIVER AT HUBBARD'S RANCH, NEAR GRANDVIEW,[1] OREG.

Location.—In sec. 34, T. 10 S., R. 10 E., about 20 miles from Grandview, 35 miles from Sisters, and 16 miles above the mouth of the river, 9 miles above the station at Riggs ranch, and 2 miles below Whitewater Creek, the lowest large tributary.
Records available.—April 24, 1910, to December 31, 1912.
Drainage area.—299 square miles.
Gage.—Vertical staff on right bank.
Channel.—Gravel and bowlders; possibly shifting. Two channels below gage. Right channel carries about 10 second-feet.
Discharge measurements.—Made from a standard car and cable half a mile below the gage.
Winter flow.—No material effect of ice.
Diversions.—A few small private irrigation ditches take out above the station.
Accuracy.—The measurements made do not cover the range of stage.
Cooperation.—Gage heights furnished without cost to the Survey by C. T. Hubbard.

Monthly discharge of Metolius River at Hubbard's ranch, near Grandview, Oreg., for 1912.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
March	1,610	1,450	1,510	92,800	A.
April	1,610	1,450	1,500	89,300	A.
May	1,700	1,450	1,580	97,200	A.
June	1,880	1,610	1,670	99,400	B.
July	1,610	1,530	1,540	94,700	B.
August	1,610	1,450	1,490	91,600	A.
September	1,530	1,370	1,420	84,500	A.
October	1,450	1,370	1,400	86,100	A.
November	1,700	1,370	1,470	87,500	B.
December	1,530	1,370	1,380	84,800	A.
The period				908,000	

METOLIUS RIVER AT RIGGS RANCH, NEAR SISTERS, OREG.

Location.—In the NE. ¼ sec. 28, T. 11 S., R. 11 E., about 26 miles north of Sisters and 7 miles above the mouth of the river.
Records available.—October 22, 1908, to October 21, 1912.
Drainage area.—347 square miles.
Gage.—Vertical staff.
Channel.—Gravel and bowlders; practically permanent.
Discharge measurements.—Made from a standard car and cable 50 feet above the gage.
Winter flow.—Probably not affected by ice, as stream is fed almost entirely by springs.
Diversions.—A few small private irrigation ditches divert water from this river above the station.
Storage.—No storage developed.
Accuracy.—Permanent rating curve developed, probably very close.

[1] Described in previous reports as "near Sisters."

Monthly discharge of Metolius River at Riggs ranch, near Sisters, Oreg., for 1908–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1908–9.					
October 22–31	1,740	1,490	1,550	30,700	A.
November	1,650	1,490	1,510	89,800	A.
December	1,570	1,410	1,470	90,400	A.
January	2,320	1,410	1,650	101,000	A.
February	1,830	1,570	1,640	91,100	A.
March	1,650	1,570	1,620	99,600	A.
April	1,650	1,570	1,610	95,800	A.
May	1,740	1,570	1,640	101,000	A.
June	1,830	1,650	1,710	102,000	A.
July	1,650	1,570	1,610	99,000	A.
August	1,650	1,490	1,530	94,100	A.
September	1,530	1,410	1,470	87,500	A.
The period				1,080,000	
1909–10.					
October	1,490	1,410	1,450	89,200	A.
November	3,890	1,410	1,870	111,000	A.
December	2,020	1,570	1,730	106,000	A.
January	1,880	1,530	1,610	99,000	A.
February	1,920	1,570	1,610	89,400	A.
March	2,770	1,780	2,090	129,000	A.
April	1,830	1,700	1,750	104,000	A.
May	1,920	1,700	1,740	107,000	A.
June	1,740	1,610	1,650	98,200	A.
July	1,610	1,570	1,600	98,400	A.
August	1,570	1,490	1,540	94,700	A.
September	1,530	1,450	1,490	88,700	A.
The year	3,890	1,410	1,680	1,210,000	
1910–11.					
October	1,830	1,450	1,490	91,600	A.
November	1,920	1,450	1,580	94,000	A.
December	1,830	1,530	1,610	99,000	A.
January	1,650	1,490	1,520	93,500	A.
February	1,490	1,410	1,490	82,800	A.
March	1,650	1,410	1,490	91,600	A.
April	1,570	1,490	1,550	92,200	A.
May	1,650	1,570	1,610	99,000	A.
June	1,830	1,650	1,670	99,400	A.
July	1,650	1,570	1,620	99,600	A.
August	1,570	1,490	1,500	92,200	A.
September	1,570	1,490	1,490	88,700	A.
The year	1,920	1,410	1,550	1,120,000	
1911–12.					
October	1,490	1,410	1,440	88,500	A.
November	1,570	1,410	1,470	87,500	A.
December	1,490	1,410	1,420	87,300	A.
January	2,020	1,330	1,590	97,800	A.
February	2,430	1,650	1,860	107,000	A.
March	1,830	1,650	1,680	103,000	A.
April	1,740	1,650	1,660	98,800	A.
May	2,020	1,650	1,760	108,000	A.
June	2,120	1,740	1,890	112,000	A.
July	1,740	1,650	1,660	102,000	A.
August	1,830	1,650	1,660	102,000	A.
September	1,650	1,490	1,580	94,000	A.
The year	2,430	1,330	1,640	1,190,000	
1912.					
October 1–21	1,490	1,490	1,490	62,100	A.

LAKE CREEK NEAR SISTERS, OREG.

Location.—In the SE. ¼ sec. 24, T. 13 S., R. 8 E., one-fourth mile below outlet of Suttle Lake and 6 miles from Allingham ranger station, 6 miles above mouth, 19 miles northwest of Sisters.

Records available.—May to November, 1911; March to September, 1912; occasional readings.

Drainage area.—20.5 square miles.

Gage.—Vertical staff spiked to an alder on right bank.

Channel.—Gravel; practically permanent.

Discharge measurements.—Made by wading at different sections.

Winter flow.—No winter records yet; probably not materially affected by ice.

Diversions.—None.

Accuracy.—Estimates roughly approximate.

Cooperation.—Gage readings furnished by Perry A. South and L. D. Weist.

Monthly discharge of Lake Creek near Sisters, Oreg., for 1911–12.

Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).	Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).
1911.			1911–12.		
June	69	4,110	March	59	3,630
July	43	2,640	April	52	3,090
August	37	2,280	May	75	4,610
September	33	1,960	June	89	5,300
			July	49	3,010
1911–12.			August	41	2,520
October	30	1,840	September	38	2,260
November	42	2,500			

WHITEWATER CREEK AT MOUTH, NEAR GRANDVIEW, OREG.

Location.—In sec. 28, T. 10 S., R. 10 E., one-fourth mile above the mouth of creek, 15 miles northwest of Grandview and 27 miles north of Sisters by road.

Records available.—May 28, 1911, to December 31, 1912. Gage read about once a week.

Drainage area.—Not measured.

Gage.—Vertical staff secured to alder on right bank; prior to September 18, 1911, vertical staff at about same location and datum.

Channel.—Gravel and small bowlders. Control formed by a fallen tree.

Discharge measurements.—Made by wading.

Winter flow.—Little if any affected by ice, at least in the afternoon when the gage is usually read.

Diurnal fluctuation.—Considerable at times of rapid melting of snow.

Accuracy.—Records good for low water, when the stream is steady, but only approximate at high water.

Cooperation.—Maintained in cooperation with the Office of Indian Affairs.

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Monthly discharge of Whitewater Creek near Grandview, Oreg., for 1911–12.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
June 2–30	201	123	152	8,740	C.
July	183	118	140	8,610	C.
August	117	71	84.3	5,180	C.
September	71	48	62.9	3,740	B.
1911–12.					
October	57	46	47.7	2,930	B.
November	66	48	58.6	3,490	B.
December	63	41	51.4	3,160	B.
January	802	46	134	8,240	C.
February	370	91	145	8,340	C.
March	108	58	76.5	4,700	B.
April	91	58	76.6	4,560	B.
May	259	88	163	10,000	C.
June	394	152	221	13,200	C.
July	177	127	151	9,280	C.
August	325	74	119	7,320	B.
September	129	49	71.0	4,220	B.
The year	802	41	110	79,400	
1912.					
October	88	45	55.8	3,430	B.
November	239	54	92.2	5,490	B.
December	122	46	57.2	3,520	B.

SHITIKE CREEK AT WARM SPRING, OREG.

Location.—In the NE. ¼ sec. 26, T. 9 S., R. 12 E., at Warm Spring, about 2 miles above the mouth of the creek and below all tributaries.

Records available.—June 11, 1911, to December 31, 1912.

Drainage area.—Not measured.

Gage.—Vertical staff on left bank opposite store.

Channel.—Gravel and sand; liable to shift somewhat.

Discharge measurements.—Made by wading or from footbridge.

Winter flow.—Apparently unaffected by ice.

Diversion.—Probably no diversion above the station.

Accuracy.—Results for 1911 and 1912 good except for high water and for certain periods not covered by measurements, during which channel may have shifted.

Cooperation.—Station maintained in cooperation with the Office of Indian Affairs.

Monthly discharge of Shitike Creek at Warm Spring, Oreg., for 1911–12.

Month.	Discharge in second-feet.			Run-off (in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
June 11–30	248	120	151	5,970	B.
July	134	66	93.2	5,730	B.
August	75	50	59.8	3,680	B.
September	86	50	61.9	3,680	B.
1911–12.					
October	66	57	57.3	3,520	B.
November	147	57	72.9	4,340	B.
December	75	57	63.6	3,910	B.
January	593	57	172	10,600	B.
February	383	112	195	11,200	B.
March	265	190	212	13,000	B.
April	190	102	135	8,030	A.
May	296	112	188	11,600	A.
June	338	148	200	11,900	B.
July	161	102	125	7,690	A.
August	102	66	80.2	4,930	A.
September	112	58	67.2	4,000	A.
The year	593	57	131	94,700	
1912.					
October	73	58	62.5	3,840	A.
November	112	66	83.9	4,990	B.
December	135	73	82.8	5,090	B.

WARM SPRINGS RIVER NEAR WARM SPRING, OREG.

Location.—In the NE. ¼ sec. 19, T. 8 S., R. 13 E., at bridge on road between Warm Spring and Simnasho, 9 miles from the former and 15 miles from the latter.

Records available.—July 29, 1911, to December 31, 1912, fragmentary.

Drainage area.—Not measured.

Gage.—Vertical staff spiked to pier of old bridge.

Channel.—Gravel; practically permanent.

Discharge measurements.—Made from stringer of old bridge or by wading.

Winter flow.—River probably never freezes.

Diversions.—None.

Accuracy.—Rating curve good; accuracy depends on gage readings which well cover the low water. Results for high water only approximate.

Cooperation.—Station maintained in cooperation with the Office of Indian Affairs.

Monthly discharge of Warm Springs River near Warm Spring, Oreg., for 1911–12.

Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).	Accuracy.	Month.	Mean discharge in second-feet.	Run-off (total in acre-feet).	Accuracy.
1911.				1912.			
August	268	16,500	B.	August	289	17,800	B.
September	266	15,800	B.	September	302	18,000	B.
October	266	16,400	B.	October	295	18,100	B.
November	292	17,400	C.	November	342	20,400	A.
December	890	24,000	B.	December	323	19,900	B.
	.....	90,100		The period	.....	115,000	
1912.							
July	345	21,200	B.				

WHITE RIVER NEAR TYGH VALLEY, OREG.

Location.—In sec. 10, T. 4 S., R. 13 E., 1 mile south of Tygh Valley, 1 mile above mouth of Tygh Creek, and 4 miles above the White River Falls plant of the Pacific Power & Light Co.

Records available.—June 18, 1911, to December 31, 1912.

Drainage area.—Not measured.

Gage.—Vertical staff on lower corner of left pier of highway bridge.

Channel.—Gravel and sand; shifting. White River carries a heavy load of glacial sediment at times.

Discharge measurements.—Made from lower side of highway bridge.

Winter flow.—Affected by ice; ice jams occasionally form during extremely cold weather.

Diversions.—Probably no diversion from White River above the station, although diversion of water for irrigation lands south of lower White River is doubtless feasible.

Accuracy.—Results good during low water, but somewhat uncertain at other times, as not enough measurements have been made to determine possible shifts.

Monthly discharge of White River near Tygh Valley, Oreg., for 1911–12.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
June 18–30	378	263	302	7,780	A.
July	259	127	179	11,000	A.
August	139	102	112	6,890	A.
September	244	102	143	8,510	A.
October	189	127	139	8,550	A.
November 1–15	498	127	245	7,290	B.
The period				50,000	
1912.					
January 13–31			1,370	51,600	C.
February	1,520	510	918	52,800	B.
March	485	300	361	22,200	B.
April	845	410	562	33,400	B.
May	1,120	560	768	47,200	B.
June	670	320	491	29,200	B.
July	320	180	233	14,300	A.
August	210	150	167	10,300	A.
September	252	150	170	10,100	A.
October	228	156	175	10,800	A.
November	360	156	236	14,000	B.
December	510	174	201	12,400	B.
The period				308,000	

TYGH CREEK AT TYGH VALLEY, OREG.

Location.—In sec. 3, T. 4 S., R. 13 E., about one-fourth mile north of the Tygh Valley post office, 100 feet below the wagon bridge, and about 1 mile above mouth of river.

Records available.—June 9 to September 30, 1911; March 8 to October 15, 1912.

Drainage area.—Not measured.

Gage.—Vertical staff.

Channel.—Gravel and sand; shifts somewhat.

Discharge measurements.—Made from downstream rail of the highway bridge at Tygh Valley, or by wading.

Winter flow.—Materially affected by ice; no records obtained during the winter.

Accuracy.—Results good during low water; uncertain at higher stages on account of possible shifts.

Monthly discharge of Tygh Creek at Tygh Valley, Oreg., for 1911–12.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1911.					
June 11–30	130	66	92.3	3,660	A.
July	63	14	30.0	1,840	A.
August	16	11	14.9	916	A.
September	74	11	31.1	1,850	A.
October	30	22	25.8	1,590	B.
The period				9,860	
1912.					
March 9–31	196	94	121	5,500	B.
April	282	150	179	10,700	C.
May	282	150	216	13,300	C.
June	200	85	155	9,220	B.
July	85	32	48.0	2,950	A.
August	34	23	27.7	1,700	A.
September	44	23	28.7	1,710	A.
October 1–15	32	25	29.5	878	A.
The period				46,000	

CANAL STATIONS.

CENTRAL OREGON CANAL AT BEND, OREG.

Location.—In sec. 7, T. 18 S., R. 12 E. Willamette meridian, at a flume section 1 mile below the division point where the waters in the main diversion canal are divided between this canal and the Pilot Butte canal, about 2 miles south of Bend, Oreg.

Records available.—May 11, 1905, to December 31, 1912.

Gage.—A vertical staff consisting of a painted strip of galvanized iron nailed to the inside of flume on right side.

Channel.—A plank flume of rectangular cross section provided with batting on bottom cracks. Flume rather unstable, but the rating appears not to change.

Discharge measurements.—Made from yoke of flume at gage section.

Winter flow.—Canal operated almost continuously. The flow in winter is small in volume. The fall through the section of the gage is sufficient to maintain open channel at all times.

Accuracy.—Records accurate. Earlier records of discharge of over 100 second-feet subject to revision on account of measurements made at depth giving erroneous results.

Cooperation.—Station maintained in cooperation with the Central Oregon Irrigation Co.

Monthly discharge of Central Oregon canal near Bend, Oreg., for 1905–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
March 11–17	25	0	14.9	207	B.
June	74	0	36.6	2,180	B.
July	48	0	19.5	1,200	B.
August	48	0	26.8	1,650	B.
September	70	20	43.4	2,580	A.
1905–6.					
October	105	0	45.9	2,820	A.
November	82	16	65.6	3,900	B.
December	94	0	54.8	3,370	B.
January	96	0	35.2	2,160	B.
February	105	0	26.2	1,460	B.
March	74	0	28.0	1,720	A.
April	70	12	49.6	2,950	A.
May	74	0	58.0	3,570	A.
June	97	70	86.5	5,150	A.
July	138	103	118	7,260	A.
August	138	124	131	8,060	A.
September	138	130	134	7,970	A.
The year	138	0	69.4	50,400	
1906–7.					
October	133	118	128	7,870	A.
November	114	0	48.5	2,890	A.
December	100	47	73.8	4,540	A.
January	65	0	17.7	1,090	B.
February	97	0	50.0	2,780	B.
March	96	34	83.5	5,130	A.
April	112	94	100	5,950	A.
May	146	98	126	7,750	A.
June	182	128	148	8,810	A.
July	187	0	121	7,440	A.
August	194	112	156	9,590	A.
September	134	92	118	7,020	A.
The year	194	0	97.5	70,900	

Monthly discharge of Central Oregon canal near Bend, Oreg., for 1905–1912—Contd.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1907–8.					
October	134	0	104	6,400	A.
November	118	41	104	6,190	A.
December	118	0	69.3	4,260	A.
January	102	0	32.0	1,970	B.
February	100	0	15.7	903	B.
March	118	0	23.3	1,430	B.
April	112	57	86.4	5,140	A.
May	146	112	136	8,360	A.
June	170	146	158	9,400	A.
July	207	170	201	12,400	A.
August	226	194	205	12,600	A.
September	194	176	185	11,000	A.
The year	226	0	110	80,100	
1908–9.					
October	176	107	141	8,670	A.
November	107	35	56.1	3,340	A.
December	128	0	43.1	2,650	B.
January	97	0	9.71	597	B.
February	97	0	39.1	2,170	B.
March	97	32	72.6	4,460	A.
April	164	88	128	7,620	A.
May	214	164	194	11,900	A.
June	240	25	191	11,400	A.
July	256	0	144	8,850	A.
August	246	172	224	13,800	A.
September	200	146	172	10,200	A.
The year	256	0	118	85,700	
1909–10.					
October	152	112	122	7,500	A.
November	123	0	21.7	1,290	A.
December	83	0	9.10	560	B.
January	88	0	17.2	1,060	B.
February	88	0	25.3	1,410	B.
March	102	0	46.4	2,850	A.
April	170	83	124	7,380	A.
May	246	0	160	9,840	A.
June	252	8	208	12,400	A.
July	272	214	258	15,900	A.
August	272	0	132	8,120	A.
September	233	38	192	11,400	A.
The year	272	0	110	79,700	
1910–11.					
October	182	158	170	10,500	A.
November	158	0	47.8	2,840	A.
December	123	12	69.7	4,290	A.
January	146	0	27.1	1,670	B.
February	123	8	25.0	1,390	B.
March	107	0	43.3	2,660	B.
April	182	74	130	7,740	A.
May	207	182	195	12,000	A.
June	272	9	226	13,400	A.
July	272	170	250	15,400	A.
August	272	22	250	15,400	A.
September	233	152	184	10,900	A.
The year	272	0	135	98,200	
1911–12.					
October	158	123	133	8,180	A.
November	134	0	41.4	2,460	A.
December	134	0	19.0	1,170	A.
January	92	0	15.3	941	B.
February	123	0	23.6	1,360	A.
March	123	0	42.1	2,590	A.
April	123	0	60.2	3,580	A.
May	246	0	172	10,600	A.
June	272	88	248	14,800	A.
July	272	8	239	14,700	A.
August	246	220	241	14,800	A.
September	233	158	180	10,700	A.
The year	272	0	118	85,900	
1912.					
October	194	146	174	10,700	A.
November	158	0	132	7,860	A.
December	112	0	22.9	1,410	A.

PILOT BUTTE CANAL NEAR BEND, OREG.

Location.—In sec. 7, T. 18 S., R. 12 E., at a point in the canal directly opposite the gaging station on Central Oregon canal, about 2 miles south of Bend and 1 mile below the division point where the waters are divided between this canal and the Central Oregon canal.

Records available.—March 6, 1905, to December 31, 1912.

Gage.—Vertical staff on right bank directly opposite the gage in flume of Central Oregon canal.

Channel.—Gage section is in rock and is permanent.

Discharge measurements.—Made by wading at the gage or from a highway bridge half a mile below the gage.

Winter flow.—Operated intermittently during the frozen season to provide water for stock and domestic purposes. No ice effect.

Accuracy.—Conditions favorable; results excellent.

Cooperation.—Station maintained in cooperation with the Central Oregon Irrigation Co.

Monthly discharge of Pilot Butte canal near Bend, Oreg., for 1905–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1905.					
March 6-31	49	8	27.2	1,400	B.
April 1-5[a]	41	29	31.4	311	B.
June	68.6	12.6	55.7	3,310	B.
July	89.9	0	56.3	3,460	B.
August	85.7	0	66.8	4,110	B.
September	111	73	88.6	5,270	B.
1905-6.					
October	88	5	76.5	4,700	B.
November	60	36	56.7	3,370	B.
December	48	0	26.1	1,610	B.
January	48	0	10.8	664	B.
February	48	0	31.4	1,740	A.
March	48	0	16.6	1,020	A.
April	119	16	52.9	3,150	A.
May	111	31	79.7	4,900	A.
June	117	73	97.0	5,770	A.
July	144	103	136	8,360	A.
August	148	0	129	7,930	A.
September	121	92	120	7,140	A.
The year	148	0	69.4	50,400	
1906-7.					
October	121	22	108	6,640	A.
November	89	0	20.6	1,230	B.
December	44	11	31.4	1,930	B.
January	12	0	3.0	184	B.
February	53	0	26.2	1,460	A.
March	39	39	39.0	2,400	A.
April	95	39	71.4	4,250	A.
May	127	95	110	6,760	A.
June	162	103	151	8,980	A.
July	166	0	118	7,260	A.
August	162	98	148	9,100	A.
September	144	73	108	6,430	A.
The year	166	0	77.8	56,600	

[a] Water was turned out of canal April 6, and for a month or more all the water was in the river. There was some diversion in latter part of May.

Monthly discharge of Pilot Butte canal near Bend, Oreg., for 1905–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1907–8.					
October	144	1	99.5	6,120	A.
November	136	0	66.1	3,930	A.
December	162	0	24.1	1,480	A.
January	66	0	19.4	1,190	B.
February	80	0	24.8	1,430	A.
March	80	0	61.4	3,780	A.
April	127	66	96.6	5,750	A.
May	127	0	114	7,010	A.
June	172	127	150	8,930	A.
July	212	182	204	12,500	A.
August	218	182	204	12,500	A.
September	182	91	148	8,810	A.
The year	218	0	101	73,400	
1908–9.					
October	136	95	123	7,560	A.
November	111	0	31.8	1,890	B.
December	60	0	13.4	824	B.
January	42	0	1.4	86.1	B.
February	60	0	22.0	1,220	B.
March	73	17	52.7	3,240	A.
April	111	73	93.4	5,560	A.
May	172	111	150	9,220	A.
June	182	153	176	10,500	A.
July	212	0	128	7,870	A.
August	202	108	182	11,200	A.
September	144	108	131	7,800	A.
The year	212	0	92.1	67,000	
1909–10.					
October	111	0	91.4	5,620	A.
November	66	0	15.2	904	B.
December	38	0	1.7	105	B.
January	42	0	4.0	246	B.
February	53	0	11.0	611	B.
March	66	0	29.6	1,820	A.
April	144	73	91.8	5,460	A.
May	172	0	121	7,440	A.
June	192	136	185	11,000	A.
July	202	192	197	12,100	A.
August	202	148	189	11,600	A.
September	172	92	145	8,630	A.
The year	202	0	90.1	65,500	
1910–11.					
October	130	111	118	7,260	A.
November	111	0	34.9	2,080	A.
December	88	0	24.0	1,480	A.
January	77	0	11.5	707	B.
February	53	0	3.4	189	B.
March	73	0	18.1	1,110	A.
April	144	0	80.7	4,800	A.
May	162	60	143	8,790	A.
June	192	2	175	10,400	A.
July	212	182	196	12,100	A.
August	202	9	182	11,200	A.
September	192	111	138	8,210	A.
The year	212	0	93.7	68,300	
1911–12.					
October	111	83	105	6,460	A.
November	95	0	56.0	3,330	A.
December	66	0	9.2	566	B.
January	60	0	10.3	633	B.
February	66	0	12.0	690	B.
March	73	0	23.3	1,430	A.
April	80	0	43.8	2,610	A.
May	182	80	134	8,240	A.
June	202	24	185	11,000	A.
July	226	178	212	13,000	A.
August	233	182	214	13,200	A.
September	180	127	146	8,690	A.
The year	233	0	95.9	69,800	
1912.					
October	162	88	117	7,190	A.
November	95	0	75.4	4,490	A.
December	83	0	9.6	590	B.

WIMER CANAL NEAR LAIDLAW, OREG.

Location.—In sec. 2, T. 18 S., R. 10 E., about 15 miles from Laidlaw, half a mile below the intake and below controlling spillway.

Records available.—1906 to 1912. Observations in 1906–7 taken just below intake and above controlling spillway.

Gage.—Vertical staff; no change in datum since April 1, 1908.

Channel.—Flume.

Discharge measurements.—Made by wading or from yoke of flume.

Winter flow.—Not operated during season of ice.

Accuracy.—Good except in 1911 and 1912, during which time sufficient measurements have not been made to determine possible changes in rating.

Cooperation.—Station maintained in cooperation with the Columbia Southern Irrigation Co.

Monthly discharge of Wimer canal near Laidlaw, Oreg., for 1906–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1906.					
June 16–30	49	42	44.5	1,320	B.
July	50	19	34.5	2,120	C.
August	18	16	16.5	1,010	C.
September	24	16	16.4	976	C.
October	35	0	17.0	1,050	C.
The period				6,480	
1907.					
April 19–30	24	22	23.0	548	C.
May	45	23	31.9	1,960	B.
June	48	18	31.8	1,890	B.
July	39	30	34.7	2,130	B.
August	34	27	30.2	1,860	B.
September	27	24	25.6	1,520	B.
October	27	0	23.0	1,410	B.
The period				11,300	
1908.					
April	14.2	0	10.3	613	A.
May	16.8	13.0	14.7	904	A.
June	27.0	16.8	22.4	1,330	A.
July	30.0	25.5	28.8	1,770	A.
August	30.0	19.6	26.0	1,600	A.
September	21.0	15.5	20.6	1,230	A.
October	21.0	10.7	15.6	959	A.
The period				8,410	
1909.					
April 19–30	13.3	9.1	10.7	255	A.
May	16.4	0	12.3	756	B.
June	29.3	15.9	18.2	1,080	A.
July	34.4	22.9	30.7	1,890	A.
August	31.3	20.0	29.8	1,830	A.
September	22.0	18.6	19.9	1,180	A.
October	21.4	20.8	21.2	1,300	A.
The period				8,290	
1910.					
April 11–30	27	12	22.6	897	A.
May	30	24	24.9	1,530	A.
June	30	21	24.8	1,480	A.
July 1–9	33	27	28.4	507	A.
1911.					
April 7–30	22	11	16.2	771	B.
May	24	15	21.5	1,320	B.
June	26	0	19.2	1,140	B.
July	32	24	27.9	1,720	B.
August	26	18	20.3	1,250	B.
September	18	18	18.0	1,070	B.
October	18	9	12.7	781	B.
The period				8,050	

Monthly discharge of Wimer canal near Laidlaw, Oreg., for 1906–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1912.					
April	12.4	0	8.78	522	B.
May	19.0	8.0	13.9	855	B.
June	23.7	19.8	22.4	1,330	B.
July	25.0	17.2	23.4	1,440	B.
August	21.1	12.4	14.9	916	B.
September	16.0	8.0	9.38	558	B.
October	8.0	0	3.87	238	B.
The period				5,860	

COLUMBIA SOUTHERN CANAL NEAR LAIDLAW, OREG.

Location.—In sec. 2, T. 18 S., R. 10 E., about 15 miles from Laidlaw and one-fourth mile below head gate.

Records available.—1906 to 1912, irrigating season.

Gage.—Vertical staff on the upstream side of a wasteway flume, about one-fourth mile below intake.

Channel.—Flume.

Discharge measurements.—Made by wading or from a foot log at the gage.

Winter flow.—Canal not operated during season of ice.

Accuracy.—Rating curve well determined for unobstructed channel. Records for 1911–12 somewhat uncertain on account of insufficient measurements to detect possible changes in channel.

Cooperation.—Gage readings furnished by the Columbia Southern Irrigation Co.

Monthly discharge of Columbia Southern canal near Laidlaw, Oreg., for 1906–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1906.					
May 15-31	69	64	67.2	2,260	A.
June	82	60	66.6	3,960	A.
July	114	74	91.7	5,640	A.
August	69	64	66.3	4,080	A.
September	64	62	62.4	3,710	A.
October	64	55	61.3	3,770	A.
The period				23,400	
1907.					
April	45	27	40.0	2,380	A.
May	79	41	66.9	4,110	A.
June	112	79	99.1	5,900	A.
July	126	98	116	7,130	A.
August	126	63	77.8	4,780	A.
September	73	63	66.8	3,970	A.
October	63	58	60.7	3,730	A.
The period				32,000	
1908.					
April	50	0	33.1	1,970	A.
May	73	37	54.9	3,380	A.
June	98	73	88.4	5,260	A.
July	112	85	109	6,700	A.
August	85	58	63.7	3,920	A.
September	63	58	58.3	3,470	A.
October	58	54	54.8	3,370	A.
The period				28,100	

Monthly discharge of Columbia Southern canal near Laidlaw, Oreg., for 1906–1912—Continued.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1909.					
April 6–30	64	2	43.6	2,160	A.
May	104	64	88.3	5,430	A.
June	114	104	106	6,310	A.
July	117	74	103	6,330	A.
August	73	47	55.3	3,400	A.
September	64	50	53.4	3,180	A.
October	54	46	48.4	2,980	A.
The period				29,800	
1910.					
April	64	38	47.9	2,850	A.
May	111	64	77.3	4,750	A.
June	118	85	105	6,250	A.
July	91	54	74.4	4,570	A.
August	59	50	55.6	3,420	A.
September 1–11	64	59	59.5	1,300	A.
The period				23,100	
1911.					
April	62	0	38.6	2,300	B.
May	91	61	78.2	4,810	B.
June	119	98	106	6,310	B.
July	119	49	92.8	5,710	B.
August	49	41	45.3	2,790	B
September	63	41	45.6	2,710	B
October	45	28	37.4	2,300	B.
The period				26,900	
1912.					
February	34	0	5.3	305	B.
March	0	0	0	0	
April	54	0	37.7	2,240	B.
May	91	38	64.6	3,970	B.
June	118	91	101	6,010	A.
July	118	91	111	6,820	A.
August	91	52	66.1	4,060	B.
September	71	50	55.7	3,310	B.
October 1–15	59	50	53.0	1,580	B.
The period				28,300	

McALLISTER'S DITCH NEAR SISTERS, OREG.

Location.—About 100 yards below intake, in the SW. ¼ sec. 30, T. 15 S., R. 10 E., below first spillway.

Records available.—May 2 to November 22, 1909 (from 1909 to 1911, inclusive, station was above spillway); June 29, 1910, to December 31, 1912.

Gage.—Plug above weir at mean level of crest on which heights of water are measured. Gage used, 1909–1911, was vertical staff in side of ditch.

Channel.—Sharp-crested Cippoletti weir 5 feet long; no velocity of approach; formerly earth section of canal.

Discharge measurements.—From cross piece of waste gate or by wading.

Winter flow.—Water shut off in freezing weather.

Accuracy.—Results, 1909–1911, are subject to much uncertainty because of infrequent measurements and changes in conditions. Gage heights also were liable to be affected by changes in the wasteway just below the station. Records for 1912 are not directly comparable with those for previous years, as there is some water wasted from the spillway which would pass old gage but not the weir.

Monthly discharge of McAllister's ditch near Sisters, Oreg., for 1909–1912.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).	Accuracy.
	Maximum.	Minimum.	Mean.		
1909.					
May 2–31	22	13	15.4	916	B.
June	27	17	21.6	1,290	B.
July	20	13	16.8	1,030	B.
August	17	11	13.1	806	B.
September	15	8.4	10.4	619	C.
The period				4,660	
1909–10.					
October	11	7.6	8.15	501	C.
November	25	0	8.18	487	C.
July	18	14	15.1	928	B.
August	12.5	7.6	10.5	646	B.
September	14	5.9	8.07	480	B.
1910–11.					
October	11.5	3.1	4.49	276	B.
November	6.6	2.2	3.42	204	B.
December	3.1	2.2	2.25	138	C.
January	5.3	0	1.16	71	C.
February			0	0	
March	3.6	0	1.28	79	C.
April	4.2	2.2	2.72	162	C.
May	6.0	3.6	4.29	264	C.
June	18	8.1	13.2	786	B.
July	13	7.4	9.57	588	B.
August	14	4.2	5.76	354	B.
September	6.6	1.0	5.63	335	C.
The year			4.48	3,260	
1911–12.					
October	5.3	4.2	5.26	323	C.
November	5.3	0	4.32	257	C.
December			0	0	
January			0	0	
February			0	0	
March	2.7	0	.65	40	A.
April	5.6	2.8	3.80	226	A.
May	10.3	3.9	6.42	395	A.
June	8.2	4.3	5.79	345	A.
July	7.8	0	4.71	290	A.
August	7.4	0	3.67	226	A.
September	8.8	0	4.27	254	A.
The year				2,360	
1912.					
October	2.7	1.5	1.93	119	A.
November	4.3	1.3	2.17	129	A.
December	2.5	0	.87	53	A.

SUMMARIES OF DISCHARGE FOR PRINCIPAL STATIONS.

In order to bring the large number of stream-flow records available on Deschutes River into convenient form for comparison and use, tables have been prepared summarizing the yearly maximum, minimum, and mean discharge and totals in acre-feet for all stations for which the records cover four or more continuous years. These summaries, like the estimates of monthly discharge, have been made out for the climatologic year beginning October 1 and ending September 30.

The irrigation season in many localities, especially in northerly latitudes, closes with September, and the climatologic year thus includes one period of storage and one of growth. At the beginning

of the year ground storage is usually at a minimum; there is no snow on the ground, practically no water is held over, and the run-off recorded for the period constitutes an actual year's supply that should be directly comparable with the rainfall, if such a relation may be assumed to exist.

Yearly discharge of Deschutes River at Allen's ranch, near Lava, Oreg., 1905–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1905 (Feb. 17–Sept. 30)	382	89	212	95,200	.....
1905–6	559	79	193	139,000	70
1906–7	1,890	89	356	258,000	130
1907–8	687	120	254	184,000	92
1908–9	575	115	246	178,000	89
1909–10	2,150	115	385	279,000	140
1910–11	559	106	222	161,000	81
1911–12	760	97	271	197,000	99
Mean	.....	.....	275	199,000	.....

Yearly discharge of Deschutes River at Benham Falls, Oreg., 1904–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1904–5 [a]	2,700	1,490	1,950	1,410,000	116
1905–6	1,920	1,080	1,520	1,100,000	90
1906–7	4,000	1,160	1,840	1,340,000	110
1907–8	2,560	1,280	1,740	1,260,000	103
1908–9	2,280	1,170	1,620	1,170,000	96
1909–10	4,760	1,330	1,750	1,270,000	104
1910–11	1,780	1,180	1,490	1,080,000	89
1911–12	2,260	1,000	1,590	1,160,000	95
Mean	.....	.....	1,690	1,220,000	.....

[a] Mean for October–December, 1904, estimated 2,000 second-feet.

Yearly discharge of Deschutes River at Moody, Oreg., 1897–1899, 1906–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1897–98 [a]	11,700	4,920	6,720	4,870,000	95
1898–99	16,000	4,100	7,670	5,560,000	109
1906–7	30,600	5,080	7,870	5,700,000	111
1907–8	22,200	.....	6,800	4,940,000	96
1908–9	14,200	5,080	6,450	4,670,000	91
1909–10	26,900	.....	7,860	5,690,000	111
1910–11	10,800	4,820	6,110	4,420,000	86
1911–12	17,900	4,080	7,080	5,100,000	100
Mean	.....	.....	7,070	5,120,000	.....

[a] October, 1897, estimated 6,000 second-feet.

Yearly discharge of Tumalo Creek near Laidlaw, Oreg., 1906–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1906–7	820	80	180	130,000	138
1907–8	462	62	128	92,700	99
1908–9	440	50	111	80,000	85
1909–10	.....	.....	139	101,000	108
1910–11	396	.....	109	78,500	84
1911–12	468	61	112	81,000	86
Mean	.....	.....	130	93,900	.....

Yearly discharge of Squaw Creek near Sisters, Oreg., 1906–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1906–7	990	58	147	106,000	126
1907–8	335	59	108	78,000	93
1908–9	378	.....	99.9	72,800	86
1909–10	1,960	54	135	97,800	116
1910–11	344	42	105	75,900	90
1911–12	395	32	104	75,100	89
Mean	.....	.....	116	84,300	.....

Yearly discharge of Crooked River near Prineville, Oreg., 1908–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1908–9 [a]	2,350	20	261	189,000	70
1909–10	9,080	5.0	519	375,000	139
1910–11	2,980	4.0	282	204,000	76
1911–12	3,000	11	424	308,000	114
Mean	.....	.....	372	269,000	.....

[a] October, 1908, estimated 40 second-feet.

Yearly discharge of Metolius River near Sisters, Oreg., 1908–1912.

Year.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Acre-feet.	Per cent of mean.
1908–9 [a]	2,320	1,410	1,580	1,140,000	98
1909–10	3,890	1,410	1,670	1,210,000	104
1910–11	1,920	1,410	1,550	1,120,000	97
1911–12	2,430	1,330	1,640	1,190,000	103
Mean	.....	.....	1,610	1,160,000	.....

[a] October, 1908, estimated 1,500 second-feet.

The following tables show the minimum flow, with dates, at stations on Deschutes River and its principal western tributaries, but the period selected for study of minimum flow, or duration of low

water, is that between successive annual spring floods. The minima for two successive calendar years may occur in the same low water period, only a few days or weeks apart, and this is even more likely to occur where a climatologic year is used extending from low water to low water. On the upper part of Deschutes River, the month of greatest flow, taking the mean of the 8 years, is May, with June a close second. The division of the year for the computation of the minimum has accordingly been made between May 31 and June 1.

Minimum discharge of Deschutes River at Allen's ranch, near Lava, Oreg., 1905–1912.

Period June–May.	Minimum for one day.		Lowest week.		Ratio of mean for week to mean for periods.
	Date.	Discharge.	Date.	Mean daily discharge.	
		Sec.-ft.		*Sec.-ft.*	
1905–6	Nov. 15	79	Nov. 10–16	85.6	0.76
1906–7	Nov. 13	89	Oct. 26–Nov. 1	97.0	.87
1907–8	Nov. 18–19	141	Nov. 13–19	145	1.30
1908–9	Oct. 8–10	115	Oct. 6–12	118	1.05
1909–10	Nov. 14	115	Oct. 4–20	124	1.11
1910–11	Oct. 28–Nov. 6	115	Oct. 31–Nov. 6	115	1.03
1911–12	Nov. 1–4, Dec. 21	97	Nov. 1–7 [a]	100	.89
Mean		107		112	

[a] May have been lower during period of ice.

Minimum discharge of Deschutes River at Benham Falls, Oreg., 1905–1912.

Year.	Minimum for one day.		Lowest week.		Ratio of mean for week to mean for periods.
	Date.	Discharge.	Date.	Mean daily discharge.	
		Sec.-ft.		*Sec.-ft.*	
1905–6	Dec. 23	1,080	Dec. 19–25	1,240	0.95
1906–7	Jan. 15	1,160	Oct. 29–Nov. 4	1,290	.99
1907–8	Feb. 1	1,280	Mar. 4–10	1,380	1.06
1908–9	Dec. 18	1,170	Dec. 14–20	1,330	1.02
1909–10	Jan. 4–5	1,330	Jan. 2–8	1,420	1.09
1910–11	Jan. 23	1,180	Feb. 27–Mar. 5	1,280	.98
1911–12	Jan. 4	1,000	Dec. 30–Jan. 4	1,180	.91
Mean		1,170		1,300	

Minimum discharge of Deschutes River at Moro and Moody, Oreg., 1897–1899, 1906–1912.

Year.	Minimum for one day.		Lowest week.		Ratio of mean for week to mean for 1906–1911.
	Date.	Discharge.	Date.	Mean daily discharge.	
		Sec.-ft.		*Sec.-ft.*	
1897–8	October, November, March, April.	6,030	Oct. 24–30	6,030	1.18
1898–9	Dec. 16–18	4,100	Dec. 13–19	4,240	.83
1906–7	September, October	5,080	Sept. 1–Oct. 16	5,080	.99
1907–8	July to November	5,660	July 27–Aug. 23, etc	5,660	1.10
1908–9	Sept. 30	[a] 5,280	September, October	5,300	1.03
1909–10	Aug. 24–31	5,080	Aug. 24–30	5,080	.99
1910–11	July 27	[a] 5,170	August [b]	5,180	1.01
1911–12	Jan. 5–7	4,080	Jan. 2–8	4,470	.87
Mean		5,060		5,130	

[a] Readings fragmentary. [b] Estimated.

Minimum discharge of Metolius River at Riggs ranch, near Sisters, Oreg., 1908–1912.

Year.	Minimum for one day.		Lowest week.		Ratio of mean for week to mean for periods.
	Date.	Discharge.	Date.	Mean daily discharge	
		Sec.-ft.		*Sec. ft.*	
1908–9	Dec. 12–20, Jan. 11–15	1,410	Dec. 14–20	1,410	1.01
1909–10	September–November	1,410	Oct. 24–30	1,420	1.02
1910–11	Feb. 28–Mar. 10	1,410	Feb. 28–Mar. 10	1,410	1.01
1911–12	Jan. 2–8	1,330	Jan. 2–8	1,330	.96
Mean				1,390	

An examination of the yearly means and minima and their relation to the mean for the period shows in a striking manner the remarkable constancy of flow of the Deschutes, particularly in the upper section, compared with most streams. Thus at Benham Falls the highest year is only 15 per cent above and the lowest 11 per cent below the 8-year mean. At Moody, the variation is about the same, +11 and −14. Deschutes (Little) River at Allen's ranch, which receives relatively less of its water from springs, shows maximum variations of +40 and −19; Tumalo Creek, +38 and −15; Squaw Creek, +26 and −14; and Crooked River, +26 and −23.

None of the records on tributaries cover 1904, which was in general the year of greatest flow in the last 10 in central Oregon, or 1905, which was in many localities the lowest. Thus it can not be safely assumed that either extreme of run-off has yet been reached or even closely approached. It will be noted that the highest year at Benham Falls was 1904–5, which in many localities was one of extreme drought, whereas 1912, elsewhere generally high, was here below the mean. This was caused by and aptly illustrates the long-delayed effect of rainfall on run-off in the Deschutes River basin. The extremely high snowfall and rainfall of 1904 filled up the deep springs which continued to discharge large volumes of water well into 1905. The longest period of deficient run-off began in the early summer of 1910 and culminated in January, 1912. The snow melted and ran off early in 1910, the summer of that year was very dry, the following winter was one of very deficient snowfall; there were few rains in the fall of 1911, and the snows of 1911–12 came rather later than usual. The springs seemed to run steadily lower and then the flow suddenly decreased during the extreme cold snap in the first week in January, 1912, when nearly all records of low water were broken. Then came a thaw which caused the rapid melting of snow, apparently affecting all streams except Squaw Creek. That stream reached its minimum in March, after all the others had shown a considerable recovery from these extreme low points.

For about 8 miles below Black Butte a large amount of water enters Metolius River from springs in the side of the stream. They are very noticeable, but only one is so situated that its discharge can be measured. This spring, known as the Heisings, enters Jacks Creek, a second tributary on the west. A number of tributary streams enter the Metolius—Lake, Jacks, Canyon, Cabot, Jefferson, and Whitewater—all from the west side and from the east slope of the Cascades.

The following table, showing the minimum flow of Metolius River in different sections, is based on records of the gaging stations that have been maintained below Lake Creek and at two points below Whitewater Creek, and miscellaneous measurements of all the tributaries and of the river below Canyon Creek.

Low-water discharge in second-feet of Metolius River and tributaries.

Metolius River above Lake Creek	100
Metolius River at Allingham ranger station	325
Jacks Creek, including Heising's spring	175
Canyon Creek	70
Springs between Allingham and Allen's ranch	290
Metolius River at Allen's ranch, sec. 11, T. 12 S., R. 9 E	860
Cabot Creek	70
Jefferson Creek	70
Whitewater	40
Springs, Allen's ranch to Hubbard's ranch	130
Metolius River at Hubbard's ranch	1,170
Metolius River at Riggs and mouth	1,330

DURATION OF LOW-WATER PERIOD.

The water-power value of any stream or power site and the size of feasible development depend fully as much on the length of the low-water period as on its maximum intensity. The length of the period in each year for which the discharge is less than any given quantity is shown for Deschutes River at Allen's ranch, Benham Falls, Moody, and Moro, East Fork near Crescent and Metolius River near Sisters, by tables which were prepared by counting the number of discharges in the year that fall below a given discharge, usually that for the lowest even tenth of gage height, and then for increasing discharges until the average period of deficiency is equal to about half the year, sometimes a little greater on a stream as steady as the Deschutes.

For Benham Falls and Moro the year has been studied in two periods—the irrigating season, May to September, and the nonirrigating season, October to April. These two periods have then been combined to a climatologic year May to April, because May usually falls in a period of high water and the year thus contains only one

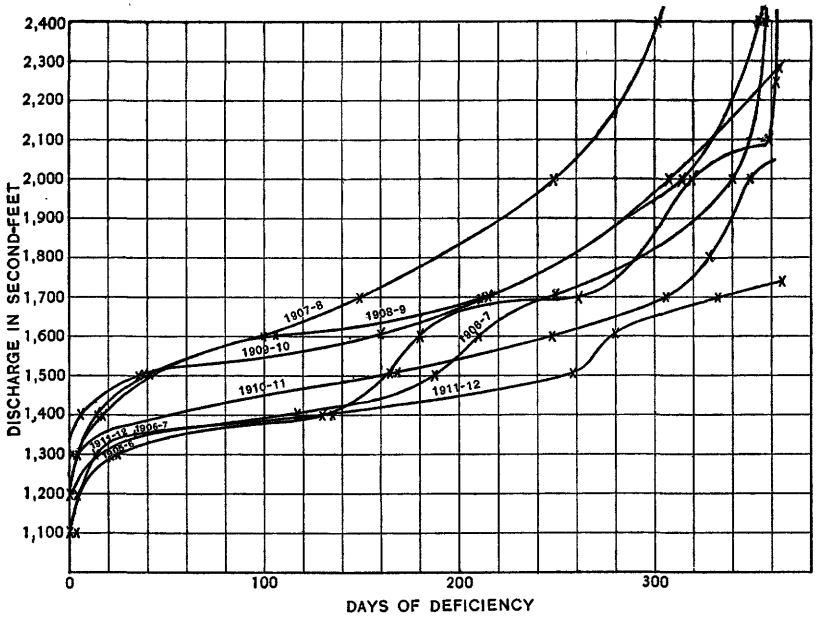


FIGURE 1.—Diagram showing number of days deficient discharge on Deschutes River at Benham Falls, May 1 to April 30.

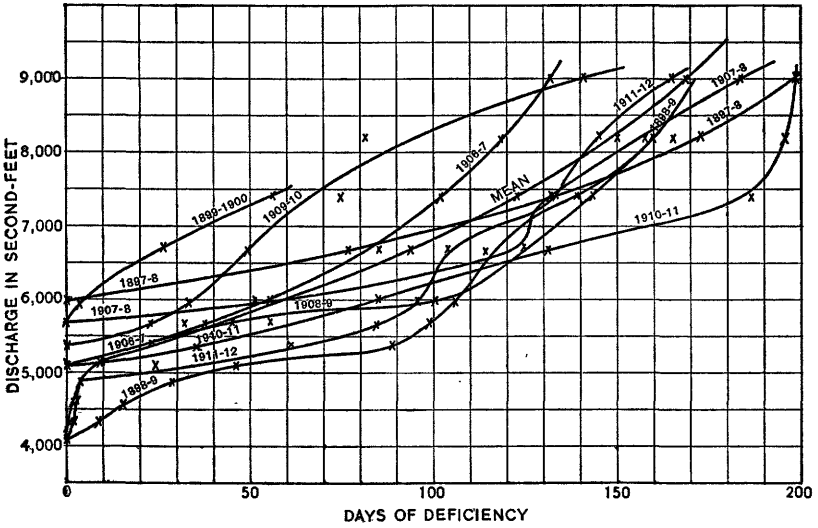


FIGURE 2.—Diagram showing number of days deficient discharge on Deschutes River at Moro and Moody, in the nonirrigating season, October to April.

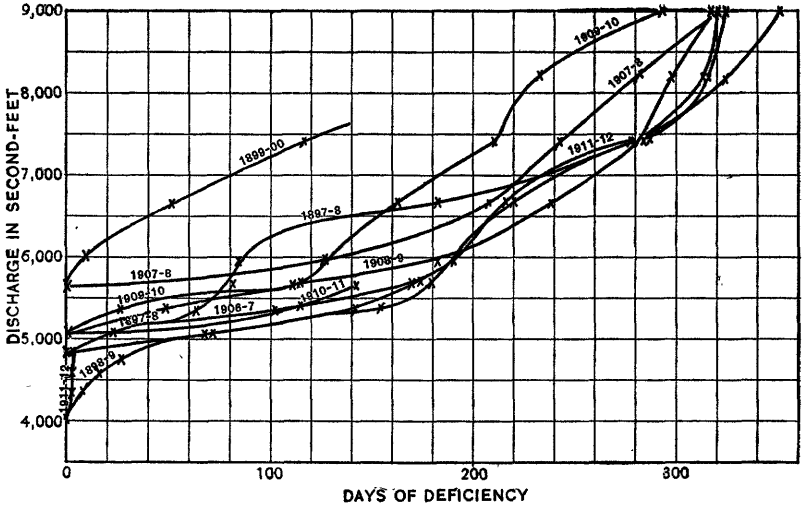


FIGURE 3.—Diagram showing number of days deficient discharge on Deschutes River at Moro and Moody May 1 to April 30.

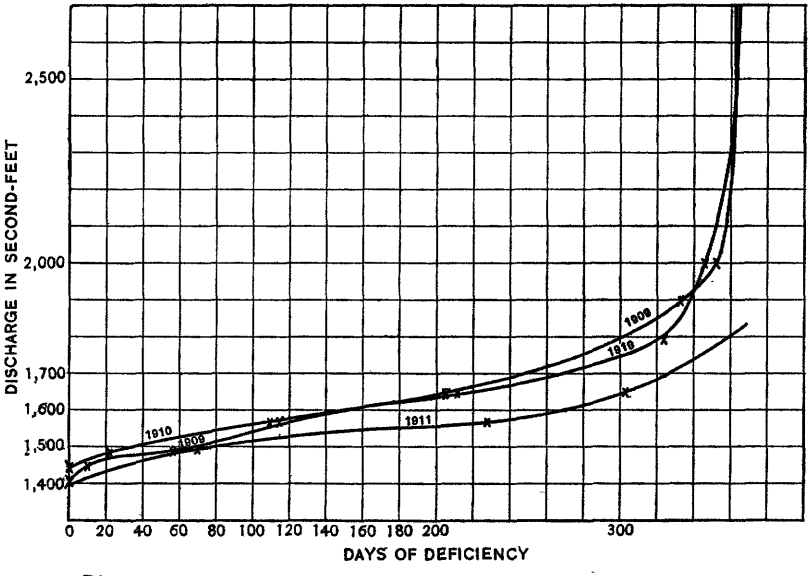


FIGURE 4.—Diagram showing number of days deficient discharge on Metolius River near Sisters, for calendar year.

season of low discharge, instead of parts of two as would be the case if the calendar year were used or a period beginning October 1 to November 1.

The calendar year is the period used for Little River at Allen's ranch, East Fork and the Metolius, largely as a matter of convenience. Metolius River is so steady that it is almost immaterial what period is selected.

The tables have been reduced to graphic form by plotting the discharges and days of deficiency for each year as coordinates and drawing the curves through the points (figs. 1–4). These curves represent approximately those that would be obtained if the daily discharges for the year were plotted in order of magnitude. They show at a glance the relative characteristics of flow of the several years, but they fail in one important particular, in that they do not show whether the low-water period is continuous or broken by a rise of more or less duration. This information can be derived only from a study of the daily discharges.

One notable feature of nearly all the curves is that they tend to dip down on the left, showing a decreased discharge for a relatively short period. This seems to be the result of special conditions not fully understood which retard the flow for a short period.

COMPARISONS OF DISCHARGES AT ADJACENT STATIONS.

PURPOSE OF COMPARISON.

Comparisons of recorded discharges at different stations on the same stream may serve three purposes—the detection of errors, the determination of inflow or losses in the stream, and the determination of a basis for extending a short record from a longer one.

BENHAM FALLS AND BEND.

Within a stretch of 36 miles, from Benham Falls to Cline Falls, four gaging stations have been maintained on Deschutes River, with intermediate stations at Bend and Laidlaw, and records of the only important diversions—the Central Oregon and Pilot Butte canals. The sum of discharges at Bend and of the two canals should be directly comparable with the discharge at Benham Falls. That it is comparable is indicated by the fact that the yearly means do not differ more than 3 per cent. The discharge at Benham Falls in 1910 was 3 per cent less than the total, most of the difference coming in January to April. There was probably some actual inflow into the river during these months, as the snowfall of the winter was heavy, extending down into the lower levels, and it ran off quickly without sinking into the ground as much as usual, especially in March, which shows the greatest gain in discharge, 12 per cent. The comparisons appear to indicate that all the records are fairly reliable.

Comparison of discharges, in second-feet, of Deschutes River and canals near Bend, Oreg., with Deschutes River at Benham Falls, 1909–1912.

Month.	Deschutes at Bend.	Pilot Butte canal.	Central Oregon canal.	Total.	Deschutes at Benham Falls.	Difference per cent.
1909.						
January	1,560	1.4	9.7	1,570	1,650	+ 5
February	1,550	22.0	39.1	1,610	1,620	0
March	1,440	52.7	72.6	1,570	1,570	0
April	1,510	93.4	128	1,730	1,720	0
May	1,450	150	194	1,790	1,790	0
June	1,420	176	191	1,790	1,790	0
July	1,340	128	144	1,610	1,600	0
August	1,090	182	224	1,500	1,530	+ 2
September	1,180	131	172	1,480	1,520	+ 3
October	1,240	91.4	122	1,450	1,480	+ 2
November	2,070	15.2	21.7	2,110	2,040	− 3
December	2,030	1.7	9.1	2,040	1,930	− 5
The year	1,490	87.3	111	1,700	1,690	− 1
1910.						
January	1,640	4.0	17.2	1,660	1,530	− 8
February	1,590	11.0	25.3	1,630	1,590	− 2
March	2,290	29.6	46.4	2,370	2,090	−12
April	1,890	91.8	124	2,100	1,950	− 7
May	1,720	121	160	2,000	1,980	− 1
June	1,360	185	208	1,750	1,750	0
July	1,130	197	258	1,580	1,610	+ 2
August	1,210	189	132	1,530	1,540	0
September	1,160	145	192	1,500	1,500	0
October	1,200	118	170	1,490	1,470	− 1
November	1,420	34.9	47.8	1,500	1,490	0
December	1,470	24.0	69.7	1,560	1,560	0
The year	1,510	96.2	121	1,730	1,670	− 3
1911.						
January	1,330	11.5	27.1	1,370	1,420	+ 4
February	1,330	3.4	25.0	1,360	1,360	0
March	1,340	18.1	43.3	1,400	1,410	+ 1
April	1,350	80.7	130	1,560	1,570	+ 1
May	1,310	143	195	1,650	1,670	+ 1
June	1,270	175	226	1,670	1,710	+ 2
July	1,050	196	250	1,500	1,500	0
August	918	182	250	1,350	1,380	+ 2
September	1,050	138	184	1,370	1,390	+ 1
October	1,130	105	133	1,370	1,360	− 1
November	1,310	56.0	41.4	1,410	1,380	− 2
December	1,260	9.2	19.0	1,290	1,280	− 1
The year	1,220	93.6	128	1,440	1,450	+ 1
1912.						
January	1,380	10.3	15.3	1,410	1,380	− 2
February	1,510	12.0	23.6	1,550	1,560	+ 1
March	1,360	23.3	42.1	1,430	1,430	0
April	1,430	43.8	60.2	1,530	1,590	+ 4
May	1,580	134	172	1,890	1,890	0
June	1,690	185	248	2,120	2,150	+ 1
July	1,310	212	239	1,760	1,800	+ 2
August	1,210	214	241	1,660	1,690	+ 2
September	1,400	146	180	1,730	1,670	+ 4
October	1,390	117	174	1,680	1,590	− 5
November	1,490	75.4	132	1,700	1,620	− 5
December	1,570	9.6	22.9	1,600	1,500	− 6
The year	1,440	98.9	129	1,670	1,660	− 1

NOTE.—Percentages based on Bend plus canals.

BEND, LAIDLAW, AND CLINE FALLS.

Between Bend and Cline Falls there is no appreciable surface inflow except Tumalo Creek, the discharge of which has been included in making the comparisons. The records at the three points apparently show a gain between Bend and Laidlaw and a loss between

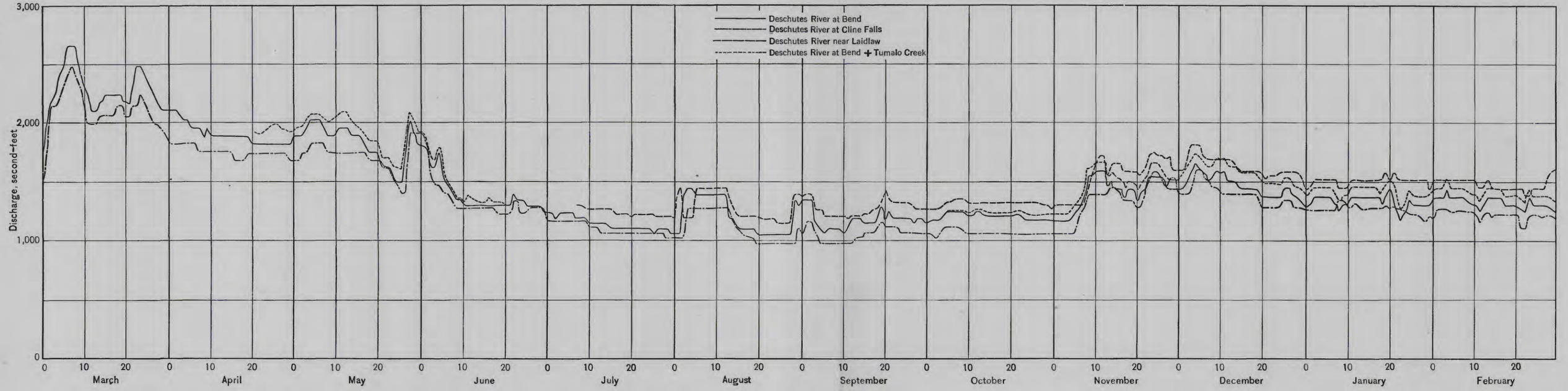
Laidlaw and Cline Falls. The mean gain is within the probable error of the record at either station, especially Laidlaw, which may be somewhat too high on account of the indifferent conditions for measurements. The loss might be accounted for by the fact that the ground water in the porous lava rock over which the river flows is far below the river level; the current is swift, and the water, mostly from large springs, carries little sediment, so that there is little tendency for the cracks or crevices to silt up, even in long periods. It is, however, entirely possible that the loss is more apparent than real. Possible loss or gain below Cline Falls is immaterial, as it is very unlikely that there will be any permanent flow below Cline Falls after the river is fully utilized for irrigation.

Comparison of discharge, in second-feet, of Deschutes River at Bend, Laidlaw, and Cline Falls, Oreg., 1910–1912.

Month.	Discharge.			Increase or decrease.		
	Bend plus Tumalo Creek at mouth.	Laidlaw.[a]	Cline Falls.	Bend to Laidlaw.	Laidlaw to Cline Falls.	Bend to Cline Falls.
1910.						
March	2,440	.....	2,100	.....	.....	−340
April	2,050	.....	1,740	.....	.....	−310
May	1,810	.....	1,710	.....	.....	−100
June	1,390	.....	1,310	.....	.....	− 80
July	1,130	.....	1,090	.....	.....	− 40
August	1,210	1,260	1,110	+50	−150	−100
September	1,170	1,240	1,050	+70	−190	−120
October	1,280	1,290	1,070	+10	−220	−210
November	1,510	1,550	1,350	+40	−200	−160
December	1,580	1,630	1,380	+50	−250	−200
1911.						
January	1,410	1,500	1,250	+90	−250	−160
February	1,420	1,470	1,220	+50	−250	−200
March	1,400	1,490	.....	+90	.....	.....
April	1,400	1,470	.....	+70	.....	.....
May	1,340	1,420	.....	+80	.....	.....
June	1,410	1,480	.....	+70	.....	.....
July	1,070	1,140	.....	+70	.....	.....
August	924	949	.....	+25	.....	.....
September	1,050	1,080	.....	+30	.....	.....
October	1,140	1,180	.....	+40	.....	.....
November	1,370	1,360	.....	+10	.....	.....
December	1,330	1,390	.....	+60	.....	.....
1912.						
January	1,450	1,500	.....	+50	.....	.....
February	1,600	1,620	.....	+20	.....	.....
March	1,430	1,470	1,200	+40	−270	−230
April	1,450	1,520	1,270	+70	−250	−180
May	1,660	1,690	1,430	+30	−260	−230
June	1,860	1,870	1,670	+10	−200	−190
July	1,350	1,410	1,220	+60	−190	−130
August	1,230	1,230	1,090	.....	−140	−140
September	1,430	1,360	1,200	−70	−160	−230
October	1,430	.....	1,190	.....	.....	−240
November	1,560	.....	1,330	.....	.....	−230
December	1,660	.....	1,430	.....	.....	−230
Mean	.....	.....	.....	+43	−213	[b]−184

[a] Diversions in two small canals not included. See p. 29.
[b] Later measurements indicate the probability of no loss between Bend and Cline Falls.

The results of the comparison are also indicated in the diagram forming Plate II.



HYDROGRAPH COMPARING FLOW AT STATIONS ON DESCHUTES RIVER.

MECCA AND MOODY.

The inflow between Mecca and Moody comes from Warm Springs and White rivers from the west, Trout Creek from the east, and a number of small streams from both sides.

Trout Creek and the small creeks are probably intermittent. Warm Springs and White rivers have a large perennial flow. Records of discharge are available on Warm Springs River below all tributaries and on White River and Tygh Creek just above their junction, thus accounting for practically all the inflow from tributaries except during the winter and spring, when there is run-off from rains and melting snow.

There remains an inflow of more than 400 second-feet at low water, which must enter from springs at various points, and of 1,000 to 3,000 second-feet during the winter. There are springs at a number of points in this stretch of river and numerous tributaries, but as their contributions have never been measured or estimated, the distribution of the inflow can be made only approximately. (See p. 116.) As the total inflow at low water amounts to only about 10 per cent of the flow at Mecca, no material error is introduced if it is assumed that the unmeasured inflow is equally distributed between the mouth of Warm Springs and White rivers.

Comparison of discharge, in second-feet, of Deschutes River at Mecca and Moody, and inflow, 1911–1912.

Month.	Deschutes River at Mecca.	Warm Springs River.	White River.	Tygh Creek.	Total discharge.	Deschutes at Moody.	Difference between total discharge and discharge at Moody.	Difference between discharge at Mecca and Moody.
1911.								
June 7–30	4,890	[a] 656	302	92	5,930	6,340	410	1,460
July	4,360	[a] 406	179	30	4,975	5,260	285	900
August	4,050	268	112	15	4,445	4,850	405	800
September	4,150	266	143	31	4,590	4,930	340	780
October	4,090	266	139	26	4,521	4,990	469	900
November	4,210	292	245	90	4,831	5,440	603	1,230
December	4,300	390	192	.....	4,882	5,340	458	1,040
1912.								
January	5,050	[a] 748	688	.....	6,486	7,940	1,454	2,890
February	5,940	[a] 847	918	300	8,005	9,720	1,715	3,780
March	5,200	[a] 922	361	121	6,604	6,920	316	1,720
April	6,460	[a] 587	562	179	7,788	9,550	1,762	3,090
May	7,100	804	768	216	8,888	9,770	882	2,670
June	6,020	[a] 870	491	155	7,536	7,980	444	1,960
July	4,850	345	233	48	5,476	5,910	434	1,060
August	4,550	289	167	28	5,034	5,390	356	840
September	4,520	302	170	29	5,021	5,520	499	1,000
October	4,390	295	175	30	4,890	5,480	590	1,090
November	4,770	342	236	[b] 70	5,418	6,030	612	1,260
December	4,670	323	201	[b] 60	5,254	6,000	746	1,330

[a] Estimated from comparisons with Shitike Creek. [b] Estimated.

NOTE.—Mean difference between total discharge and discharge at Moody for low-water months, August to October, 1911, and March, 1912, and June–October, 1912, 428 second-feet.

ECONOMIC DISTRIBUTION OF WATER OF DESCHUTES RIVER.

By JOHN H. LEWIS, State engineer of Oregon.

PRESENT AND PROSPECTIVE USE.

The waters of Deschutes River and its tributaries have three principal fields of utility—for domestic supply, for irrigation, and for power development. It is important to the future prosperity of the State that these waters be put to the highest use. To accomplish this, and in order that the greatest good may come to the greatest number, it appears advisable that a comprehensive plan of development be presented and discussed.

Domestic use is the highest use to which water can be put, as water is absolutely necessary for the maintenance of life. Irrigation comes next, as in the arid region the meager rainfall must be supplemented by water diverted from streams to produce ordinary agricultural crops. Under such conditions irrigation therefore affects the production of food supplies. The use of water for power development is less important than either of the other uses, as power can be obtained from many other sources than from falling water.

Development in the arid States depends largely on the diversion and use of water. To facilitate diversion many States have declared the beneficial use of water to be a public use and necessity, in order that the power of eminent domain may be extended to make easy the acquirement of necessary rights of way. Certain of these beneficial or public uses are of a higher order than others, and these States have later, by statutes, fixed the order of preference, so that water which has been applied to a lower use may be taken by process of law upon due compensation and may be applied to the higher use. Public necessity through increased population makes such transfers necessary.

As early as 1893 (session laws, p. 150) the State of Oregon provided that "When the waters of any natural stream are not sufficient for the service of all those desiring the use of the same, those using the water for domestic purposes shall, subject to such limitations as may be prescribed by law, have the preference over those claiming such water for any other purpose, and those using the water for agricultural purposes shall have the preference over those using the same for manufacturing purposes." Though this section has not yet been passed upon by the courts, it is believed that it authorizes the condemnation of the lower use only, in favor of application to a higher use.

It is believed to be poor public policy for a State to permit the construction of water-power plants on that portion of a stream where it is apparent that in a few years the water should and probably will

be diverted for irrigation. It is likewise poor policy to permit the diversion of water from one drainage basin where it can be used for both power and irrigation to another basin where it can be used for power only and where irrigation is not absolutely necessary. Especially is this true when it is known that on other streams in the vicinity of such proposed power projects there is far more undeveloped power than can be put to use in many years and where the cost of development will be little, if any, greater.

It is not deemed necessary, under present conditions, to enter into any great degree of refinement in justifying a State policy of withholding water from one use for application to another. It is estimated by the Oregon Conservation Commission that there is in Oregon more than 3,300,000 undeveloped horsepower which is running to waste. Not one-tenth of this amount is developed at the present time. The same authority, in its report for 1912, states that the mean yearly run-off from 36 streams, which have been measured for a number of years by the United States Geological Survey in cooperation with the State, amounts to 39,996,000 acre-feet, only one-fourth of which is capable of ever being utilized for irrigation.[1]

It can be stated on fairly good authority that there are in Oregon at least 2,000,000 acres which can be irrigated at a cost which is fully warranted under present-day conditions, say from $30 to $60 per acre. This land, now largely in private ownership, is worth perhaps $5 to $30 per acre; it supports at most one family for each 320 acres. Irrigated and improved the same lands would be worth from $100 to $200 per acre and would support six to ten times the present population.[2]

With almost unlimited water-power resources and with limited possibilities for irrigation development, it appears to be a wise public policy to prevent water-right complications by restricting power development along streams where storage or diversion of water for irrigation is possible. Furthermore, with irrigation on the upper portion of a stream, the water powers on the lower portion may be improved rather than injured, as a result of uniformity of flow from return seepage.

If Deschutes River were an isolated stream (see comparative profiles, fig. 5, p. 74) with a prospective demand for full development of its possibilities for water power and irrigation, it would be necessary to balance the necessities and values of one use against those of the other, but electric power can now be transmitted from 200 to 300 miles, if necessary, to replace any power destroyed by irrigation.

By thus analyzing present and prospective uses and following a preconceived plan for the highest development of the waters of each stream basin, the State can avoid future complications, encourage irrigation development, and prevent the destruction of property

[1] Oregon Conservation Commission Rept. 1912, p. 36. [2] Idem, p. 45.

necessary in applying water to one use in order to put the water to a higher use, a needless waste which is often found essential under the old method of proceeding without a comprehensive plan.

Owing to the peculiarities of climate, soil, topography, and geology, which prevail in different parts of the Deschutes basin, there can be but little difference in opinion as to what the ultimate distribution of the available water supply should be.

The drainage basin is 170 miles long and 125 miles wide at its widest point (see Pl. I, p. 20), and varies in elevation from about 130 feet at the mouth of the river to over 11,000 feet above sea level at

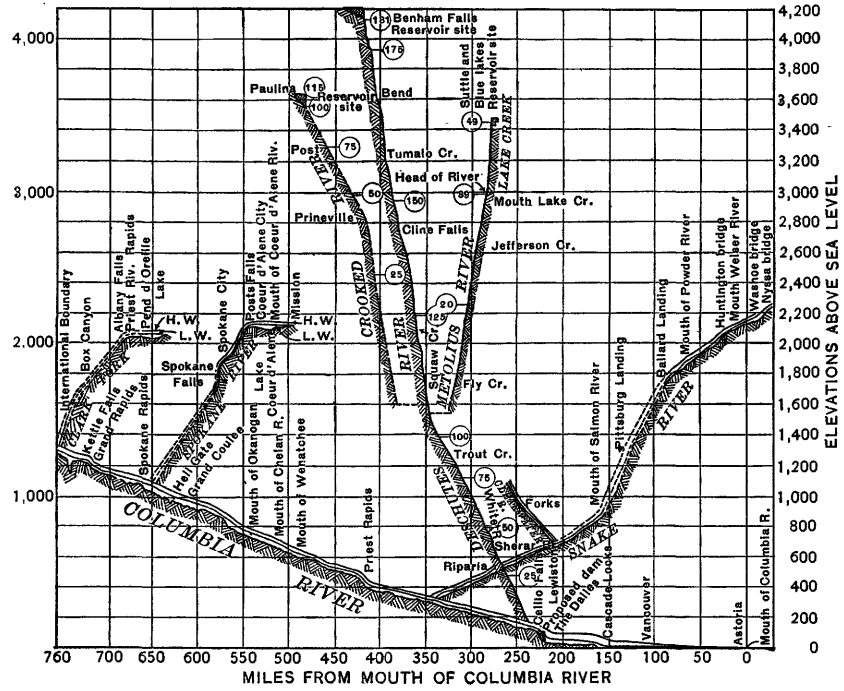


FIGURE 5.—Profiles of Deschutes, Metolius, and Crooked rivers compared with profiles of Columbia and other rivers.

the summit of Mount Hood. It is comparatively undeveloped but is rich in agricultural, timber, mineral, and water resources. Deschutes River flows northward through the center of this area, approximately parallel to and 90 miles east of Willamette River, which also flows northward and through one of the largest, most fertile, and prosperous valleys in the State. About 62 per cent of the total population of the State is located in the Willamette Valley. Both valleys are supplied with competing transcontinental railway lines, and the navigable Columbia River lies on the north. The high Cascade Range, averaging from 5,000 to 7,000 feet in elevation, broken by 10 towering snow-clad peaks, separates these two valleys.

This range is covered with a dense forest growth and serves to cool to the precipitation point the moisture-laden winds that blow in from the Pacific. The combination of heavy precipitation with the rapid descent of the mountains to sea level gives to Oregon her enormous water-power resources. The surface formation of pumiceous sand underlain with lava, and the numerous lakes in the upper part of the Deschutes basin serve to equalize the flow throughout the year, thus producing one of the most remarkable power streams in the world.

This power is within easy transmission distance from tidewater, is adjacent to the most populous district in the State, is surrounded by innumerable raw resources, and needs only the magic touch of capital intelligently applied to produce enormous wealth for shipment over existing rail and water lines to the markets of the world.

The distribution of water in the Deschutes basin can best be discussed under three heads—power, irrigation, and storage.

Power development should be restricted to the lower Deschutes, irrigation to the central stretch between the towns of Bend, Prineville, Madras, and Sisters, and storage to that part of the basin to the south, east, and west of the irrigation district.

POWER.

Power should be developed only on lower Deschutes and Metolius rivers or on those tributaries of the Deschutes on which the water can be used for power above the points of possible diversion for irrigation, such as Tumalo Creek.

Though it is impossible to predict with certainty the time or amount of return seepage from an extensive irrigation project such as is possible in the central part of the Deschutes basin, it is believed that the fullest use of the upper Deschutes River for irrigation will not seriously impair possibilities for power development on the lower river, and in fact may even be a benefit, as a part of the return water will doubtless reach the river during the winter months, which usually constitute the low-water season.

Practically all seepage water will probably return above the mouth of Metolius River, which is 111 miles from and 1,400 feet above the mouth of the Deschutes. Though the average fall in this lower section of Deschutes River is only about 13 feet to the mile (see Pl. III, at end of volume), good dam sites are numerous and almost every foot of available fall can be utilized, as shown elsewhere in this report. With 50,000 acre-feet of storage on the headwaters of Crooked River to supplement the low-water flow for power development, 4,500 cubic feet a second can probably be depended on for power at the mouth of the Deschutes, with all waters of Deschutes River at Bend, of Tumalo and Squaw creeks, and 150,000 acre-feet of the flow of Crooked

River fully utilized for irrigation. At the 14 dam sites selected over 504,000 brake horsepower can be developed.

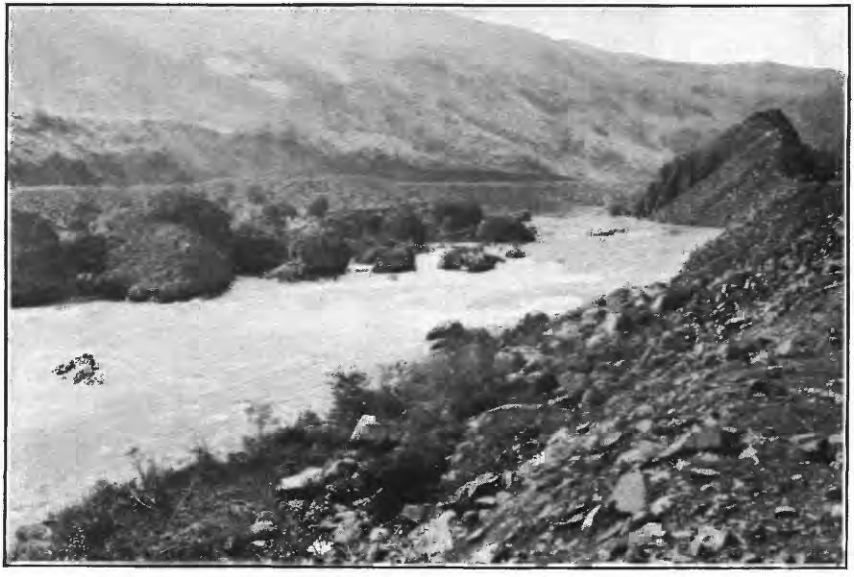
Metolius River has an average fall of 39.5 feet to the mile in the 48 miles from Blue Lake to its mouth (Pl. IV, at end of volume). Within a few miles from its source this stream is augmented by short creeks that carry large quantities of water from the high snow-clad mountains to the west, so that in volume the lower half of Metolius River compares favorably with Deschutes River at Bend. At the four power sites selected on this stream approximately 100,000 brake horsepower can be developed, as shown elsewhere.

Crooked River from about 7 miles below Prineville to its mouth, a distance of about 30 miles, has a fall approximating that of lower Metolius River but only a small water supply. During the irrigation season no water passes Prineville, and only a small amount of seepage water enters the canyon below. About 7 miles above its mouth this flow is materially increased by the flow of Opal Springs, in sec. 33, T. 12 S., R. 12 E. Much of the fall in lower Crooked River will, however, be destroyed by the suggested dam in the Deschutes just below the junction of the two streams. From Prineville to Paulina, a distance of 78 miles measured along the stream, Crooked River has an average fall of approximately 10.5 feet to the mile.

From Cline Falls (Pl. V, *A*) to Columbia River, a distance of 144 miles, Deschutes River flows through a deep rock-walled canyon (Pl. V, *B*), which has been gradually cut by the action of water through layer after layer of basaltic rock to a depth of 500 to 2,000 feet or more. This canyon winds through a broad, rolling plateau covered with a scattering growth of sagebrush and juniper which gradually changes to a straggly pine and later to a dense pine timber as the mountains are approached on either side. The soil is a fine volcanic ash, light in color when dry and rich brown when wet, and under irrigation would doubtless be found very fertile. The precipitation on this plateau in Sherman County and the north half of Wasco County ranges from 12 to 15 inches a year. This, with the favorable moisture-retaining character of the soil, makes an ideal dry-farm wheat-producing district. The Deschutes Canyon is not discernible to one looking across this plateau when standing in these wheat fields a mile or so from its edge.

A very small amount of water can be diverted on this plateau from the tributaries of the lower river, and the valleys along such streams as White, Warm Springs, and other rivers and creeks on the Warm Springs Indian reservation, and along Trout and Willow creeks on the opposite side of the Deschutes, are so small or the water supply is so meager as to make extensive irrigation impracticable. These creeks in general flow in canyons from 100 to 1,000 feet deep. The annual rainfall seems to diminish as one goes south, thus making dry farming more hazardous.

A. CLINE FALLS, DESCHUTES RIVER.



B. CANYON OF DESCHUTES RIVER IN SEC. 16, T. 5 S., R. 11 E.

The east half of the Indian reservation is a gently rolling prairie about 300,000 acres in extent, averaging 2,600 feet in elevation, with a gradual slope east to the Deschutes Canyon. A layer of soil 6 inches to 2 feet thick rests on lava rock, which in many places protrudes above the surface, and much of the apparently good soil is covered with lava bowlders, thus making the whole area appear very unattractive for agriculture.

IRRIGATION.

Across the river from the Indian reservation a plateau known as Agency Plain and the Haystack country extends from Crooked River nearly to Trout Creek in a broad, rolling prairie about 150,000 acres in extent. This land is almost exclusively in private ownership, having been entered in 1903 and 1904, when it was discovered that grain crops could be grown with some success. The district is free from surface rock and is largely in cultivation. As in most of the plateau wheat districts of Oregon, domestic and stock water must be hauled many miles. This discourages intensive agriculture and favors the growth of large individual or company holdings. A preliminary examination of this tract indicates that about 100,000 acres may be irrigated from Deschutes River.

Metolius River breaks forth suddenly as a large spring at the base of Black Butte, an extinct volcano, which rises several thousand feet above the surrounding plateau. It flows northward to the Indian reservation, where it has cut a deep canyon through the narrow precipitous ridge which extends northward from the base of Black Butte. By constructing an expensive dam and a long canal leading from the big bend in this stream where it breaks through this ridge, it may be possible to divert water upon 30,000 to 50,000 acres of land lying east of the ridge and south of Metolius River. It is believed, however, that present conditions will not justify the cost of construction of such a gravity project.

It is doubtful if water can be pumped to any great extent from Metolius River or if it can be carried through an inverted rock tunnel siphon for irrigation on the opposite side of Deschutes River.

A good dam site apparently exists at the outlet of Suttle Lake. A dam at this point more than 18 feet high will back water up over Blue Lake, thus giving sufficient storage to control the drainage into both these lakes. This drainage may possibly be augmented by canals crossing through a saddle from the west side of the Cascade Range, thus collecting the drainage from both sides of Mount Washington and Three Fingered Jack, according to the topographic maps accompanying Professional Paper 9 of the United States Geological Survey. It is believed that water stored in these lakes can at moderate expense be diverted around the south side of Black Butte for the irrigation

of lands in the vicinity of the town of Sisters. Sufficient data as to water supply are not available to determine definitely what area can ultimately be irrigated from this source, but it will probably be in the neighborhood of 10,000 acres. The diversion of the summer flow and storage at the outlet of Suttle Lake for irrigation can not materially affect the flow of the Metolius available for power development.

Squaw Creek is entirely diverted during the summer for the irrigation of 16,480 acres in the vicinity of Sisters. No satisfactory sites have been located on this stream for winter storage.

Tumalo Creek has a fall of 1,500 feet in approximately 12 miles of its course above the intake of the proposed low-line diversion canal leading to the Wimer reservoir site in secs. 29, 30, 31, and 32, T. 16 S., R. 11 E. Willamette meridian. This basin will have a capacity of 36,000 acre-feet with water 73 feet deep at the proposed dam site. This capacity is sufficient to regulate the flow of Tumalo Creek and also of Crater Creek, which can be turned over the divide by the construction of a short diversion canal. The combined flow of these streams may be sufficient for the reclamation of 30,000 acres of irrigable land if seepage losses are not excessive. Approximately 10,000 horsepower can be developed in this stream without in any way conflicting with irrigation, an amount which would be sufficient to supply commercial power for this district for many years to come. Ice may, however, prevent the development of power near the head of this stream during the winter months.

An appropriation of $450,000 was made by the State legislature in February, 1913, for the completion of that part of this project which was originally segregated under the Carey Act and known as the Columbia Southern project. The promoters, under a defective contract, were permitted by the State to sell water rights to approximately 18,000 acres of land where the regular flow of the stream would not thoroughly irrigate one-fifth such amount. After failure of the original company and after repeated efforts on the part of the Desert Land Board to enlist private capital for the completion of the project, including the necessary storage, the legislature made an appropriation which is to be returned within 10 years, with interest at the rate of 6 per cent, including $5 per acre in addition thereto for the State's reclamation fund. It is estimated that 23,500 acres will thus be reclaimed. The price to settlers will be based on actual cost and will not be known definitely until construction work is well advanced.

The Crooked River drainage basin is more barren and desert-like than that of any of the other important tributaries of Deschutes River. Its discharge fluctuates, for different seasons at Prineville, from about 5 second-feet to 5,000 second-feet, the floods occurring during the spring break-up. Its low-water flow is fully appropriated at or above Prineville, and a considerable area is dependent on early spring irriga-

tion to mature at least one crop. The total area irrigated during the spring months by Crooked River and its tributaries in 1910 amounted to 27,960 acres, which is more than is now irrigated by Deschutes River itself and its tributaries. Of this area 3,209 acres is located below Prineville and irrigated from Crooked River and McKay Creek, and 3,783 acres are irrigated from Ochoco Creek and its tributaries. In T. 14 S., R. 21 E., 3,537 acres are irrigated, and in Tps. 19 and 20 S., R. 22 E., 2,058 acres, mostly wild-grass meadow, are irrigated. The largest body of irrigated land is located just above Paulina, at the junction of the numerous tributaries which meet in that vicinity.

A suggested dam about 1 mile below the junction of the North and South forks of Crooked River in sec. 6, T. 17 S., R. 21 E., to hold 170 feet depth of water, will create a lake of 6,250 acres and store 360,000 acre-feet, according to preliminary investigations by the United States Reclamation Service. If these figures are confirmed by careful surveys, this reservoir will hold more water than is necessary to supply the irrigable land along the stream. However, water can be diverted from Crooked River a short distance above Prineville and conducted through a canal approximately 50 miles long and cover the 100,000 acres of irrigable land on Agency Plain. A hasty examination of this latter project indicates that it will cost more to irrigate such lands from Crooked River than from the Deschutes. It is believed that the value of these lands when irrigated will justify the construction of even the Crooked River project.

Various authorities claim that 10,000 to 43,000 acres additional can be irrigated from Crooked River in the vicinity of Prineville, and about 7,000 acres in the various pockets along the stream above Prineville and below the reservoir site. This irrigation will require about 150,000 acre-feet of water, leaving about 80,000 acre-feet to supplement the flow in the lower Deschutes River for power development, the rest of the reservoir capacity being used to equalize the flow between wet and dry years. Some additional storage for irrigation or power can be had along Ochoco Creek, but it is believed to be quite expensive.

Below Cline Falls on Deschutes River it is practically impossible to divert water by gravity from the main stream for irrigation. Between Cline Falls and Benham Falls the canyon is 100 feet or more deep in places, but at other points the stream comes near enough to the surface of the plateau so that, it appears, water can be diverted without excessive cost. The extent of present diversions and vested rights to water in the vicinity of Bend has been described elsewhere in this report.

With the fullest development of the Deschutes through storage thousands of acres of arid land in addition to that now in process of

reclamation from the ordinary summer flow of the stream can ultimately be brought under cultivation in Crook County.

The entire flow of Deschutes River in the vicinity of Bend, amounting to 1,220,000 acre-feet per annum, can be regulated by constructing a dam just above Benham Falls (Pl. VI, *A*), if foundations and other conditions prove feasible and if no better site can be found. To store the surplus winter flow this reservoir should have a capacity of at least 700,000 acre-feet, to insure which the water surface at the dam site should be raised 65.3 feet, flooding 25,630 acres. This dam site is 14 miles south of Bend and 181 miles from and 4,014 feet above the mouth of Deschutes River. In a straight line it is only about 115 miles to the Columbia. Throughout the summer season, as water is released for irrigation, there will be, at a point just below Benham Falls, a flow which will compare favorably with that of the lower Deschutes and which can be used for power development in diminishing quantities as it passes the various diversion dams to the last diversion below Laidlaw. This power can be developed at small cost, incidental to irrigation development, and can be used for pumping water to other lands or transmitted to the Willamette Valley for use during the low-water period to supplement power development. More detailed studies should be made in order to estimate even approximately the value of this summer power.

It can be safely stated that more land can be found available for irrigation below the proposed Benham Falls reservoir site than there is water to supply. There is 60,000 acres in what is known as the Benham Falls Carey Act segregation, which lies east of the town of Bend and which can be reached by a gravity canal with its intake immediately below the proposed dam. In the vicinity of Bend there is about 20,000 acres of timber land, which will be cut over within a few years and may eventually require water for irrigation. Approximately 100,000 acres northeast of Bend are to be irrigated from the regular flow of the stream under existing projects. The people on Agency Plain must have domestic water supply in the near future, and it is believed that they will be eager to sign up their lands to insure both irrigation and domestic supply from the suggested Benham Falls reservoir. From this source possibly 100,000 acres can be irrigated. The aggregate area of these tracts is 286,000 acres. There is about 6,000 acres of land on the narrow peninsula between the Deschutes and Crooked River canyons. The total area below Benham Falls which can ultimately be irrigated through the complete regulation of Deschutes River is only about 280,000 acres.

Any one of these districts could be omitted from a general scheme of construction, leaving the water to be applied to other tracts whose owners are more eager to obtain the benefits of irrigation. Because of the shortage in water supply for feasible gravity projects it is

A. BENHAM FALLS, ON DESCHUTES RIVER IN SEC. 9, T. 19 S., R. 11 E.

B. FALLS ON DESCHUTES RIVER IN SEC. 27, T. 18 S., R. 11 E., NEAR BEND.

doubtful if any extensive pumping projects will ever be undertaken in the upper Deschutes basin, where surplus summer power can be developed incidental to gravity diversions.

STORAGE.

The entire drainage area above Benham Falls can be considered a natural reservoir site. Underground water can be found at many places by digging from 4 to 8 feet through the loose pumiceous sand. An underground river running northward through Tps. 22 and 23 S., R. 10 E., can be traced for 10 or 12 miles by a narrow natural meadow terminating in the East Fork of the Deschutes, where numerous springs appear. The streams in this section are entirely different in character from those in all other sections of the basin. The water flows quietly and with scarcely a ripple through natural grass meadows, which are but a few feet above the water surface. At the edge of such a meadow a low bench appears, from the top of which the ground slopes very gradually to the crest of the divide. It is believed that all water originating in this upper basin comes to the surface at Benham Falls.

Natural reservoir sites exist at Crane Prairie, Odell Lake, Crescent Lake, Big Marsh (which is about 5 miles southeast of Crescent Lake), Paulina Lakes, and Benham Falls. Davis Lake has an underground outlet which will doubless prevent its use as a reservoir site.

Almost the entire drainage basin above Benham Falls, 48 miles in maximum length by about 42 miles in width, could be irrigated if there were no better use to which the water could be applied. This land is largely included in national forests and much of it is covered by jack pine poor in quality and of little commercial value at the present time. For the purposes of this report it has been assumed that water is to be allotted for only 80,000 acres in this upper basin. This, with a duty of 3 acre-feet at the intake will require annually 240,000 acre-feet of water. It is estimated that 50 per cent of this amount will reappear as seepage for storage in the proposed Benham Falls reservoir.

It is believed that 180,000 acre-feet of the total water reserved for the upper basin can be obtained from the regular flow of Little River (a name by which the Middle Fork, here considered the main stream, is locally known), supplemented by storage in Crescent and Odell lakes, the balance of 60,000 acre-feet to be diverted from West Fork, which is locally known as Big River.

The State, operating under the Carey Act, is now engaged in the reclamation of 30,000 acres in Tps. 21, 22, and 23 S., R. 10 E. This leaves only 50,000 acres of new land to be supplied with water. As a canal from Odell Lake will pass below the outlet of Crescent Lake and Big Marsh, and follow close to the summit of the Walker Range to a divide near the northeast corner of T. 25 S., R. 11 E., from which

point water will flow by natural channel to the Fort Rock desert, comprising about 300,000 acres near Silver Lake, it is apparent that there will be no difficulty in finding 50,000 acres of additional land upon which to apply such water.

A canal diverting water from the West Fork, in sec. 17, T. 21 S., R. 8 E., just below the outlet of the proposed Crane Prairie reservoir site, may be possible of construction southward, to the west of Davis Lake, to supply the greater part of the best lands in the Walker basin.

Paulina Lakes are said to be craters of an extinct volcano. Being near the summit of the range their drainage area is small and the outflowing stream is now fully utilized.

DOMESTIC SUPPLY.

Domestic use is the highest use to which water can be put. However, the prospective use for such purpose will be so small in comparison with the total used for irrigation and power that it can be secured, if necessary, by condemnation, without much financial loss due to failure of the general plans to comprehend such use.

The quality of the water available for domestic supplies in the Deschutes Valley, however, will have an important bearing on the future settlement of this district, and the preservation of its natural purity is an important duty that the State owes not only to the present but also to the future residents of this district. (See pp. 85–86.)

Anticipating a rapid development and settlement of the Deschutes River basin and recognizing the difficulty in enforcing proper sanitary regulations within the valley after it will have become densely populated, the legislature enacted a law making it–

unlawful for any person or persons, company, association, or corporation, to put or deposit in Deschutes River, or any tributary thereof, or artificial canal or ditch, in which the waters of said Deschutes River run, any sewage, refuse, waste, or polluting matter, or any dead animal carcass or part thereof, or any matter which either by itself, or in connection with any other substance, will corrupt or impair the quality of the water of said river for domestic or municipal purposes. The penalty for violation of this statute is a fine of $25 to $500 and imprisonment in the county jail from ten days to three months, or both such fine and imprisonment. (Chapter 45, Laws of Oregon, 1911, p. 66.)

This statute will compel all towns and cities to make definite plans at the outset for the disposal of sewage in some other way than by the usual method of discharging into surface streams. It is comparatively easy at the outset to compel development along right lines, but once sewers are constructed discharging into public streams, it will take the sacrifice of many lives through water-borne diseases and the useless waste of much money to remedy such conditions. Already the town of Bend has shown a disposition to conform with this law by preparing plans for the discharge of its sewage out on the desert at a point below the bed of the stream.

SUMMARY.

From information now in hand it appears that more than 600,000 horsepower can be developed and that approximately 500,000 acres of arid land can ultimately be irrigated from Deschutes River and its tributaries. These figures are itemized as follows:

Utilization of water of Deschutes River basin.

Power:	Brake horsepower.
Lower Deschutes River (14 sites)	504,070
Metolius River (4 sites)	98,289
	602,359

Power possibilities on other tributaries have not been investigated.

Irrigation:	Acres.
Metolius River, by canal from Suttle Lake	10,000
Squaw Creek, irrigated or claimed	16,480
Tumalo Creek, water available for	30,000
Crooked River, irrigated	27,960
Crooked River, additional irrigable, estimated	25,000
Paulina Creek, irrigated	700
Deschutes River at Bend, projects under way	100,000
Deschutes River, by storage in suggested Benham Falls reservoir	180,000
Deschutes River, by storage and regular flow south of suggested Benham Falls reservoir	80,000
Total, omitting many small tributaries of the lower Deschutes	470,140

Every drop of water in the Deschutes River basin, comprising 9,180 square miles, can and eventually will be put to beneficial use. If the development of this stream is left to private capital without public consideration of the effect of each new project on the comprehensive plan for the development of the valley as a whole enormous waste may take place before the highest use of these waters is attained. For immediate gain small and relatively expensive reservoirs might be built where a few large reservoirs could be made to serve all purposes. Power plants might be built at points where all the water should eventually be diverted or stored for irrigation. Power companies using plants on the lower river might attempt to secure such vested rights as would not permit the subsequent storage or diversion of water at points above for irrigation, when in fact the return seepage from such diversions, if permitted, would probably benefit rather than injure such power development. Extensive storage to supplement the flow of water in the lower river for power should not be permitted on Deschutes River above Bend but should be confined to Crooked River, from which stream the diversion of water for irrigation is more difficult. With this exception, all the water in the upper two-thirds of Deschutes River basin should be reserved for irrigation, as our supply of undeveloped water power is probably far beyond the needs of the

present generation, and further the area of semiarid land between the towns of Bend, Prineville, Sisters, and Madras, susceptible of irrigation from Deschutes River, is considerably in excess of the available water supply. To make possible the highest use of Deschutes River we must persuade the railroad company for its own interest to relocate its line south of Bend prior to construction, as for 15 miles it passes through the Benham Falls reservoir site, whereas at but little if any greater expense it could be located a little farther to the east and above the proposed water level. All these matters are believed to be within the control of the public if a comprehensive plan of development is adopted and subsequently adhered to and enforced. The preservation of the natural purity of these waters for domestic supplies is already protected by State law.

Neither the State nor the Nation can long afford to pursue a policy of preventing power development in a particular district in aid of irrigation without extending every aid and encouragement to secure the diversion and use of this reserved water for the higher use of irrigation. When there is any question as to the proper policy to adopt, the benefit of the doubt should be resolved in favor of present use.

The foregoing plan for the highest development of the waters of the Deschutes River basin, though based only on incomplete and to some extent very meager information, is believed to be sufficiently accurate to suggest to the administrative authorities—both State and national—the line of action that will be for the greatest good to the greatest number. The State water laws make it the duty of the State engineer to refer all applications for water privileges which menace either the safety or the welfare of the public to the State water board, and this board has full power to direct their refusal, if after full hearing public interest demands.

With such a plan approved by the Interior Department of the United States, which has broad powers relating to extensive public lands in this district, the public interest should be more clearly defined and more easily protected.

ACCURACY OF IRRIGATION DATA.

This report deals primarily with the quantity of water available for use in the Deschutes basin and with the water-power possibilities. The discussion relative to possibilities of irrigation is, however, incidental to the report, for it is necessary to know the amount of water to be reserved for irrigation in order to estimate the residue available for power development. The information with respect to areas irrigated or susceptible of irrigation has been compiled from various sources and supplemented by observations of the writer when in the field on other work. It is believed to be sufficiently accurate for the purpose intended.

The great possibilities for irrigation development as disclosed by this compilation were presented in the Fourth Biennial Report of the State Engineer to the Oregon Legislature, with the result that $50,000 was appropriated for the investigation of the Deschutes project along with others, the sum not to become available except for work carried on in cooperation with the United States. Within a few days after the passage of this act, in February, 1913, an equal amount of money was allotted from the United States reclamation fund, and cooperation in these investigations was authorized. Borings are now being made to ascertain the character of the formations at the proposed dam sites and the various canal lines are being located with sufficient accuracy to give a reliable estimate as to the cost of construction. A detailed report dealing with the possibilities of irrigation on Deschutes River basin will be issued on the completion of these investigations.

QUALITY OF WATER.

By WALTON VAN WINKLE.[1]

Deschutes River proper drains a region in which the exposed rocks are Tertiary lavas, tuffs, and basalts, and the mineral matter carried in solution is made up largely of salts of sodium, chiefly bicarbonate, leached directly from the disintegrating rock material. The total amount of dissolved matter carried is small, averaging at Bend between 65 and 75 parts per million, and at the mouth about 25 parts per million more. Seasonal variations in mineral content, at least above the confluence of Crooked River, are very small, owing to the remarkable constancy of volume of the run-off. The water of the upper Deschutes is excellent for irrigation, industrial, or domestic use. The amount of soap consumed by the hardening constituents in it is trifling, no treatment is in general required to prevent formation of scale in boilers, a quarter of a pound of lime to a thousand gallons of water at most being an ample corrective, and the water will not foam or cause corrosion in boilers. Though the water is soft it contains sufficient gas and dissolved mineral matter to render it palatable and wholesome. With proper precautions against contamination by human agencies the water is almost ideal for domestic use. As almost no suspended matter is carried by it, no trouble from silting up of reservoirs or sedimentation basins need be feared. In short, the water compares favorably with the better waters used for municipal supply in this country or in Europe. Though not so low in mineral content as Portland's supply from Bull Run, it is superior in this respect to the new supply of Los Angeles from Owens River, to the present supply of San Francisco, to supplies of any of the Middle Western cities, and to many of those on the Atlantic seaboard.

Crooked River furnishes only a small quantity of water to the Deschutes but is its chief tributary in point of size of drainage area.

[1] From U. S. Geol. Survey Water-Supply Paper 363.

It flows from the highlands in the southeastern corner of Crook County westward to the Deschutes, which it enters below the mouth of Opal Canyon. The drainage basin is almost completely covered with tuffs and lavas and contains only a few exposures of Tertiary lake sediments. Though the water is of the same general type as that of Deschutes River it is less uniform in quality, much harder, and less free from suspended matter, owing to the much greater fluctuations in discharge to which it is subject. The marked seasonal variations in quality influence the water of the Deschutes very little because of the relatively small run-off of Crooked River, and the water below the confluence of the two streams is still of good quality and only slightly harder than the water at Bend. During high water the mineral content of Crooked River water is nearly the same as that of Deschutes River, and it is only at low water that high mineralization and consequent poorer quality are apparent. The chief effect of Crooked River on Deschutes River is the increased charge of suspended matter imported by it, but even this is not enough to increase the turbidity of Deschutes River to a very great amount.

White River, which originates in glaciers on Mount Hood, adds much suspended matter to the lower Deschutes in summer, but its effects are not of great significance. The combined effects of the tributary streams on Deschutes River water increase the suspended solids to not more than 150 parts per million at times of greatest turbidity and to an unnoticeable extent during winter and spring.

AVAILABILITY OF THE WATER SUPPLY.

By F. F. Henshaw.

EVAPORATION.

When water must be stored in a large but relatively shallow reservoir loss by evaporation becomes a serious consideration. As no records of evaporation have been kept in the immediate vicinity of Deschutes River, records that have been obtained in other mountain and plateau areas of the West and that are thought to be valuable for comparative studies are presented in the following tables:

Evaporation at stations in areas comparable with drainage basin of Deschutes River.

Klamath River near Keno, Oreg.

[120 miles south-southwest of Bend; altitude, 4,080 feet.]

Month.	1904	1905	1906	1907	1908	1909	Mean.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
January	.....	1.19	.....	.....	.....	0.02	.....	.....
February	.....	.78	.....	.....	0.83	.18	.....	.....
March	.....	.78	.....	.....	1.20	.29	0.76	0.06
April	.....	2.69	3.03	.....	2.81	3.87	3.10	.26
May	.....	4.12	4.58	.....	3.38	4.47	4.14	.34
June	.....	6.20	4.04	3.29	5.60	6.65	5.16	.43
July	.....	7.57	5.87	4.70	8.01	6.06	6.44	.54
August	6.66	7.03	4.69	6.30	7.40	6.65	6.46	.54
September	5.12	6.15	3.76	4.05	4.62	4.68	4.73	.39
October	2.01	1.98	2.22	2.42	2.17	2.76	2.26	.19
November	.....	.46	.....	1.17	.89	.83	.84	.07

Evaporation at stations in areas comparable with drainage basin of Deschutes River—Continued.

Tule Lake at Merrill, Oreg.

[140 miles south-southeast of Bend; altitude, 4,060 feet.]

Month.	1904	1905	1906	1907	1908	1909	Mean.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
January	.....	0.11	0.24	0.07	0.17	0.50	0.22
February	.....	.04	.18	.17	.15	.05	.23
March	.....	.28	.22	.32	.25	.45	.30
April	.....	.36	.18	.41	.31	.36	.32
May	.....	.37	.57	.82	.41	.45	.52
June	.....	.46	.44	.48	.54	.51	.49
July	.....	.77	.49	.64	.69	.69	.66
August	0.92	.61	.65	.61	.51	.62	.65
September	.43	.50	.50	.45	.52	.38	.46
October	.28	.31	.28	.20	.27	.31	.28
November	.33	.31	.17	.26	.35	.27	.28
December	.35	.40	.15	.24	.30	.....	.24
The year	2.31	4.52	4.07	4.67	4.47	4.59	4.65

Moses Lake at Neppel, Wash.

[270 miles north-northeast of Bend; altitude, 1,040 feet.]

Month.	1909	1911	1912	Mean.	Mean.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Feet.*
February	.....	.....	0.06	0.06	0.01
March	.....	.....	.76	.76	.06
April	.....	.....	3.43	3.43	.29
May	.....	5.08	5.08	5.08	.42
June	.....	6.01	7.21	6.61	.55
July	7.20	6.85	8.01	7.35	.61
August	6.63	6.53	8.05	7.07	.59
September	4.14	4.07	5.65	4.62	.38
October	.76	2.47	3.36	2.92	.24
November	.....	.....	2.27	2.27	.19
December	.....	.....	.23	.23	.02
The period	.....	.....	.....	40.40	3.36

Lake Tahoe at Tahoe, Cal.

[350 miles south-southeast of Bend; altitude, 6,225 feet.]

Month.	1900	1901	1902	1903	1904	1905	1906
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	.....	0.84	1.02	0.70	1.17	1.81	1.12
February	.....	.70	.87	.84	.47	1.30	.98
March	.....	.77	1.24	1.88	.56	1.78	1.20
April	.....	1.25	1.85	2.75	1.38	2.46	1.42
May	2.44	2.42	1.08	3.20	3.19	2.50	2.26
June	3.89	3.35	2.45	3.90	3.80	3.57	2.39
July	4.00	4.42	3.40	5.62	4.42	4.76	4.30
August	5.15	6.50	3.45	4.66	4.73	5.27	4.55
September	3.10	4.12	3.40	4.27	3.27	4.74	3.94
October	2.15	2.65	3.09	3.33	2.86	3.82	3.70
November	1.38	2.09	2.15	2.53	2.77	2.78	1.35
December	1.33	1.44	.85	1.44	1.59	1.85	.62

The records for all these stations, except for Tule Lake, represent observations with standard evaporation pans. The recorded values for Tule Lake were derived by the United States Reclamation Service from studies of inflow in Lost River, the source of Tule Lake, and the fluctuation of level of the lake itself. It is reasonably certain that some water flows from the lake through the porous lava beds

which form its southern margin, and the estimated losses by evaporation are therefore probably too large, but as the error must be nearly constant month by month the records serve as a valuable aid in estimating losses in winter when the evaporation pans are unreliable. The amount of evaporation assumed for Benham Falls, based on a study of these records and shown in the following table, is probably conservatively large. The estimate of precipitation on the Benham Falls reservoir site is the average of the means of precipitation at Bend and Crescent, as given by the Weather Bureau in Summary of climatologic data of United States, as the site is almost halfway in a straight line between these two points.

Estimated precipitation and evaporation from water surface (in feet) at Benham Falls, Oreg.

Month.	Evaporation.	Precipitation.	Assumed net loss.
January	0.10	0.22	0.00
February	.10	.19	.00
March	.15	.18	.10
April	.30	.08	.20
May	.50	.12	.40
June	.50	.08	.40
July	.60	.06	.50
August	.60	.03	.60
September	.50	.04	.50
October	.30	.07	.20
November	.15	.15	.10
December	.10	.20	.00
The year	3.90	1.42	3.00

In order to determine the net quantity of water to be made available by any reservoir the estimated gross storage must be reduced by the estimated evaporation from the mean water surface.

The effect of evaporation on run-off is measured not by the actual evaporation from water surface but by the difference between the losses from water surface and from the land surface in its original condition. The transpiration of moisture from the rank growth of grass and tules in a marsh may be greater than from open water. For example, loss by evaporation from water surface caused by the flooding of an area like Big Marsh on upper Deschutes River would probably be no greater, and might be less, than the present loss due to plant growth. In the winter, when the surface is frozen and snow covered for two or three months, evaporation must be practically identical from ground and water surfaces and must be almost negligible in plans for storage. On a relatively flat area, such as the site of the suggested reservoir above Benham Falls, the rainfall during the growing season is probably all transpired by vegetation. During such periods the net loss in run-off caused by flooding would therefore be the difference between evaporation from water surface and rainfall. (See table.)

DUTY OF WATER.

The irrigating season in the Deschutes River basin lasts as a rule from 100 to 120 days, although some water is used outside of what is considered the season proper.

In contracts with some of the companies operating under the Carey Act it is stipulated that there shall be delivered on the land 1.8 feet of water in 90 days, May 23 to August 20. Allowing about 30 per cent loss in canals, this amount will equal 2.6 acre-feet per acre at the point of diversion for the 90 days. Enough water is required at either end of the season to bring the total diversion to at least 3.3 acre-feet per acre. For all tracts on the east side of the river below Benham Falls and for some on the west it is necessary to supply water for domestic use during the entire year. The amount diverted from October to April is in general about 10 per cent of the total. The monthly duty assumed for the several tracts and the total diversion is indicated in the following tables:

Monthly use of water in acre-feet and per cent of total on Deschutes projects (measured at point of diversion).

Month.	Above Benham Falls.		Benham Falls to Bend.		Below Laidlaw.	
	Acre-feet.	Per cent of total.	Acre-feet.	Per cent of total.	Acre-feet.	Per cent of total.
April					0.16	5
May	0.24	8	0.33	10	.33	10
June	.45	15	.66	20	.56	17
July	1.05	35	.82	25	.83	25
August	.96	32	.83	25	.82	25
September	.30	10	.33	10	.30	9
October to April			.33	10	[a].30	[a]9
Total	3.00	100	3.30	100	3.30	100

[a] October to March.

RETURN WATERS.

A part of the water applied to the land will reenter the stream at points lower down, the proportionate amount depending on the character of construction on canals and laterals, soils, method of application, and other factors. Little definite information is available as to seepage losses and return waters on Deschutes River projects, and any values that might be determined for present conditions would probably not be applicable in the future, when all the water would be used and seepage losses minimized. It is therefore necessary to make arbitrary assumptions as to the probable amount of water returned and also as to the place at which the water will reach the river.

There are two points at which the Deschutes receives large contributions from springs, one in the Benham Falls reservoir site and the other near the mouth of Crooked River. At the first, Spring River, a stream less than a mile long, discharges 180 to 300 second-feet into the Deschutes just below the mouth of West Fork, and Fall River, also entirely spring fed, enters West Fork near its mouth. Comparisons between discharge at Benham Falls and the forks above indicate that there may be seepage into the river which can not be accounted for by Spring River. It would therefore appear that the ground water is rising in this section of the river, and that any seepage from an irrigated tract above this point would rise here. Between Benham Falls and the mouth of Crooked River there are no visible springs, but large springs enter the lower part of Crooked River and there are probably some that deliver water directly to the Deschutes near this point. Comparison of the discharge of the Deschutes River at Mecca with that of the river and its two main tributaries above, indicates that during the low water of 1912 these springs must have been furnishing between 1,600 and 1,700 second-feet of water. As the seepage from the irrigated lands in the Deschutes and Crooked River basins must join the body of ground water from which these springs are fed, it has been assumed that all return waters will enter the Deschutes at the mouth of Crooked River.

It has also been assumed that of the water diverted above Benham Falls 50 per cent will return and be available for storage in a reservoir at that point, and that of the water diverted below Benham Falls 35 per cent will return at the junction of Crooked River with the Deschutes. Furthermore, it has been assumed that the return will take place gradually and uniformly throughout the year—an assumption justified by the fact that the return water does not reach the river directly but first joins the ground water in the porous lava.

These assumptions lead to the following estimate of future return waters at Crooked River:

Total possible diversions.

	Acre-feet.
Deschutes River between Benham Falls and Cline Falls	1,053,000
Tumalo Creek	72,800
Crooked River	150,000
	1,275,800

The equivalent mean discharge is 1,760 second-feet, of which it is assumed that 35 per cent, or 620 second-feet, will return to the river.

The amount returned under the conditions existing for the last seven years has been estimated by averaging diversions from October 1 to September 30, and assuming that 35 per cent of the diverted water returned to the river above the mouth of Crooked River between July 1 and June 30 of the following year, as shown in the table.

Mean diversions and estimated return waters from Deschutes River and tributaries, 1905–1912.

Mean diversions.		Return waters.	
Year (Oct. 1–Sept. 30).	Second-feet.	Year (July–June).	Second-feet.
1905–6	177	1906–7	62
1906–7	234	1907–8	82
1907–8	262	1908–9	92
1908–9	262	1909–10	92
1909–10	248	1910–11	87
1910–11	273	1911–12	95
1911–12	262	1912–13	92

The net effect of diversions and return, month by month, is shown in the table on page 114.

POSSIBLE USE OF WATER FOR IRRIGATION.

ABOVE BENHAM FALLS.

Two fairly distinct projects are possible of development above Benham Falls—one by direct diversion from the natural flow of West Fork near Crane Prairie, the other by diversion from Deschutes River near the mouth of East Fork, supplemented by storage on Big Marsh and Crescent and Odell lakes.

The water supply for the second project consists, during the irrigating season, of the total flow of Deschutes River below East Fork plus that of Odell Lake outlet; during the storage season it includes the flow at the Big Marsh dam site and the two lakes. As the discharge records at these storage sites cover only short periods, it has been necessary to estimate discharges by comparing the records of the Deschutes at Allen's ranch. Out of the eight years during which records are available at Allen's ranch (or at Lapine, which gives practically the same record) there were records on East Fork for five and one-half years. The difference between the discharges at these two points represents the flow of Deschutes River above East Fork, practically all of which can be stored either in Big Marsh or in Crescent Lake. The data for the division of the supply between the two forks are rather meager, but the total amount available for storage can be closely approximated. The records on which these estimates are based are compared in the following tables:

Comparison of discharges (in acre-feet) of upper Deschutes River and tributaries in 1912.

Month.	Big Marsh outlet.	Crescent Lake outlet.	East Fork of Deschutes.	Deschutes at Lapine.	Deschutes above East Fork.[a]
April	7,260	2,230	4,840	15,900	11,100
May	15,100	4,160	13,000	33,200	20,200
June	15,600	9,100	14,800	39,700	24,900
July	5,790	8,240	5,380	20,800	15,400
August	2,670	4,730	3,190	11,400	8,210
September	2,280	3,700	2,770	9,340	6,570
The period	48,700	32,160	43,980	130,340	86,380

[a] Obtained by subtracting discharge of East Fork record from discharge of Deschutes at Lapine record.

Relations (in percentages) between discharge of upper Deschutes River and its tributaries.

Month.	Big Marsh outlet to Deschutes at Lapine.	Crescent Lake outlet to Deschutes at Lapine.	East Fork to Deschutes at Lapine.	Big Marsh outlet to Deschutes above East Fork.	Crescent Lake outlet to Deschutes above East Fork.	Big Marsh outlet to East Fork at Crescent.
April	46	14	30	65	20	150
May	47	13	40	75	21	116
June	39	23	37	63	37	105
July	28	40	26	38	54	108
August	23	42	28	33	58	84
September	24	40	30	35	56	82
The period	37	25	34	56	37	111

Comparison of mean monthly discharge in second-feet, Deschutes River at Allen's ranch and East Fork at Crescent.

Month.	1905			1906			1907			1908		
	Deschutes.	East Fork.	Percentage.	Deschutes.	East Fork.	Percentage.	Deschutes.	East Fork.	Percentage.	Deschutes.	East Fork.	Percentage.
January	.....	76.6	....	166	88.8	56	220	89.7	41	300	58.1	19
February	.....	74.0	....	123	97.3	79	793	183	23	170	70.8	42
March	319	64.7	20	136	80.8	59	345	104	30	271	60.9	22
April	274	65.4	24	332	89.3	27	570	18.4	32	.....	.....	....
May	278	74.7	27	445	124	28	696	195	28	.....	.....	....
June	241	62.8	26	369	111	30	558	151	27	.....	.....	....
July	141	35.1	25	220	65.2	30	330	76.5	23	.....	.....	....
August	107	28.0	26	122	37.1	30	227	47.5	21	.....	.....	....
September	90.9	25.5	28	108	36.2	33	196	42.0	21	.....	.....	....
October	100	31.9	32	103	35.4	34	161	35.5	22	.....	.....	....
November	90.6	23.6	26	13.7	52.1	38	157	35.2	22	.....	.....	....
December	99.2	23.6	24	144	51.8	36	287	68.9	24	.....	.....	....
The year	.....	50.5	26	200	72.2	32	378	101	27	.....	.....	28

Month.	1910			1911			1912			Mean of percentages.
	Deschutes.	East Fork.	Percentage.	Deschutes.	East Fork.	Percentage.	Deschutes.	East Fork.	Percentage.	
January	.....	.....	....	150	59.7	40	240	.....	....	33
February	.....	.....	....	170	67.1	39	299	.....	....	35
March	.....	.....	....	174	87.1	50	179	46.2	26	30
April	.....	.....	....	256	74.3	29	270	81.3	30	28
May	.....	.....	....	416	105	25	540	213	40	30
June	.....	.....	....	487	139	29	668	248	37	30
July	.....	.....	....	226	54.2	24	339	87.5	26	26
August	.....	.....	....	125	35.8	29	185	51.8	28	27
September	.....	.....	....	128	34.4	27	157	46.5	30	28
October	138	35.7	26	118	35.5	30	.....	.....	....	29
November	162	50.5	31	143	(44.3)	....	.....	.....	....	29
December	229	57.0	25	114	(35.3)	....	.....	.....	....	27
The year	.....	.....	27	209	.....	32	.....	.....	31	29

NOTE.—Percentage for January, February, and March, 1906, discarded on account of ice at East Fork. Percentage of 28 has been used in discussion, as some other values for winter months are probably too high on account of ice.

Miscellaneous measurements made at Crescent Lake outlet prior to 1912 do not afford a sufficient basis for estimates of discharge. The winter flow of Crescent Lake outlet is probably low compared with that of the other tributaries of the upper Deschutes, but reliable winter records are lacking. For periods covered by records on East Fork the most reliable estimates for both Big Marsh outlet and Crescent Lake outlet can be made by taking percentages of the

differences between the discharge of the Deschutes at Allen's ranch and that of the East Fork at Crescent. The discharge of Crescent Lake outlet has been estimated by applying the following percentages. It has been assumed that the percentage decreases gradually from September to April.

Percentages used for computing probable discharges of Crescent Lake outlet.

Month.	Applied to record of discharge of Deschutes River at Allen's ranch.	Applied to discharge of Deschutes River at Allen's ranch minus discharge of East Fork at Crescent.	Month.	Applied to record of discharge of Deschutes River at Allen's ranch.	Applied to discharge of Deschutes River at Allen's ranch minus discharge of East Fork at Crescent.
January	25	35	July	40	50
February	20	30	August	40	55
March	16	25	September	40	55
April	14	20	October	40	50
May	13	20	November	35	45
June	23	35	December	30	40

The sum of the discharges of the outlets of Crescent Lake and Big Marsh appear to nearly equal the difference between the discharge of the Deschutes at Allen's ranch and that of the East Fork at Crescent, except possibly for a period in February and March, when the snow is melting from the lower areas. Thus the total water supply from the upper Deschutes that is available for storage can be determined very closely. For periods not covered by records of the East Fork the determination is subject to greater uncertainty.

The quantity of water indicated by the records at the station on Big Marsh outlet is not all available for storage, as the dam site is 2 or 3 miles farther upstream, at a point where the drainage area is smaller—31 square miles as compared with 50 at the station. A part of the intermediate area is drained by a creek that can probably be diverted into the reservoir, and the rate of run-off from the lower area should therefore be less than that from the area tributary to the dam. The run-off available for storage in Big Marsh has therefore been estimated as 80 per cent of that at the station, and the percentages for reducing discharge at Allen's ranch to discharge at Big Marsh taken as follows:

Percentages used in computing probable discharge of Big Marsh outlet.

Month.	Applied to discharge of Deschutes River at Allen's ranch.	Applied to discharge of Deschutes River at Allen's ranch minus that of East Fork at Crescent.	Month.	Applied to discharge of Deschutes River at Allen's ranch.	Applied to discharge of Deschutes River at Allen's ranch minus that of East Fork at Crescent.
January	30	45	July	22	30
February	30	50	August	20	25
March	35	50	September	20	25
April	37	50	October	20	30
May	38	60	November	25	35
June	31	50	December	25	40

The relation between the discharge of the Deschutes and that of Odell Lake is shown by the following table:

Comparisons of discharge of Odell Lake outlet with that of Deschutes River at Allen's ranch and Lapine, 1912.

Month.	Deschutes River.	Odell Lake outlet.	Per cent.	Month.	Deschutes River.	Odell Lake outlet.	Per cent.
	Acre-feet.	*Acre-feet.*			*Acre-feet.*	*Acre-feet.*	
January	14,800	7,380	50	July	20,800	6,760	32
February	17,200	9,200	53	August	11,400	3,440	30
March	11,400	4,300	38	September	9,340	4,170	45
April	15,900	4,170	26				
May	33,200	9,220	28	The period	174,000	62,900	36
June	39,700	14,300	36				

NOTE.—As the records for Odell Lake for January to March are very uncertain the ratio used has been reduced to 34.

The discharges estimated by means of the percentages in the preceding tables are shown in the following table:

Estimated monthly discharge, in acre-feet, of upper Deschutes River and tributaries, 1905–1912.

Month.	1 Deschutes River at Allen's ranch.	2 East Fork at Crescent.	3 Big Marsh outlet.	4 Crescent Lake outlet.	5 Odell Lake outlet.	Total of 2, 3, 4, and 5.	Total of 3, 4, and 5.
1905.							
January	16,800	4,710	5,440	4,230	5,700	20,100	15,400
February	14,700	4,110	5,300	3,180	5,000	17,600	13,500
March	19,600	3,980	7,800	3,900	6,660	22,300	18,400
April	16,300	3,890	6,200	2,480	5,540	18,100	14,200
May	17,100	4,590	7,500	2,500	5,810	20,400	.....
June	14,300	3,740	5,300	3,710	4,900	17,600	.....
July	8,670	2,160	1,850	3,260	2,950	10,200	.....
August	6,580	1,720	1,220	2,670	2,240	7,850	.....
September	5,410	1,520	980	2,140	1,840	6,480	.....
October	6,150	1,960	1,260	2,100	2,090	7,410	5,450
November	5,390	1,400	1,400	1,800	1,830	6,430	5,030
December	6,100	1,450	1,900	1,900	2,070	7,320	5,870
The year	137,000	35,200	46,200	33,900	46,600	162,000	.....
1906.							
January	10,200	2,860	3,060	2,550	3,500	12,000	9,110
February	6,830	1,910	2,050	1,370	2,320	7,650	5,740
March	8,360	2,340	2,930	1,340	2,840	9,450	7,110
April	19,800	5,310	7,250	2,900	5,730	21,200	15,900
May	27,400	7,620	11,900	3,960	9,410	32,900	.....
June	22,000	6,600	7,700	5,390	7,480	27,200	.....
July	13,500	4,010	2,840	4,740	4,590	16,200	.....
August	7,500	2,280	1,380	2,870	2,560	9,090	.....
September	6,430	2,150	1,070	2,360	2,190	7,770	.....
October	6,330	2,180	1,240	2,080	2,150	7,650	5,470
November	8,150	3,100	1,770	2,270	2,770	9,910	6,810
December	8,850	3,190	2,260	2,260	3,010	10,700	7,530
The year	145,000	43,600	45,400	34,100	48,600	172,000	.....
1907.							
January	13,500	5,220	3,720	2,900	4,590	16,400	11,200
February	44,000	10,200	11,900	10,100	15,000	47,200	37,000
March	21,200	6,400	7,400	3,700	7,200	24,700	18,300
April	33,900	10,900	11,500	4,600	11,500	38,500	27,600
May	42,800	12,000	18,500	7,160	14,600	52,300	.....
June	33,200	8,980	12,100	8,460	11,300	40,800	.....
July	20,300	4,700	4,680	7,800	6,900	24,100	.....
August	14,000	2,920	2,780	6,100	4,760	16,600	.....
September	11,700	2,500	2,300	5,060	3,980	13,800	.....
October	9,900	2,180	2,320	3,860	3,320	11,700	9,500
November	9,340	2,090	2,540	3,260	3,180	11,100	8,980
December	17,600	4,240	5,360	5,360	5,980	20,900	16,700
The year	271,000	72,600	85,100	68,400	92,300	318,000	.....

Estimated monthly discharge, in acre-feet, of upper Deschutes River and tributaries, 1905–1912—Continued.

Month.	1 Deschutes River at Allen's ranch.	2 East Fork at Crescent.	3 Big Marsh outlet.	4 Crescent Lake outlet.	5 Odell Lake outlet.	Total of 2, 3, 4, and 5.	Total of 3, 4, and 5.
1908.							
January	18,400	3,570	6,660	5,180	6,260	21,700	18,100
February	9,780	4,070	2,860	1,710	3,330	12,000	7,900
March	16,700	3,740	6,500	3,250	5,680	19,200	15,400
April	24,200	6,800	8,960	3,390	8,230	27,400	20,600
May	25,600	7,160	9,730	3,330	8,700	28,900	.....
June	20,200	5,660	6,260	4,650	6,860	23,400	.....
July	15,600	4,370	3,430	6,240	5,300	19,300	.....
August	8,550	2,400	1,710	3,420	2,910	10,400	.....
September	8,390	2,350	1,680	3,360	2,850	10,200	.....
October	10,700	3,000	2,140	4,280	3,640	13,100	10,100
November	10,700	3,000	2,680	3,740	3,640	13,100	10,100
December	11,100	3,110	2,780	3,330	3,770	13,000	9,880
The year	180,000	49,200	55,400	45,900	61,200	212,000	.....
1909.							
January	9,220	2,580	2,760	2,300	3,140	10,800	8,200
February	11,100	3,110	3,330	2,220	3,780	12,400	9,330
March	12,500	3,500	4,380	2,000	4,250	14,100	10,600
April	21,100	5,900	7,810	2,950	7,180	23,800	17,900
May	28,200	7,800	10,700	3,670	9,590	31,800	.....
June	29,000	8,110	8,990	6,670	9,860	33,600	.....
July	16,200	4,530	3,560	6,480	5,510	20,100	.....
August	9,840	2,760	1,970	3,930	3,350	12,000	.....
September	8,510	2,380	1,700	3,400	2,880	10,400	.....
October	7,990	2,240	1,600	3,200	2,720	9,760	7,520
November	33,100	9,270	8,280	12,600	11,300	41,400	32,200
December	46,000	12,900	11,500	13,800	15,600	53,800	40,900
The year	233,000	65,100	66,600	63,200	79,200	274,000	.....
1910.							
January	21,500	6,020	6,450	5,380	7,310	25,200	19,100
February	19,400	5,430	5,820	3,880	6,600	21,700	16,300
March	43,800	12,300	15,300	7,010	14,900	49,500	37,200
April	29,900	8,330	11,100	4,190	10,200	33,800	25,500
May	31,700	8,880	12,000	4,120	10,800	35,800	.....
June	17,200	4,820	5,330	3,960	5,850	10,000	.....
July	11,400	3,190	2,510	4,560	3,880	14,100	.....
August	8,730	2,450	1,750	3,490	2,970	10,700	.....
September	7,860	2,200	1,570	3,150	2,680	9,600	.....
October	8,480	2,200	1,880	3,140	2,890	10,100	7,910
November	9,640	3,000	2,320	2,990	3,280	11,600	8,590
December	14,100	3,500	4,240	4,240	4,800	16,800	13,300
The year	224,000	62,300	70,300	50,100	76,200	259,000	.....
1911.							
January	9,220	3,140	2,740	2,130	3,140	11,200	8,010
February	9,440	3,730	2,360	1,410	3,210	10,700	6,980
March	10,700	5,360	2,670	1,340	3,640	13,000	7,650
April	15,200	4,420	5,400	2,160	5,170	17,200	12,700
May	25,600	6,460	11,500	3,820	8,710	30,500	.....
June	29,000	8,270	10,400	7,240	9,870	35,800	.....
July	13,900	3,330	3,180	5,300	4,730	16,500	.....
August	7,690	2,200	1,210	3,020	2,620	9,050	.....
September	7,620	2,050	1,390	3,060	2,590	9,090	.....
October	7,260	2,180	1,520	2,540	2,470	8,710	6,530
November	8,510	2,640	2,050	2,640	2,880	10,200	7,570
December	7,010	2,170	1,940	1,940	2,380	8,430	6,260
The year	151,000	46,000	46,400	36,600	51,400	180,000	.....
1912.							
January	14,800	4,050	4,440	3,730	7,380	19,600	15,600
February	17,200	4,220	5,850	3,850	9,200	23,100	18,900
March	11,400	2,840	4,280	2,150	4,300	13,600	10,700
April	15,900	4,840	5,810	2,230	4,170	17,000	12,200
May	33,200	13,000	12,100	4,160	9,220	38,500	.....
June	39,700	14,800	12,500	9,100	14,300	50,700	.....
July	20,800	5,380	4,630	8,240	6,760	25,000	.....
August	11,400	3,190	2,170	4,730	3,440	13,500	.....
September	9,340	2,770	1,820	3,700	4,170	12,500	.....
October	.....	2,590	1,760	4,410	4,500	13,300	10,700
November	.....	2,820	3,250	4,640	4,500	15,200	12,500
December	.....	1,830	2,210	4,820	5,000	13,900	12,000
The year	.....	62,300	60,800	55,800	76,900	256,000	.....

A study has been made of the probable history of operation of the upper projects, in order to show the amount of storage required, the amount of water spilled, the deficiencies in supply, and the net effect on the flow of the river at Benham Falls. In the following table, Column 1 shows the amount of water available for October to April; it is the sum of the estimated values given in the preceding table for Big Marsh, Crescent, and Odell lakes, and for the irrigating season—May to September—it includes also the discharge of the East Fork, which can always be used by direct diversions, except possibly a small amount of water at the beginning and end of the season, when the demand will be less than the inflow below the reservoirs. Column 2 gives the amount required for irrigation as derived by means of the table on page 89. The difference between columns 1 and 2, shown in column 3, indicates the amount of water that can be stored or must be drawn to supply the demand. Column 4 represents the successive summation of values in column 3, subject to the limitation that the value must not exceed 120,000 acre-feet, the assumed capacity of reservoirs, nor become negative. Column 5 shows the overflow or the amount that the summations made in column 4 exceeds 120,000; also the deficiency, when these summations introduce negative values; the values in this column are for individual months and are not a summation. Column 6 shows the requirements of the project assumed to divert its supply direct from the natural flow of West Fork. Column 7 shows the quantity by which the flow at Benham Falls is assumed to be reduced (or increased) as a result of the operation of these upper projects, and is obtained by adding columns 1 and 6, deducting 10,000 acre-feet, and changing the sign; that is, the flow below the project is reduced by the total amount available for diversion or storage, and increased by the estimated 10,000 acre-feet monthly return water. When water is spilled the amount of such loss must be deducted from the results in column 1 before adding. It will be noted that when the total flow at the three reservoir sites is less than 10,000 acre-feet there is an increase at Benham Falls.

Study of manipulation of storage for possible projects on Deschutes River above Benham Falls, 1905–1912.

[Quantities in acre-feet.]

Month.	1 Available run-off.	2 Required for irrigation.	3 Excess and deficiency in water supply.	4 In reservoir at end of month.	5 Overflow (+) or deficiency (−).	6 Diverted from West Fork.	7 Effect on run-off at Benham Falls.
1905.							
January	[a] 15,400		15,400	[b] 85,400			− 5,400
February	[a] 13,500		13,500	98,900			− 3,500
March	[a] 18,400		18,400	117,300			− 8,400
April	[a] 14,200		14,200	120,000	+11,500		+ 7,300
May	[c] 20,400	14,400	6,000	120,000	+ 6,000	4,800	− 9,200
June	[c] 17,600	27,000	− 9,400	110,600		9,000	− 16,600
July	[c] 10,200	63,000	−52,800	57,800		21,000	− 21,200
August	[c] 7,850	57,600	−49,800	8,000		19,200	− 17,050
September	[c] 6,480	18,000	−11,500	00	− 3,500	6,000	− 2,480
October	[a] 5,450		+ 5,450	5,450			+ 4,550
November	[a] 5,030		5,030	10,480			+ 4,970
December	[a] 5,870		5,870	16,350			+ 4,130
The year	140,000	180,000			+17,500 − 3,500	60,000	+ 20,950 − 83,830
1906.							
January	[a] 9,110		9,110	25,460			+ 890
February	[a] 5,740		5,740	31,200			+ 4,260
March	[a] 7,110		7,110	38,310			+ 2,890
April	[a] 15,900		15,900	54,210			− 5,900
May	[c] 32,900	14,400	18,500	72,710		4,800	− 27,700
June	[c] 27,200	27,000	200	72,910		9,000	− 26,200
July	[c] 16,200	63,000	−46,800	26,110		21,000	− 27,200
August	[c] 9,090	57,600	−48,500	00	−22,390	19,200	− 18,290
September	[c] 7,770	18,000	−10,200	00	−10,200	6,000	− 3,770
October	[a] 5,470		+ 5,470	5,470			+ 4,530
November	[a] 6,810		6,810	12,280			+ 3,190
December	[a] 7,530		7,530	19,810			+ 2,470
The year	151,000	180,000			−32,590	60,000	+ 18,230 −109,060
1907.							
January	[a] 11,200		11,200	31,010			− 1,200
February	[a] 37,000		37,000	68,010			− 27,000
March	[a] 18,300		18,300	86,310			− 8,300
April	[a] 27,600		27,600	113,910			− 17,600
May	[c] 52,300	14,400	37,900	120,000	+31,810	4,800	+ 15,290
June	[c] 40,800	27,000	13,800	120,000	+13,800	9,000	− 26,000
July	[c] 24,100	63,000	−38,900	81,000		21,000	− 35,100
August	[c] 16,600	57,600	−41,000	40,100		19,200	− 25,800
September	[c] 13,800	18,000	− 4,200	35,900		6,000	− 9,800
October	[a] 9,500		+ 9,500	45,400			+ 500
November	[a] 8,980		+ 8,980	54,380			+ 1,020
December	[a] 16,700		16,700	71,080			− 6,700
The year	277,000	180,000			+45,610	60,000	−172,790 + 1,520
1908.							
January	[a] 18,100		18,100	89,180			− 8,100
February	[a] 7,900		7,900	97,080			+ 2,100
March	[a] 15,400		15,400	112,480			− 5,400
April	[a] 20,600		20,600	120,000	+13,080		+ 2,480
May	[c] 28,900	14,400	14,500	120,000	+14,500	4,800	− 9,200
June	[c] 23,400	27,000	− 3,600	116,400		9,000	− 22,400
July	[c] 19,300	63,000	−43,700	72,700		21,000	− 30,300
August	[c] 10,400	57,600	−47,200	25,500		19,200	− 19,600
September	[c] 10,200	18,000	− 7,800	17,700		6,000	− 6,200
October	[a] 10,100		+10,100	27,800			− 100
November	[a] 10,100		10,100	37,900			− 100
December	[a] 9,880		9,880	47,780			+ 120
The year	184,000	180,000			+27,580	60,000	−101,400 + 4,700

[a] Sum of discharges at Big Marsh outlet, Crescent Lake outlet, and Odell Lake outlet.
[b] Content of reservoir at beginning of the month assumed as 70,000 acre-feet.
[c] Sum of discharges East Fork of Deschutes, Big Marsh outlet, and Crescent and Odell lakes.

Study of manipulation of storage for possible projects on Deschutes River above Benham Falls, 1905–1912—Continued.

Month.	1 Available run-off.	2 Required for irrigation.	3 Excess and deficiency in water supply.	4 In reservoir at end of month.	5 Overflow (+) or deficiency (−).	6 Diverted from West Fork.	7 Effect on run-off at Benham Falls.
1909.							
January	[a] 8,200	.....	8,200	55,980	.....	.....	+ 1,800
February	[a] 9,330	.....	9,330	65,310	.....	.....	+ 670
March	[a] 10,600	.....	10,600	75,910	.....	.....	− 600
April	[a] 17,900	.....	17,900	93,810	.....	.....	− 7,900
May	[b] 31,800	14,400	17,400	111,210	.....	4,800	− 26,600
June	[b] 33,600	27,000	6,600	117,810	.....	9,000	− 32,600
July	[b] 20,100	63,000	−42,900	74,910	.....	21,000	− 31,100
August	[b] 12,000	57,600	−45,600	29,310	.....	19,200	− 21,200
September	[b] 10,400	18,000	− 7,600	21,710	.....	6,000	− 6,400
October	[a] 7,520	.....	+ 7,520	29,230	.....	.....	+ 2,480
November	[a] 32,200	.....	32,200	61,430	.....	.....	− 22,200
December	[a] 40,900	.....	40,900	102,330	.....	.....	− 30,900
The year	235,000	180,000	.....	.....	.....	60,000	−179,500 + 4,950
1910.							
January	[a] 19,100	.....	19,100	120,000	+ 1,430	.....	− 7,670
February	[a] 16,300	.....	16,300	120,000	+ 16,300	.....	+ 10,000
March	[a] 37,200	.....	37,200	120,000	+ 37,200	.....	+ 10,000
April	[a] 25,500	.....	25,500	120,000	+ 25,500	.....	+ 10,000
May	[b] 35,800	14,400	21,400	120,000	+ 21,400	4,800	− 9,200
June	[b] 20,000	27,000	− 7,000	113,000	.....	9,000	− 19,000
July	[b] 14,100	63,000	−48,900	64,100	.....	21,000	− 25,100
August	[b] 10,700	57,600	−46,900	17,200	.....	19,200	− 19,900
September	[b] 9,600	18,000	− 8,400	8,800	.....	6,000	− 5,600
October	[a] 7,910	.....	+ 7,910	16,710	.....	.....	+ 2,090
November	[a] 8,590	.....	8,590	25,300	.....	.....	+ 1,410
December	[a] 13,300	.....	13,300	38,600	.....	.....	− 3,300
The year	218,000	180,000	.....	.....	+101,830	60,000	− 89,770 + 33,500
1911.							
January	[a] 8,010	.....	8,010	46,610	.....	.....	+ 1,990
February	[a] 6,980	.....	6,980	53,590	.....	.....	+ 3,020
March	[a] 7,650	.....	7,650	61,240	.....	.....	+ 2,350
April	[a] 12,700	.....	12,700	73,940	.....	.....	− 2,700
May	[b] 30,500	14,400	16,100	90,040	.....	4,800	− 25,300
June	[b] 35,800	27,000	8,800	98,840	.....	9,000	− 34,800
July	[b] 16,500	63,000	−46,500	52,340	.....	21,000	− 27,500
August	[b] 9,050	57,600	−48,600	3,740	.....	19,200	− 18,250
September	[b] 9,090	18,000	− 8,910	0	− 5,170	6,000	− 5,090
October	[a] 6,530	.....	+ 6,530	6,530	.....	.....	+ 3,470
November	[a] 7,570	.....	7,570	14,100	.....	.....	+ 2,430
December	[a] 6,260	.....	6,260	20,360	.....	.....	+ 3,740
The year	157,000	180,000	.....	.....	− 5,170	60,000	−113,640 + 17,000
1912.							
January	[a] 15,600	.....	15,600	35,960	.....	.....	− 5,600
February	[a] 18,900	.....	18,900	54,860	.....	.....	− 8,900
March	[a] 10,700	.....	10,700	65,560	.....	.....	− 700
April	[a] 12,200	.....	12,200	77,760	.....	.....	− 2,200
May	[b] 38,500	14,400	26,100	103,860	.....	4,800	− 33,300
June	[b] 50,700	27,000	23,700	120,000	+ 7,560	9,000	− 42,140
July	[b] 25,000	63,000	−38,000	82,000	.....	21,000	− 36,000
August	[b] 13,500	57,600	−44,100	37,900	.....	19,200	− 22,700
September	[b] 12,500	18,000	− 5,500	32,400	.....	6,000	− 8,500
October	[a] 10,700	.....	+10,700	43,100	.....	.....	− 700
November	[a] 12,400	.....	12,400	55,500	.....	.....	− 2,400
December	[a] 12,000	.....	12,000	67,500	.....	.....	− 2,000
The year	233,000	180,000	.....	.....	+ 7,560	60,000	−165,140

[a] Sum of discharges at Big Marsh outlet, Crescent Lake outlet, and Odell Lake outlet.
[b] Sum of discharges East Fork of Deschutes, Big Marsh outlet, and Crescent and Odell lakes.

The results shown in columns 4 and 5 are depicted graphically in figure 6. In this diagram the values in column 4 are shown as a

coordinate with time, the resulting graph showing the fluctuation of stored water. When water is spilled, this fact is indicated by the extension of the graph above the 120,000 acre-foot line representing full reservoir. A new scale above this indicates the monthly summation of loss over spillway during any period of excess. When the period of excess is over, the graph breaks and begins again at 120,000 acre-feet. Similarly, the summations of deficiencies are plotted

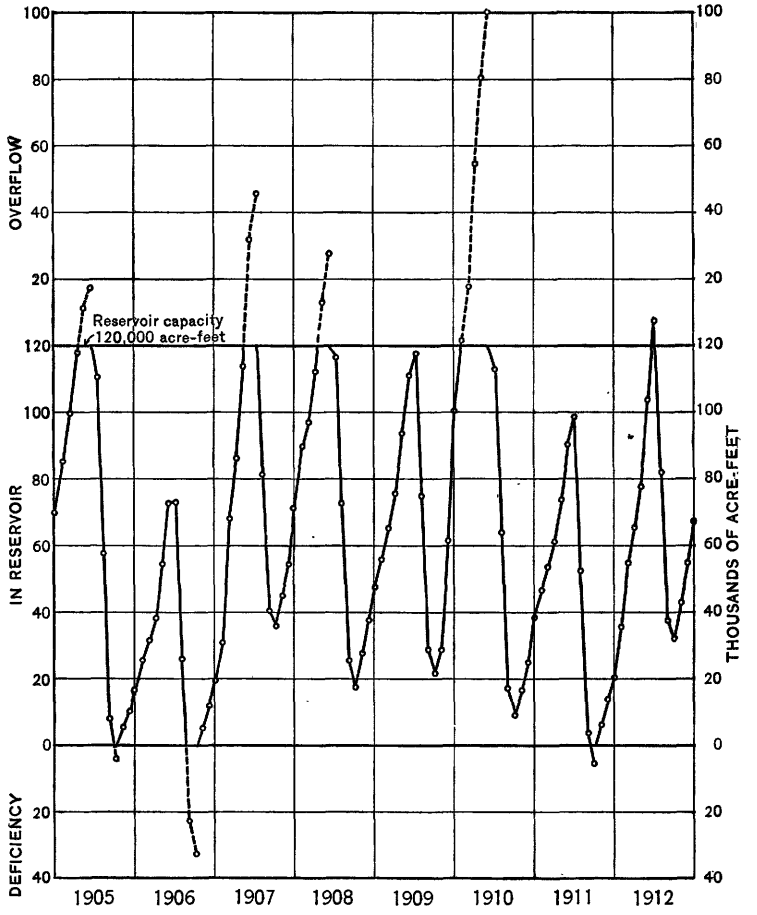


FIGURE 6.—Mass diagram showing possible manipulation of storage in connection with project on upper Deschutes River.

below the zero of storage. During five of the eight years for which the discharge is plotted the reservoir would have overflowed and in three years deficiencies would have occurred. In two years the deficiencies would have been so slight as to be negligible, while in the third they would have amounted to 18 per cent of the yearly use. To have obviated this deficiency the storage capacity should have been increased by the amount of the deficiency—32,400 acre-feet, or

26 per cent of the assumed capacity of 120,000 acre-feet—and as this extra capacity could have been used only once in eight years, it is doubtful whether it would be economical to provide it.

POSSIBLE USE BELOW BENHAM FALLS.

The amount of water available for storage and diversion from Deschutes River in the vicinity of Benham Falls is assumed to be shown by the records at Benham Falls and West's ranch, supplemented, when no other records on this section of the river are available, by the summation of the records at Bend, and of the Central Oregon and Pilot Butte canals. The comparisons (p. 69) indicate some inflow between Benham Falls and Bend during the nonirrigating season, but this inflow would then be available for domestic supply. Some water from Tumalo Creek will find its way into the Deschutes if the feed canal for the Wimer or Tumalo reservoir, into which Tumalo Creek is to be diverted, is made somewhat smaller than the spring flood flow of the creek. The supplies from both sources are, however, too small and too uncertain to be counted upon, and the operation of the project has accordingly been figured on the basis of discharge at Benham Falls.

The records of discharge at Benham Falls (pp. 25 to 26) show a mean annual discharge of 1,220,000 acre-feet, ranging from a minimum of 1,080,000 acre-feet in the year October, 1910, to September, 1911, to a maximum of 1,410,000 acre-feet for the year October, 1904, to September, 1905.

The areas of the suggested Benham Falls reservoir at different levels have been carefully measured and the capacities computed as shown in the following table and in figure 7.

Table showing area and capacity of suggested Benham Falls reservoir, Deschutes River.

Elevation above sea level.	Depth of water.	Area.	Capacity of section.	Total capacity.
Feet.	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*
4,146	0	65	0	0
4,150	4	260	650	650
4,155	9	1,370	4,080	4,730
4,160	14	2,550	9,800	14,500
4,165	19	4,370	17,300	31,800
4,170	24	6,370	26,900	58,700
4,175	29	8,670	37,600	96,300
4,180	34	11,000	49,000	145,300
4,185	39	12,800	59,300	204,600
4,190	44	15,000	69,400	274,000
4,195	49	16,800	79,500	353,500
4,200	54	19,500	90,800	444,300
4,205	59	[a] 22,200	104,000	[a] 548,000
4,210	64	[a] 24,900	118,000	[a] 666,000
	69	[a] 27,800	132,000	[a] 798,000

[a] Estimated from extension of curve of area.

In the study of the use of water stored in the suggested reservoir at Benham Falls, losses due to evaporation must be taken into account, as the reservoir is relatively broad and shallow. Strictly the mean area of water surface during any given month should be used in computing the loss for that month, but such refinement of method is apparently unnecessary in view of the many uncertainties involved in the whole record, especially in regard to depth of evaporation.

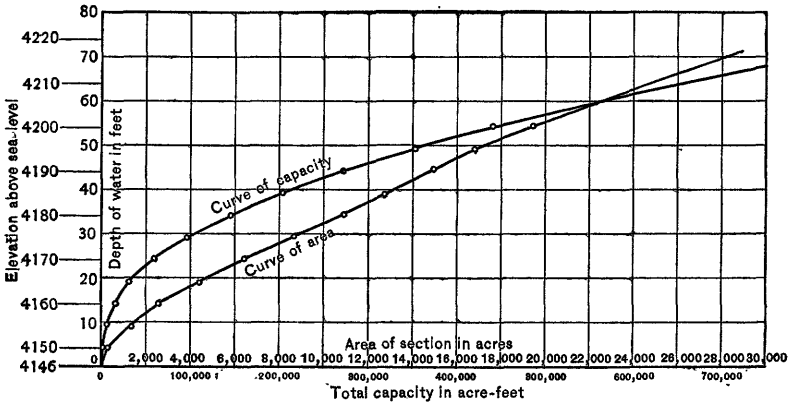


FIGURE 7.—Curves of area and capacity for suggested reservoir at Benham Falls.

The assumptions as to the quantity of water to be used on the various tracts are indicated by the following table:

Total assumed use of water in acre-feet, from suggested Benham Falls reservoir.

Month.	Benham Falls tract.	Central Oregon tract.	Cline Falls tracts.		Total.
			Use.	Losses from river.	
January	3,500	4,000	6,000	.....	13,500
February	3,500	4,000	6,000	.....	13,500
March	3,500	4,000	6,000	.....	13,500
April	4,000	6,000	20,800	.....	30,800
May	26,400	33,000	42,900	6,000	108,300
June	52,800	66,000	72,800	6,000	197,600
July	66,400	83,000	107,900	6,000	263,300
August	65,600	82,000	106,600	6,000	260,200
September	26,400	33,000	39,000	6,000	104,400
October	4,900	7,000	9,000	.....	20,900
November	3,500	4,000	6,000	.....	13,500
December	3,500	4,000	6,000	.....	13,500
	264,000	330,000	429,000	30,000	1,053,000

The results of a study of the probable manipulation of storage for the suggested Benham Falls reservoir, similar in general to that for the upper projects, are shown in the table on pages 103–104. Column 1 gives the discharge at Benham Falls as modified by storage and diversion above. Column 2 shows the total quantity required for irrigation as given in detail in the table above. Column 3 gives the evapo-

ration losses, in feet, of depth and total loss in acre-feet for each month, using the area of water surface for the end of the previous month. It will be noted that during the summer months, when evaporation is greatest, the water in reservoir is falling. This method, therefore, tends to give results that are too high and accordingly err on the side of safety. Column 4 is the sum of columns 2 and 3. Column 5 is the difference between the supply (column 1) and the total use (column 4). Column 6 gives the successive summation of the values in column 5, subject to the limitation of capacity of reservoir—700,000

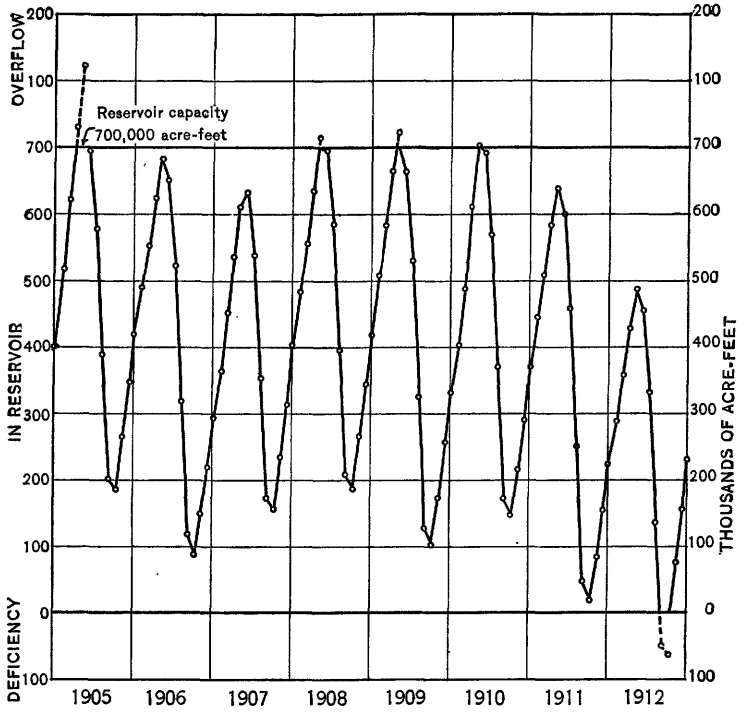


FIGURE 8.—Mass diagram showing manipulation of storage in suggested reservoir at Benham Falls.

acre-feet. Column 7 is the area corresponding to the capacity given in column 6. Column 8 shows the excess or deficiency as compared with the capacity—700,000 acre-feet.

The results shown in columns 7 and 8 are depicted graphically in figure 8, as were the results for the suggested project above Benham Falls (p. 99). The uniformity of recurrence of the rise and fall of storage level appears very remarkable when compared with similar diagrams for other streams or even for the upper project on the same stream.

Possible manipulation of storage at suggested reservoir at Benham Falls, 1905–1912.

Month.	1	2	3		4	5	6	7	8
	Discharge as modified by diversions above.	Required for irrigation.	Evaporation.		Total evaporation and use.	Increase in volume of storage.	Quantity in reservoir at end of month.	Area of water surface at end of month.	Overflow (+) or deficiency (−).
			Depth.	Loss.					
1905.									
	Acre-feet.	*Acre-feet.*	*Feet.*	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acres.*	*Acre-feet.*
January	132,600	13,500	0.0	0	13,500	119,100	[a] 519,100	21,500	.....
February	116,500	13,500	.0	0	13,500	103,000	622,100	23,900	.....
March	124,600	13,500	.1	2,400	15,900	108,700	700,000	25,600	+30,800
April	130,300	30,800	.2	5,100	35,900	94,000	700,000	25,600	+94,400
May	114,800	108,300	.4	10,200	118,500	− 3,700	696,300	25,600	.....
June	91,400	197,600	.4	10,200	207,800	−116,400	579,900	23,000	.....
July	83,800	263,300	.5	11,500	274,800	−191,000	388,900	17,900	.....
August	82,600	260,200	.6	10,700	270,900	−188,300	200,600	12,800	.....
September	93,900	104,400	.5	6,400	110,800	− 16,900	183,700	12,200	.....
October	104,200	20,900	.2	2,400	23,300	+ 80,900	264,600	14,700	.....
November	97,800	13,500	.1	1,500	15,000	+ 82,800	347,400	16,700	.....
December	83,400	13,500	.0	0	13,500	+ 69,900	417,300	18,700	.....
The year	1,255,900	1,053,000	2.9	60,400	1,113,400	+142,500	.....	.....	+125,200
1906.									
January	84,500	13,500	.0	0	13,500	+ 71,000	488,300	20,700	.....
February	78,200	13,500	.0	0	13,500	+ 64,700	553,000	22,300	.....
March	86,500	13,500	.1	2,200	15,700	+ 70,800	623,800	24,000	.....
April	96,100	30,800	.2	4,800	35,600	+ 60,500	684,300	25,300	.....
May	85,300	108,300	.4	10,200	118,500	− 33,200	651,100	23,400	.....
June	78,800	197,600	.4	9,400	207,000	−128,200	522,900	21,600	.....
July	69,700	263,300	.5	10,800	274,100	−204,400	318,500	16,000	.....
August	68,400	260,200	.6	9,600	269,800	−201,400	117,100	9,800	.....
September	77,800	104,400	.5	4,900	109,300	− 31,500	85,600	8,100	.....
October	85,700	20,900	.2	1,600	22,500	+ 63,200	148,800	11,100	.....
November	84,700	13,500	.1	1,100	14,600	+ 70,100	218,900	13,400	.....
December	88,000	13,500	.0	0	13,500	+ 74,500	293,400	15,500	.....
The year	983,700	1,053,000	2.9	54,600	1,107,600	−123,900	.....	.....	.....
1907.									
January	84,300	13,500	.0	0	13,500	+ 70,800	364,200	17,100	.....
February	101,000	13,500	.0	0	13,500	+ 87,500	451,700	19,700	.....
March	99,700	13,500	.1	2,000	15,500	+ 84,200	535,900	21,900	.....
April	111,400	30,800	.2	4,200	35,000	+ 76,400	612,300	23,700	.....
May	138,700	108,300	.4	9,500	117,800	+ 20,900	633,200	24,200	.....
June	114,000	197,600	.4	9,700	207,300	− 93,300	539,900	22,000	.....
July	88,900	263,300	.5	11,000	274,300	−185,400	354,500	16,800	.....
August	88,200	260,200	.6	10,100	270,300	−182,100	172,400	11,900	.....
September	95,200	104,400	.5	6,000	110,400	− 15,200	157,200	11,400	.....
October	100,500	20,900	.2	2,300	23,200	+ 77,300	234,500	13,800	.....
November	95,000	13,500	.1	1,400	14,900	+ 80,100	314,600	15,900	.....
December	102,300	13,500	.0	0	13,500	+ 88,800	403,400	18,300	.....
The year	1,219,200	1,053,000	2.9	56,200	1,109,200	+110,000	.....	.....	.....
1908.									
January	96,900	13,500	.0	0	13,500	+ 83,400	486,800	20,600	.....
February	84,900	13,500	.0	0	13,500	+ 71,400	558,200	22,500	.....
March	93,000	13,500	.1	2,200	15,700	+ 77,300	635,500	24,200	.....
April	114,500	30,800	.2	4,800	35,600	+ 78,900	700,000	25,600	+14,400
May	115,800	108,300	.4	10,200	118,500	− 2,700	697,300	25,600	.....
June	96,600	197,600	.4	10,200	207,800	−111,200	586,100	23,100	.....
July	85,700	263,300	.5	11,600	274,900	−189,200	396,900	18,100	.....
August	83,400	260,200	.6	10,900	271,100	−187,700	209,200	13,000	.....
September	90,200	104,400	.5	6,500	110,900	− 20,700	188,500	12,400	.....
October	101,900	20,900	.2	2,500	23,400	+ 78,500	267,000	14,800	.....
November	93,300	13,500	.1	1,500	15,000	+ 78,300	345,300	16,600	.....
December	88,000	13,500	.0	0	13,500	+ 74,500	419,800	18,800	.....
The year	1,144,200	1,053,000	2.9	60,400	1,113,400	+ 30,800	.....	.....	+14,400
1909.									
January	102,800	13,500	.0	0	13,500	+ 89,300	509,100	21,200	.....
February	90,700	13,500	.0	0	13,500	+ 77,200	586,300	23,200	.....
March	95,900	13,500	.1	2,300	15,800	+ 80,100	666,400	24,900	.....
April	94,100	30,800	.2	5,000	35,800	+ 58,300	700,000	25,600	+24,700
May	83,400	108,300	.4	10,200	118,500	− 35,100	664,900	24,900	.....
June	74,400	197,600	.4	10,000	207,600	−133,200	531,700	21,800	.....

[a] Content of reservoir at beginning of month assumed as 400,000 acre-feet.

Possible manipulation of storage at suggested reservoir at Benham Falls, 1905–1912—Con.

Month.	1 Discharge as modified by diversions above.	2 Required for irrigation.	3 Evaporation. Depth.	3 Evaporation. Loss.	4 Total evaporation and use.	5 Increase in volume of storage.	6 Quantity in reservoir at end of month.	7 Area of water surface at end of month.	8 Overflow (+) or deficiency (−).
1909.	*Acre-feet.*	*Acre-feet.*	*Feet.*	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acres.*	*Acre-feet.*
July	67,300	263,300	0.5	10,900	274,200	−206,900	324,800	16,100	.....
August	72,900	260,200	.6	9,700	269,900	−197,000	127,800	10,200	.....
September	84,000	104,400	.5	5,100	109,500	− 25,500	102,300	9,000	.....
October	93,500	20,900	.2	1,800	22,700	+ 70,800	173,100	11,900	.....
November	98,800	13,500	.1	1,200	14,700	+ 84,100	257,200	14,500	.....
December	88,100	13,500	.0	0	13,500	+ 74,600	331,800	16,300	.....
The year	1,045,900	1,053,000	2.9	56,200	1,109,200	− 63,300	.....	.....	+24,700
1910.									
January	86,400	13,500	.0	0	13,500	+ 72,900	404,700	18,300	.....
February	98,300	13,500	.0	0	13,500	+ 84,800	489,500	20,700	.....
March	139,000	13,500	.1	2,100	15,600	+123,400	612,900	23,700	.....
April	126,000	30,800	.2	4,700	35,500	+ 90,500	700,000	25,600	.....
May	112,800	108,300	.4	10,200	118,500	− 5,700	694,300	25,500	+ 3,400
June	85,000	197,600	.4	10,200	207,800	−122,800	571,500	22,800	.....
July	73,900	263,300	.5	11,900	275,200	−201,300	370,200	17,300	.....
August	74,800	260,200	.6	10,400	270,600	−195,800	174,400	11,900	.....
September	83,700	104,400	.5	6,000	110,400	− 26,700	147,700	11,100	.....
October	92,500	20,900	.2	2,200	23,100	+ 69,400	217,100	13,300	.....
November	90,100	13,500	.1	1,300	14,800	+ 75,300	292,400	15,400	.....
December	92,600	13,500	.0	0	13,500	+ 79,100	371,500	17,300	.....
The year	1,155,100	1,053,000	2.9	59,000	1,112,000	+ 43,100	.....	.....	+ 3,400
1911.									
January	89,300	13,500	.0	0	13,500	+ 75,800	447,300	19,600	.....
February	78,500	13,500	.0	0	13,500	+ 65,000	512,300	21,300	.....
March	88,400	13,500	.1	2,100	15,600	+ 72,800	585,100	23,100	.....
April	90,700	30,800	.2	4,600	35,400	+ 55,300	640,400	24,300	.....
May	77,700	108,300	.4	9,700	118,000	− 40,300	600,100	23,400	.....
June	67,200	197,600	.4	9,400	207,000	−139,800	460,300	19,900	.....
July	64,700	263,300	.5	10,000	273,300	−208,600	251,700	14,300	.....
August	66,600	260,200	.6	8,600	268,800	−202,200	49,500	5,700	.....
September	77,600	104,400	.5	2,800	107,200	− 29,600	19,900	3,100	.....
October	87,100	20,900	.2	600	21,500	+ 65,600	+ 85,500	8,100	.....
November	84,500	13,500	.1	800	14,300	+ 70,200	155,700	11,300	.....
December	82,400	13,500	.0	0	13,500	+ 68,900	224,600	13,500	.....
									.....
The year	954,700	1,053,000	2.9	48,600	1,101,600	−146,900	.....	.....	.....
1912.									
January	79,200	13,500	.0	0	13,500	+ 65,700	290,300	15,400	.....
February	80,800	13,500	.0	0	13,500	+ 67,300	357,600	16,900	.....
March	87,200	13,500	.1	1,700	15,200	+ 72,000	429,600	19,100	.....
April	92,400	30,800	.2	3,800	34,600	+ 57,800	487,400	20,600	.....
May	82,700	108,300	.4	8,200	116,500	− 33,800	453,600	19,700	.....
June	85,900	197,600	.4	7,900	205,500	119,600	334,000	16,400	.....
July	75,000	263,300	.5	8,200	271,500	−196,500	137,500	10,700	.....
August	81,300	260,200	.6	6,400	266,600	−185,300	0	0	−47,800
September	90,900	104,400	.5	0	104,400	− 13,500	0	0	−13,500
October	97,100	20,900	.2	0	20,900	+ 76,100	76,200	7,500	.....
November	94,000	13,500	.1	800	14,300	+ 79,700	155,900	11,400	.....
December	90,200	13,500	.0	0	13,500	+ 76,700	232,600	13,800	.....
The year	1,036,700	1,053,000	2.9	37,000	1,090,000	− 61,300	.....	.....	−61,300

In only one year out of eight would an appreciable amount of water have been spilled, namely, in 1905, and in only one year, 1912, would there have been a deficiency, the excess shown amounting to 12 per cent and the deficiency to 6 per cent of the total yearly use.

The reservoir would have filled to within 10 per cent of its total capacity every year except 1912.

The reduction of the reservoir capacity to 600,000 acre-feet would have caused a deficiency in 1911 of about 80,000 acre-feet, or 8 per cent, and would have increased that of 1912 to 161,000, or 15 per cent. The additional cost of raising the dam 4 feet would probably not be great enough to make it worth while to save in storage capacity.

POSSIBLE USE FROM TUMALO CREEK.

The lands that can be watered most economically from Tumalo Creek are those embraced in the segregation which was formerly being developed by the Columbia Southern Irrigation Co. under the Carey Act and which has generally been referred to as the Columbia Southern project. This project has recently (1913) been taken over by the State and its name changed to the Tumalo project.

The essential features of the Tumalo project involve a reservoir (the Wimer) in a basin immediately adjoining the irrigable lands. Into this basin the waters of Tumalo Creek are diverted by a feed canal about 7 miles long. Thus the layout of the project differs materially from that of projects on the upper Deschutes, where the suggested reservoirs are above the main project canal and the water must be applied to the land directly from the canal, the capacity of which must equal the maximum demand. On Tumalo Creek the economical capacity of the canal is determined by the regimen of the unregulated flow of the stream.

In connection with a study of the stream made to ascertain the probable extent of economical development, the following table has been prepared, showing the number of days on which the flow of the creek fell below certain discharges.

Discharge deficiency of Tumalo Creek near Laidlaw, Oreg.

Discharge (second-feet).	Days of deficient discharge October to September.				Discharge (second-feet).	Days of deficient discharge October to September.			
	1908–09	1909–10	1910–11	1911–12		1908–09	1909–10	1910–11	1911–12
65.....	16	6	49	88	140.....	290	239	308	284
70.....	20	11	83	112	160.....	308	269	315	292
75.....	35	11	116	144	180.....	317	293	326	304
80.....	121	80	145	190	200.....	329	314	332	322
90.....	208	119	204	233	220.....	334	329	335	332
100.....	259	140	237	261	240.....	341	340	338	332
110.....	271	176	254	271	260.....	352	351	348	339
120.....	278	217	274	277	280.....	357	354	353	347

NOTE.—The maximum discharge for 1908–9 was 440 second-feet; for 1909–10 it was estimated at 1,940 second-feet; for 1910–11 it was 396 second-feet; and for 1911–12 it was 468 second-feet.

The table indicates that for the three years of lowest flow—1908–9, 1910–11, and 1911–12—a canal with a capacity of 120 second-feet would have been full on an average of 89 days and the discharge would have been deficient for 276 days, and a canal of 200 second-

foot capacity would have run full for only 37 days. An increase of 1 second-foot of capacity would have delivered an additional 73 acre-feet annually. A 300 second-foot canal would have been full only six days in 1911, 11 days in 1912, and five days in 1909, an average for the three years of seven days. The economical capacity of the canal would seem to be considerably less than 300 second-feet and little if any over 200. The storage requirements for the project have therefore been figured on the basis of a 200 second-foot capacity for diversion canal.

The monthly discharge of Tumalo Creek is shown on pages 38 to 41, and the results of the study of storage manipulation appear in the following table:

Possible manipulation of suggested storage reservoir obtaining water from Tumalo Creek.

[Quantities in acre-feet.]

Month.	Total run-off.	Lost on account of limited capacity of diversion canal.	Run-off available for diversion.	Required for irrigation.	Increase in volume of storage.	In reservoir at end of month.	Overflow.
1906.							
January	.....	.....	.....	.....	.....	.....	.....
February	.....	.....	.....	.....	.....	.....	.....
March	.....	.....	.....	.....	.....	.....	.....
April	.....	.....	.....	.....	.....	.....	.....
May 15–31	7,350	1,340	6,010	.....	.....	30,000	.....
June	14,500	3,330	11,200	12,600	− 1,400	28,600	.....
July	12,900	3,340	9,560	16,800	− 7,140	21,460	.....
August	5,040	0	5,040	16,800	−11,800	9,660	.....
September	4,910	0	4,910	8,400	− 2,490	7,170	.....
October	6,270	73	6,200	2,800	+ 3,400	10,570	.....
November	14,400	4,190	10,200	.....	10,200	20,770	.....
December	8,920	1,120	7,800	.....	7,800	28,570	.....
The year	74,300	13,400	60,900	.....	−22,830	.....	.....
1907.							
January	7,380	0	7,380	.....	7,380	30,000	5,950
February	11,400	1,120	10,300	.....	10,300	30,000	10,300
March	9,280	0	9,280	.....	9,280	30,000	9,280
April	8,390	0	8,390	5,600	2,790	30,000	2,790
May	16,700	4,610	12,100	9,800	2,300	30,000	2,300
June	18,600	7,210	11,400	12,600	− 1,200	28,800	.....
July	16,300	4,190	12,100	16,800	− 4,700	24,100	.....
August	6,890	0	6,890	16,800	− 9,910	14,190	.....
September	5,860	0	5,860	8,400	− 2,540	11,650	.....
October	5,470	0	5,470	2,800	+ 2,670	14,320	.....
November	4,430	0	4,430	.....	4,430	18,750	.....
December	5,290	0	5,290	.....	5,290	24,040	.....
The year	116,000	17,100	98,900	72,800	{−18,350 +53,450}	.....	30,620
1908.							
January	5,540	0	5,540	.....	5,540	29,580	.....
February	5,630	0	5,630	.....	5,630	30,000	5,110
March	5,440	0	5,440	.....	5,440	30,000	5,440
April	7,560	0	7,560	5,600	1,960	30,000	1,960
May	9,590	0	9,590	9,800	− 210	29,790	.....
June	17,000	5,330	11,700	12,600	− 900	28,890	.....
July	16,200	4,670	11,500	16,800	− 5,300	23,590	.....
August	5,540	0	5,540	16,800	−11,300	12,290	.....
September	5,000	0	5,000	8,400	− 3,400	8,890	.....
October	5,820	0	5,820	2,800	+ 3,020	11,910	.....
November	4,760	0	4,760	.....	4,760	16,670	.....
December	4,290	0	4,290	.....	4,290	20,960	.....
The year	92,400	10,000	82,400	72,800	{−21,110 +30,960}	.....	12,610

Possible manipulation of suggested storage reservoir obtaining water from Tumalo Creek—Continued.

Month.	Total run-off.	Lost on account of limited capacity of diversion canal.	Run-off available for diversion.	Required for irrigation.	Increase in volume of storage.	In reservoir at end of month.	Overflow.
1909.							
January	4,840	0	4,840	.....	4,840	25,800	.....
February	4,290	0	4,290	.....	4,290	30,000	90
March	4,670	0	4,670	.....	4,670	30,000	4,670
April	5,420	0	5,420	5,600	− 180	29,820	.....
May	10,400	428	10,000	9,800	+ 200	30,000	20
June	15,800	3,900	11,900	12,600	− 700	29,300	.....
July	9,350	89	9,260	16,800	− 7,540	21,760	.....
August	5,580	0	5,580	16,800	−11,200	10,560	.....
September	4,960	0	4,960	8,400	− 3,400	7,120	.....
October	4,890	0	4,890	2,800	+ 2,090	9,210	.....
November	14,300	6,440	7,860	.....	7,860	17,070	.....
December	10,900	962	9,940	.....	9,940	27,010	.....
The year	95,400	11,800	83,600	72,800	− 180 −22,880 +25,870 + 200	.....	4,780
1910.							
January	7,070	0	7,070	.....	7,070	30,000	4,080
February	5,410	0	5,410	.....	5,410	30,000	5,410
March	9,100	323	8,780	.....	8,780	30,000	8,780
April	11,200	0	11,200	5,600	5,600	30,000	5,600
May	12,100	712	11,400	9,800	1,600	30,000	1,600
June	9,580	296	9,190	12,600	− 3,310	26,690	.....
July	6,330	0	6,330	16,800	−10,500	16,190	.....
August	4,860	0	4,860	16,800	−11,900	4,290	.....
September	4,760	0	4,760	8,400	− 3,640	650	.....
October	5,680	0	5,680	2,800	+ 2,880	3,530	.....
November	5,180	0	5,180	.....	5,180	8,710	.....
December	6,820	0	6,820	.....	6,820	15,530	.....
The year	88,100	1,320	86,800	72,800	+48,350 −29,350	.....	25,470
1911.							
January	5,060	0	5,060	.....	5,060	20,590	.....
February	5,040	0	5,040	.....	5,040	25,630	.....
March	3,870	0	3,870	.....	3,870	29,500	.....
April	5,670	0	5,670	5,600	70	29,570	.....
May	8,240	87	8,150	9,800	− 1,650	27,920	.....
June	15,900	4,220	11,700	12,600	− 900	27,020	.....
July	8,610	222	8,390	16,800	− 8,410	18,610	.....
August	4,430	0	4,430	16,800	−12,400	6,210	.....
September	4,040	0	4,040	8,400	− 4,360	1,850	.....
October	4,000	0	4,000	2,800	+ 1,200	3,050	.....
November	3,690	0	3,690	.....	3,690	6,740	.....
December	4,300	0	4,300	.....	4,300	11,040	.....
The year	72,800	4,530	68,300	72,800	+28,920 −27,720	.....	.....
1912.							
January	5,650	0	5,650	.....	5,650	16,690	.....
February	4,940	0	4,940	.....	4,940	21,630	.....
March	4,140	0	4,140	.....	4,140	25,770	.....
April	4,510	0	4,510	5,600	− 1,110	24,660	.....
May	10,100	726	9,370	9,800	− 430	24,230	.....
June	17,500	5,630	11,900	12,600	− 700	23,530	.....
July	10,700	329	10,400	16,800	− 6,400	17,130	.....
August	6,100	87	6,010	16,800	−10,000	7,130	.....
September	5,370	0	5,370	8,400	− 3,030	4,100	.....
October	4,510	0	4,510	2,800	+ 1,710	5,810	.....
November	3,990	0	3,990	.....	+ 3,990	8,800	.....
December	5,610	18	5,590	.....	5,590	12,390	.....
The year	83,100	6,790	76,400	72,800	+23,920 −21,670	.....	.....

The capacity of the reservoir has been assumed as 30,000 acre-feet. This with a 200 second-foot canal will suffice to irrigate 28,000

acres. The greatest amount necessarily drawn from storage for a 28,000-acre project would have been 29,300 acre-feet in 1910, or about 1 acre-foot per acre irrigated. There would have been a considerable surplus of water every year except 1911 and 1912, but to have carried this water from a wet to a dry year would have necessitated the development of additional storage equivalent to the draft for two or three years, which is probably out of the question on account of the cost.

The table showing manipulation of storage for this project differs only in details from the tables for Deschutes River. The duty of water has been assumed at practically the same values as have been used by the State engineer. The contracts under the Carey Act have called for the delivery of a quantity of water equal to a depth of about 1.8 feet on the land between April 15 and October 15. Assuming a loss of 30 per cent in distributing system—an assumption probably safe—the total diversion must be 2.6 acre-feet per acre or 72,800 acre-feet for the project. It is assumed that the water will be distributed throughout the growing season as follows:

Distribution of water from Tumalo project.

Month.	Depth.	Total diversion.
	Feet.	*Acre-feet.*
April	0.2	5,600
May	.35	9,800
June	.45	12,600
July	.6	16,800
August	.6	16,800
September	.3	8,400
October	.1	2,800
	2.6	72,800

Gains to the water supply would result from (1) inflow below the upper station and point of diversion of feed canal at certain times in early spring, (2) inflow to reservoir from a spring tributary to Bull Creek, (3) inflow to reservoir from tributary area, and (4) precipitation on reservoir. There would be losses due to seepage from feed canal, to obstruction of feed canal by ice, and to evaporation from reservoir.

IRRIGATION FROM CROOKED RIVER.

The average run-off of Crooked River measured at the Prineville station above Ochoco Creek from 1908 to 1912 was 269,000 acre-feet. Storage may be provided by constructing a reservoir at the forks of the river, 12 miles above Post. Records at this point from 1908 to 1911 indicate that nearly the entire flow can be controlled, as the average discharge during winter and spring is 92 per cent of that at Prineville station, but the period covered is too short to give assurance that the records show extremes of flow, or that they even give a correct mean. The records have therefore been compared with

those of John Day River at McDonald, and the means of monthly ratios have been used to extend the Crooked River record back to 1906.

The lands around Madras and the Agency Plains can be reached from Crooked River, but probably at a considerably greater cost than from Deschutes River. The land available for irrigation in the immediate valley of Crooked River, estimated at 50,000 acres, will require 150,000 acre-feet of water, or about two-thirds of the available flow. The other third can be used to reinforce the flow of lower Deschutes River during low periods for power development. The full utilization of Crooked River is therefore considered in connection with power development from the Deschutes. (See p. 117.)

POSSIBLE USE OF WATER FOR POWER DEVELOPMENT.

CONDITIONS OF STUDY.

The utilization of Deschutes River for power development has been studied for three assumed conditions:

1. For the use of the natural minimum discharge, the basis being the lowest recorded weekly flow, corrected for diversion if necessary.
2. For maximum storage at Benham Falls operated for power alone.
3. For discharge as affected by storage and irrigation on the Deschutes augmented by storage on Crooked River.

The first assumption is made chiefly for purposes of comparing the Deschutes with other streams for which power studies have been made on this basis, and gives results far in excess of those obtainable when projects on the upper Deschutes are developed, even if all water from the upper river is not stored and used for irrigation.

The second assumption departs even more than the first from probable future conditions and is presented chiefly to compare the utility of the stream for irrigation and for power. The third assumption involves the maximum development of irrigation and the utilization of return waters as already outlined.

MINIMUM NATURAL FLOW AVAILABLE FOR POWER.

The average minimum discharge at Benham Falls, as determined from a record covering seven years, is 1,330 second-feet and occurs in the winter.

The minimum weekly discharge in the period covered by records occurred in the first week in January, 1912. The discharge at Benham Falls, 1,180 second-feet, was unaffected by diversions. No records were being kept on Tumalo Creek at the time, but it is estimated to have been carrying 60 second-feet. The flow of Squaw Creek, which was affected by ice, is estimated at 50 second-feet.

These discharges have been added to that of Deschutes River at Benham Falls to give the probable minimum below the two tributaries. No allowance has been made for the apparent gain between

Bend and Laidlaw or for the possible loss between Laidlaw and Cline Falls, for both are questionable, and it is assumed that the probable method of development of this power—by diversion in a concrete-lined canal—would practically eliminate seepage losses.

The Deschutes probably receives little inflow between White River and the mouth, therefore, the Moody station gives the discharge in this whole section. The Mecca station shows the discharge through the section between Shitike Creek and Warm Springs River, and it has been assumed that by subtracting the discharge of Shitike Creek, it shows the discharge between that stream and the Metolius, Comparison of the records at Mecca and Moody shows a larger inflow than can be accounted for in Warm Springs and White rivers, the excess amounting to 300 or 400 second-feet at low water and considerably more during the winter and early spring. The permanent flow comes from springs; the intermittent flow is derived from rains and melting snows on the intervening area.

The lowest weekly flow on the lower river, as observed at Moody, was 4,080 second-feet January 2–8, 1912. At Mecca it was lowest January 4–10, 1912, the mean for the week being 3,550 second-feet, but there was a flow of only 3,300 second-feet for the three days, January 6–8, 1912. No records were being kept on Warm Spring River, and the gage heights on White River were evidently affected by ice; the flow of these streams can be estimated at 250 and 150 second-feet, respectively, for the lowest week, with a fair degree of certainty. The unmeasured inflow of about 400 second-feet, assumed to come in equally at these two points (p. 116) brings the total inflow between Mecca and Moody to 750 second-feet. The minima at these two points have been adjusted to 3,350 and 4,100 second-feet, respectively, or just a little greater than the absolute minimum at both points, but considerably lower than that during the lowest week at Mecca.

The minimum flow available for power development at various points is shown in the following table:

Minimum natural flow available for power at points in Deschutes River basin.

Stream and location.	Section No.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Minimum discharge.
Deschutes River:		*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sec.-ft.*
Benham Falls	1	181	4,145	.....	.....	.....	1,180
Tumalo Creek	2	160	3,240	21	905	43	1,240
Squaw Creek	3	123	2,105	37	1,135	31	1,290
Metolius River	4	111	1,555	12	550	46	3,290
Shitike Creek	5	97	1,360	14	195	14	3,350
Warm Springs River	6	84	1,230	13	130	10	3,780
White River	7	46	750	38	480	13	4,100
Mouth	8	0	131	46	619	13	4,100
Metolius River:							
Head	.....	41	2,980	.....	.....	.....	100
Jacks Creek	1	36	2,860	5	120	24	600
Jefferson Creek	2	29	2,646	7	214	31	1,000
Whitewater Creek	3	18	2,205	11	441	40	1,170
Riggs ranch	4	8	1,780	10	425	42	1,330
Mouth	5	0	1,556	8	224	28	1,330

THEORETICAL HORSEPOWER.

The following tables give the theoretical horsepower per foot fall that may be developed at different rates of discharge, and show the number of days on which the discharge and corresponding horsepower were respectively less than the amounts given in the columns for discharge and horsepower. In using these tables allowance should be made for the various losses, the principal ones being the wheel loss, which may be as large as 20 per cent, and the head loss, which may be as large as 5 per cent.

Discharge and horsepower, Deschutes River at Allen's ranch, near Lava, Oreg.

Gage heights (feet).	Discharge (second-feet).	Theoretical horsepower per foot fall.	Days of deficient discharge.						
			1905	1906	1907	1908	1909	1910	1911
5.0	89	10	5	0	.....	.....	.....	.....	0
5.2	106	12	112	34	0	0	0	0	18
5.4	125	14	156	86	2	23	3	10	73
5.6	147	17	174	132	4	64	51	79	143
5.8	173	20	179	149	59	118	132	127	203
6.0	205	23	184	164	105	167	181	151	256

Discharge and horsepower table for Deschutes River at Benham Falls, Oreg., 1905–1912.

12 months period, May to April.

Discharge (second-feet).	Theoretical horsepower per foot fall.	Days of deficient discharge.						
		1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12
1,100	125	1	.....	.....	.....	.....	.....	2
1,200	136	3	1	.....	1	.....	1	3
1,300	148	26	14	1	3	.....	3	16
1,400	159	131	116	16	13	3	50	132
1,500	171	163	187	41	37	38	165	259
1,600	182	178	209	99	127	159	247	.....
1,700	193	264	245	148	210	211	304	.....

Irrigating season, May to September.

1,100	125	.....	.....	.....	.....	.....	.....	.....
1,200	136	.....	.....	.....	.....	.....	.....	.....
1,300	148	.....	0	.....	.....	.....	.....	0
1,400	159	.....	27	.....	.....	.....	0	37
1,500	171	1	70	.....	0	0	15	81
1,600	182	8	84	.....	8	80	66	86
1,700	193	52	110	0	47	99	96	126

Nonirrigating season, October to April.

1,100	125	1	.....	.....	.....	.....	.....	2
1,200	136	3	1	.....	1	.....	1	3
1,300	148	26	14	1	3	.....	3	16
1,400	159	131	89	16	13	3	50	95
1,500	171	162	117	46	37	38	150	178
1,600	182	170	125	99	119	79	181	.....
1,700	193	212	135	148	163	112	212	.....

Discharge and horsepower table for Deschutes River at Moro and Moody, Oreg., 1897–1899, 1906–1912.

Nonirrigating season, October to April.

Gage heights (feet).	Discharge (second-feet).	Theoretical horsepower per foot fall.	Days of deficient discharge.									
			Moro.			Moody.						
			1897–98	1898–99	1899–1900	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	Mean.
1.9	4,080	464	.....	0	.....	.....	.....	.....	.....	.....	0	0
2.0	4,320	491	.....	9	.....	.....	.....	.....	.....	.....	3	1
2.1	4,560	518	.....	15	.....	.....	.....	.....	.....	.....	3	2
2.2	4,820	548	.....	28	.....	.....	.....	.....	.....	.....	4	4
2.3	5,080	577	.....	46	.....	0	.....	0	.....	0	24	8
2.4	5,360	609	.....	89	.....	36	.....	23	0	36	61	27
2.5	5,660	643	.....	98	0	37	0	45	32	55	84	39
2.6	5,980	680	0	106	5	51	55	100	33	85	95	59
2.8	6,680	759	77	114	26	85	124	125	49	131	104	93
3.0	7,420	843	133	139	56	102	132	143	75	187	133	122
3.2	8,200	932	172	160	.....	119	158	165	81	196	145	150
3.4	9,000	1,020	198	171	.....	131	182	168	141	198	164	.....

Period May to April.

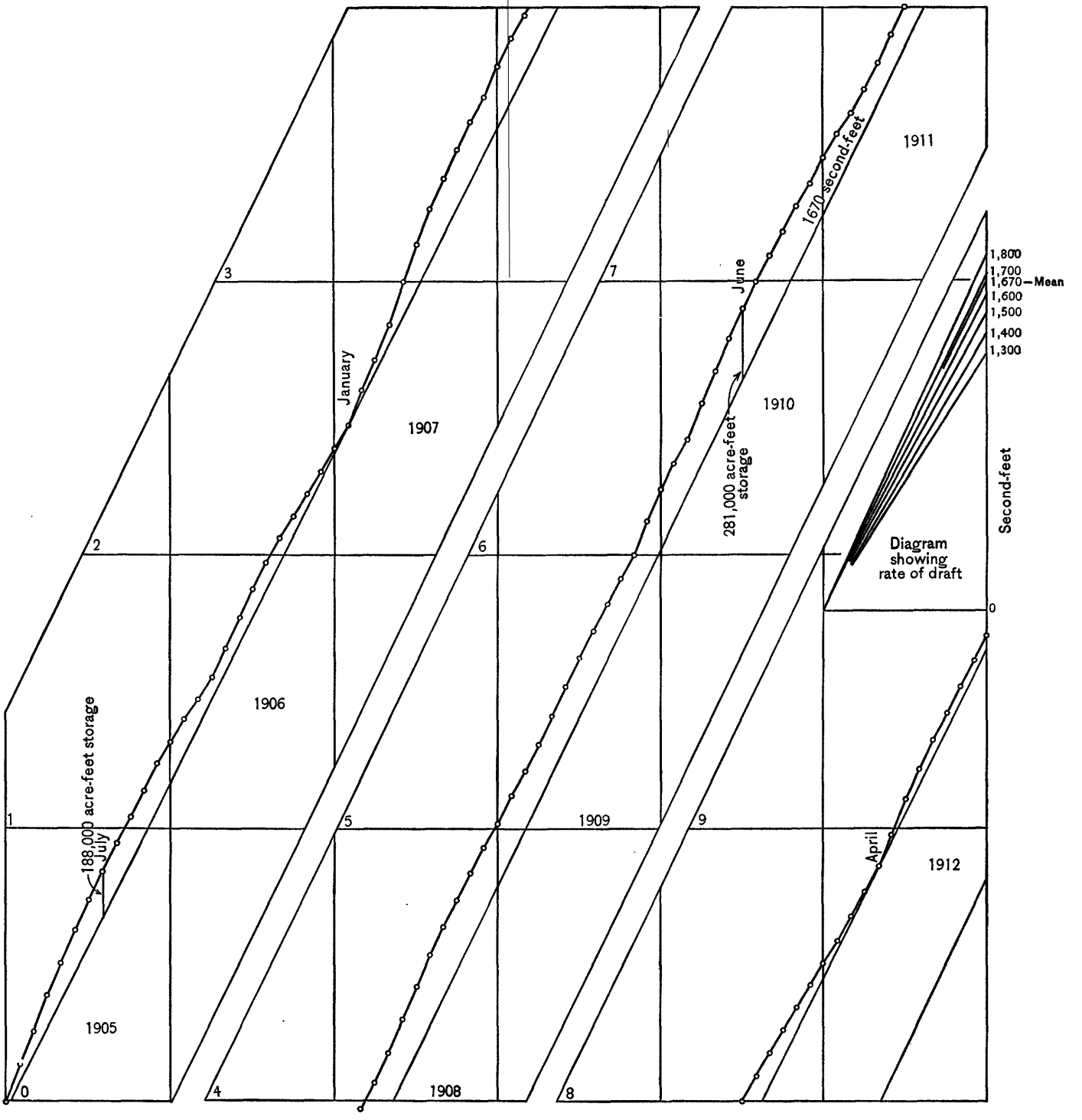
1.9	4,080	464	.....	0	.....	.....	.....	.....	.....	.....	0	0
2.0	4,320	491	.....	9	.....	.....	.....	.....	.....	.....	3	1
2.1	4,560	518	.....	15	.....	.....	.....	.....	.....	.....	3	2
2.2	4,820	548	0	28	.....	.....	.....	.....	.....	.....	4	4
2.3	5,080	577	22	68	.....	0	.....	0	0	0	70	8
2.4	5,360	609	64	153	.....	101	.....	46	27	111	141	27
2.5	5,660	643	81	179	0	166	0	110	114	143	170	39
2.6	5,980	680	84	190	8	.....	127	182	128	.....	190	59
2.8	6,680	759	182	219	52	.....	209	239	163	.....	217	93
3.0	7,420	843	276	282	118	.....	242	286	211	.....	285	122
3.2	8,200	932	325	313	.....	.....	281	315	233	.....	298	150
3.4	9,000	1,020	351	324	.....	.....	321	321	294	.....	317	.....

Irrigating season, May to September.

2.2	4,820	548	0	.....	0	.....	0	0	0	0	.....	.....
2.3	5,080	577	22	.....	65	.....	23	27	75	46	.....	.....
2.4	5,360	609	64	.....	129	0	65	82	88	80	.....	.....
2.5	5,660	643	81	0	.....	72	82	95	.....	86	.....	.....
2.6	5,980	680	84	3	.....	85	114	114	.....	95	.....	.....
2.8	6,680	759	105	26	.....	110	143	136	.....	113	.....	.....
3.0	7,420	843	143	62	.....	123	150	152	.....	152	.....	.....
3.2	8,200	932	153	73	.....	139	153	153	.....	153	.....	.....
3.4	9,000	1,020	153	82	.....	.....	.....	.....	.....	153	.....	.....

Discharge and horsepower table for Metolius River near Sisters, Oreg., 1909–1911.

Gage height (feet).	Discharge (second-(feet).	Theoretical horsepower per foot fall.	Days of deficient discharge.		
			1909	1910	1911
0.5	1,410	160	0	0	0
.6	1,490	169	55	21	68
.7	1,570	178	116	110	227
.8	1,650	188	203	210	302



MASS CURVE SHOWING REGULATION OF DESCHUTES RIVER AT PROPOSED BENHAM FALLS RESERVOIR FOR POWER DEVELOPMENT.

Discharge and horsepower table for East Fork of Deschutes River near Crescent, Oreg., 1905–1911.

Discharge (second-feet).	Theoretical horsepower per foot fall.	Days of deficient discharge.			
		1905	1906	1907	1910–11[a]
10	1.1	0	.....	.....	.....
20	2.3	15	0	.....	.....
30	3.4	98	1	0	0
40	4.5	160	79	72	102
50	5.7	174	138	131	163
60	6.8	186	156	145	193

[a] October to September.

WATER STORED AT BENHAM FALLS.

The water supply of Deschutes River available for power could be materially augmented by storage at Benham Falls operated to regulate the discharge for that purpose, especially that part of the discharge of the upper part of the river nearest the suggested reservoir. The discharge that could be maintained and the amount of storage required can best be studied by the aid of a mass curve or vector diagram, Plate VII, which shows that with respect to the vector line representing a discharge of 1,670 second-feet—the mean for the eight years—the mass was increasing up to June 30, 1910, then decreasing until April 30, 1912. The ordinate from the vector line drawn through the point for the later date to the point on the graph for June 30, 1910, is equal to 249,000 acre-feet. The point on the graph for April 30, 1912, is 31,600 acre-feet below this vector line. Therefore the draft from storage between these dates would equal 281,000 acre-feet—the capacity required to maintain a constant discharge of 1,670 second-feet. Therefore the quantity of water which may be made available for power above Tumalo Creek by the suggested reservoir at Benham Falls is estimated at 1,670 second-feet and the other discharges for stretches lower down have been increased to 1,670 second-feet or 490 second-feet over the minimum.

EFFECT OF FUTURE DIVERSION.

The substantially complete control of the discharge of Deschutes River, Tumalo Creek, and Crooked River for irrigation would practically remove contribution of discharge from the drainage area of these three streams above the points of diversion. Water from all three will, of course, reach the lower river, but this overflow will always cease when the flow is materially above the minimum, and therefore will not appreciably affect the low-water discharge. The effect of future diversions on the regimen of the lower river is indicated by the

following table, which shows the observed discharge at Moody, the correction which must be applied to reduce that discharge to the flow that would have occurred had there been no irrigation, the resulting natural flow, and the discharge under future conditions. The probable effect of future diversions as indicated in the table is the difference between the observed discharge at the points of diversion or storage and the estimated return waters, 620 second-feet, and is always negative, the observed discharge being greater than the return waters.

Effect of future irrigation on discharge (in second-feet) of Deschutes River at Moody.

Month.	Observed discharge at Moody.	Correction for past diversions.	Natural discharge.	Correction for future diversions.	Discharge under future conditions.
1906.					
July	5,800	+318	6,120	−1,190	4,930
August	5,360	+280	5,640	− 900	4,740
September	5,080	+270	5,350	− 870	4,480
October	5,180	+252	5,430	− 850	4,580
November	7,290	+ 7	7,300	−1,140	6,160
December	6,720	+ 43	6,760	−1,110	5,650
1907.					
January	6,720	− 41	6,680	−1,160	5,520
February	13,900	+ 14	13,900	−4,300	9,600
March	9,590	+ 61	9,650	−3,050	6,600
April	11,900	+158	12,100	−3,540	8,560
May	8,950	+273	9,220	−2,640	6,580
June	7,250	+368	7,620	−2,110	5,510
July	6,230	+308	6,540	−1,710	4,830
August	5,670	+330	5,000	−1,390	4,610
September	5,660	+237	5,900	−1,290	4,610
October	5,660	+206	5,870	−1,160	4,710
November	5,980	+ 88	6,070	−1,160	4,910
December	8,720	+ 11	8,730	−1,400	7,330
The year	7,970				
1908.					
January	7,420	− 31	7,390	−1,330	6,060
February	6,110	− 41	6,070	−1,130	4,940
March	8,600	+ 2	8,600	−1,880	6,720
April	8,510	+144	8,650	−2,340	6,310
May	7,340	+238	7,580	−1,820	5,760
June	6,500	+336	6,840	−1,720	5,120
July	6,000	+451	6,450	−1,570	4,880
August	5,400	+407	5,810	−1,170	4,640
September	5,300	+320	5,620	−1,110	4,510
October	5,300	+243	5,540	−1,200	4,340
November	5,970	− 4	5,970	−1,120	4,850
December	5,710	− 36	5,670	− 960	4,710
The year	6,530				
1909.					
January	7,470	− 81	7,390	−1,300	6,090
February	7,180	− 31	7,150	−1,270	5,880
March	7,520	+ 34	7,550	−1,720	5,830
April	8,390	+170	8,560	−2,140	6,420
May	7,040	+352	7,390	−1,620	5,770
June	6,760	+399	7,160	−1,500	5,660
July	5,580	+314	5,890	−1,170	4,720
August	5,260	+399	5,660	−1,030	4,630
September	5,360	+284	5,640	−1,020	4,620
October	5,540	+190	5,730	−1,000	4,730
November	9,380	− 55	9,320	−2,090	7,230
December	8,710	− 81	8,630	−1,700	6,930
The year	7,010				

Effect of future irrigation on discharge (in second-feet) of Deschutes River at Moody—Con.

Month.	Observed discharge at Moody.	Correction for past diversions.	Natural discharge.	Correction for future diversions.	Discharge under future conditions.
1910.					
January	9,420	− 61	9,360	−1,380	7,980
February	8,110	− 56	8,050	−1,760	6,290
March	14,300	− 16	14,300	−3,520	10,780
April	8,740	+187	8,930	−2,120	6,810
May	7,960	+291	8,250	−1,740	6,510
June	6,320	+431	6,750	−1,300	5,450
July	5,400	+470	5,870	−1,100	4,770
August	5,180	+313	5,490	−1,000	4,490
September	5,230	+285	5,520	− 980	4,540
October	5,290	+201	5,490	− 980	4,510
November	6,300	− 04	6,300	−1,060	5,240
December	6,820	+ 7	6,830	−1,320	5,510
The year	7,430				
1911.					
January	6,350	− 48	6,300	−1,030	5,270
February	5,710	− 59	5,650	−1,000	4,650
March	7,210	− 26	7,180	−1,890	5,290
April	7,450	+176	7,630	−1,820	5,810
May	6,810	+351	7,160	−1,480	5,680
June	6,380	+439	6,820	−1,400	5,420
July	5,260	+477	5,740	−1,040	4,700
August	4,850	+402	5,250	− 840	4,410
September	4,930	+291	5,220	− 860	4,360
October	4,990	+193	5,180	− 850	4,330
November	5,440	+ 2	5,440	− 880	4,560
December	5,340	− 67	5,270	− 800	4,470
The year	5,890				
1912.					
January	7,940	− 70	7,870	−1,170	6,700
February	9,720	− 54	9,670	−1,630	8,040
March	6,920	− 30	6,890	−1,210	5,680
April	9,550	+ 56	9,610	−2,370	7,240
May	9,770	+290	10,060	−2,720	7,340
June	7,980	+461	8,440	−2,060	6,380
July	5,910	+493	6,400	−1,390	5,010
August	5,390	+444	5,830	−1,180	4,650
September	5,520	+299	5,820	−1,160	4,660
October	5,480	+229	5,710	−1,090	4,620
November	6,030	+114	6,140	−1,160	4,980
December	6,000	− 59	5,940	−1,080	4,860
The year	7,170				

The distribution of the unmeasured flow of the Deschutes between Warm Springs and White rivers is shown by the following table (p. 116). It has been assumed that one-half of it comes in at the mouth of each of the two tributary rivers in addition to the flow of the rivers themselves.

The second column shows the discharge at Mecca with the same reduction that has been found applicable to Moody to give the discharge under assumed future conditions of storage and irrigation. The other columns are self-explanatory.

Distribution of inflow between Mecca and Moody.

Month.	Discharge under assumed conditions.		Inflow between Mecca and Moody.			Discharge between Warm Springs and White rivers.
	Mecca.	Moody.	At Warm Spring River.	At White River.	Total.	
1911.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
June	3,960	5,420	860	600	1,460	4,820
July	3,820	4,720	550	350	900	4,370
August	3,720	4,520	470	330	800	4,190
September	3,720	4,500	440	340	780	4,160
October	3,600	4,500	500	400	900	4,000
November	3,390	4,620	590	640	1,230	3,980
December	3,540	4,580	620	420	1,040	4,160
1912.						
January	3,810	6,700	1,470	1,420	2,890	5,280
February	4,260	8,040	1,710	3,070	3,780	5,970
March	3,960	5,680	1,080	640	1,720	5,040
April	4,150	7,240	1,470	1,620	3,090	5,620
May	4,670	7,340	1,240	1,430	2,670	5,920
June	4,420	6,380	1,090	870	1,960	5,510
July	3,950	5,010	560	500	1,060	4,510
August	3,810	4,650	470	370	840	4,280
September	3,660	4,660	550	450	1,000	4,210
October	3,530	4,620	590	500	1,090	4,120
November	3,720	4,980	650	610	1,260	4,370
December	3,530	4,860	690	640	1,330	4,220

This table indicates a possible minimum monthly discharge of 3,390 second-feet ultimately available at Mecca, corresponding to a discharge of about 3,330 second-feet above Shitike Creek and 3,980 below Warm Springs River. The latter is, of course, subject to the uncertainty as to the location of the inflow from springs between Mecca and Moody. The estimates of minima used by Prof. McCaustland in his part of the report, of 3,400 second-feet from the Metolius to Warm Springs River and 3,700 second-feet from Warm Springs to White River, are probably fairly accurate.

POWER FROM WATER USED FOR IRRIGATION.

In the estimate of the rate of distribution of water to irrigated lands (p. 89), it was assumed that a small quantity, about 10 per cent of the total yearly flow—equivalent to an average discharge of 220 second-feet—would have to be released during the winter for domestic use. This would be available for power development between the reservoir and the points of diversion.

During the summer months a large amount of water would be available for power in the stretch of river between the suggested reservoir at Benham Falls and the lower diversion below Laidlaw. This power could be used to supply some demand that would be active only during this period, such as pumping water for irrigation or furnishing auxiliary power to some plant for which the flow otherwise available is deficient during July and August. The utilization of the power of the upper Deschutes for either of these purposes

would probably involve long transmission lines and may not be commercially feasible for many years, but it presents possibilities that should not be overlooked in an estimate of the total potential power of the Deschutes.

POWER FROM WATER STORED ON CROOKED RIVER.

The general regimen of the lower Deschutes is very uniform, but there are relatively short periods in which the discharge falls within 100 to 500 second-feet of the minimum. The minimum flow available for power in this section could be materially increased by the release of a relatively small amount of water that could be stored on Crooked River, the water supply of which is apparently sufficient not only to irrigate 50,000 acres of land in its own valley but also to supply deficiencies in flow below 4,500 second-feet on the lower river.

A study of the manipulation of possible storage on Crooked River for months during which the mean discharge of Deschutes at Moody is less than 4,500 second-feet has been made to determine the quantity of water necessary to release in order to supply deficiencies below this minimum. This quantity is generally larger than would be indicated by the deficiency of the monthly mean below 4,500, as during a few days in each month the flow will exceed 4,500 second-feet.

The estimated areas and capacities of the suggested reservoir on Crooked River are shown by the following table, prepared from data furnished by the United States Reclamation Service:

Approximate area and capacity of Crooked River storage reservoir.

Elevation above sea level.	Area.	Difference in area per foot of gage height.	Capacity.	Difference in capacity per foot of gage height.
Feet.	*Acres.*	*Acres.*	*Acre-feet.*	*Acre-feet.*
3,480	0	.....	0	.....
3,490	30	3	150	15
3,500	100	7	800	65
3,510	250	15	2,600	180
3,520	420	17	6,000	340
3,530	1,350	93	15,000	900
3,540	1,850	50	31,000	1,600
3,550	2,350	50	52,000	2,100
3,560	2,900	55	78,000	2,600
3,570	3,700	80	111,000	3,300
3,580	4,300	60	152,000	4,100
3,590	5,000	70	200,000	4,800
3,600	5,500	50	252,000	5,200
3,610	6,000	50	310,000	5,800
3,620	6,300	50	372,000	6,200

The results of study of storage manipulation on Crooked River are presented in the following table in substantially the same manner as those for Deschutes River and Tumalo Creek:

Manipulation of storage at suggested reservoir on Crooked River.

Month.	Required for irrigation along Crooked River.	Deficiencies below 4,500 second-feet on lower Deschutes River.	Total suggested use.	Evaporation.	Total use and evaporation.	Discharge of Crooked River.	Excesses and deficiencies.	In reservoir at end of month.	Area of water surface.	Overflow.
1906.	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acres.*	*Acre-ft.*
January	.....	.....	.....	0	0	7,500	7,500	22,500	.....	.....
February	.....	.....	.....	0	0	21,700	21,700	44,200	2,100	.....
March	.....	.....	.....	200	200	65,200	65,000	109,200	3,600	.....
April	7,500	.....	7,500	700	8,200	95,900	87,700	180,000	4,700	16,900
May	18,000	.....	18,000	1,900	19,900	18,800	− 1,100	178,900	4,700	.....
June	27,000	.....	27,000	1,900	28,900	7,910	− 21,000	157,900	4,400	.....
July	37,500	.....	37,500	2,700	39,700	2,520	− 37,200	120,700	3,900	.....
August	37,500	.....	37,500	2,300	39,800	1,660	− 38,100	82,600	3,000	.....
September	15,000	1,190	16,200	1,500	17,700	2,320	− 15,400	67,200	2,700	.....
October	7,500	633	8,100	500	8,600	3,500	− 5,100	62,100	2,600	.....
November	.....	.....	.....	300	300	8,810	− 8,500	70,600	2,800	.....
December	.....	.....	.....	0	0	12,100	− 12,100	82,700	3,100	16,900
The year	150,000	1,800	151,800	11,500	163,300	247,900	{+202,500 −117,900}	.....	.....	.....
1907.										
January	.....	.....	.....	0	0	16,400	+ 16,400	99,100	3,400	.....
February	.....	.....	.....	0	0	134,000	+134,000	180,000	4,700	33,100
March	.....	.....	.....	500	500	109,000	+108,500	180,000	4,700	108,500
April	7,500	.....	7,500	900	8,400	120,000	111,600	180,000	4,700	111,600
May	18,000	.....	18,000	1,900	19,900	29,300	+ 9,400	180,000	4,700	9,400
June	27,000	.....	27,000	1,900	28,900	3,750	− 25,200	154,800	4,300	.....
July	37,500	.....	37,500	2,200	39,700	2,710	− 37,000	117,800	3,500	.....
August	37,500	.....	37,500	2,300	39,800	2,280	− 37,500	80,300	3,000	.....
September	15,000	0	15,000	1,500	16,500	2,320	− 14,200	66,100	2,700	.....
October	7,500	.....	2,500	500	8,000	3,810	− 4,200	61,900	2,600	.....
November	.....	.....	.....	300	300	7,500	+ 7,200	69,100	2,800	.....
December	.....	.....	.....	0	0	9,840	+ 9,800	78,900	3,000	.....
The year	150,000	.....	150,000	12,000	162,000	440,900	{+396,900 −118,100}	.....	.....	282,600
1908.										
January	.....	.....	.....	0	0	10,100	+ 10,100	89,000	3,200	.....
February	.....	.....	.....	0	0	12,300	+ 12,300	101,300	3,500	.....
March	.....	.....	.....	400	400	49,600	+ 49,200	150,500	4,300	.....
April	7,500	.....	7,500	900	8,400	61,500	+ 53,100	180,000	4,700	23,600
May	18,000	.....	18,000	1,900	19,900	15,300	− 4,600	175,400	4,600	.....
June	27,000	.....	27,000	1,800	28,800	3,570	− 25,200	150,200	4,300	.....
July	37,500	.....	37,500	2,200	39,700	2,210	− 37,500	112,700	3,700	.....
August	37,500	.....	37,500	2,200	39,700	1,290	− 38,400	74,300	3,900	.....
September	15,000	196	15,200	1,400	16,600	1,790	− 14,800	59,500	2,500	.....
October	7,500	9,840	17,300	500	17,800	4,300	− 13,500	46,000	2,200	.....
November	.....	.....	.....	200	200	5,060	+ 4,900	50,900	2,300	.....
December	.....	.....	.....	0	0	4,920	+ 4,900	55,800	2,400	.....
The year	150,000	10,000	160,000	11,500	171,500	171,900	{+134,500 −134,000}	.....	.....	23,600
1909.										
January	.....	.....	.....	0	0	11,600	+ 11,600	67,400	2,700	.....
February	.....	.....	.....	0	0	21,900	+ 21,900	89,300	3,200	.....
March	.....	.....	.....	300	300	43,000	+ 42,700	132,000	4,000	.....
April	7,500	.....	7,500	800	8,300	68,000	+ 59,700	180,000	4,700	11,700
May	18,000	.....	18,000	1,900	19,900	17,200	− 2,700	177,300	4,700	.....
June	27,000	.....	27,000	1,900	28,900	4,090	− 24.800	152,500	4,300	.....
July	37,500	.....	37,500	2,200	39,200	2,260	− 37,400	115,100	3,800	.....
August	37,500	793	38,300	1,900	40,200	1,600	− 38,600	76,500	2,900	.....
September	15,000	637	15,600	1,400	17,000	2,120	− 14,900	61,600	2,600	.....

Manipulation of storage at suggested reservoir on Crooked River—Continued.

Month.	Required for irrigation along Crooked River.	Deficiencies below 4,500 second-feet on lower Deschutes River.	Total suggested use.	Evaporation.	Total use and evaporation.	Discharge of Crooked River.	Excesses and deficiencies.	In reservoir at end of month.	Area of water surface.	Overflow.
	Acre-ft.	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acres.*	*Acre-ft.*
October	7,500	.....	7,500	500	8,000	3,160	− 4,800	56,800	2,500	.....
November	.....	.....	.....	200	200	25,600	+ 25,400	82,200	3,000	.....
December	.....	.....	.....	0	0	13,200	+ 13,200	95,400	3,300	.....
The year	150,000	1,400	151,400	11,100	162,500	213,700	{+174,000 −123,200}	.....	.....	11,700
1910.										
January	.....	.....	.....	0	0	21,600	+ 21,600	117,000	3,800	.....
February	.....	.....	.....	0	0	38,300	+ 38,300	155,300	4,400	.....
March	.....	.....	.....	400	400	117,000	+116,600	180,000	4,700	91,900
April	7,500	.....	7,500	900	8,400	37,400	+ 29,000	180,000	4,700	29,000
May	18,000	.....	18,000	1,900	19,900	11,500	− 8,400	171,600	4,600	.....
June	27,000	.....	27,000	1,800	28,800	857	− 27,900	143,700	4,200	.....
July	37,500	.....	37,500	2,100	39,600	548	− 39,100	104,600	3,600	.....
August	37,500	615	38,100	2,200	40,300	347	− 40,000	64,600	2,600	.....
September	15,000	.....	15,000	1,300	16,300	1,110	− 15,200	49,400	2,300	.....
October	7,500	812	8,300	500	8,800	2,820	− 6,000	43,400	2,200	.....
November	.....	238	200	200	400	6,070	+ 5,700	49,100	2,300	.....
December	.....	.....	.....	0	0	16,800	+ 16,800	65,900	2,700	.....
The year	150,000	1,700	151,600	11,300	162,900	254,300	{+228,000 −136,600}	.....	.....	120,900
1911.										
January	.....	1,730	1,700	0	1,700	8,980	+ 7,300	73,200	2,800	.....
February	.....	1,980	2,000	0	2,000	9,660	+ 7,700	80,900	3,000	.....
March	.....	1,670	1,700	300	2,000	62,700	+ 60,700	141,600	4,100	.....
April	7,500	.....	7,500	800	8,300	52,600	+ 49,300	180,000	4,700	10,900
May	18,000	.....	18,000	1,900	19,900	18,200	− 1,700	178,300	4,700	.....
June	27,000	.....	27,000	1,900	28,900	2,650	− 26,200	152,100	4,300	.....
July	37,500	1,430	38,900	2,200	41,100	1,080	− 40,000	112,100	3,700	.....
August	37,500	6,640	44,100	2,200	46,300	572	− 45,700	66,400	2,700	.....
September	15,000	8,330	23,300	1,400	24,700	1,080	− 23,600	42,800	2,100	.....
October	7,500	10,500	18,000	400	18,400	3,120	− 15,300	27,500	1,700	.....
November	.....	3,290	3,300	200	3,500	3,650	+ 200	27,200	1,800	.....
December	.....	7,070	7,100	0	7,100	4,560	− 2,500	25,200	1,700	.....
The year	150,000	42,600	122,600	11,300	203,900	168,900	{+119,900 −155,000}	.....	.....	10,900
1912.										
January	.....	12,200	12,200	0	12,200	19,600	+ 7,400	32,600	1,900	.....
February	.....	.....	0	0	0	35,000	+ 35,000	67,600	2,700	.....
March	.....	.....	0	300	300	20,300	+ 20,000	87,600	3,200	.....
April	7,500	.....	7,500	600	8,100	95,200	+ 87,100	174,700	4,600	.....
May	18,000	.....	18,000	1,800	19,800	91,600	+ 71,800	180,000	4,700	66,500
June	27,000	.....	27,000	1,900	28,900	17,800	− 11,100	168,900	4,500	.....
July	37,500	.....	37,500	2,200	39,700	4,120	− 35,600	133,300	4,000	.....
August	37,500	.....	37,500	2,400	39,900	2,040	− 37,900	95,400	3,400	.....
September	15,000	.....	15,000	1,700	16,700	2,040	− 14,700	80,700	3,000	.....
October	7,500	.....	7,500	600	8,100	3,020	− 5,100	75,600	2,900	.....
November	.....	.....	0	300	300	4,680	+ 4,400	80,000	3,000	.....
December	.....	.....	0	0	0	7,000	+ 7,000	87,000	3,200	.....
The year	150,000	12,200	162,200	11,800	174,000	302,400	{+232,700 −104,400}	.....	.....	66,500

The table shows the monthly requirements for irrigation, the volume of water (in acre-feet) required to maintain a discharge of 4,500 second-feet in Deschutes River below White River, the monthly evaporation, the available flow of Crooked River at the reservoir, as shown by records of the Post station November to March, and at the

point of diversion, as represented by the Prineville station April to October, the area of water surface corresponding to the volume of storage, and the quantity of water spilled in any month after the reservoir becomes filled to capacity—180,000 acre-feet.

The figures indicate that the reservoir would have been filled each spring without exception, but the quantity spilled in 1911 would have been very small, and in 1909 it would have been less than 5 per cent of the total run-off. Although never empty, the reservoir would have had only 13,000 acre-feet left at the end of the period of deficiency on lower Deschutes River in the early part of January, 1912. The assumed capacity is, therefore, possibly 13,000 acre-feet too great. The annual draft might be increased by 10,000 or 20,000 acre-feet by holding over water from wet years, like 1907 or 1910, but the increase in storage required would be considerable and the expense might not be warranted. The maximum storage capacity required for irrigation alone would have been 135,000 acre-feet in 1910; the maximum for power alone, 49,400, July, 1911, to January, 1912.

DEVELOPED WATER POWERS IN THE DESCHUTES DRAINAGE BASIN.

By W. B. Heroy.

Because of the relatively sparse population of the Deschutes basin and the few towns of sufficient importance to afford a market for power, little progress has been made in the utilization of water power. There are, however, at least three plants in operation—one on the main Deschutes River, one on Crooked River, and one on White River—with an aggregate capacity of 2,900 kilowatts. Descriptions of these plants, based in part upon data published in engineering journals, follow.

BEND PLANT.[1]

Near the town of Bend in the north half of sec. 32, T. 17 S., R. 12 E., a small rock-fill dam has been constructed across Deschutes River to develop water power. At the east end of the dam a forebay has been constructed from which water is admitted to the wheels in the power house. Only half of the power house has been completed, housing at the present time one unit. The station is, however, of modern concrete and brick construction and may ultimately be enlarged to a capacity of 1,400 horsepower. The plant operates under a head of 15 feet.

The unit now installed consists of an S. Morgan Smith turbine, directly connected to a 250 kilovolt-ampere alternating-current generator. Electric power and light are furnished to Bend, and the pumps for municipal water supply are also operated electrically.

[1] Described in The Journal of Electricity, vol. 31, p. 319, 1913.

The plant was originally constructed by the Bend Water, Light & Power Co. in 1910 but has recently been acquired by the Central Oregon Power Co. This company is said to be controlled by the same interests as the Deschutes Power Co. The cost of the plant and distribution system has been slightly over $100,000.

CROOKED RIVER PLANT.

A hydroelectric plant has been constructed to utilize the flow of the lower stretch of Crooked River, below Opal Springs. The diversion canal takes directly out of the river in the SE. ¼ SW. ¼ sec. 11, T. 12 S., R. 12 E., and conducts the water to the power house, which is situated in the NE. ¼ SW. ¼ of the same section. The canal is about 2,300 feet in length and the head obtained is approximately 33 feet.

One unit has been installed, consisting of one Leffel water wheel, one direct-current generator, 14 kilowatts, 125 volts, 112 amperes, and one alternating-current generator, 400 kilowatts, 2,300 volts, 100 amperes. The distribution system supplies Prineville, Redmond, Madras, Metolius, and Culver, 73 miles of transmission lines having been constructed. The plant is capable of being enlarged to a capacity of 3,900 horsepower, and by means of a diversion dam the head can be increased to 38 feet. Eleven hundred second-feet of water has been appropriated.

The plant was constructed by the Cove Power Co. but has recently been purchased by the Deschutes Power Co., having offices at 521 First Avenue, Spokane, Wash. The officers of the company are Samuel Galland, president; W. C. Sivyer, vice president; Bert L. Sivyer, secretary and treasurer; and L. M. Simpson, general manager. The cost of the plant, equipment, and transmission system is reported to be about $228,000.

WHITE RIVER PLANT.[1]

A short distance west of Deschutes River White River falls from the Deschutes plateau into a canyon, forming a number of picturesque cascades. Advantage of this natural water power has been taken and a hydroelectric plant installed. The entire development is located on the northeast quarter of sec. 7, T. 4 S., R. 14 E.

A concrete dam, 8 feet high, has been built across the river above the falls and diverts the water into a settling basin, the use of which is necessitated because of the large amount of sediment carried by White River. The water is thence conveyed through a 48-inch wood-stave pipe about 500 feet to a second settling basin, which acts also as a forebay reservoir. A 60-inch wood-stave and steel pressure pipe 430 feet long, leading to the power house, gives a head of 149 feet.

[1] Described in The Journal of Electricity, vol. 29, p. 227.

The power house contains three Pelton-Frances turbines, two installed in 1911 having a capacity of 1,000 horsepower each, and one in 1912 of 1,600 horsepower. The older wheels are each connected to 500-kilowatt, 60-cycle, 3-phase generators, while the new wheel connects to a 1,250-kilowatt machine. Two 40-kilowatt and one 60-kilowatt exciters have also been installed.

Power is developed at 2,300 volts but is stepped up to 66,000 volts for transmission 27 miles to The Dalles. Here connection is made with a transmission line leading to Hood River, where a small hydroelectric plant of 325 kilowatts is tied into the same circuit. A branch line extends to Dufur.

The plant was constructed by the Wasco Warehouse Milling Co., now a subsidiary of the Pacific Power & Light Co., which supplies electricity to a large territory in southern Washington and northern Oregon. The Pacific Power & Light Co. is controlled by the American Power & Light Co., a subsidiary of the General Electric Co.

UNDEVELOPED POWER SITES.

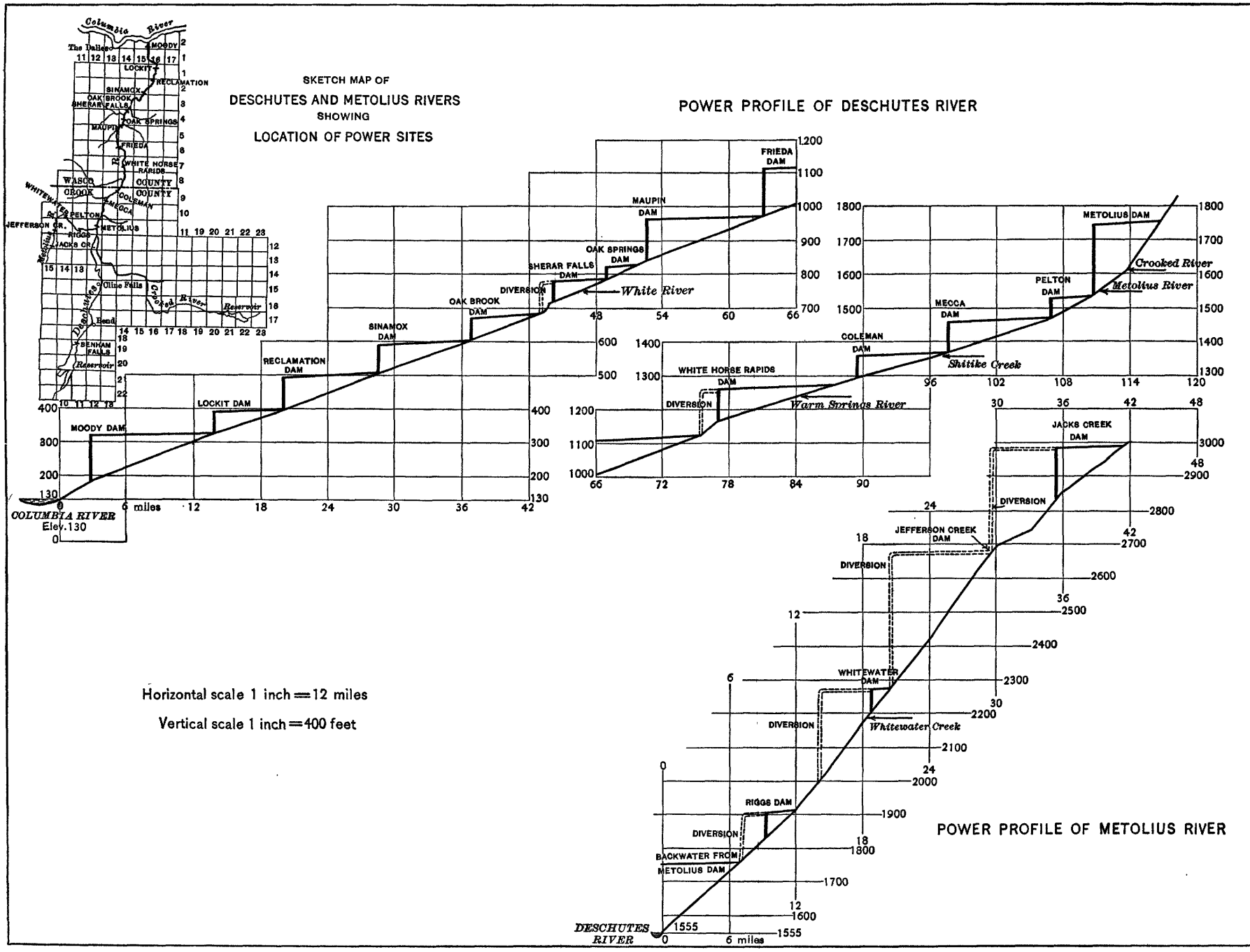
By E. J. McCaustland.

METHODS OF DEVELOPMENT.

In any contemplated water-power development all other possible uses of the water should be carefully considered and should be given full weight in reaching a conclusion. It has been contended that the full development of power in certain regions has led to the exhaustion of the natural resources, such as lumber, iron, and coal. It is thus reasonable to ask whether such development was for the ultimate good of these regions or whether it would not have been wise to delay development until it could proceed without exhausting natural resources. But whether development is to proceed as a whole or by a system of units in response to pressing demand, knowledge of the possibilities and the limitations of the water powers is of primary importance to the owners of the rights.

In order to determine such possibilities and limitations, complete and accurate data are essential. It should not be forgotten, however, that accuracy in this connection is merely relative, and that for preliminary investigations a range of 10 to 15 per cent is well within the limit of error to be expected.

The minimum power available at any site is that which may be developed during the period of lowest flow of the stream—a period ordinarily extending over a few days or weeks during some rather definite season of the year; as during other portions of the year a much greater power may be developed, it is, as a rule, wise not to design a plant for an actual minimum stream flow, but to plan for a flow somewhat in excess of this minimum and to provide for auxiliary



POWER PROFILES OF METOLIUS AND DESCHUTES RIVERS.

power to carry the load over the periods of shortage. The additional power that may be obtained over and above that available with minimum flow may amount to many times the minimum power, the range depending, of course, on the variations of flow in the stream to be developed.

The use of reservoirs at the head waters of power streams, in which precipitation may be collected and stored and released as necessary, may increase the amount of power that may be developed to a degree materially above the minimum. Such storage also tends to prevent flooding of the stream and allows the construction of less expensive dams, head works, and spillways. On Deschutes River the fall is too great to allow much pondage behind power dams, but a large reservoir site exists on Crooked River in T. 17 S., R. 21 E. Willamette meridian, where a dam of moderate height will provide storage for water that may be released during the low-water season to increase the minimum flow of the stream.

A scheme for the development of the power of Deschutes River to its utmost economical limits must so provide for the utilization of the dam sites that any one may be built without interfering in any way with later developments, either up or down the stream. Suitable power sites do not exist at all points along the river, but those selected for description seem feasible of economic development by dams so proportioned that each will back the water up to the next most likely site above. (See Pl. VIII.)

MARKET FOR POWER.

At the present time there is practically no active market to justify the development of any considerable amount of power along Deschutes River. A small power plant is now in operation at Bend, about 160 miles from Columbia River, but the maximum output of this plant will not exceed 1,500 horsepower and only a small part of this total is now in demand. It is probable that when central Oregon becomes more densely populated, the need for the products of the country, such as timber, wool, and leather, may encourage the building of a number of small factories and thus bring into local use a part of the ultimate power that may be developed along the river. It is not to be expected, however, that all the potential power of the Deschutes at any point will be thus used locally, and it follows that transmission lines must be constructed to make this power available at long distances from the source of development. Fortunately at each of the sites here described enough power may be developed to make transmission economical up to and possibly beyond a distance of 200 to 300 miles.

The price for which electric power along the river can be sold must be determined by considering the local cost of power, and this cost will depend, for some time at least, on the prevailing prices of coal

or oil. Wood is now and may for some time be used in small plants, but it will never be an important factor in the problem of possible waterpower development along the Deschutes. The comparatively large investments necessary for the development of any one of these power sites and the small demand for power that may be expected for some time after beginning operations will make the fixed and operating charges high, and therefore power can not be sold as cheaply as if the whole output could be used from the beginning.

AVAILABLE FLOW.

The stream-flow records collected by the United States Geological Survey and presented in preceding pages indicate the amount of water available for continuous power development as follows:

Water available for power development in Deschutes River basin.

	Second-feet.
On Metolius River:	
Jacks Creek site	600
Jefferson Creek site	1,000
Whitewater site	1,200
Riggs site	1,400
On Deschutes River:	
Metolius, Pelton, and Mecca sites	3,400
Coleman, White Horse Rapids, Frieda, Maupin, and Oak Springs sites	3,700
All other sites on lower Deschutes River	4,500

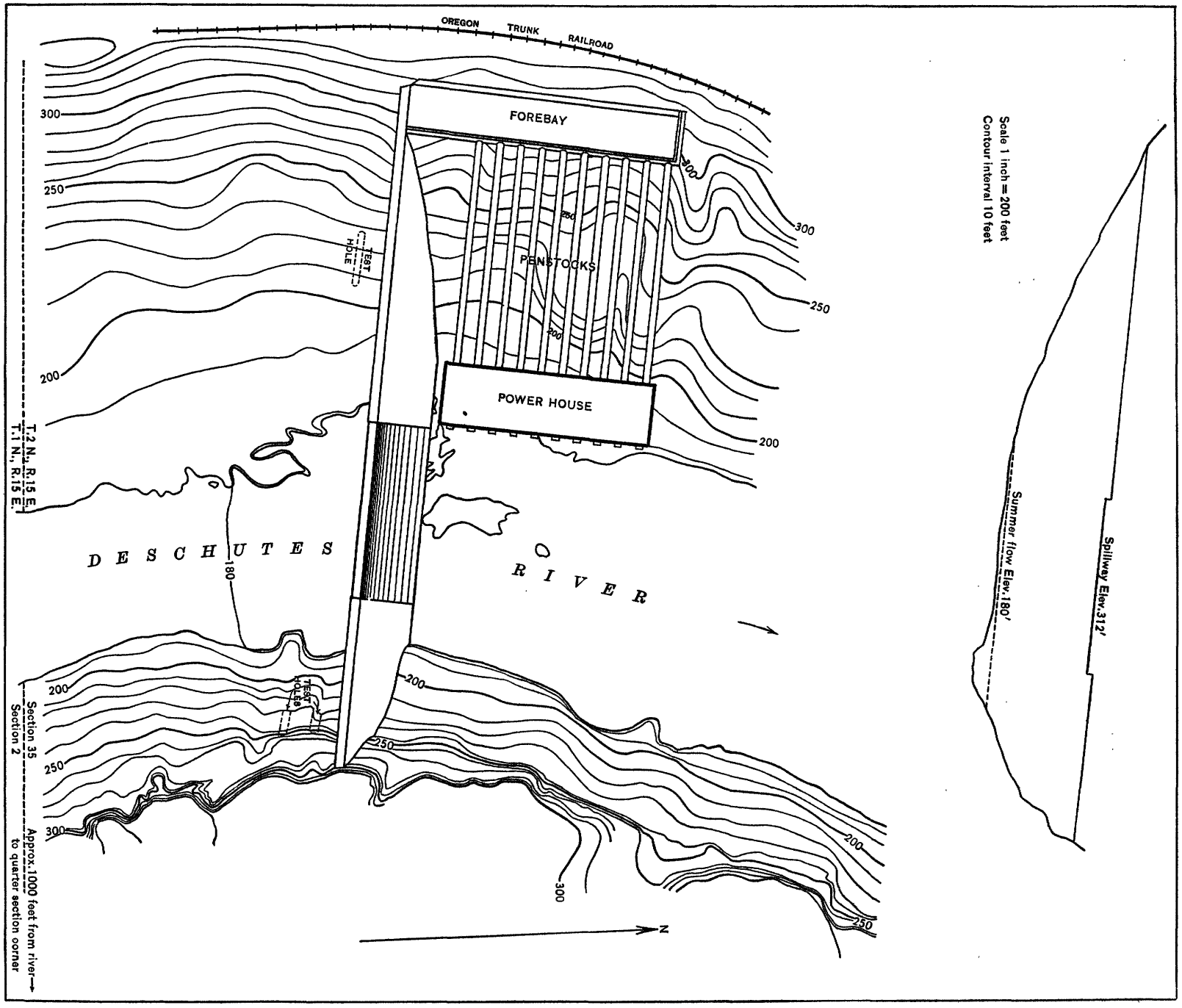
FIELD STUDIES.

To determine the most available sites some weeks were spent in the field studying the river, a journey being made on foot along the river canyon from the Columbia to Bend and every likely dam site being noted. The most satisfactory were then surveyed in detail and a line of soundings was taken across the river at the approximate crest line of the proposed dam. From these surveys maps were made (Pls. IX–XXV) to a scale of 100 feet to the inch with contours at 10-foot intervals. Each map shows also the layout of a possible development. Cross sections plotted from the contours and soundings afforded a basis for the estimates of quantities of material in the dams and other structures.

SITES ON DESCHUTES RIVER.

General conditions.—Among the many conditions that favor Deschutes River as a power stream are its remarkably uniform flow, its comparative freedom from drift and suspended matter that might be injurious to or interfere with the operation of water wheels, and the little difficulty to be apprehended from the formation of ice.

The course of the Deschutes is now paralleled by a line of railway on each bank. Whatever reduction in costs of construction might



MAP OF MOODY POWER SITE.

result from this proximity of a cheap means of transportation will, however, be somewhat more than offset by the cost imposed by the necessity of changing the alignment of these railway tracks in order to bring their grade above the crests of the various dams. A casual examination of the topographic features of the valley of the Deschutes would lead one to the belief that it abounds in power sites that afford opportunities for the construction of high dams at low cost. A more careful examination, however, discloses the fact that sites having both the foundation and flanking river walls suitable for high-head developments are not numerous, particularly if low cost of power is the criterion of choice. At almost any point along the river a good foundation may be found, and in many places a rock wall exists on one side of the stream and in close proximity to it; but it is rather unusual to find places where the canyon narrows down and has rock walls on both sides of the stream and near enough to it to insure short dams. The river valley varies in width from 200 to 1,200 feet. Where the stream approaches one side of this valley the natural rock walls on that side afford excellent abutments for masonry dams, but a very long structure is likely to be necessary in order to reach suitable abutment on the opposite side.

A careful examination of the river below the mouth of the Metolius and a consideration of the proper balancing of the natural conditions favoring the construction of dams, and the heights to which such dams could be built in order that the backwater from one would just reach the base of the next dam above, have led to the selection of 14 sites suitable for development. The total fall in the Deschutes from the limit of backwater of the dam farthest upstream to Columbia River is about 1,615 feet, of which 1,406 feet can be utilized at the selected sites by means of diversion lines leading from dams of the heights assumed.

The type of development that appears most suitable for the Deschutes comprises masonry dams, near-by power houses, and very short diversion lines, except at the White Horse Rapids, Maupin, and Sherar Falls sites, where longer diversion lines would be needed.

Moody power site.—Located in the SW. ¼ sec. 35, T. 2 N., R. 15 E. Willamette meridian. The bed of the river at this point is solid rock and the right bank is also solid rock and fully exposed. A test pit sunk on the left bank shows solid rock at the depth of a few feet, under a thin covering of soil. As indicated on the map (Pl. IX) the power house may be placed on the left bank of the stream and reached by penstocks from a forebay to extend along the hillside parallel to the axis of the river.

The power house should probably be built as near to the dam as possible and yet kept on an entirely separate foundation.

It is estimated that a dam 180 feet high built at this point would make available a power head of 132 feet, by which 54,000 brake horse-

power (40,000 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 4,500 second-feet. A solid gravity dam, 180 feet high, at this site would involve the excavation of about 52,000 cubic yards of material and the placing of about 243,000 cubic yards of masonry.

Lockit power site.—Located in the NE. ¼ sec. 8, T. 1 S., R. 16 E. Willamette meridian. At this site the river bed and the right wall appear to be of solid basalt, but the left bank is more or less covered with loose, disintegrated rock. The sketch (Pl. X) indicates a possible layout similar to that at the Moody site. A dam at this point, 94 feet high, would make available a power head of 70 feet, by which 28,630 brake horsepower (21,500 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 4,500 second-feet. A solid gravity dam, 94 feet high, at this site would involve the excavation of about 16,000 cubic yards of material and the placing of about 56,000 cubic yards of masonry.

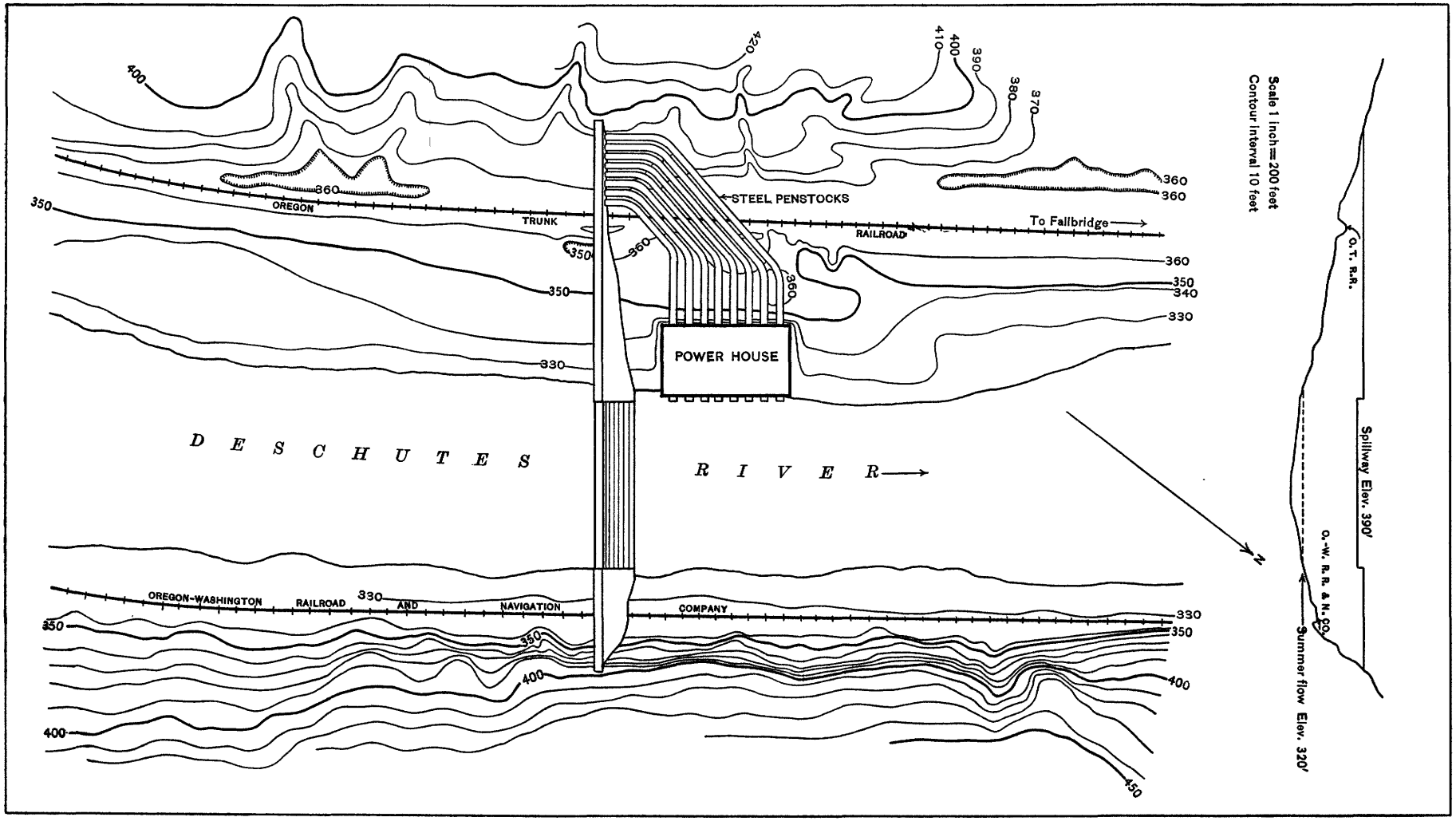
Reclamation power site.—Located between secs. 5 and 6, T. 2 S., R. 16 E. Willamette meridian. Information concerning the bottom of the river at this point is lacking. The right bank is a basaltic cliff and the left is seemingly of solid rock covered lightly with poor soil. As indicated on the map (Pl. XI) the power house at this site may be placed about 800 feet below the dam.

It is estimated that a dam 118 feet high at this site would make available a power head of 92 feet, by which 37,600 brake horsepower (28,000 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 4,500 second-feet. The building of a dam of this height would involve the excavation of about 24,000 cubic yards of material and the placing of about 91,000 cubic yards of masonry.

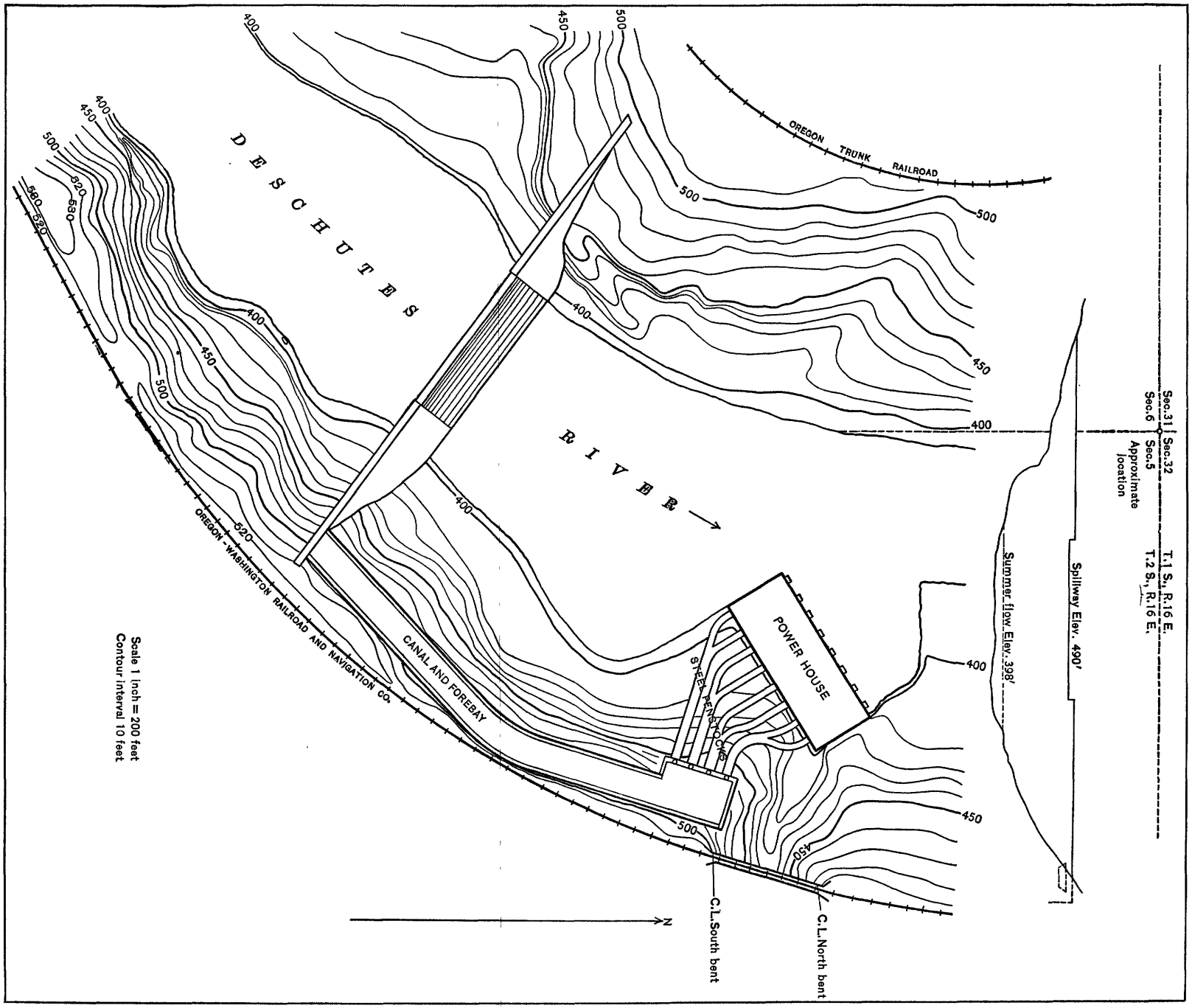
Sinamox power site.—Located in the S. ½ sec. 34, T. 2 S., R. 15 E. Willamette meridian. At this point the river flows in a narrow channel and a ledge of basalt apparently furnishes excellent foundation and abutments on both sides. The topography suggests that the power house may be placed in close proximity to the dam, but if so placed it would be necessary to construct a massive wing wall to afford protection at times of flood (Pl. XII).

It is estimated that a dam 104 feet high built at this point would provide a power head of 87 feet, by which 35,600 brake horsepower (26,500 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 4,500 second-feet. A solid gravity dam 104 feet high at this site would involve the excavation of about 13,000 cubic yards of material and the placing of about 57,000 cubic yards of masonry.

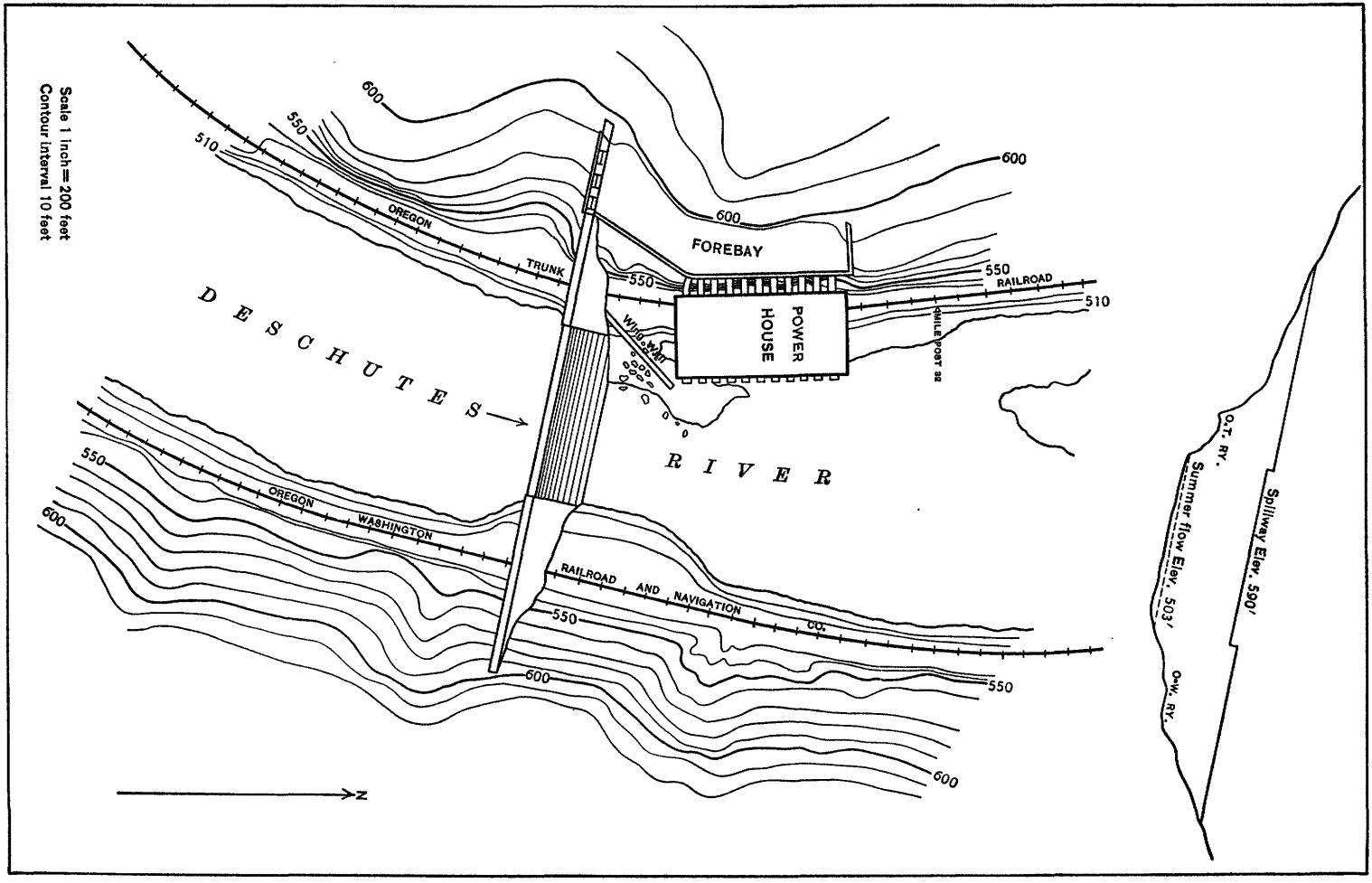
Oak Brook power site.—Located in the NW. ¼ sec. 18, T. 3 S., R. 15 E. Willamette meridian. The channel of the river is narrow



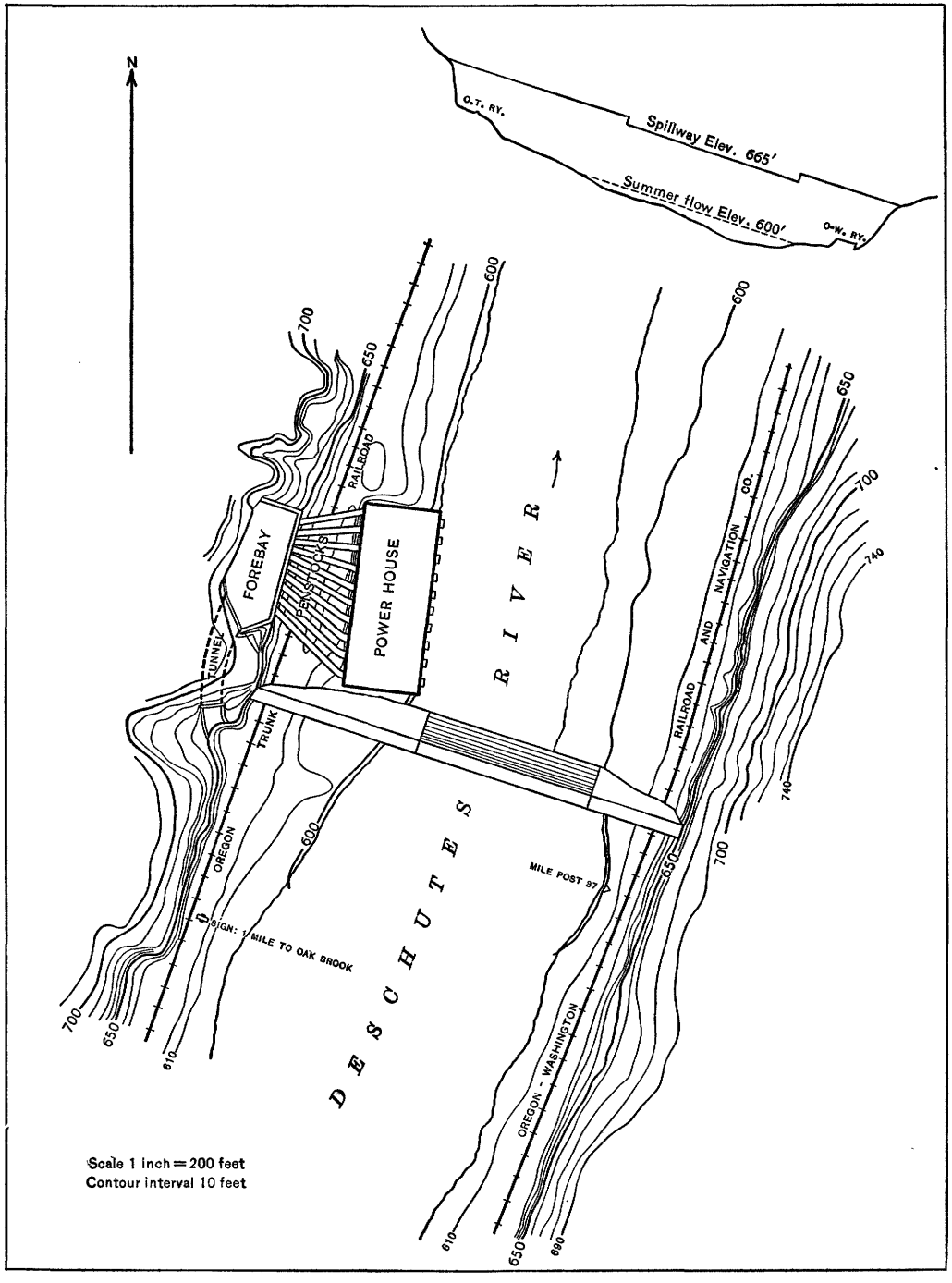
MAP OF LOCKIT POWER SITE.



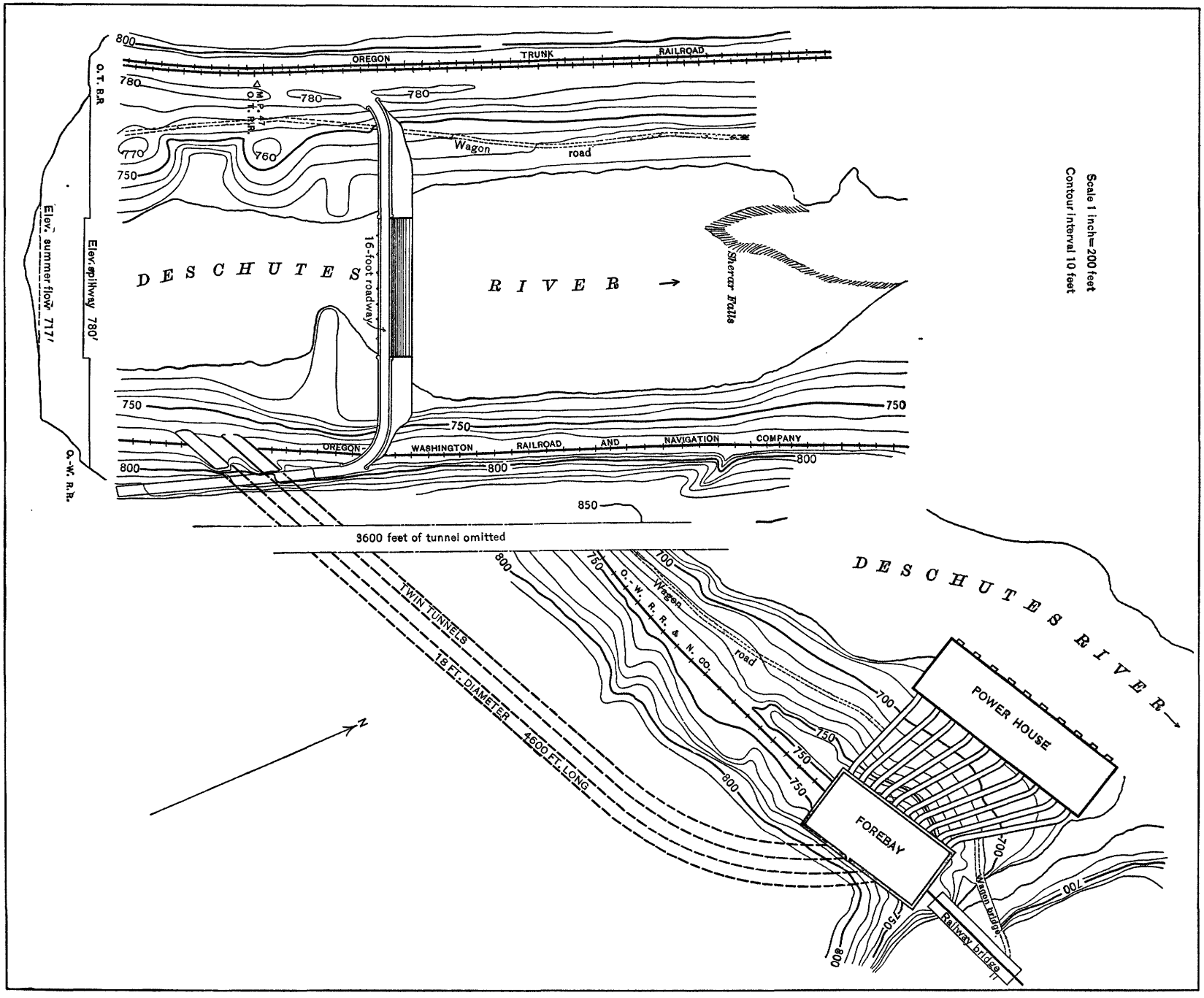
MAP OF RECLAMATION POWER SITE.



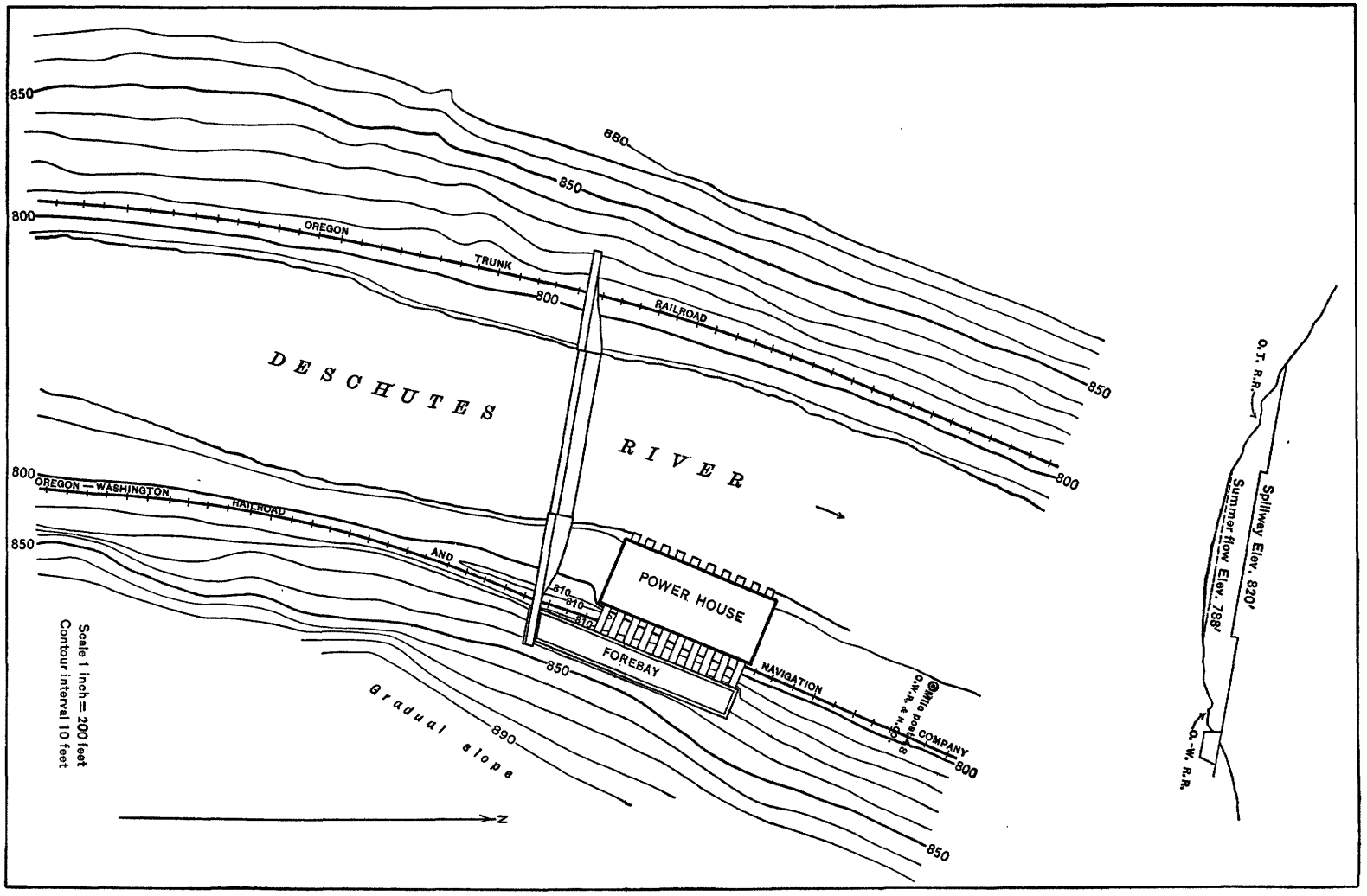
MAP OF SINAMOX POWER SITE.



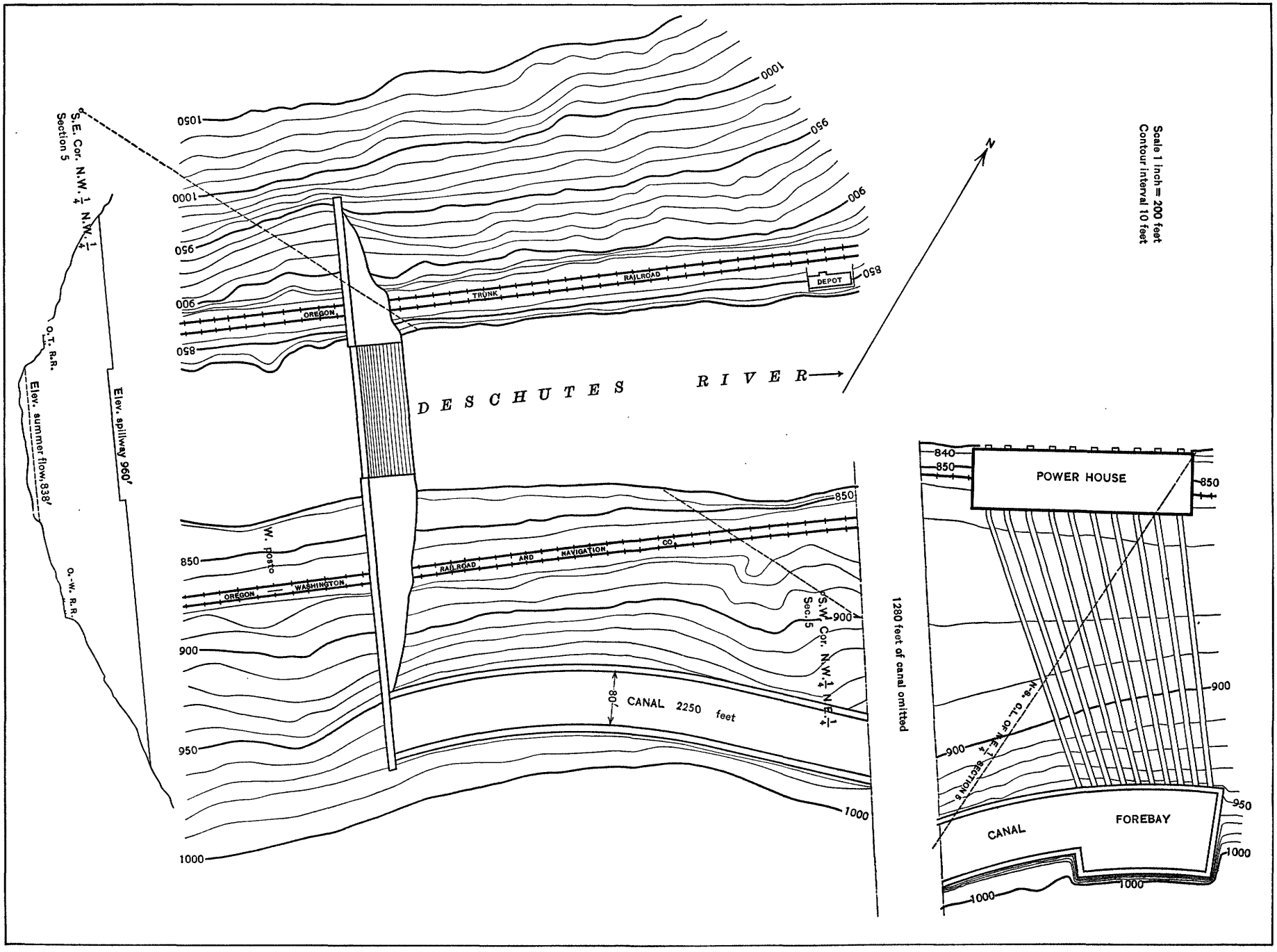
MAP OF OAK BROOK POWER SITE.



MAP OF SHERAR FALLS POWER SITE.



MAP OF OAK SPRINGS POWER SITE.



MAP OF MAUPIN POWER SITE.

and both banks and the bed of the stream are apparently composed of solid rock. A possible layout is indicated on the map (Pl. XIII).

A dam 98 feet high, built at this site, would afford a power head of 65 feet, by which 26,500 brake horsepower (19,800 kilowatts) would be developed by wheels realizing 80 per cent efficiency, with 4,500 second-feet of flow. The building of a solid gravity dam, 98 feet high, at this point would involve the excavation of about 13,000 cubic yards of material and the placing of about 50,000 cubic yards of masonry.

Sherar Falls power site.—Located in the NW. ¼ NE. ¼ sec. 3, T. 4 S., R. 14 E. Willamette meridian. The river below Sherar Falls flows in a very narrow channel and has a pronounced slope for some distance. As shown on the map (Pl. XIV), the site may be utilized by constructing a dam about 600 feet upstream from the crest of the falls, and diverting the water through tunnels to a forebay above the power house to be built at the mouth of Buck Creek canyon. By making the dam sufficiently high to raise the water about 63 feet, or to an elevation of 780 feet, and using the diversion lines a total head of approximately 100 feet could be obtained. Conditions at the surface indicate that the tunnels would be in solid rock for their entire length of 4,600 feet.

The necessary height of the dam is estimated at 88 feet. With a flow of 4,500 second-feet, 40,900 brake horsepower (30,500 kilowatts) would be developed by wheels realizing 80 per cent efficiency. A solid gravity dam, 88 feet high, at this site would involve the excavation of about 11,000 cubic yards of material and the placing of 41,000 cubic yards of masonry.

Oak Springs power site.—Located in the NE. ¼ sec. 20, T. 4 S., R. 14 E. Willamette meridian. The slope of the river between the backwater from the Sherar Falls site and the position of the Maupin site farther up stream can be utilized by building a dam 50 feet high (Pl. XV). This dam will afford a power head of 32 feet by which 10,824 brake horsepower (8,100 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 3,700 second-feet. The building of this dam would involve the excavation of about 6,500 cubic yards of material and the placing of 15,000 cubic yards of masonry.

Maupin power site.—Located in the SE. ¼ NW. ¼ sec. 5, T. 5 S., R. 14 E. Willamette meridian. The Maupin site offers a good abutment for a dam on the left bank, but the bed of the stream is strewn with bowlders and the depth to bedrock is uncertain. The map (Pl. XVI) indicates that this site could be utilized by means of a dam 148 feet high, which would afford a power head of 132 feet. With a flow of 3,700 second-feet, 44,496 brake horsepower (33,100 kilowatts) could be developed with wheels realizing 80 per cent efficiency. The building of the dam would involve the excavation

of about 27,000 cubic yards of material and the placing of about 146,000 cubic yards of masonry.

Frieda power site.—Located in the NE. ¼ sec. 13, T. 6 S., R. 13 E. Willamette meridian. At this dam site the bed of the stream appears to be of solid rock and walls for abutments are excellent. If this site is utilized the power house can be built close to the dam (Pl. XVII).

It is estimated that a dam 178 feet high would make available at this point a power head of 140 feet, by which 47,360 brake horsepower (35,200 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 3,700 second-feet. The construction of such a dam would involve the excavation of about 47,000 cubic yards of material and the placing of about 198,000 cubic yards of masonry.

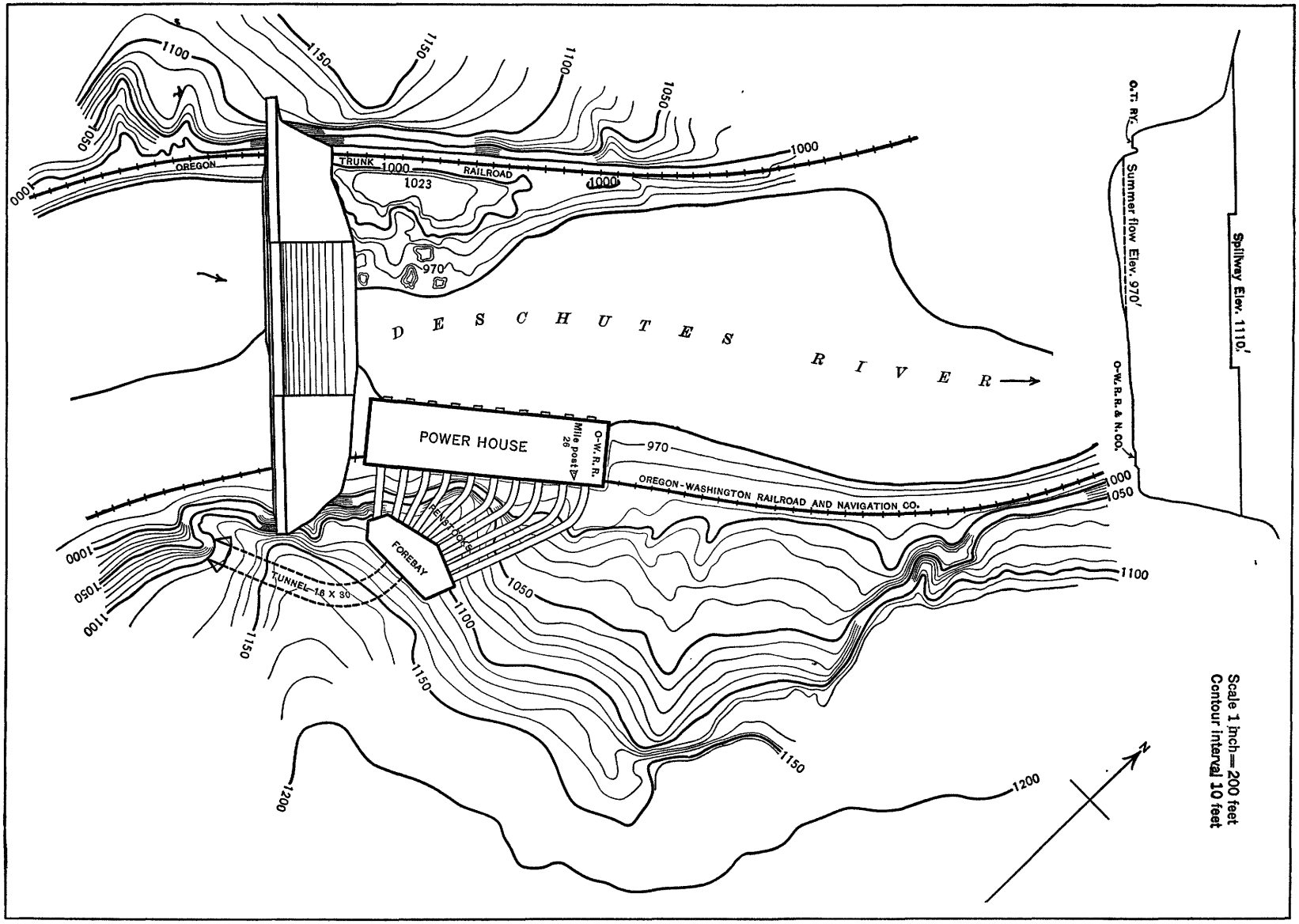
White Horse Rapids power site.—Located in the NE. ¼ NE. ¼ sec. 29, T. 7 S., R. 14 E. Willamette meridian, just above the White Horse Rapids. The river bed and the banks at this site are apparently suitable for foundations. A possible method of development is indicated by the map (Pl. XVIII).

It is estimated that a dam 122 feet high built at this site would, in connection with a diversion line 6,500 feet long, make available a power head of 138 feet, by which 47,200 brake horsepower (35,100 kilowatts) would be developed by wheels of 80 per cent efficiency, with a flow of 3,700 second-feet. A solid gravity dam, 122 feet high, built at this site would involve the excavation of about 14,000 cubic yards of material and the placing of about 57,000 cubic yards of masonry.

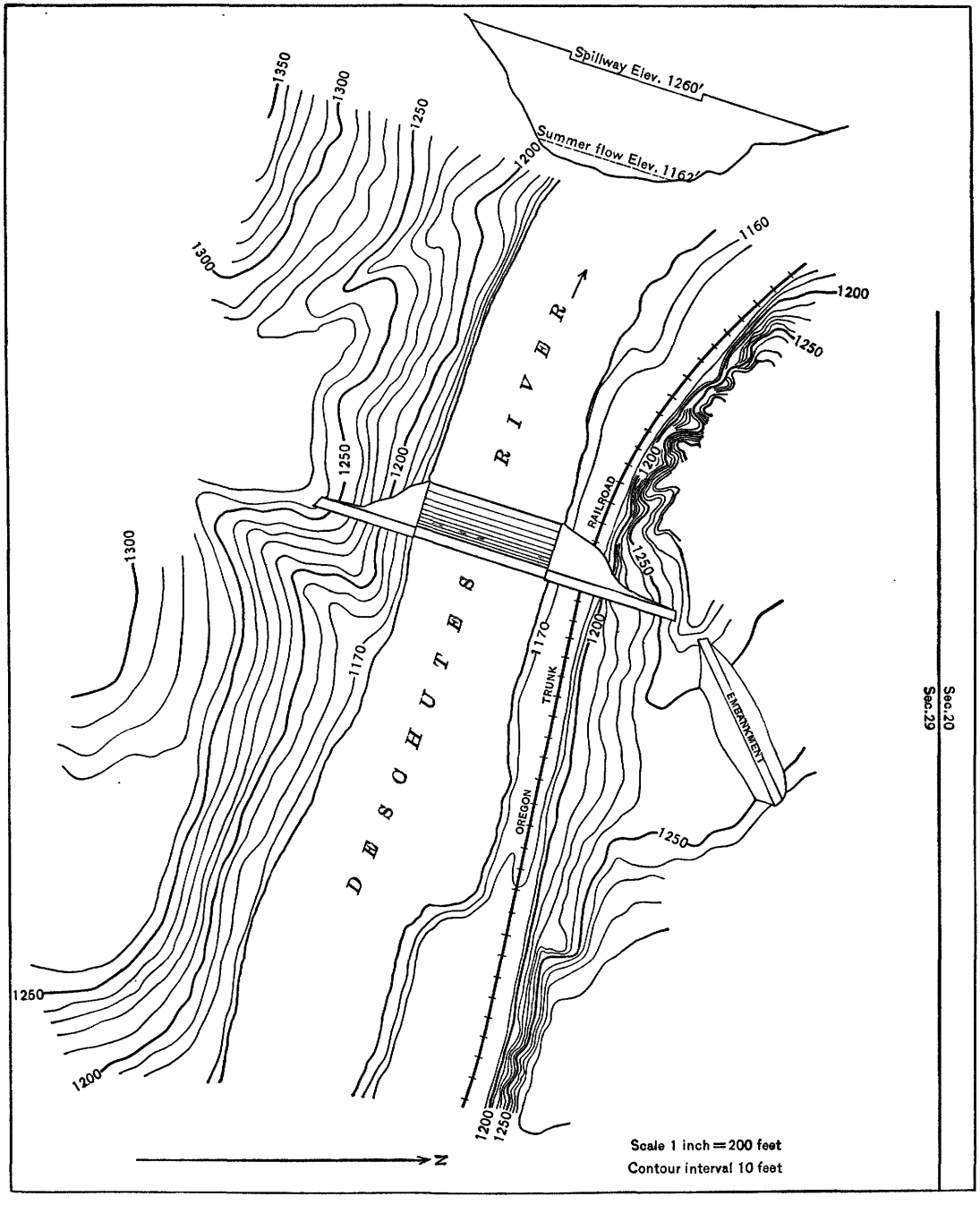
Coleman power site.—Located in the NE. ¼ NE. ¼ sec. 12, T. 9 S., R. 13 E. Willamette meridian. The river bed and banks at this site appear less satisfactory than at some others along the stream, but perfectly safe construction is doubtless feasible. A possible layout is shown on the map (Pl. XIX).

It is estimated that a dam, 78 feet high, built at this point would make available a power head of 58 feet by which 19,680 brake horsepower (14,700 kilowatts) would be developed by wheels of 80 per cent efficiency, with a flow of 3,700 second-feet. The building of a solid gravity dam 78 feet high would involve the excavation of about 11,000 cubic yards of material and the placing of about 37,000 cubic yards of masonry.

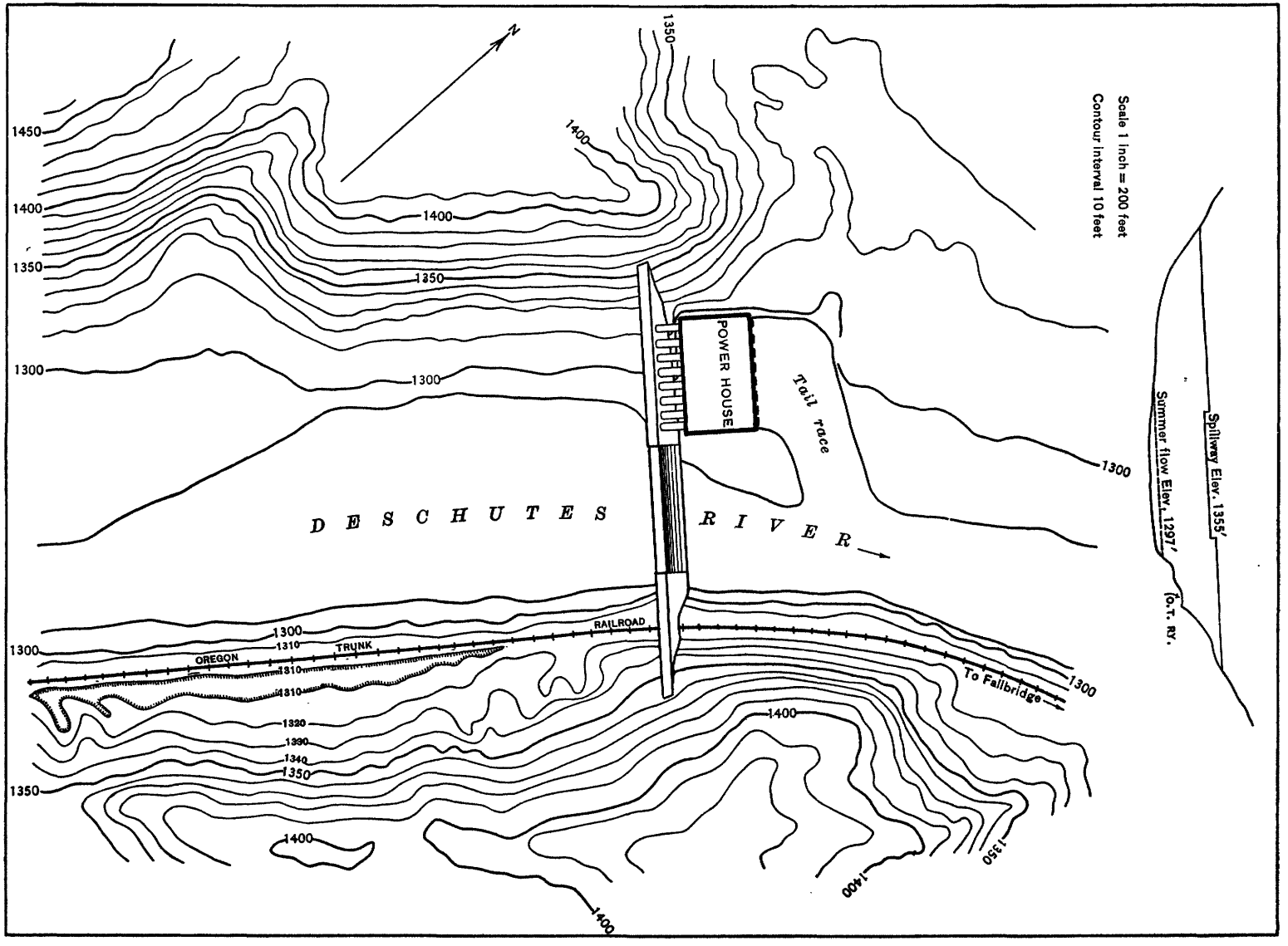
Mecca power site.—Located in the S. ½ sec. 30, T. 9 S., R. 13 E. Willamette meridian. The river bed at this point is strewn with bowlders. The right bank is probably composed of rock to a point very near the surface, but the condition of the left bank is more doubtful, and special investigation would be needed to estimate closely the amount of excavation necessary to reach a solid foundation. The map (Pl. XX) indicates the possible utilization of the site by power house on the right bank close to the dam.



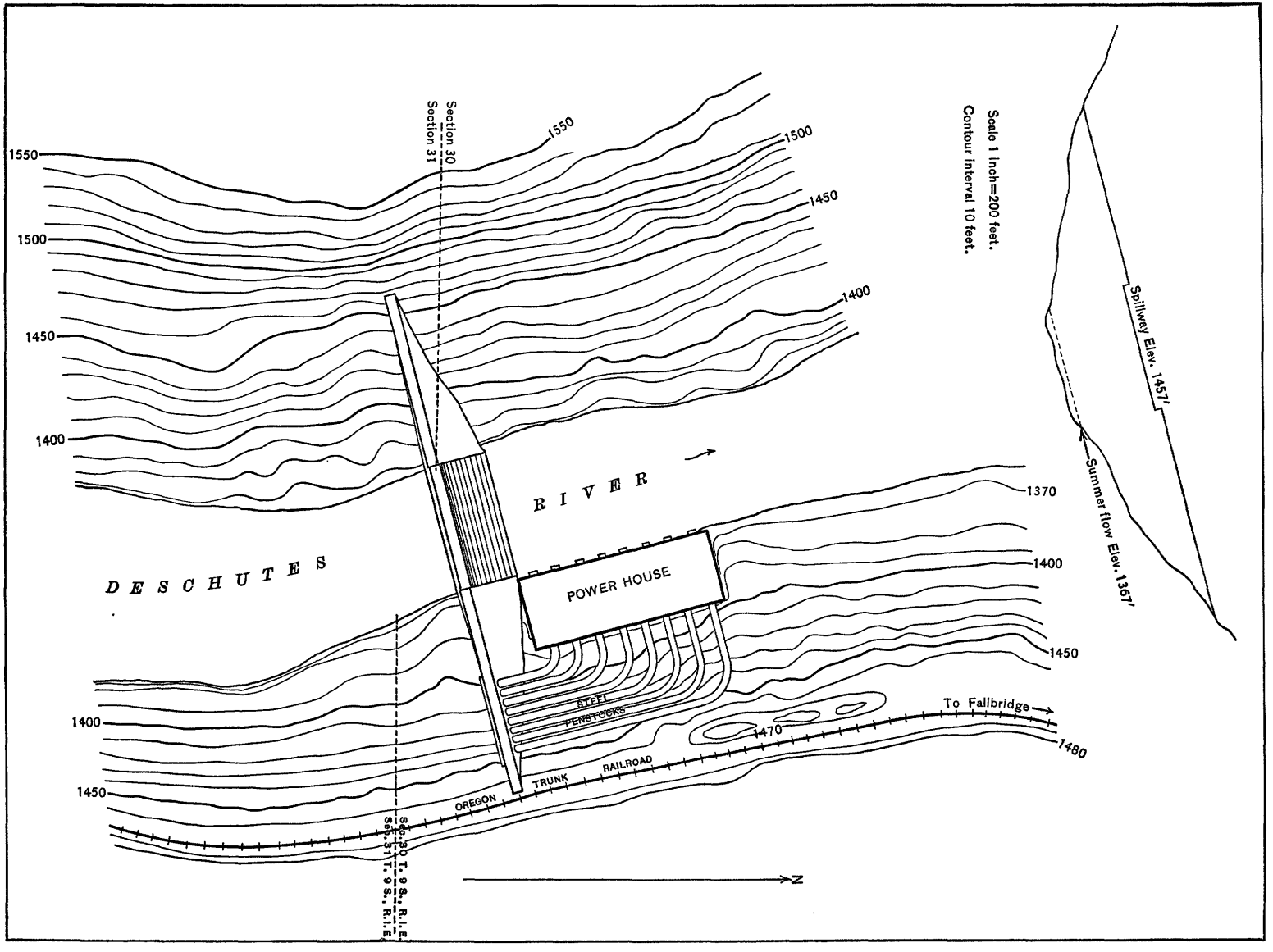
MAP OF FRIEDA POWER SITE.



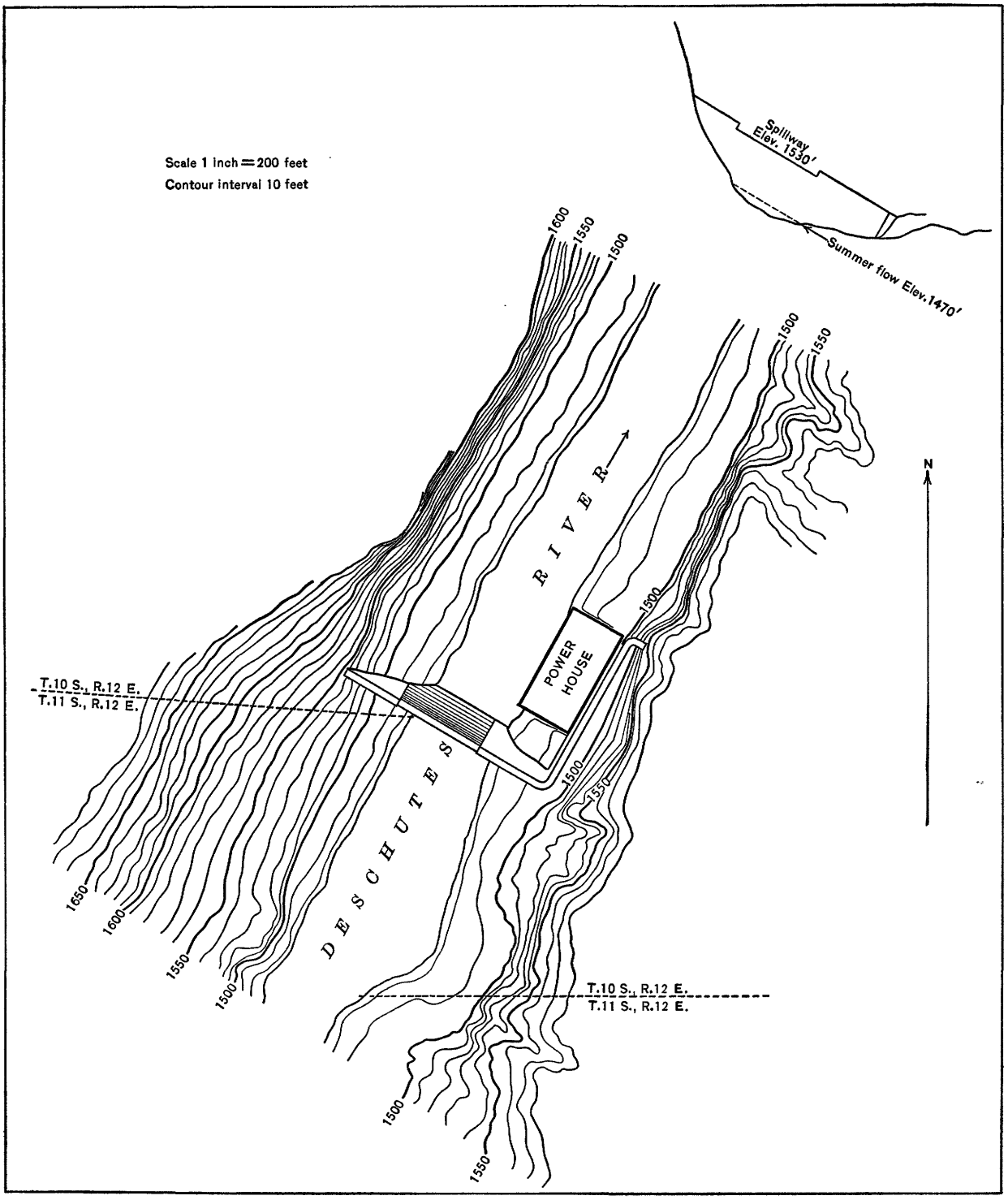
MAP OF HORSE RAPIDS POWER SITE.



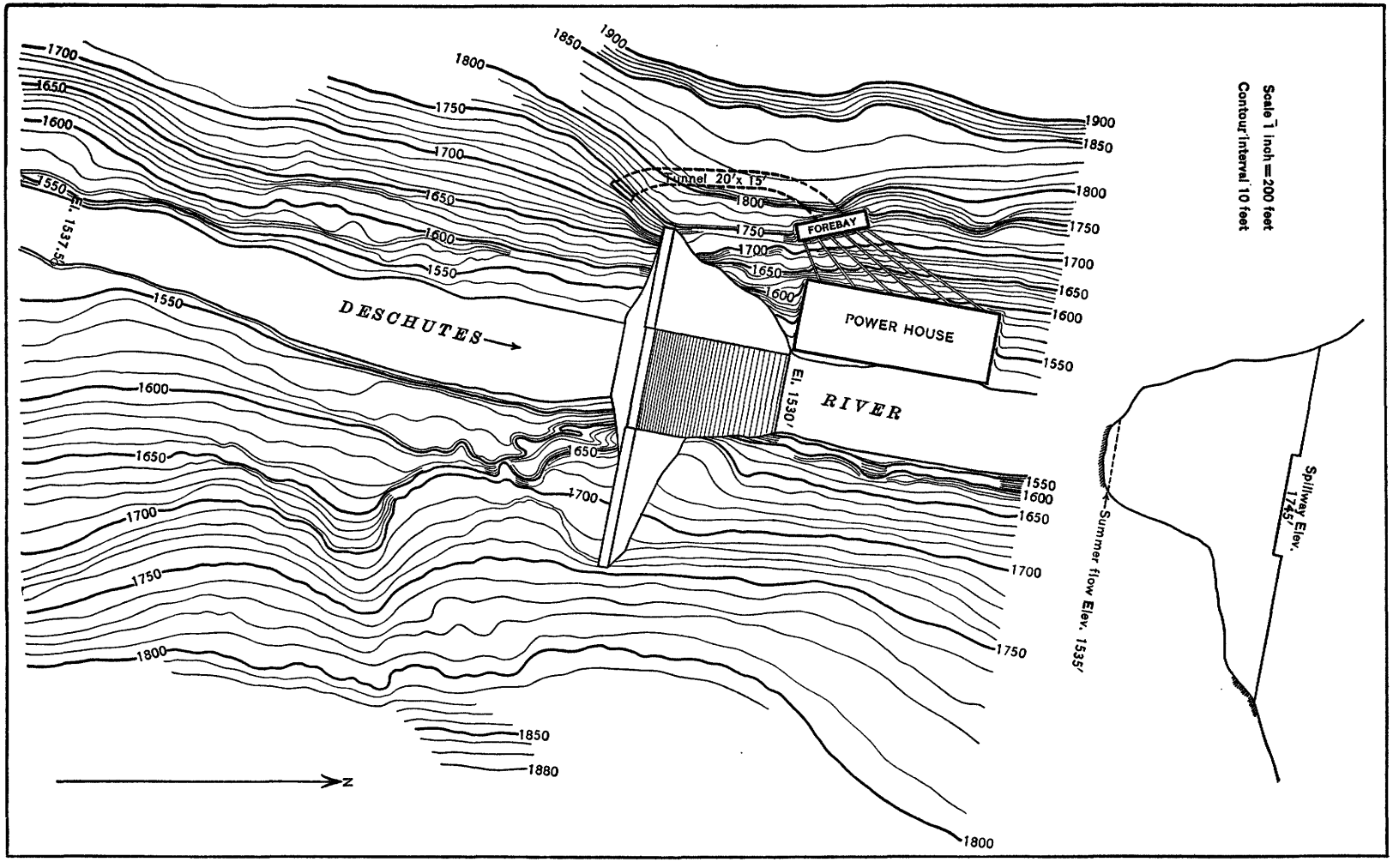
MAP OF COLEMAN POWER SITE.



MAP OF MECCA POWER SITE.



MAP OF PELTON POWER SITE.



MAP OF METOLIUS POWER SITE.

It is estimated that a dam 110 feet high would make available a power head of 90 feet, by which 27,760 brake horsepower (20,750 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 3,400 second-feet. A solid gravity dam, 110 feet high at this point would involve the excavation of 11,000 cubic yards of material and the placing of about 65,000 cubic yards of masonry.

Pelton power site.—Located in the S. ½ sec. 35, T. 10 S., R. 12 E. Willamette meridian. Conditions at the Pelton power site (Pl. XXI) indicate banks and river bed suitable for the construction of a dam.

It is estimated that a dam 84 feet high built at this site would make available a power head of 60 feet, by which 18,560 brake horsepower (13,800 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 3,400 second-feet. The construction of a solid gravity dam 84 feet high would involve the excavation of about 7,000 cubic yards of material and the placing of about 22,000 cubic yards of masonry.

Metolius power site.—Located in the NE. ¼ sec. 22, T. 11 S., R. 12 E. Willamette meridian. This site is in a narrow rock-walled canyon and affords the best opportunity on the river for the construction of a high masonry dam. The layout of a possible development is shown on the map (Pl. XXII).

It is estimated that a dam 236 feet high built at this point would make available a power head of 210 feet, by which 64,960 brake horsepower (48,700 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 3,400 second-feet. A solid gravity dam, 236 feet high, built at this point would involve the excavation of about 38,000 cubic yards of material and the placing of about 183,000 cubic yards of masonry.

SITES ON METOLIUS RIVER.

General conditions.—Metolius River is like the Deschutes in that it is a stream of clear water of fairly uniform flow and carries practically no drift. It is probable also that the formation of ice will never be a disturbing factor in the operation of power plants along its course.

In its general character and in its possibilities of power development, however, it is quite unlike the Deschutes. Its fall from its headwaters to the confluence with the Deschutes averages about 35 feet to the mile, but along its entire length of 41 miles there are only a few places where the sites are at all suitable for the construction of dams of greater height than 20 to 25 feet. In order to concentrate the development of power in large units suitable for economical transmission, diversion lines must be planned—either open canals or pipe lines under low pressure. The low-lying bench lands along the stream make it easy and reasonably cheap to construct these diversion lines and they may be carried for long distances

down the valley in order to take advantage of the natural fall of the stream. For the construction of low dams rock foundations and rock walls reaching to a height of 15 to 25 feet are everywhere to be found. This height is sufficient to allow the construction of proper intakes to the diversion lines and to provide spillways for the flood waters.

Transportation to the vicinity of the plants on this river must be provided by constructing wagon roads and railways, and the costs of such construction will be a material item in the cost of the developed horsepower.

Riggs power site.—Located in the W. ½ sec. 28, T. 11 S., R. 11 W. Willamette meridian. The Riggs power site on Metolius River is at a point a few miles above backwater from Metolius dam. The river bed and right bank probably afford conditions favorable for foundation and abutment, but the condition of the left bank is uncertain. A possible layout is indicated on the map (Pl. XXIII).

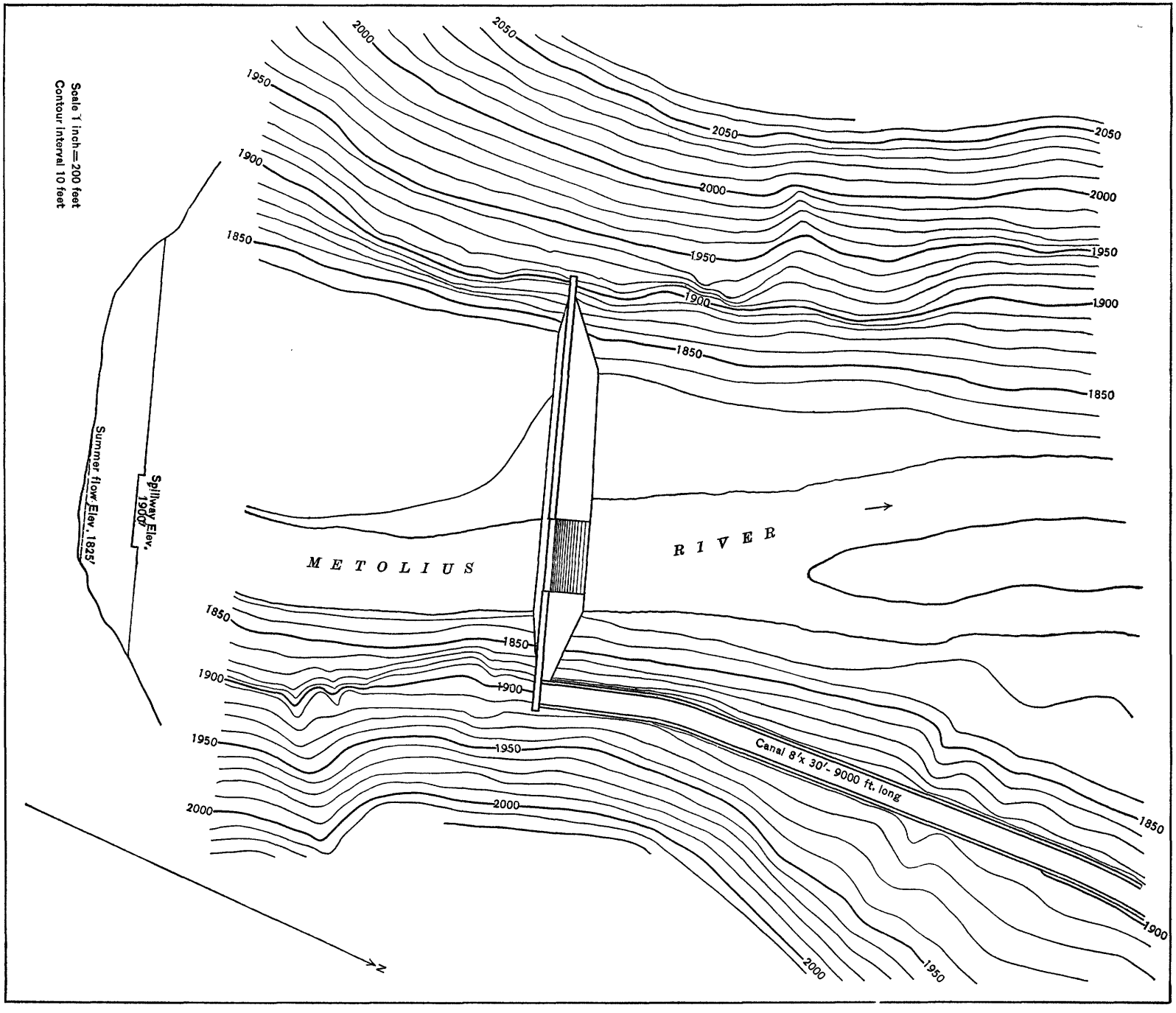
It is estimated that a dam 90 feet high, built at this point, and a diversion canal 9,000 feet long would make available a power head of 135 feet, by which 17,200 brake horsepower (12,800 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 1,400 second-feet. A solid gravity dam at this site would involve the excavation of about 16,000 cubic yards of material and the placing of about 58,000 cubic yards of masonry.

Whitewater power site.—Located in sec. 28, T. 10 S., R. 10 E. Willamette meridian. The utilization of the Whitewater power site would require a comparatively long dam and a canal diversion line about 4 miles long on the bank of Metolius River, as shown on the map (Pl. XXIV). Surface indications suggest good foundations at the dam site.

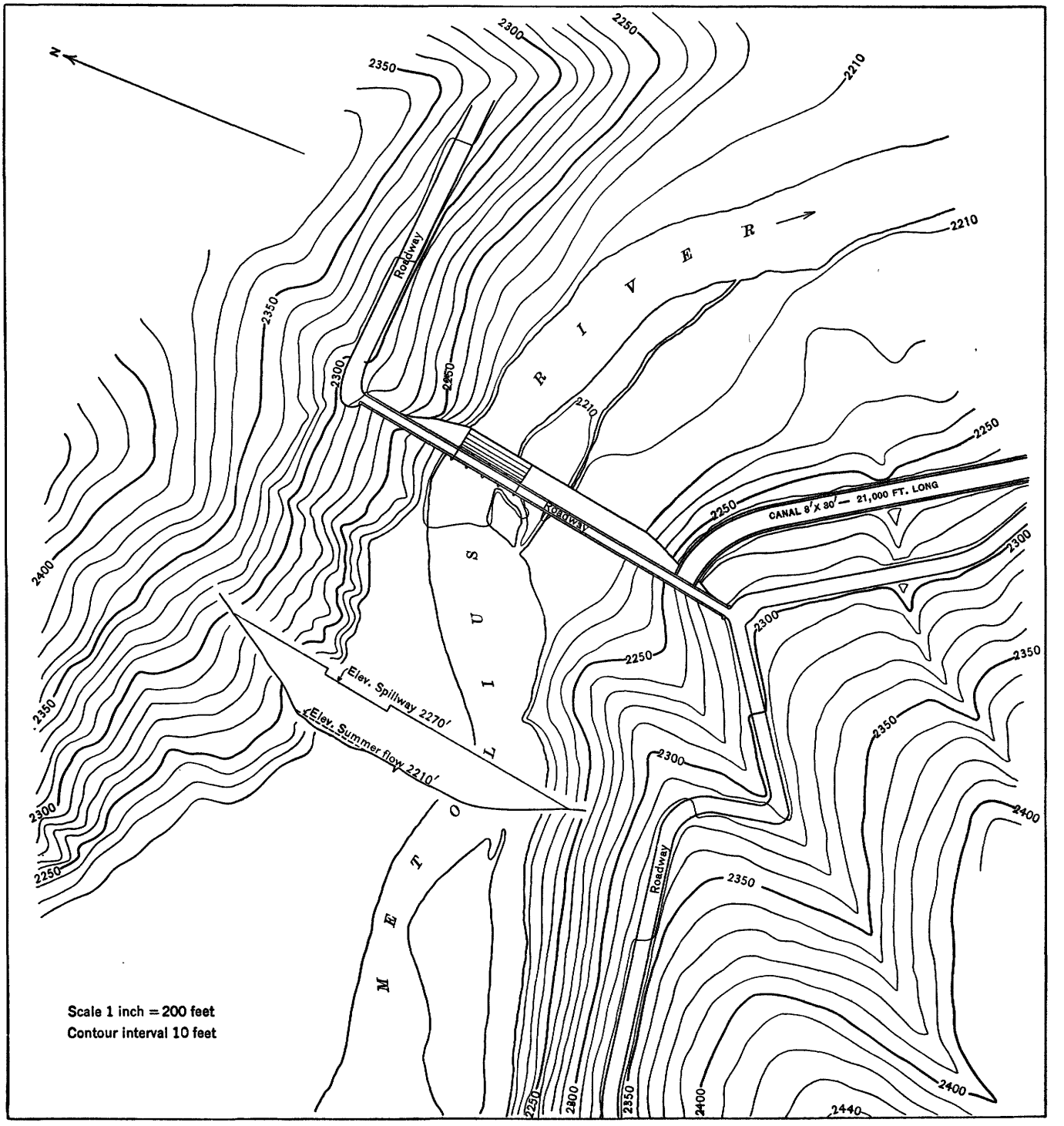
It is estimated that a dam 78 feet high, built at this point would, with diversion line, make available a power head of 260 feet, by which 28,363 brake horsepower (21,100 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 1,200 second-feet. A solid gravity dam 78 feet high built at this site would involve the excavation of about 7,000 cubic yards of material and the placing of about 24,000 cubic yards of masonry.

Jefferson Creek power site.—Located in the SE. ¼ sec. 35, T. 11 S., R. 9 E. Willamette meridian. The Jefferson Creek site might be developed by means of a dam high enough to raise the water to the first low bench lands along the left bank of the stream, and a diversion canal which would carry the water nearly 9 miles to the point suggested for a power house.

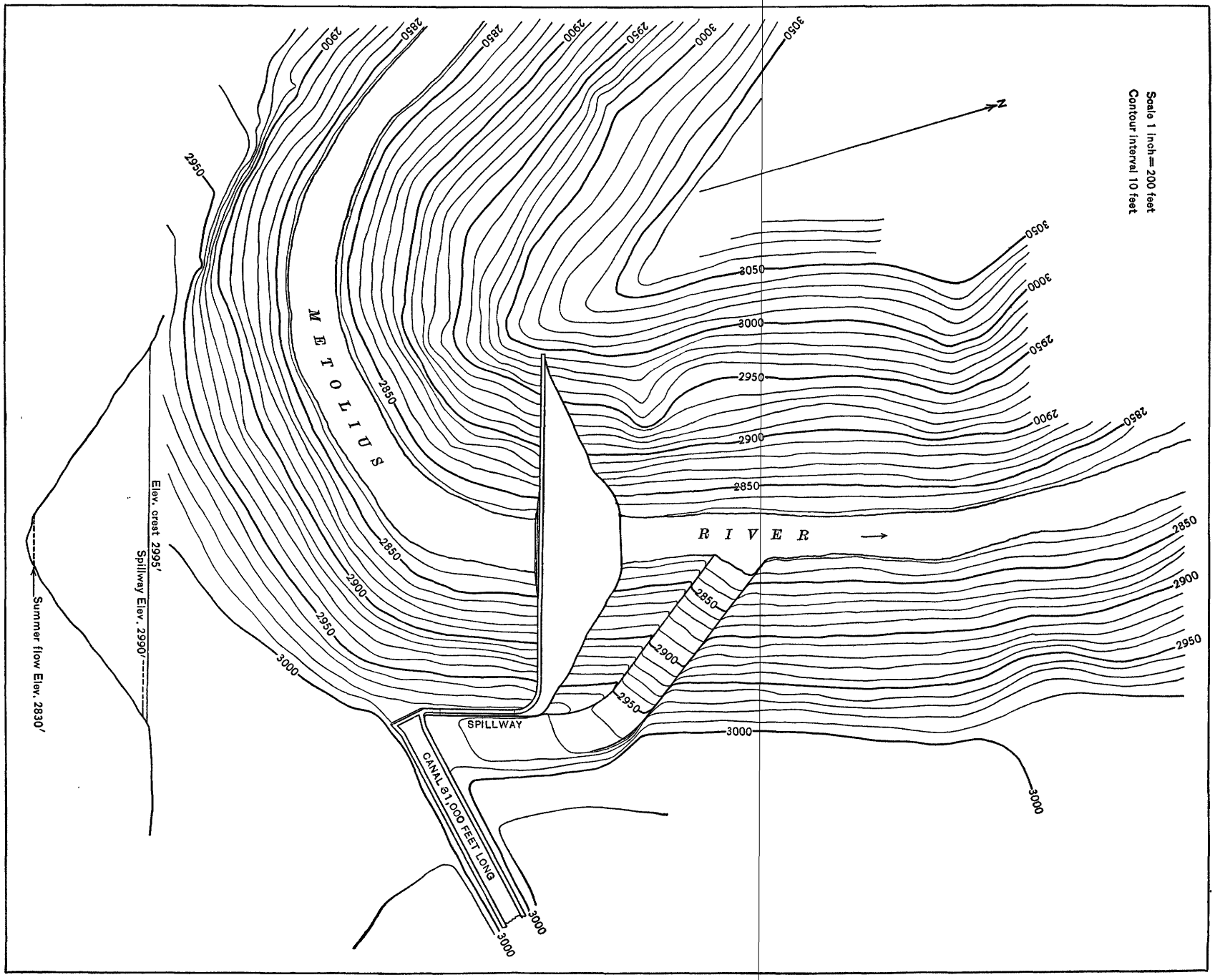
It is estimated that a dam 20 feet high built at this point would, with diversion line, afford a power head of 400 feet, by which 36,363 brake horsepower (27,100 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 1 000 second-feet. The



MAP OF RIGGS POWER SITE ON METOLIUS RIVER.



MAP OF WHITEWATER POWER SITE ON METOLIUS RIVER.



MAP OF JACKS CREEK POWER SITE ON METOLIUS RIVER.

building of this dam would involve the excavation of about 300 cubic yards of material and the placing of about 1,000 cubic yards of masonry.

Jacks Creek power site.—Located in the SE. ¼ sec. 27, T. 12 S., R. 9 E. Willamette meridian. This site is near the headwaters of the Metolius, in a narrow rock-walled canyon in which a dam 172 feet high would back the water to the actual source of the stream. The layout indicated on the map (Pl. XXV) shows diversion of the water through a canal of slight fall on the right bank to a point below the Allen ranch, making a line about 6 miles long; at this point the water is dropped to the level of the river. The investigation indicates that the development of power with the amount of water here available will be expensive under any circumstances, whether by building a high dam, a long diversion canal, or a combination of both.

It is estimated that a dam 172 feet high built at this point would, with diversion line, make available a power head of 300 feet, by which 16,363 brake horsepower (12,206 kilowatts) would be developed by wheels of 80 per cent efficiency with a flow of 600 second-feet. A solid gravity dam 172 feet high built at this point would involve the excavation of about 15,000 cubic yards of material and the placing of about 108,000 cubic yards of masonry.

SUMMARY.

The following table presents, for convenience of reference, a summary of the power available at the sites on the Deschutes and Metolius rivers:

Power available at sites on Deschutes and Metolius rivers.

	Brake horsepower.	Kilowatts.
DESCHUTES RIVER.		
Moody	54,000	40,000
Lockit	28,630	21,500
Reclamation	37,600	28,000
Sinamox	35,600	26,500
Oak Brook	26,500	19,800
Sherar Falls	40,900	30,500
Oak Springs	10,824	8,100
Maupin	44,496	33,100
Frieda	47,360	35,200
White Horse Rapids	47,200	35,100
Coleman	19,680	14,700
Mecca	27,760	20,750
Pelton	18,560	13,800
Metolius	64,960	48,700
	504,070	.....
METOLIUS RIVER.		
Riggs	17,200	12,800
Whitewater	28,363	21,100
Jefferson Creek	36,363	27,100
Jacks Creek	16,363	12,206
	98,289	.....
Grand total	602,359	.....

All of the sites are on withdrawn land except the first five on the Deschutes, namely, Moody, Lockit, Reclamation, Sinamox, and Oak Brook, and the construction of dams on these sites would flood withdrawn land. The amount of tillable land flooded by the construction of any of these dams is negligible. A few miles of county road would be submerged in the lower canyon.

WATER RIGHTS AND APPROPRIATIONS.

By JOHN H. LEWIS, State engineer of Oregon.

OLD AND NEW WATER LAW OF OREGON.

A brief discussion of the old and new laws relating to water appears necessary for a proper understanding of the water-right situation on Deschutes River. Afterward the relation of State control and national control of streams will be discussed as a proper basis for outlining the need for further water legislation.

Owing to the fact that many States have not yet undertaken seriously the administration of their water resources, and to the great lack of uniformity in the water laws of those Western States which have legislated on the subject, it is believed that a discussion of Oregon's new water code will be of general interest, especially since the National Irrigation Congress has, by resolution, recommended this law as a model for other States. Further, the National Irrigation Congress has approved the report of its special investigation committee on interstate rights, to the effect that:

> If there is to be any protection of priorities across State lines it should be by a Federal administrative system corresponding in character to that needed for the establishing and protection of rights within a State.[1]

This view of the interstate question is rapidly being accepted by many people, and the Oregon law may therefore serve eventually as a model for a Federal administrative system.

Under the early laws and customs of miners a water right could be initiated by constructing a ditch and diverting water without any public record whatever. Later it was provided that the beginning of construction work could be postponed for six months without loss of priority if a notice of the intention to appropriate water was posted near the proposed point of diversion and a copy of this notice recorded in the office of the county clerk. There was no public supervision as to what might be claimed in such notice; consequently all claimed many times the water they expected to use, and many claimed all the water in the stream at the proposed point of diversion. After construction work was begun, with or without the posting of a notice, the law provided that it should be carried on diligently to completion. It was not necessary to make final proof or to file other evidence of the completion of a right to appropriate water.

[1] National Irrigation Congress Official Proc. Fifteenth meeting, Sacramento, Sept. 2–7, 1907, p. 267.

The public records were therefore incomplete at best and of little value to the general public. Under such a system, or rather lack of system, it was impossible to get reliable record evidence of title to water. Constructed works depreciated in value and litigation increased in volume as the streams became overappropriated. It was absolutely impossible for a prospective investor to ascertain how much of the water in any stream was necessary to satisfy vested rights or how much, if any, was available for new appropriations. Under such conditions development was so greatly retarded as to arouse the people of Oregon to the necessity of providing a comprehensive system of titles to water.

The new water code became effective February 24, 1909.. It does not rest upon any specific provisions of the State constitution but rests rather upon the police power of the State to regulate diversions from streams for the preservation of the peace and safety of the people. History has shown that without such State regulation endless strife, litigation, and even bloodshed must inevitably result.

These public waters are of two classes, first, those to which rights to use vested under the early customs and laws, and, second, those which were unappropriated at the time of the adoption of the new code. The new law deals with both classes and declares that "all waters within the State from all sources of supply belong to the public." There is a distinction between the ownership of the property in water itself and the ownership of a right to the use of certain waters. The law makes no provisions for the protection of navigation rights. It, however, can give but little relief in our border territory, as most of the streams rise in California, Nevada, Idaho, or Washington, and flow into Oregon. A few flow in the opposite direction, and some cross the line several times. There are many interstate difficulties which can not be settled by the Oregon law, no matter how favorable its provisions. These must await some action by Congress or some reciprocal legislation by the States interested.

A board, of which the State engineer is chairman, was created to administer this public property. It is the duty of this board to ascertain and record all rights to the use of waters which became vested prior to the adoption of the new law; to grant rights for beneficial use in the State's unappropriated waters to those who make proper application therefor; to protect all recorded rights to the use of water by regulating diversions from streams.

The creation of a central office, with almost complete power over water matters, and the limitation of franchises to the use of water for power purposes to a period of 40 years are perhaps the leading features of the Oregon law. Before discussing its operation in the order as outlined above, it appears advisable to give a few facts tending to show its value to the public.

VALUE OF THE WATER CODE.

A summary of the first three and one-half years' operation of the water code, ending December 1, 1912, shows the following results:

The estimated cost of works to be constructed under permits issued by the State engineer is $44,366,425. The cost of all irrigation enterprises constructed prior to the adoption of this law was $12,760,214, as shown by the recent Government census.

Two thousand six hundred and eighty applications to appropriate water for various uses have been made during this period, only 1,746 of which have so far been granted and become permits.

There will be added to the State's resources 973,640 acres of irrigated land and 176,978 additional developed horsepower if these projects are all carried out as planned. The census for 1910 shows only 686,129 acres irrigated in Oregon prior to that date.

The permit holders paid to the State of Oregon prior to approval $47,592. This amount is $7,592 in excess of the total appropriation for the administrative work of the State engineer's department for four years. The system is, therefore, not only self-supporting, but produces some revenue for the relief of the general taxpayer.

One thousand and sixty-eight different rights to water have been defined and recorded by the administrative board during this period, affecting 106,686 acres of irrigated lands on 15 different streams, without a single appeal to the supreme court. Formerly almost every water case was appealed to the highest tribunal and the decision delayed many years.

It is believed that the foregoing facts clearly indicate that this definite State policy relating to water has already demonstrated its usefulness and that ultimately it will be found of inestimable value to Oregon. This system of water titles is the basis for all future development of our water resources, for without it neither private nor public funds could be invested with any degree of certainty.

DETERMINATION OF OLD RIGHTS.

It would be impossible to distribute water for the protection of vested rights or to ascertain how much water is unappropriated and available for new uses without a reliable record of all vested rights to the use of water.

The determination of these rights is one of the principal duties of the water board, composed of the State engineer and the superintendents of the two water divisions into which the State is divided.

The United States District Court for Oregon in a recent opinion (Oct. 7, 1912), handed down in the determination of the relative rights from Silvies River (199 Fed., p. 495), says concerning this board, after discussing the procedure, that these adjudication proceedings

are purely administrative in character until such time as "the board has completed its examination, made its determination, and filed its report" with the circuit court for confirmation.

Until the report is made and filed with the court there is no action or suit within the meaning of the (Federal) removable statute. It is a case where divers and sundry parties are entitled to use so much of the waters of a stream as they have put to beneficial use, and the purpose is to ascertain their respective rights by a simple, economical, effective, and comprehensive proceeding, and is not a separable controversy between different claimants.

I am also impressed [says the court] with the soundness of the view that a proceeding for the adjudication and determination of the rights to the use of the waters within the State, instituted and conducted as provided in the legislative act of 1909, is, in effect, a proceeding on behalf of the State through an administrative or executive board to have judicially settled, in an economical and practical way, the rights of various claimants to the use of the waters of a stream or source of supply and thus avoid the uncertainty as to water titles and the long and vexatious controversies concerning the same which have heretofore greatly retarded the material development of the State.

While the board follows, where practicable, the usual legal procedure, yet it is free to depart from such practice whenever necessary to facilitate action. It is not bound by the complicated legal rules of pleadings and of evidence. This freedom of action is believed to account for its unprecedented success in the adjudication of these early rights.

WATER-RIGHT CERTIFICATE.

Upon final adjudication of each old right a certificate is issued to the owner and is recorded in the county courthouse. This water-right certificate is record evidence of title. Ultimately all old rights as well as new rights will be put upon the same basis and properly indexed for quick reference in the central office. They will also be published in tabular form by stream systems for the benefit of the water masters and the public.

The fundamental principles of a water right in Oregon are few and simple and are all embodied in the water-right certificate. They rest on beneficial use, qualified by priority of use, purpose of use, period of use, place of use, and quantity of water.

Beneficial use is the basis of the right. Water monopolies, the barter and sale of water apart from the use, and speculating in water are all prevented by this fundamental principle.

The priority is a date. In case of shortage the latest appropriator is shut off to protect those having prior rights.

The purpose must be stated specifically—such as irrigation, power, domestic use, etc. Changes from one purpose to another without loss of priority should be prohibited as against public policy, because different amounts of water are consumed in different uses. Most changes seriously affect other rights below.

The period of use, whether for summer irrigation, winter storage, or for domestic purposes throughout the year, is an important qualification.

The place of use is specifically defined to the nearest 40-acre subdivision. Changes in location affect return seepage, and if permitted would make all water titles unstable. The making of water appurtenant to the place of use is the basis for the system of records.

The quantity of water is the amount beneficially used, but the maximum limit must be fixed in each case, so that subsequent appropriators may have some guide as to the maximum limit of vested rights.

The name and address of the owner and the name of the stream are also given in each certificate.

THE GRANTING OF RIGHTS.

The public record in the central office is kept up to date by the provision requiring all applicants who appropriate water under the new law to make an application to the State engineer and secure a permit before taking any steps toward diverting water. It is made a misdemeanor to "use, store, or divert any water until after the issuance of a permit to appropriate such water."

Each application must be accompanied by a map showing plan of construction, and no application will be approved for more water than can be put to beneficial use. The State engineer is authorized to limit an application to a less quantity of water than that applied for if there exists substantial reason for such limitation. An application may be denied where the proposed use conflicts with determined rights or is a menace to the safety or welfare of the public.

Work must be begun within one year from the date of approval and be completed within a reasonable time thereafter as fixed in the permit, not to exceed five years. Additional time is allowed after completion within which to apply the water to beneficial use, not to exceed four years for the largest project.

Permits to appropriate water are divided into three classes: (*a*) Those for direct diversion of the regular stream flow; (*b*) those for the enlargement of existing works; and (*c*) those for the storage of water. A secondary permit must be taken out by anyone desiring to use stored water. The application must be accompanied by documentary evidence showing a permanent and sufficient interest in the reservoir to supply the necessary water. This arrangement is necessary for a proper distribution of water by the water masters.

Annual proof must be filed to show compliance with law, and a water-right certificate is issued to the permit holder upon making final proof. This certificate grants only so much of the water, within the limits of his permit, as he has put to beneficial use.

By this system an investor is fully protected during the period of construction and development. It is the purpose of the law to make definite and certain not only vested water rights but also those in process of development. The procedure for initiating new rights is simple and clearly set out in the law.

PROTECTION OF RIGHTS.

The primary object of this public record obtained through adjudication proceedings by the water board and through the permit system as outlined above is to furnish a proper basis for the protection of water rights by the State. The accomplishment of this object furnishes at the same time the necessary basis for all future investments in works for the utilization of water.

The responsibility of protecting vested rights in water is placed upon the same board which originally adjudicated the rights. This board is all the better fitted for this important task because of having thoroughly studied the situation in advance. To have the adjudications made by the courts and the distribution made by the board would in many respects be undesirable. The adjudication proceedings are only incidental to the principal duty of the board in distributing water. This is a continuing task and the real work for which the administrative machinery was created.

To facilitate the distribution of water, the State has been divided into two divisions, each under a superintendent. Each division is divided into districts as rapidly as rights are determined and the need arises. Each district is in charge of a water master, who reports to the division superintendent.

It is the duty of these water masters to regulate the headgates of ditches so as to insure the delivery of water in accordance with established rights and to prevent waste. They have authority to make arrests for the diversion of water without right and to compel the installation of necessary measuring devices and headgates. If a shortage occurs the ditch of the last appropriator is closed to protect prior rights.

If water is stored at the head of a stream and the natural channel used to convey such water to the place of use, the water master must set all headgates so as to admit only the amount to which each is entitled in order to insure the delivery of stored water less the amount lost in seepage and evaporation.

When a shortage occurs at any point along a stream that flows through one or more districts the fact is communicated by telephone to the water master of the district above, who must remedy the situation if within his power. The old method of regulating streams by injunction proceedings before the courts was found to be slow, expensive, and entirely inadequate for the protection of the water user.

PROTECTION OF PUBLIC INTEREST.

The law makes it the "duty of the board" not only to protect vested rights but also to protect the public interest in the granting of new rights. All applications which menace the safety or the welfare of the public or conflict with determined rights shall be referred to the water board for consideration. "It shall be the duty of the board to enter an order directing the refusal of such application, if after full hearing, the public interest demands it."

This feature of the law was upheld by the supreme court of Oregon in the case of Cookingham *v.* Lewis (114 Pac., 88). It marks a distinct advance in the matter of water law. It is believed this is the first case where the public interest under such a statute has been considered by the courts.

RIPARIAN RIGHTS.

Until the new water code was adopted there was much uncertainty as to whether the common-law doctrine of England or the statute-law doctrine of appropriation and use was the fundamental law of the State relating to water.

The courts had uniformly held that litigants must stand upon their rights either as appropriators or as riparian owners; they could not do both. So when the legislature undertook to establish a definite State policy it had to choose between these two conflicting doctrines, for it could not prescribe that all streams should flow undiminished and unpolluted to the ocean to satisfy riparian landowners, and at the same time permit diversions for beneficial use under the doctrine of appropriation.

Owing to the fact that "the necessities of the people require that water shall be diverted for irrigation and other beneficial uses, because of the peculiarities of soil and climate," the doctrine of appropriation for beneficial use was selected as the basis of the new water law.

Because of these peculiarities of climate and soil it was apparent to the courts that the strict common-law doctrine established at the outset was inapplicable to conditions in Oregon. A gradual departure from this doctrine has been in process until the present time, when a riparian right is considered of almost no practical value.

The opinion of the supreme court of Oregon in the case of Hough et al. *v.* Porter et al. (98 Pac., 1083) clearly, as regards use for other than domestic purposes, abrogates the common-law rule respecting riparian rights as to all lands settled upon or entered since March 3, 1877, the date of passage by Congress of the desert-land act (19 Stat., 377).

This case would indicate that the riparian rights for lands taken prior to such date was limited practically to the amount necessary to

satisfy the natural wants of man, as "every riparian owner, therefore, regardless of the date of settlement, is entitled to the quantity of water reasonably essential to his domestic use and for the watering of his stock, including sufficient supply for the proper irrigation of such garden produce as may be essential to the proper sustenance of his family." (Syllabus.)

The effect of the case of Jones *v.* Conn (39 Oreg., 30) was substantially to abrogate riparian rights in Oregon as early as 1901. It was held in this case that the courts could not decree any specific quantity of water to a riparian owner. The right was fluctuating, depending on the reasonable use by all other riparian owners. In time it might be rendered of little value by other owners of riparian rights diverting and using their proportionate share of the stream. Riparian lands could be extended even beyond the watershed of the stream by subsequently purchasing adjoining lands.

This decree did not suit either of the parties affected, as it was apparent that a right which could not be specifically defined could not be protected and was therefore of little value. Both parties accordingly petitioned for a rehearing. After spending about $20,000 in litigation to protect his riparian rights, one of the parties has since abandoned the common-law theory and become an appropriator under the new law.

Out of approximately 2,000 claims to water which have been filed in adjudication proceedings before the board, only four have claimed as riparian owners, and even these proved rights by appropriation. For all practical purposes the common-law doctrine of riparian rights can therefore be considered a dead issue in Oregon.

STATE OR NATIONAL CONTROL.

The present chaotic condition of titles to water appears to be due to the uncertainties arising from the division of control between the States and the Nation. For administrative purposes the drainage basin is the logical unit. State lines have been located, however, mainly without regard to drainage lines, and for this reason complete State control is impracticable. Complete Federal control appears also impossible for constitutional reasons. It is believed, however, that Congress has power at this time largely to put an end to this confusion by passing a comprehensive law regulating diversions from interstate and navigable streams, leaving to the State those matters which are distinctly local.

The State is supposed to exercise control over all streams within its borders, except as to navigability and related questions. Under such theory New York State has provided that "no waters of this State shall be diverted without the State." California has enacted a similar law. Such an unneighborly attitude between water users on

streams within the State is the reason why State administrative codes have been enacted. Now that the waters of interstate streams are becoming overappropriated, we find the different States quarreling as to its proper distribution, and the same reasons that have compelled the adoption of State water laws will ultimately compel the adoption of an interstate or national law.

Where streams flow through or border on two or more States, each State is entitled to an "equitable apportionment of benefits" of such interstate stream without regard to the statutes or laws of either State. While the doctrine of State control has been thus limited by the Supreme Court of the United States in the case of Kansas *v.* Colorado (206 U. S., 46), yet Congress has, up to the present time, enacted no positive legislation defining what shall constitute such equitable apportionment or how rights in the various States can be defined and protected, or how new rights to surplus waters can be definitely initiated without fear of subsequently being enjoined by users in a lower State.

Pending such legislation we have a system of government by injunction. If the construction of a dam or an irrigation system in an upper State is found to affect detrimentally the flow in the lower State, the injured State or its citizens can resort to the Federal courts to enjoin the wrongful diversion. But there is no governmental body to whom the investor can appeal prior to the construction of his works to ascertain whether or not such proposed diversion is within the law and, if so, to grant him a permit which will assure him adequate protection in his investment.

This system of government by injunction is disastrous to progress. At best it is slow, expensive, and unsatisfactory. A court decree when rendered remains fixed and settles only the question in controversy, while conditions on either side of the State line are constantly changing through new diversions or through changes in channel due to floods. Such changes may render a court decree of no value.

The State of Kansas attempted to enjoin alleged excessive diversions from Arkansas River in Colorado by a suit before the Supreme Court of the United States. After consuming eight years in the examination of 347 witnesses, the taking of 8,559 typewritten pages of testimony, and the making of 122 exhibits at a cost of approximately $200,000, no relief was granted. The court found that diversions in Colorado materially depleted the flow in Kansas to the injury of its citizens and said:

> At the same time it is obvious that if the depletion of the waters of the river by Colorado continues to increase there will come a time when Kansas may justly say that there is no longer an equitable division of benefits and may rightfully call for relief against the action of Colorado.

Under such conditions of the law not only is further progress discouraged but the present value of existing works in Kansas is seriously affected, and large projects will not be undertaken in Colorado through fear of subsequently being enjoined by a court which might take a different view because of the new conditions which have arisen. In view of the enormous expenditure in time and money to secure the above decree, the State of Kansas or its citizens will endure great wrong before again resorting to the courts. The present system, because of the expense and delay of litigation, may result in a denial of justice as between States.

If there is to be an equitable apportionment of benefits between States as to interstate waters, it appears that Congress is the only body now authorized to establish rules by which such apportionment of benefits can be determined in advance. If Congress should prescribe that priority of appropriation and beneficial use should constitute an equitable apportionment of interstate waters as between States, it is quite probable that the Supreme Court of the United States would uphold such law on the ground that the question involved is one within the jurisdiction of the legislative branch.

Such a law would apply to interstate streams whether navigable or not. It should also apply equally to all tributaries of such streams within the respective States, for it is only by controlling diversions along every section of the stream, including its source, that the water at any point can in practice be controlled.

As to navigable waters, the United States without question has the right to enact "all needed measures to preserve the navigability of navigable watercourses of the country even against any State action." (United States *v.* Rio Grande Dam & Irrigation Co., 174 U. S., 690, 703.)

If the jurisdiction of the General Government over interstate commerce and its natural highways vests in such Government the right to control and preserve the navigability of navigable waters, it must follow by necessary implication that Congress can also exercise such control over the nonnavigable tributaries of such stream as is necessary to preserve such navigability. For without control of diversions and of flood-water storage on source streams, complete control of the navigability of a stream is impracticable.

Between these two theories of State control and National control we thus find a vast twilight zone of uncertain authority, as there are but few streams within a State which are not navigable, or interstate, or tributaries of navigable or interstate streams. Only a few small streams along the Atlantic and Pacific coasts and in the great interior basin rise and terminate within a State.

LAND COMPLICATIONS.

Land ownership serves to complicate the water-right situation and thus widen this twilight zone of uncertain authority. With reference to water rights, all land entered since March 3, 1877, has in Oregon a status different from that of land entered prior to such date. The desert-land act of 1877 has been held in Oregon to abolish riparian rights to all lands subsequently entered, whereas lands entered prior to such date seem to possess some theoretical advantage. This common-law right, however, is so indefinite as to be of no practical value, as no two court decisions can be found which agree as to the extent of riparian lands, what constitutes a reasonable use of water on such lands, or for what uses a common-law right attaches. These uncertainties, coupled with those arising from the facts that no specific quantity of water can be decreed by the court to a riparian claimant and that one can not claim both as an appropriator and also as a riparian owner, make such rights in Oregon of little practical value.

Under the theory of State control Oregon has extended the right of eminent domain in certain cases, so that lands in private ownership can be condemned if necessary to permit the application of water to beneficial use. Public lands, however, can not be condemned under State laws. By referring to the section of this report dealing with water-power withdrawals, it will be observed that a very large percentage of the important water-power sites along Deschutes and Metolius rivers are now controlled by the United States, as but few dams can be constructed to an economical height without overflowing property of the United States. This property is held in the form of water-power withdrawals, Indian reservations, or national forests.

FEDERAL CONTROL THROUGH LAND OWNERSHIP.

There appears to be no very secure foundation for the theory of State control of waters on the public domain. Neither the act of 1866 or the desert-land act of 1877 can be considered as an irrevocable grant to the State. The first act merely confirms rights which have become vested by appropriation and use under the local laws and customs, and the act of 1877 strengthens this view of the former act and, in addition, enacts that all surplus water, together with all other sources of water supply upon the public lands and not navigable, shall be held free for appropriation and use for three purposes—(1) irrigation, (2) mining, and (3) manufacturing. This is merely an offer and does not bind the United States until the offer is accepted and the water diverted and used for one of these purposes.

Concerning this question of State control of waters on Federal lands, the Supreme Court of the United States held in the case of the

United States *v.* Rio Grande Dam & Irrigation Co. (174 U. S., 690, 703) that—

> Although this power of changing the common-law rules as to streams within its domain undoubtedly belongs to each State, yet two limitations must be recognized: First, that in the absence of specific authority from Congress a State can not by its legislation destroy the right of the United States, as the owner of lands bordering on a stream, to the continued flow of its waters, so far at least as may be necessary for the beneficial use of the Government property; second, that it is limited by the superior power of the General Government to secure the uninterrupted navigability of all navigable streams within the limits of the United States.

Kinney comments as follows:

> In other words, the court holds that the jurisdiction of the United States over the natural watercourses (upon the public domain) is superior and paramount to the jurisdiction of any State; and that all needed measures may be taken by the Government to preserve the watercourses of the country for at least the two purposes named above, even against the action of any State, in authorizing, under its laws, appropriations to be made. The court, especially in the Kansas-Colorado and Rio Grande cases, clearly intimates, to say the least, that the Government might also make other claims to the water than for its use for navigation or as a riparian owner. Whether it will do so time alone can tell.[1]
>
> The Government is still the owner of the surplus of the waters flowing upon the public domain, or rather the owner of all the waters flowing thereon remaining after deducting the rights to the use of the same which have vested in and accrued in some legal way to individuals and companies. * * *
>
> It therefore follows as the result of the ownership by the United States of the waters flowing upon the public domain that any dedication by a State of all the waters flowing within its boundaries to the State or to the public amounts to but little in the face of any claim which might be made by the Government, at least to all the surplus or unused waters within the State.[2]

Kinney states further that Congress could, if it saw fit, have laid claim to the necessary surplus water for projects constructed under the reclamation act by virtue of the fact that title to the surplus waters flowing over the public domain is in the Government, and not under the State laws, as was provided in section 8 of such act. Much confusion within the States may eventually result where Congress has reserved water for Indian reservations and which after many years has never been used by the Indians but has in the meantime been used by others below.

It therefore appears from these authorities and from the wording of the acts in question that Congress could, if it saw fit, repeal at any time existing laws relating to water and adopt some new law for all surplus and unappropriated waters on the public domain. In such an emergency we would have divided control within the Western States to such an extent as to make any control impracticable except through the closest cooperation.

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[1] Irrigation and water rights, 2d ed., p. 1096.

[2] Idem, p. 692.

INDIRECT CONTROL BY THE UNITED STATES.

For all practical purposes the United States controls both land and water upon the "public lands, forests, and other reservations" within the Western States for irrigation, power, and other beneficial uses.

The "regulations concerning rights of way through the public lands and reservations of the United States" issued by the Department of the Interior, March 1, 1913, and the regulations concerning water power in the "Use book" of the Forest Service would be no more complete respecting power development had the United States full control and the States no control whatever over water. While these regulations deal only with the development of water power, under the provisions of the act of February 15, 1901 (31 Stat., 790), there appears to be no reason why these departments could not, for applications made under the same law, issue other regulations imposing an annual charge and limiting franchises for the use of water for irrigation, domestic, and other purposes where any part of a reservoir, ditch, canal, or pipe line necessary for such use was located on Government reserves. Most irrigation rights of way are, however, granted under the provisions of the act of March 3, 1891 (26 Stat., 1095).

The permits for water-power development, when issued, bind the permittee to construct the works in accordance with approved plans, to begin and complete construction within a fixed time, to operate the works, and to pay annually in advance a graduated rental charge per horsepower per annum, ranging from 10 cents to $1. For good cause a lower rental may be fixed. These permits by the terms of the statute must be revocable at the will of the Secretary but usually terminate in 50 years, unless renewed by application made not less than two years prior to such date of expiration.

These restrictions are very much the same as those imposed by the State under water permits except for the revocable character of the Federal permit. The Federal regulations, however, require the applicant for right of way to present "a duly certified copy of such notice or application, if any, as is required to be posted or filed, or both, to initiate the appropriation of water under the local laws." The State franchise limitation in Oregon is 40 years and different periods are prescribed within which the various steps to be taken in perfecting the water rights and those prescribed for perfecting the land rights must be taken.

For years it was assumed that such rights of way were to be granted free to encourage development in the West, except perhaps for the payment for timber or other Federal property destroyed. Recently, under a new policy, this act has been construed to authorize the administrative departments to impose annual charges and other restrictions on the use of public land for power development.

If the State also adopts the revenue policy, as is the case in Oregon, there is a possibility that the combined charges will be so high as to make development impracticable in competition with fuel power. Under such a policy rates for electricity in the Pacific States may become higher than in many Eastern States, because of the higher price of coal used in competing plants. Those States having abundant water-power resources might, by excessive charges, be deprived of any special benefits therefrom, such as now accrue to other States through the presence of cheap coal.

STATE WATER-POWER POLICY.

Oregon is believed to be the first State in the Union to limit the term of all franchises for the use of water for power development and to impose an annual tax on the basis of each horsepower developed. These restrictions were adopted in 1909 and imposed only on new developments. In 1911 a small annual license fee was imposed on existing power plants, the revenue to be used primarily for the purpose of gathering information necessary to promote new developments. This measure was intended to afford full information as to the extent of vested rights.

The first law limited franchises to the use of water for power development to a period of 40 years from the date of initiation of the right and required the payment of an annual tax, to be adjusted from time to time by the State water board. This tax is fixed at not less than 25 cents nor more than $2 per horsepower per annum, depending on the percentage of power developed under the appropriation which is put to beneficial use. So far only the minimum fee has been assessed by the administrative authorities, which, with an assumed plant efficiency of 50 per cent, makes the tax only 12½ cents per theoretical horsepower. The uncertainty as to whether the minimum or maximum charge will be imposed by the State under this law has as serious effect on development as the revocable permit issued by the United States for power privileges on Government lands.

The annual license fee is collected only from those plants which used water prior to the adoption of the power tax law in 1909 on the theory that State regulation of streams is necessary for the orderly development of the industry. This fee is graduated, being 10 cents for each theoretical horsepower claimed up to and including 100, 5 cents for each horsepower from 100 to 1,000, and 1 cent for each horsepower in excess of 1,000. Municipal plants and other power plants of less than 25 horsepower are exempt. The revenue for 1912 amounted to $3,550.86 and was expended largely on water-power surveys and investigations in cooperation with the United States Geological Survey, which contributed $3,000 for similar work in Oregon. This law is defective in that it does not reach those power

rights which were initiated prior to 1909 but on which no water was put to beneficial use until after such date. This is the class of claims of which a record was most desired. It was anticipated that a small annual fee would discourage many speculators and thus clear the field for legitimate development.

The tax law mentioned above was based on the theory of revenue for the State treasury; the license law was based on the theory of development through the collection of information to encourage the industry. These two policies are directly antagonistic. It would thus appear that no well-defined policy relating to water power has yet been adopted in Oregon.

Several leading political organizations of the State have recently advocated a policy of development as opposed to revenue, as it is believed that the indirect benefits derived through the taxation of new wealth, through added fields of employment for labor, and through the comfort and convenience of our citizens, which will come with reduced electric rates, will far exceed any possible direct benefits from taxation. To carry out the development policy and compel the application of excessive profits to the reduction of electric rates, it has been proposed by the Oregon Conservation Commission that the State construct enough plants to regulate the market and insure cheap prices. It is apparent to all that the revenue policy advocated in the East, where water power is scarce, is not applicable to a sparsely settled State, where water power is abundant and taxable wealth is needed.

We have in the streams of Oregon something over 3,300,000 horsepower, which is now running to waste. To produce this power in steam engines would consume 36,000,000 tons of coal annually, which, at $4 a ton, would be worth $144,000,000. We are beginning to appreciate the fact that this power is of no value unless put to use, that there is only a very small market at prevailing commercial prices, that the higher the tax the less power will be used and the lower the tax the greater the use, provided prices are based on cost of production rather than on the principle of all the traffic will bear. It is apparent that the using of all this power during the life of the present generation will be a benefit rather than an injury to posterity so long as franchises are limited to a reasonable period.

RIGHTS ON DESCHUTES RIVER.

PLAN OF DISCUSSION.

Having outlined above the general nature of a water right under the old and the new laws of Oregon, and having disposed of the question of riparian rights, we are now in a position to discuss the water-right situation on Deschutes River and its tributaries. These rights will be summarized briefly under three heads, as follows:

1. Rights initiated under the new water code since February 24, 1909.

2. Old rights which have been adjudicated and recorded under the new water law.

3. Old rights which have not yet been adjudicated, and which are therefore more or less indefinite.

Only the more important rights or claims will be discussed in detail. A summary will be presented at the close, giving an estimate of the total area irrigated in 1912.

RIGHTS UNDER NEW WATER CODE.

All rights to the use of water on Deschutes River or any other stream in the State which have been initiated since February 24, 1909, are on record in the office of the State engineer at Salem, Oreg.

Up to December 1, 1912, a total of 183 permits have been approved by the State engineer, authorizing the diversion and use of water from Deschutes River and its tributaries. Of these permits 24 are for domestic supplies, 126 for irrigation, 16 for power projects, and 17 for the purpose of storing water.

These works when completed will cost $2,329,735 and will irrigate 87,837 acres with 498 miles of main canals. A total of 11,702 horsepower will be developed and 153,507 acre-feet of water stored. The date for beginning construction, completing the same, and for applying the water to beneficial use is fixed in each case, and proof showing progress of work must be filed each year.

To irrigate this land will require 1,098 second-feet at the rate of 1 second-foot to 80 acres. Owing to the porous nature of the soil, it is believed that perhaps 50 per cent of this water will ultimately find its way back to the stream for use by lower appropriators.

The principal permits for irrigation cover 12,560 acres near Sisters to be watered by storage in Blue and Suttle lakes at the head of Metolius River, the water to be conveyed across the low divide to the west and south of Black Butte; 11,627 acres to be watered by pumping plant from Opal Springs in T. 12 S., R. 12 E.; and 3,230 acres from Deschutes River in T. 15 S., R. 12 E.

The proposed reservoir capacity is made up largely by the 32,300-acre-feet Wimer reservoir site located west of Laidlaw and to be filled by a short feed canal from Tumalo Creek, the 22,000 acre-feet of storage at the head of Metolius River in Blue and Suttle lakes, and 95,000 acre-feet to be stored in Crescent Lake, at the head of Deschutes River for the irrigation of 31,160 acres just south of the proposed Benham Falls reservoir. This latter right, however, is claimed also as of an early date by filing under the old law.

Water-power permits authorizing the development of 11,695 horsepower have been approved under the new law. Two of the

largest sites filed on are located in the deep canyon near the mouth of Crooked River and below the point where it is possible to divert water for irrigation. One of these projects contemplates the development of 5,000 horsepower in sec. 11, T. 12 S., R. 12 E., the other 1,000 horsepower in sec. 11, T. 14 S., R. 13 E., and both are expressly limited in such a way that the applicants can not object to the subsequent diversions or storage of water for irrigation at points on the stream above.

The only other power permit of importance was for the development of 5,000 horsepower at Pringle Falls, on the West Fork of Deschutes River. This permit, however, has been involved in litigation and is believed to have been canceled by the court.

OLD RIGHTS DETERMINED.

All old rights to the use of water on Squaw, Tumalo, and Paulina creeks and Crooked River, including the tributaries of these streams, have been adjudicated and recorded under the new law.

The present status of irrigation on these streams, as shown by the record, is as follows:

Irrigation rights on Crooked River and Squaw, Tumalo, and Paulina creeks.

Creek.	Irrigated land.	To be irrigated witnin fixed time.	Total.
	Acres.	*Acres.*	*Acres.*
Crooked River	27,960	.....	27,960
Squaw Creek	7,072	9,408	16,480
Tumalo Creek	3,058	25,120	28,178
Paulina Creek	530	174	704
	38,620	34,702	73,322

The total area irrigated on these four streams is therefore 38,620 acres. On three of these streams rights have been initiated for the irrigation of 34,702 acres in addition, but sufficient time has not yet elapsed within which completely to apply the water to use.

OLD RIGHTS INDEFINITE IN SCOPE.

RECORDS.

All water rights which were initiated prior to February 24, 1909, and which have not yet been adjudicated are more or less indefinite. They are based either upon a notice and record in the county courthouse or upon the actual diversion and use of water without such record.

To examine the county records relating to Deschutes River and its tributaries would require a trip of approximately 1,550 miles,

starting from and returning to any one of the following county seats, where some information is known to be recorded: Prineville, in Crook County; Moro, in Sherman County; The Dalles, in Wasco County; Eugene, in Lane County; and Klamath Falls, in Klamath County. The inconvenience of this system is in striking contrast with the new system of a central office with reliable records.

To illustrate the indefinite and almost worthless character of these county records a summary has been made of a part of the records in one of these counties. The recorded claims to the waters of Deschutes River and its tributaries above the town of Bend, in Crook County, alone, amount in the aggregate to 61,000 cubic feet per second, or about 40 times the ordinary summer flow of the stream.

Although most of these recorded claims can be disregarded, a few are known to be alive, as work has been prosecuted with some degree of diligence from the date of initiation of the right. On a number of others, one or two men have been continuously employed for a number of years in an attempt to show diligence if such rights are ever questioned. On still others little if any actual work has been performed since 1909, but some form of litigation has been in progress which the claimant believes will operate to suspend the statutory requirement of performing work with diligence to maintain the right.

DESCHUTES RIVER AT BEND.

A careful examination of conditions discloses the fact that a sufficient number of these old filings have been kept alive to consume more than the entire summer flow of Deschutes River at Bend for irrigation if all are carried to completion.

Some of this water, however, must be allowed to pass Bend in order to supply prior rights at Cline Falls, which are claimed by diversion and use without the posting of the usual notice. At this point a power plant has been constructed of sufficient capacity to pump for irrigation approximately 14 second-feet of water to a point 95 feet above the river. This power water has also been fully appropriated for irrigation by ditches which it is proposed to construct from the foot of Cline Falls to irrigate lands on both sides of the river below.

Water rights at Bend are somewhat complicated by the recent construction of a 14-foot dam across Deschutes River for the development of power. This dam serves also to maintain a pond for the storing of logs in connection with a sawmill.

At the present time only a small part of the available flow is being utilized owing to the limited power market. If, however, this market should increase in the next five or six years so as to require the entire flow of the stream, it is apparent that no further diversion or storage, other than by those having prior rights, would be possible except through purchase or condemnation of this power plant.

Adjoining Bend on the east side of the river is a tract of land approximately 12 miles wide by 25 miles long, which will ultimately be irrigated by a system of canals now in process of construction by the State under the provisions of the Carey Act. Water for this system will be diverted from the river through two intakes, one of which is located about 4 miles south of Bend, or above the power plant, the other about 1 mile below this power plant. During 1912 approximately 15,878 acres were irrigated in this project. On its completion and the putting of water to beneficial use in accordance with present plans, about 450 second-feet of water will be diverted at the intake south of Bend, and 880 second-feet at the intake north of Bend, or a total of 1,330 second-feet. The water for this latter diversion can be utilized for power, as it must pass over the dam at Bend and can still be made available for irrigation below. The water diverted above Bend will diminish to that extent the power value of the Bend plant, as the right for irrigation is believed to be prior in time. These figures as to vested rights to water represent only the judgment of the writer based upon a field investigation.

Besides these two large canals, there are two others, which contemplate the ultimate irrigation of about 9,000 acres each, in the vicinity of Bend. These rights, together with a few small rights which are believed to be vested, can, when completed, utilize a total of 1,600 second-feet of water in the vicinity of the town of Bend. This is approximately 25 second-feet in excess of the mean flow during August, as averaged for a seven-year period, without allowing for water necessary to satisfy rights at Cline Falls.

BENHAM FALLS SEGREGATION.

It is proposed to irrigate a 75,000-acre tract, containing about 60,000 acres of irrigable land, located in a compact body approximately 20 miles east of Bend, by a canal from Deschutes River, diverting water near the head of Benham Falls. This project is known as the Benham Falls Carey Act segregation. Water is claimed under the old law from the regular flow of the stream for about 10,000 acres, or 143 second-feet, the balance to be stored in what is known as the Crane Prairie reservoir site, on the West Fork of Deschutes River. A 40-foot dam 2,000 feet long will submerge at this site 8,290 acres of land and store 187,000 acre-feet of water, if available.

Most of the return seepage from these irrigation projects in the vicinity of Bend will find its way into Crooked River to the north; little will return to Deschutes River between Bend and Cline Falls.

ABOVE BENHAM FALLS.

The most important unadjudicated right to water above Benham Falls is that claimed by the Deschutes Land Co. for the irrigation of

31,000 acres which has been segregated to the State in Tps. 21, 22, and 23 S., R. 10 E., for reclamation under the Carey Act. Water for this tract will be obtained partly by direct diversion from the East Fork of Deschutes River but largely by storage in Crescent Lake at the head of the stream. A 30-foot dam at the outlet of this lake will store 92,000 acre-feet of water. It is believed that fully 20 per cent of the 510 second-feet of regular flow and stored water, ultimately to be applied to this tract between May 15 and September 1 of each year, will return as seepage to the stream during such period, which amount will approximately equal the regular low-water flow. This project so far as its effect on lower rights is concerned can therefore be disregarded.

POWER FILINGS.

A number of large water-power filings were made under the old law near the mouth of Deschutes River, and are claimed still to be in good standing, although little actual work appears to have been done. It is said that these sites have been involved in litigation for a number of years and that these uncertainties have made construction work impossible. Even if such claims are ultimately held to be invalid, the value of these sites for power development can not be seriously impaired by subsequent diversions above for irrigation, as practically all the large claims in the vicinity of Bend are already prior in time and no other extensive appropriations are possible except for water storage.

A filing on Pringle Falls in T. 21 S., R. 9 E., on the West Fork of Deschutes River, may detrimentally affect the storage of water at the proposed Crane Prairie reservoir site, or in Odell Lake, or in other basins on the headwaters of this stream. This claim has been involved in litigation for some time. Its exact status may be difficult to ascertain until such time as a comprehensive adjudication of all rights on Deschutes River has been carried to completion.

The proposed diversion of Odell Lake by tunnel through the crest of the Cascade Mountains for the development of power on Salt Creek, a tributary of the Middle Fork of Willamette River, is one of those cases in which the public is vitally concerned. This project proposes that water sufficient for the irrigation of perhaps 30,000 acres would be transferred from one basin, where irrigation is essential to the production of crops, to another where irrigation is not absolutely necessary. The increase in taxable wealth, resulting from the use of this water for power development in the Willamette Valley, would be small compared with that resulting from its use for both irrigation and power in Deschutes Valley. Probably 50 per cent of the water used for irrigation will return to the stream for

still further duty in irrigation or power development below. This application was made under the old law, but if it were made under the new water law it could be denied upon the ground that it is a menace to the general welfare of the public.

Aside from these large irrigation and power projects in process of construction, the extent of whose claims to water are more or less indefinite, it is believed that no other great uncertainties exist. The total area of land now irrigated through small ditches from the many tributaries of Deschutes River other than those mentioned above is unknown but will probably not exceed 15,000 acres. The stream-discharge records now available show the amount of water at different points in this district which remains after such land has been irrigated.

SUMMARY OF IRRIGATION RIGHTS.

It therefore appears that there was a total of about 70,000 acres of land actually irrigated by Deschutes River and its tributaries during 1912, as follows:

	Acres.
State Carey Act projects near Bend	15,878
Arnold and Swalley ditches, near Bend (estimated)	2,000
Crooked River and its tributaries	27,960
Squaw Creek	7,072
Tumalo Creek	3,058
Paulina Creek	530
All other projects (estimated)	13,502
	70,000

Water rights have been initiated under the old law for the irrigation of a large additional acreage and work is now progressing on these projects with more or less diligence, as follows:

	Acres.
On adjudicated streams	34,700
On Carey Act projects near Bend, State segregation lists 6 and 19	77,220
Arnold and Swalley ditches, near Bend	16,000
Benham Falls segregation	60,000
Deschutes Land Co., above Benham Falls	31,000
All other projects (estimated)	10,000
	228,920

Permits have been issued under the new law for the irrigation of 56,677 acres from Deschutes River and its tributaries, after deducting the claim of the Deschutes Land Co., which is filed under both the old and the new laws.

The total area in process of reclamation is therefore approximately 285,600 acres. It is doubtful if water rights for all this area will ever attach under the present date of filing or claim, and it is believed that some of the water thus appropriated will eventually revert to the public and be subject to reappropriation.

APPLICATIONS PENDING.

In addition to water permits as summarized above, there are now pending before the State engineer's department for water in this basin 41 applications, which will be acted upon as soon as surveys are complete and the necessary information furnished as required by law.

Definite action on a number of large water-power filings on the main stream between Benham Falls and the mouth of Metolius River has been suspended several years because of uncertainties.

If all the irrigation projects in the vicinity of Bend are ultimately completed in accordance with present plans, there will be no water left in the summer months for these prospective power plants. Furthermore, if these irrigation projects are not completed and the water becomes available to satisfy subsequent power permits which have been approved, it would practically defeat for all time the irrigation of several hundred thousand acres of land in Crook County. It is believed that such a condition would menace the welfare of the public within the meaning of the statute to such an extent as to warrant the State engineer in referring such applications to the water board for consideration as to the public's interest in the matter. Such board has power to direct the refusal of these applications if public interest demands.

NEW USES FOR CHEAP POWER.

Within the last few years many new uses for large amounts of cheap power have been discovered. Where it costs $40 to $60 per horsepower per annum to produce power in large steam engines, it can be produced under favorable conditions from falling water at $7 to $15 per horsepower per annum. At such low prices for electric power the manufacture of aluminum, carborundum, calcium carbide, and many other products in the electric furnace has been made a commercial success. The electric production of iron and steel appears now to be safely beyond the experimental stage. Fertilizer is now being made by extracting nitrogen from the air by the use of electricity. Cheap power can be used in many chemical processes, such as the making of oxalic acid from wood waste. It can be used in the home for the production of light, for cooking, for ironing, and, under favorable conditions, for heat. Many uses have been found for electricity on the farm and it is even claimed that electricity properly applied will greatly stimulate plant growth. The pumping of water for irrigation on any extensive scale depends upon the ability to procure a permanent supply of cheap power.

The rapid development along these lines is well illustrated by the Norwegian nitrate industry. In 1903 25 horsepower and four men were employed in the making of artificial fertilizer from the air; in

1911 200,000 horsepower and 2,000 men were employed to keep pace with the demand for these products.

It would require a capital investment of about $860,000,000 to assure the production of an amount of Norway saltpeter equal to that now consumed by the civilized world, assuming that sufficient cheap water power were available.[1]

The rapidity with which the electric furnace has been perfected for the production of iron and steel opens up another field for the utilization of cheap water power.

Three tons of pig iron per electric horsepower-year has been produced in Sweden, and Prof. Richards, of Lehigh University, believes that with a large furnace of perhaps 100 tons daily capacity as much as 5 tons per horsepower-year can be produced.[2]

These new and rapidly developing industries wherein large quantities of cheap electric power can be used should not be overlooked in the framing of a State and national water-power policy. The maximum State charge of $2 per horsepower-year may not prove a serious handicap where the wholesale rate for power is $40 to $80 per horsepower-year, whereas it may be prohibitive for those plants attempting to supply power to the new industries which can not afford to pay more than $7 to $15 per horsepower-year.

There is much power in Oregon which can be developed and sold in the vicinity of the power plants at such low prices.

COOPERATION.

METHODS.

Owing to the joint control of both land and water resources by the State and the Nation and to the inadvisability of either the State or the United States attempting independently to carry out a comprehensive policy, it appears advisable that these agencies cooperate not only for the investigation of irrigation and power projects but also in the construction of such projects.

Because few if any large irrigation projects can be found in the State where the land is largely in public ownership, the United States reclamation act has about reached the limit of its usefulness to Oregon unless the Government is willing to undertake large projects where the lands are principally in private ownership.

It will doubtless be conceded that money invested within a State from the reclamation fund is not a gift to that State. It is made a lien on the land benefited and must be paid back in time, including interest, for that portion obtained from the $20,000,000 bond issue, voted by Congress to supplement the reclamation fund. Since these funds are inadequate to meet all demands, it seems that the State

[1] Norton, T. H., Utilization of atmospheric nitrogen: Dept. Commerce and Labor, Bur. Manufactures Special Agent series No. 52, p. 76, 1912.

[2] Eng. Soc. Western Pennsylvania Proc. for March, 1912, p. 96.

directly benefited should not hesitate to extend its credit in supplying additional funds. This can be accomplished without increasing the burden of taxation, as the full investment with interest must eventually be returned to the State.

For seven years the State of Oregon has been cooperating with the United States Geological Survey in stream gaging, water-power investigations, and making topographic maps. In 1912 $56,000 was expended jointly on such work, each party contributing equally. No friction has resulted, and the work has been carried out more economically and efficiently than could have been accomplished by the State alone. This successful experience has suggested the plan of extending cooperation to include another department under the Secretary of the Interior. The plan, though involving larger expenditures, is therefore not an experiment and is the logical outgrowth of former experience.

Cooperation with the United States Reclamation Service in irrigation investigations was authorized in February, 1913, and $50,000 was appropriated for the purpose. An equal amount was allotted from the reclamation fund within a few days thereafter by Secretary Fisher, and on May 5, 1913, a contract was executed between the State engineer and Secretary Lane providing for the joint expenditure of such funds.

This contract provides that the State engineer shall withdraw the necessary water and the Secretary of the Interior the necessary land for the protection of the projects under investigation. The information collected will be published eventually in order to stimulate development by either private or public funds. The plans and water rights for any project or unit thereof will be turned over for construction to an irrigation district or other organization satisfactory to the people interested on repayment to the State and the United States of the cost of such investigations and the giving of assurance that the work will be carried out in harmony with the public interest. If it is undertaken by public funds, the State's share of the cost must be returned to a revolving fund to be used for similar investigation of other projects.

The usual promoters' profits will thus be eliminated, as full information, secured by the State and National authorities, will be available to private capital in all parts of the world. If the project looks attractive, capital can thus deal directly with the interested parties without the necessity for paying promotion costs.

If private capital can not thus be enlisted, the information will be available so that the necessary constitutional amendment and laws can be enacted whereby the credit of the State can be advanced to accomplish the work. It is common practice for a city to lend its credit for the construction of street and other municipal improve-

ments, and no reason of public policy appears why the State should not do likewise for the construction of those projects which are beyond the reach of its citizens and which are the basis for the future growth and prosperity of the State.

In voting millions of dollars for such new enterprises the people must be assured that the money will be wisely expended and eventually returned with interest. To do this will require a stable and experienced organization which can follow the work closely throughout a long period of years. Not until every dollar contributed is returned can the venture be considered a financial success. Constant shifting of responsible officers in such complicated work is sufficient to cause disaster.

To obtain the advantages of an organization free from local influences, it may be advisable that the States cooperate with the Nation in the construction of such projects. The United States reclamation act has now been in successful operation for more than 10 years and its work has been generally carried on with success. It would be much easier to expand this organization than to create a new one which would doubtless repeat all the mistakes that are necessarily attendant on the starting of a new organization. The work could be carried out by the Secretary of the Interior acting in cooperation with a State officer. It is believed that the construction of both irrigation and power projects on a large scale can be brought about more quickly through such a plan of cooperation than by each State acting apart from the Federal Government. It is believed that by this plan of cooperation the friction which now exists between those favoring State control and those favoring national control will soon die out.

ADVANTAGES OF COOPERATION.

The average cost of water per acre under irrigation projects of the United States Reclamation Service is claimed to be less than that under similar projects built by private capital, and the difference is accentuated by the better quality of Government work, better drainage provisions, and more dependable water supply.

When it is remembered that the total excavation by the United States Reclamation Service on the 8,325 miles of irrigation canals and ditches constructed in the various western States up to December 31, 1913, exceeded that for the Culebra section of the Panama Canal, it becomes apparent that the United States must have a well organized and efficient machine to carry on this work.[1]

"The United States Reclamation Service gets more actual work for a dollar than do the Harriman lines," according to H. T. Corey, an engineer who for 8 years was connected with the Harriman lines in

[1] See Eng. Record, July 11, 1914, p. 58.

California, Arizona, and Mexico.[1] This statement was based on knowledge as to costs on the Salt River, Yuma, and Orland projects of the Government.

It would thus appear that to divide the risk and insure safety in the investment of funds, the States desiring to facilitate the development of irrigation could not do better than at least to start out in cooperation with this larger and more experienced organization.

Irrigation by pumping can never be made a success until long-time contracts for electric power can be obtained at very low rates. The experience of irrigators under gravity canals in watching the water rates increase with their ability to pay has caused many western States to make water appurtenant to land, thus doing away with the common carrier canal. Not only the water but also the power must be tied to the land for successful irrigation with pumps.

The advantages of cooperation in the development and distribution of power to municipalities should be apparent to those who favor municipal control, as all the economies of a great electrical system, with its different plants operating under varying water conditions and varying loads will be made available to the cities. For several years such a plan has been in operation in the Province of Ontario, Canada. Power is purchased from private companies at Niagara Falls at $9 per horsepower per annum and is now supplied to over 30 cities at $15 to $40 per horsepower per annum. The local distribution of the power by the cities increases these prices somewhat to the consumer. It is reported that Toronto, with a population of 400,000, located 90 miles from the Falls, is now being supplied with power at $15 per horsepower per annum. As a consequence of such low rates the use of power has greatly increased and the various communities have made rapid growth because of the establishment of new industries.

UNIFORM STATE LAWS.

Uniform State laws and reciprocity between the States in granting the use of water has been suggested as a solution of water-right difficulties. This plan, however, seems impracticable and does not overcome the question of divided control with the United States.

Without some powerful and uniform pressure from outside the State there is little likelihood of ever obtaining uniformity in State laws. Reciprocity might give temporary relief in adjoining States, but many streams flow through or border three or more States, thus complicating matters.

Even in adjoining States reciprocity has not worked well. In 1911 the State of Oregon authorized the diversion of water for use in

[1] Am. Soc. Civil Eng. Trans., vol. 76, p. 718, Dec., 1913.

adjacent States. Idaho refused to pass a similar measure, and recently its supreme court, in the case of Bailey *v.* Robison, held strongly to the doctrine of State control and refused permission to divert water to Montana after a ditch had been constructed under a permit issued by the State engineer. California at the same time passed a law prohibiting the diversion of water for use outside the State.

After all the effort which has been made in the Western States to secure an equitable apportionment and distribution of the water resources, it is apparent that a satisfactory solution has not yet been reached. There are many problems which vitally affect conditions within the State but which are beyond its control and which, if unsolved, will vitally affect the peace, safety, and general welfare of the Nation.

NEEDED LEGISLATION.

There is great need at the present time for a thorough overhauling of all State and national laws relating to water to the end that the present confusion and uncertainties be eliminated. No plan of stream control can be successful unless it is in harmony with the laws of nature and is framed with the idea of overcoming not only legal but also physical difficulties. The stream basin is the logical unit for administrative purposes, therefore joint control by the State and Nation will probably eventually prevail. Some problems must doubtless be left exclusively to the State for solution, while others come more properly within the scope of the National Government.

The question as to the right of the United States to derive revenue from water-power development in the West or on navigable streams in the East and the necessity of adopting some comprehensive plan for the control of Mississippi River may require solution in the near future. Even in the Eastern States it can not be said that rights to all the public waters have become vested and nothing remains to be accomplished by legislation, for the riparian owners can not require that the devastating floods in the Ohio, Mississippi, and other rivers continue. If the various States and the nation contribute for the construction of reservoirs, there must be some law establishing and protecting priorities in reservoir flood-water rights, just as we have in Oregon for any storage project. The point at which these reservoirs must cease storing water for power or navigation must be designated each season by some interstate or National administrative officer in accordance with such law for the protection of prior riparian or vested power interests, and those using such stored water when released should pay in proportion to the benefit, if any special privilege is derived. This will necessitate the determination and recording

of existing rights as a basis for protection and also as a basis for new development.

In the Western States the serious complications arising in the equitable apportionment of benefits as to interstate waters will compel in the near future some action by Congress.

In other words, there is great need for the adoption by Congress of some comprehensive administrative system relative to interstate and navigable waters corresponding in character to that needed for the establishing and protecting of rights within a State. Such a system can be established without in any way injuring vested rights but for their benefit and protection, and it can be made to conform with the varying laws in the different States. In many Eastern States and most Western States the ordinary flow of most streams is fully appropriated, and some flood water and storage rights have been established. As these storage rights increase in number, size, and importance the difficulties which are now agitating the West can be anticipated in the East. The same law, therefore, which applies to the West should be made to apply also to the East.

THE RELATION OF THE FEDERAL GOVERNMENT TO THE DEVELOPMENT OF WATER POWER IN THE DESCHUTES BASIN.

By W. B. Heroy.

LEGAL BASIS FOR FEDERAL CONTROL.

Federal control of water-power development and its electrical transmission rests on the constitutional prerogatives of the General Government "to regulate commerce with foreign nations, and among the several States and with the Indian tribes" and "to dispose of and make all needful rules and regulations respecting the territory or other property belonging to the United States." Through the first arises its control over navigable waters and water-power development incidental thereto, which has been referred to by Mr. Lewis. Since Deschutes River is not regarded as a navigable stream, a discussion of the powers of the Federal Government in regard to navigation is not germane to the present report. The control of interstate commerce vested in the United States might be exercised if the water power generated were transmitted across State lines. There are no important power markets in other States within practicable transmission distance of the Deschutes water powers and, in fact, power developed on White Salmon River in Washington is transmitted into the State for use in the city of Portland and vicinity. It appears probable therefore that the United States will have no relation to the situation from this view point.

The power of Congress to control the disposition and use of public lands is, however, of the utmost importance in relation to the future

utilization of the water-power resources discussed in this report. The Federal Government holds public lands both as sovereign and as proprietor. As sovereign its property is alienable only with its consent. Guaranties have without exception been inserted in the enabling acts creating the various States and in their various constitutions, maintaining the integrity of its control of public lands against possible encroachments by States or individuals. Thus public lands are not subject to condemnation except where such condemnation may have been authorized by Congress, and they may be appropriated only in so far as the Federal statutes direct. Because of the ownership by the United States the lands are also free from taxation by the State. In its capacity as proprietor the United States may do with its land all things which any other proprietor may do, and the lands of the United States have all the appurtenances which the lands of any other owner may have.

When public lands are adjacent to watercourses, their rights in the water flowing in the adjacent streams are, as has been suggested by Mr. Lewis, somewhat indefinite. It seems clear, however, that under the act of July 26, 1866, and under the desert-land act of 1877, Congress has sanctioned the appropriation of the waters flowing over public lands subject to State and local regulations. Where such appropriations have actually been made and the water put to beneficial use in accordance therewith, lands still in public ownership may have thereby been deprived of a certain portion of the absolute property right originally appurtenant to them in waters flowing over or past them. But since the authority to appropriate the waters of the public lands is purely permissive it is also clear the Congress may at any time resume complete control of the unappropriated waters or legislate to any needed extent regarding them. In such a case State statutes or local regulations relating to the unappropriated waters would of necessity become ineffective in so far as they might conflict with congressional enactments. The resumption of complete control over unappropriated waters flowing over public lands would, however, as Mr. Lewis suggests, create a dual system of control without apparent advantage to the State, the General Government, or the public generally.

The chief relation which the public lands bear to the present problem arises from the fact that it is necessary to utilize portions of them for the emplacement of structures, and to overflow other portions as a result of construction of dams. In both of these cases the consent of the United States is necessary. This consent may be given by Congress in a general enactment not requiring administrative action by the officers of the Federal Government. On the other hand, Congress may empower the administrative officers to authorize the use of the public lands for the purposes needed. Frequently the concurrence

of both the legislative and executive branches is necessary, Congress defining the extent of the rights to be acquired, specifying the class of grantees, and fixing the conditions under which the grant is to be used, and the executive branch determining compliance with the statute and compatibility with public interest before making the grant effective by approval.

The earliest act of Congress dealing with rights of way across public lands for the utilization of water is section 9 of the act of July 26, 1866 (sec. 2339, R. S.). This act is of the first type above mentioned. Its language is broad and general in character, the terms describing the various purposes for which the water could be used being especially inclusive. All rights to occupy the public lands for ditches and canals rested upon this act until the passage of the act of March 3, 1891 (26 Stat., 1095), relating to rights of way for irrigation and the act of May 14, 1896 (29 Stat., 120), relating to rights of way for the development of electric power.

The question as to the effect of the passage of these later acts on the acquirement of rights under the act of 1866 has been much discussed. Though the Supreme Court has not yet been called upon to decide the question, the decision of the United States court of appeals of the eighth circuit in a case relating to the statute (United States *v.* Utah Power & Light Co.), filed November 14, 1913, is at present controlling. Because of its complete exposition of the relations of these various acts and of the powers of the Federal Government it is here inserted in full:

The United States brings its bill of complaint against the appellee, defendant below, by which it seeks perpetually to enjoin said defendant from maintaining, in whole or in part, an alleged unlawful and tortious possession and occupancy of certain public lands in Cache County, State of Utah, now forming a part of the Cache National Forest.

Appellee is a corporation organized for the purpose of supplying electrical power to all who may desire to purchase and use it. Since December, 1900, it, and its predecessor in interest, have been engaged in the continuous operation of certain hydro-electrical power works, situated on Logan River in the county and State aforesaid. These works comprise a reservoir and a flume or conduit for conveying the flow of water from the reservoir to the power works, pressure pipes and power-house station, all equipped with the necessary machinery and apparatus. The reservoir, flume, and conduit are situated wholly upon and within the lands of the United States.

It is alleged in the bill that the defendant power company holds no permission for the construction, maintenance, or use of said reservoir, flume, or conduit, nor any permission or authority to occupy or use said lands for the purpose stated from the United States or from any of its officers duly empowered by law to issue or grant the same; this, of course, stands admitted. Appellee claims to have acquired whatever rights it possesses under and by virtue of the customs, laws, and decisions of the State of Utah, as recognized and confirmed by section 9 of the act of Congress of July 26, 1866, appearing as section 2339 of the Revised Statutes, as follows:

"Whenever, by priority of possession, rights to the use of water for mining, agricultural, manufacturing, or other purposes, have vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and the decisions of courts,

the possessors and owners of such vested rights shall be maintained and protected in the same; and the right of way for the construction of ditches and canals for the purposes aforesaid is hereby acknowledged and confirmed: *Provided, however*, That whenever, after the passage of this act, any person or persons shall, in the construction of any ditch or canal, injure or damage the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage."

The Government claims: (1) That rights of way for power companies can not be acquired under this act, because such companies and their purposes were not contemplated by Congress at the time of the enactment of these laws, and were not, therefore, within the intent and meaning of those acts. (2) That in any event Congress has since made specific and comprehensive provisions defining the procedure by which, and the extent to which, the use of the public lands may be granted and acquired for the purposes of generating, manufacturing, and distributing electric power; that this legislation withdraws such uses from the terms of section 2339 of the Revised Statutes, if they were ever included therein. The legislation referred to is that of May 14, 1896, 29 Statutes, 120, which reads as follows:

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the act entitled 'An act to permit the use of the right of way through the public lands for tramroads, canals, and reservoirs, and for other purposes,' approved January twenty-first, eighteen hundred and ninety-five, be, and the same is hereby amended by adding thereto the following:

"SEC. 2. That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of right of way to the extent of twenty-five feet, together with the use of necessary grounds, not exceeding forty acres, upon the public lands and forest reservations of the United States, by any citizen or association of citizens of the United States, for the purposes of generating, manufacturing, or distributing electric power."

The Government's position is that this act, of subsequent adoption, making specific and comprehensive regulations respecting a subject conceived to be embraced within the terms of the prior more general act, withdraws that subject from the operation of the former act to the extent to which it is governed by the special provision and is *pro tanto* a substitute for the general statute formerly governing the subject matter. Under the authority of this act the Secretary of the Interior fixed and promulgated general regulations; and it is contended that since that time, as against the United States, no rights could be acquired in the public lands for purposes of generating, manufacturing, or distributing electric power except in conformity with the act of 1896 and the procedure thus established. The exclusive control of Congress over the disposition of the public lands is asserted. The alleged rights of appellee were attempted to be created since the passage of the act of 1896, and the regulations promulgated thereunder, to wit, December, 1900.

A motion to dismiss, substituted under the new equity rules for demurrer, was filed by appellee. The court below, being of opinion that the defendant had title to a right of way for its pipe lines and reservoirs under section 9 of the act of July 26, 1866, and was, therefore, under no obligation to proceed under the subsequent legislation, sustained this motion and dismisses the bill.

It is suggested, rather than insisted, that appellant is not entitled to equitable relief, because its remedy at law is complete and adequate. This point, though raised in the briefs for appellee, was not urged at the oral argument. While ejectment would seem to afford adequate relief, nevertheless the proceeding in equity has been recognized and approved. (United States *v.* Brighton Ranche Co. (C. C. A.), 26 Fed., 218; Light *v.* United States, 220 U. S., 523.) However, we agree with the trial judge that under the new equity rules the objection, if well taken, does not justify a dismissal, and that the question, therefore, need not be determined.

From the briefs the claim of right asserted by appellee would seem to be twofold in its nature. First, that the power company is entitled to be maintained and protected, so long as it may desire, in the use of rights of way over the public land, which it claims to have acquired for the purpose of putting water to a beneficial use under the customs, laws, and decisions of the State of Utah, as recognized and confirmed by section 9 of the act of Congress of July 26, 1866 (Rev. Stat., sec. 2339); that by said act and by the construction and use of its reservoir and flume, it has permission of the highest and most solemn kind from the United States Government to occupy the land in question. Second, that it is protected in its tenure because that tenure is authorized by the laws of the State of Utah, exercising sovereign and exclusive jurisdiction with respect thereto.

The proposition that absolute and perpetual rights in the public lands may be acquired for private gain by mere appropriation without purchase or compensation, and in the exercise of a State sovereignty which transcends the constitutional power of the Congress, is a somewhat startling one, and must be considered first. The Constitution of the United States (art. 4, sec. 3) provides that "Congress shall have power to dispose of and make all needful rules and regulations respecting the territory or the property belonging to the United States." This is the supreme law of the land and embodies an express grant of power to the National Government. (Light *v.* United States, 220 U. S., 537; Kansas *v.* Colorado, 206 U. S., 89.) It has been construed to mean that title and rights in and to the public lands are created by the acts of Congress, and must be governed by their provisions whether they be hard or lenient, and that no rights whatsoever can be obtained in the lands of the United States except as Congress may consent. (Rector *v.* Ashley, 6 Wall., 142; Frisbie *v.* Whitney, 9 Wall., 187; Emblem *v.* Lincoln Land Co., 184 U. S., 660; Wilcox *v.* Jackson, 13 Peters, 498; Jourdan *v.* Barrett, 4 How., 169; United States *v.* Chicago, 7 How., 185; Butte City Water Co. *v.* Baker, 196 U. S., 126; Kansas *v.* Colorado, 206 U. S., 46; Light *v.* United States, supra.) After quoting this provision of the Constitution the Supreme Court, in Jourdan *v.* Barrett, at page 184, said:

"For the disposal of public lands, therefore, in the new States, where such lands lie, Congress may provide by law; and having the constitutional power to pass the law, it is supreme; so Congress may prohibit and punish trespassers on the public lands. Having the power of disposal and of protection, Congress alone can deal with the title, and no State law, whether of limitations or otherwise, can defeat such title."

Wilcox *v.* McConnel [Jackson] dealt with public lands within the State of Illinois. Concerning the asserted power of the State to legislate respecting the title to such lands within its borders the court said:

"The effect of this would be, not that Congress had the power of disposing of the public land, and prescribing the rules and regulations concerning that disposition, but that Illinois possessed it. That would be to make the laws of Illinois paramount to those of Congress in relation to a subject confided by the Constitution to Congress only. And the practical result in this very case would be, by force of State legislation, to take from the United States their own land, against their own will, and against their own laws."

In Camfield *v.* United States (167 U. S., 518) it was held that the Government of the United States may legislate for the protection of its lands, though such legislation may involve the exercise of the police power; and may complain of and take steps to prevent acts of individuals, in fencing in its lands, even though done for the purpose of irrigation and pasturing. In the opinion Mr. Justice Brown, speaking for the court, said:

"While the lands in question are all within the State of Colorado, the Government has, with respect to its own lands, the rights of an ordinary proprietor, to maintain its possession and to prosecute trespassers. It may deal with such lands precisely as a

private individual may deal with his farming property. It may sell or withhold them from sale. It may grant them in aid of railways or other public enterprises. It may open them to preemption or homestead settlement; but it would be recreant to its duties as trustee for the people of the United States to permit any individual or private corporation to monopolize them for private gain and thereby practically drive intending settlers from the market."

In *Light v. United States*, supra, the United States had suffered its public lands to be used for pasturage; and there thus grew up a sort of implied license that those lands might be used so long as the Government did not withdraw its consent. The court held that the "failure to object, however, did not confer any vested right on the complainant, nor did it deprive the United States of the power of recalling any implied license under which the land had been used for private purposes." It held, further, that the "United States can prohibit absolutely or fix the terms on which its property may be used. As it can withhold or reserve the land, it can do so indefinitely." But it is profitless to discuss further this asserted power of the State to dispose of interests in the public lands, even though it were admitted that the subject otherwise admits of discussion, in view of the express stipulation that such lands shall remain at the sole and entire disposition of the United States. The act enabling the people of Utah to form a constitution and State government imposes the condition:

"That the people inhabiting said proposed State do agree and declare that they forever disclaim all right and title to the unappropriated public lands lying within the boundaries thereof; * * * and that until the title thereto shall have been extinguished by the United States, the same shall be and remain subject to the disposition of the United States." (Compiled laws of Utah, 1907, p. 29.)

And in the constitution of Utah subsequently adopted this provision was incorporated in terms and became a part of the organic law of that State. (Constitution of Utah, art. 3, sec. 2, Compiled laws of Utah, 1907, p. 45.) Concerning a similar provision in the Minnesota constitution, the Supreme Court has said:

"The provisions of the enabling act and the State constitution, before referred to, secure to the United States full control of the disposition of the public lands within the limits of the State. * * * It would be a part of the power reserved in Congress to determine the terms and conditions upon which title should effectually pass from the Government." (Stearns *v.* Minnesota, 179 U. S., 223–251.)

That a power may be injuriously exercised is no reason for a misconstruction of the scope and extent of that power. The Government of the United States has shown no disposition to deal unjustly with the States, nor with their citizens in this respect. (Stearns *v.* Minnesota, supra, p. 243; Oceanic Steam Nav. Co. *v.* Stranahan, 214 U. S., 320.) We must conclude, therefore, that the power of Congress to dispose of and make all needful rules and regulations respecting the territory or other property belonging to the United States, including rights of the nature here involved, is supreme; and in conferring upon the Secretary of the Interior power to establish such rules and regulations as may be necessary to supplement the legislation Congress acts within its constitutional power. (United States *v.* Grimaud, 220 U. S., 506; Light *v.* United States, 220 U. S., 523; Oceanic Steam Nav. Co. *v.* Stranahan, 214 U. S., 320.) The exertion by Congress of a power which is granted in express terms must supersede all legislation over the same subject by the States. (Michigan Central R. R. Co. *v.* Vreeland, 227 U. S., 59–66; St. Louis, Iron Mountain & Southern Railway Co. *v.* Hesterly, 228 U. S., 702; Gulf, Colorado & Santa Fe Railway Co. *v.* Hefley, 158 U. S., 98–104.)

To sustain its contention, therefore, appellee must point to some express grant by the Government, or at least to subsisting legislation from which the grant may be inferred, or by which its claims have been recognized and preserved. It must be conceded at the outset that statutes granting privileges of relinquishing rights of the public are to be strictly construed against the grantee. (Wisconsin Central Railroad

Co. *v.* United States, 164 U. S., 190; Camfield *v.* United States, 167 U. S., 518; United States *v.* Minidoka & Southwestern Railroad Co. (C. C. A.), 190 Fed., 491.) Appellee relies upon the ninth section of the act of July 26, 1866, now section 2339 of the Revised Statutes. It is important to consider the nature and extent to confer [differ] or to confirm as the case may be. In Jennison *v.* Kirk (98 U. S., 453) the Supreme Court of the United States had occasion to examine that act with this consideration in mind. Speaking through Mr. Justice Field, it said:

"The position of the plaintiff's counsel is, that of the two rights mentioned in this section, only the right to the use of water on the public lands, acquired by priority of possession, is dependent upon local customs, laws, and decisions of the courts; and that the right of way over such lands for the construction of ditches and canals is conferred absolutely upon those who have acquired the water right, and is not subject in its enjoyment to the local customs, laws, and decisions. This position, we think, can not be sustained. The object of the section was to give the sanction of the United States, the proprietor of the lands, to possessory rights, which had previously rested solely upon the local customs, laws, and decisions of the courts, and to prevent such rights from being lost on a sale of the lands. * * *

"It merely recognized the obligation of the Government to respect private rights which had grown up under its tacit consent and approval. * * *

"Whilst acknowledging the general wisdom of the regulations of miners, as sanctioned by the State and molded by its courts, and seeking to give title to possessions acquired under them, it must have occurred to the author, as it did to others, that if the title of the United States was conveyed to the holders of mining claims, the right of way of owners of ditches and canals across the claims, although then recognized by the local customs, laws, and decisions, would be thereby destroyed, unless secured by the act."

It will thus be seen that this legislation constituted no grant of specific rights by the Congress of the United States. The efficiency of local customs, laws, and decisions to supersede the disposing power of Congress is denied. The purpose was to confirm title to possessions acquired under forms and regulations sanctioned by the State and molded by its courts, with the acquiescence and tacit encouragement of the Government. The act "was rather a voluntary recognition of a preexisting right of possession, constituting a valid claim to its continued use, than the establishment of a new one." (Broder *v.* Water Co., 101 U. S., 274; Atchison *v.* Peterson, 20 Wall., 507–512.) In view of the express power conferred upon Congress by the Constitution, and reserved to it by the organic law of the State of Utah, it can not be successfully urged that such legislation committed the Government to a policy that should be irrevocable. (Light *v.* United States, 220 U. S., 523–533; Gutierres *v.* Albuquerque Land & Irrigation Co., 188 U. S., 545; United States *v.* Rio Grande Dam & Irrigation Co., 174 U. S., 690.) In the latter case it was expressly held that the act of September 19, 1890, did operate to modify and restrict section 2339. The court said:

"As this is a later declaration of Congress, so far as it modifies any privileges or rights conferred by prior statutes it must be held controlling, at least as to any rights attempted to be created since its passage; and all the proceedings of the appellees in this case were subsequent to this act."

It remains then to consider whether the Congress, prior to any possession acquired by appellee, had withdrawn or limited the recognition accorded by the act of July 26, 1866, to such extent that appellee may not rely upon that act in defense of this action.

As has been stated, the Government's position is that the act of May 14, 1896, and the rules and regulations promulgated thereunder, by making specific and comprehensive provision respecting a subject, to wit, the generation, manufacture, and distribution of electric power, conceived to be embraced within the terms of the prior and more general act, withdraws that subject from the operation of the former act to

the extent to which it is governed by such special provision and is *pro tanto* a substitute for and repeal of the general statute which formerly governed. It is a well-settled principle of construction that specific terms covering a given subject matter will prevail over general language of the same or another statute which might otherwise prove controlling. (Kepner *v.* United States, 195 U. S., 100; Jackson *v.* Chicago, Rock Island & Pacific Railway Co. (C. C. A.), 178 Fed., 432; Gilkeson *v.* Missouri Pacific Railway Co., 222 Mo., 173.)

"If the two are repugnant in any of their provisions, the latter act, without any repealing clause, operates to the extent of the repugnancy as a repeal of the first; and even where two acts are not in express terms repugnant, yet if the latter act covers the whole subject of the first, and embraces new provisions, plainly showing that it was intended as a substitute for the first act, it will operate as a repeal of that act." (United States *v.* Tynen, 11 Wall., 88–92; Daviess *v.* Fairbairn, 3 How., 636; Tracy *v.* Tuffly, 134 U. S., 206–223.)

The doctrine is very comprehensively stated in Hawkins *v.* Bare, 63 W. Va., 431, 60 S. E. Rep., 391–393. It is there said:

"Neither the intention to substitute, nor the intention to create an exception from the general law, depends upon inconsistency between the new or special act and the old or general act, in the sense of repugnancy in terms. It is inconsistency in point of intention, an obvious, but unexpressed, repugnancy. It is a mere question of whether the legislature intended to make a complete law governing the subject matter. If that be apparent, there is a substitution or an exception, as the case may be, although there is no express repeal, exception, or substitution; and the two acts might be combined by making the later or special one an addition to the older or general one, and treating it as an amendment, whereby a different result would be obtained. In every case of this kind the two courses are open to the court. Both acts may be allowed to stand and operate together by treating the later or special one as an amendment, and certain results thereby obtained, or the new or special act may be considered a substitute or exception, and the old or general statute thereby set aside either wholly or partially, and a different result so obtained; and the doubt is always resolved by the character and carried into effect."

The Government does not contend that section 2339 of the Revised Statutes has been wholly repealed, but merely that the subsequent act of 1896 has withdrawn from the operation of that section the subject of generating, manufacturing, or distributing electric power, the manner of acquiring rights of way over the public lands for those purposes, and the nature and extent of such rights. We think this contention is sound. The terms of the original statute are broad enough to include the specific form of manufacture now under consideration. (Pollock *v.* Farmers' Loan & Trust Co., 158 U. S., 601–632.) Control over the disposition of the public lands and all rights and interests therein remain unimpaired in the Congress. Evidently that body perceived that the time had come when changed conditions and the complex interests and relations of our national life demanded that, with respect to this particular form of industry, the application of the former act, as worded and construed, should be modified and restricted; therefore, it enacted the subsequent legislation. (United States *v.* Rio Grande Dam & Irrigation Co., 174 U. S., 690–708; Camfield *v.* United States, 167 U. S., 518–524.)

There can be no doubt that Congress intended to and did assume complete control of the subject matter and made and authorized specific and comprehensive provisions respecting it. This appears not only from the act in question but from other legislation connected therewith and supplemental thereto. (Act of Mar. 3, 1891, 26 Stat., 1095; act of Jan. 21, 1895, 28 Stat., 635; act of May 11, 1898, 30 Stat., 404; act of Feb. 15, 1901, 31 Stat., 790; act of Feb. 1, 1905, 33 Stat., 628; act of Mar. 4, 1911, 36 Stat., 1233, 1253.) Laws passed subsequently to appellee's possession can not of course affect any vested rights theretofore acquired, but they are pertinent as reflecting and

revealing the purpose of Congress throughout this legislation. The acts of 1891, 1901, and 1911 contain express provisions for revocation or forfeiture; in that of 1891 is found this exception:

"The privilege herein granted shall not be construed to interfere with the control of water for irrigation and other purposes under the authority of the respective States or Territories."

Obviously, that act was not intended to interfere with the operation of section 2339; but no such proviso is found in the act of May 14, 1896. That of May 11, 1898, contains this clause:

Said rights of way may be used for purposes of water transportation, for domestic purposes, or for development of power, as subsidiary to the main purpose of irrigation.

It will thus be seen that Congress has wisely adapted and molded its legislation to meet the requirements of irrigation in a "dry and thirsty land."

The result is that whatever rights to burden the public lands may have been recognized or confirmed by section 2339 of the Revised Statutes, those involving the generation, manufacture, and distribution of electric power have been withdrawn, modified, and restricted by the subsequent act of May 14, 1896. This later legislation became effective prior to the initiation of appellee's claim. The power company has not availed itself of the provisions of this later statute; therefore its rights, if any, are subordinate to those of the Government. The decree below must be reversed and the case remanded for further proceedings in accordance with the views herein expressed.

This decision makes it incumbent on those seeking to utilize the public lands for rights of way for water-power development to acquire rights of way under the specific acts which control. The specific purpose of each is explained by Mr. Grover in the following section.

Inasmuch as any control by the Federal Government of water-power development on nonnavigable streams, such as the Deschutes, rests on the ownership of public lands, it has become a well-established national policy to retain in public ownership land essential to such power development.

WATER-POWER WITHDRAWALS.

DEVELOPMENT OF POLICY.

Widespread public interest was first focused on the disposition of water powers by two messages of President Roosevelt to Congress in April, 1908, and January, 1909, vetoing special acts conferring franchises for the development of water power on the ground that adequate provision for the protection of the interests of the general public had not been incorporated therein. His attitude toward the disposition of water power was also expressed in a letter to the Senate Committee on Commerce on March 13, 1908, in which he states:

No right involving water power should be granted to any corporation in perpetuity, but only for a length of time sufficient to allow them to conduct their business profitably. A reasonable charge should, of course, be made for valuable rights and privileges which they obtain from the National Government. The values for which this charge is made will ultimately, through the natural growth and orderly development of our population and industries, reach enormous amounts. A fair share of the increase should be safeguarded for the benefit of the people from whose labor it springs.

While this question of legislative policy was being discussed, administrative action for the purpose of preventing the alienation of water power was in progress. The Reclamation Service, under instructions from Secretary Garfield, recommended for his approval withdrawals affecting approximately 3,500,0 0 acres along western rivers in the period from December 4, 1908, to February 27, 1909. These withdrawals had their legal basis in part in the general powers of the Secretary of the Interior as the supervisor of the public lands, and in part in the authority conferred by the reclamation act (act of June 17, 1902, 32 Stat., 388) to withhold from disposition public lands necessary to reclamation projects. The Forest Service, in the period from March to August, 1908, similarly recommended the withdrawal as administrative sites of a large number of small tracts within or near national forests, which were believed to occupy strategic positions with relation to future power development. The purposes of these administrative sites as regards power was not, however, generally apparent until March 2, 1909, when Secretary Garfield recommended their withdrawal from all entry except under the right-of-way acts, thus specifically holding them for use in connection with irrigation and power development. This was one of the last acts of Secretary Garfield's administration.

His successor, Secretary Ballinger, undertook almost immediately the consideration of the water-power situation and directed his attention to the advisability of retaining in force the first form and administrative withdrawals approved by Secretary Garfield. Fearing as a result of his investigation that the withdrawals rested on no secure statutory foundation, he directed their revocation, with the result that in April, 1909, nearly all the withdrawn lands were restored to entry. Strong opposition to this action developed almost immediarely, however, with the result that it was reconsidered. On April 23, 1909, after a conference between the Secretary, the Director of the Reclamation Service, and the Director of the Geological Survey, the latter was directed to "make an investigation of water-power sites on the public domain outside of national forests, which are not included within withdrawals for reclamation projects, with a view to securing at the next session of Congress legislation to control and regulate their disposition." Investigations were immediately undertaken by the Geological Survey along the lines directed, and as a result large areas of public lands controlling streams valuable for power development were promptly withdrawn. These withdrawals were styled "Temporary power site withdrawals," and were in terms in aid of legislation. The first of these withdrawals on Deschutes River reads as follows:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, June 29, 1909.

The SECRETARY OF THE INTERIOR.

SIR: In accordance with your instructions of April 23, I have the honor to submit the following recommendation, which involves 6,716 acres, 987 acres being entered land:

TEMPORARY POWER-SITE WITHDRAWAL NO. 26.

(Deschutes River, Oreg.)

In aid of proposed legislation affecting the disposal of the water-power sites on the public domain, all public lands in the following list are temporarily withdrawn, pending examination, from all forms of entry, selection, disposal, settlement, or location, and all existing claims, filings, and entries are temporarily suspended. All valid entries heretofore made may proceed up to and including the submission of final proof, but no purchase money will be received nor final certificate of entry issued until further orders.

(Willamette Principal Meridian.)

(List of Lands.)

Very respectfully, (Signed) H. C. RIZER,
Acting Director.

Approved June 30, 1909, and sent to General Land Office.

(Signed) FRANK PIERCE,
Acting Secretary.

During the next session of Congress consideration was given to the entire subject of withdrawals of public land, and as a result a general act was passed—the act of June 25, 1910 (36 Stat., 847)—authorizing the President to make withdrawals. A special act (36 Stat., 855) was passed on the same day as secs. 13 and 14 of the Indian appropriation act, authorizing the Secretary of the Interior to withdraw water-power sites on Indian reservations. Almost immediately after the passage of the general withdrawal act the President confirmed, under its provisions, all outstanding withdrawals. This order, dated July 2, 1910, reads as follows:

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, July 1, 1910.

The SECRETARY OF THE INTERIOR.

SIR: In accordance with your instructions, I recommend the withdrawal for water-power sites of the following areas:

ORDER OF WITHDRAWAL.

It is hereby ordered that those certain orders of withdrawal, made heretofore (listed by date and numbers) and including the lands more particularly described and set forth below, be, and the same are hereby ratified, confirmed, and continued in full force and effect, and the lands reserved for water-power sites, subject to all of the provisions, limitations, exceptions, and conditions contained in the act of Congress entitled "An Act to authorize the President of the United States to make withdrawals in certain cases," approved June 25, 1910:

(List of lands.)

Very respectfully,

GEO. OTIS SMITH,
Director.

JULY 1, 1910.

Respectfully referred to the President with the recommendation that same be approved.

R. A. BALLINGER,
Secretary.

Approved July 2, 1910, and referred to the Secretary of the Interior.

WM. H. TAFT,
President.

The act of June 25, 1910, made certain exceptions to the force of withdrawals in that it excluded bona fide settlements, homestead, and desert land claims, and mineral claims, except coal, oil, gas, and phosphate, from its operation. The act of August 24, 1912 (37 Stat., 497), amended the act in its relation to mineral claims, so that only metalliferous mineral deposits were excepted from its operation. Since this amendment there has been no legislative action by Congress upon this subject.

WITHDRAWALS IN THE DESCHUTES BASIN.

The first withdrawals with a view to utilization or control of the water power by the Government were not made until 1906. In connection with the John Day project of the Reclamation Service, lands along Deschutes River in T. 2 S., R. 15 E.; T. 3 S., R. 15 E.; T. 1 S., R. 16 E.; and T. 2 S., R. 16 E., were withdrawn on April 25 of that year, and in connection with the Umatilla project lands in T. 1 N., R. 15 E.; T. 2 N., R. 15 E.; and T. 1 N., R. 16 E., were withdrawn on June 25, 1906. These withdrawals, made in accordance with the authority of the reclamation act, were in the first form, from all disposition, since the Reclamation Service proposed to use the power developed at sites on the Deschutes for pumping water for irrigation. They are now in force.

On recommendation of the Director of the Reclamation Service, Secretary Garfield withdrew on October 24, 1908, under the first form, reclamation act, the lands adjacent to the Deschutes and Metolius rivers from T. 4 S., R. 14 E., to T. 11 S., R. 9 E. This withdrawal was not among those revoked by Secretary Ballinger.

After the Geological Survey was authorized to make investigations and recommend withdrawals of water-power sites, the status of lands along the Deschutes River was investigated, and certain tracts which, though included in the first form reclamation withdrawals for the John Day and Umatilla projects, were entered land and not affected by the withdrawal, were withdrawn for power purposes. In addition, the withdrawal of lands along the Deschutes was extended to include lands in Tps. 11 to 15 S., R. 12 E. This withdrawal, temporary power site withdrawal No. 26, was approved by the Acting Secretary on June 30, 1909. On December 30, 1909, the withdrawal under the first form, reclamation act of October 24, 1908, was, by the Secretary's

order, changed to temporary power site withdrawal No. 66, certain lands not valuable for power development or in private ownership being eliminated.

On July 2, 1910, these withdrawals, as well as others then outstanding in the Deschutes basin, were confirmed and continued, subject to the provisions of the withdrawal act of June 25, 1910 (36 Stat., 847). A withdrawal of the lands along Deschutes and Metolius rivers in the Warm Springs Indian Reservation which appeared to be valuable for power development was made in accordance with the provisions of the special withdrawal act relating to Indian reservations (act of June 25, 1910, 36 Stat., 855, 858) on November 1, 1910.

Other withdrawals and restorations, based upon a growing knowledge of the water-power resources of the basin and of the particular lands which are necessary for or may be utilized for this development, have been made more recently. The following table lists withdrawals and restorations in the Deschutes basin in the order of their approval, and gives the approximate acreage of each. For completeness, the outstanding withdrawals under the reclamation act are also included.

Withdrawals for the control of water power in the Deschutes basin.

Description of order.	Date of approval.	Approximate acreage withdrawn.	Approximate acreage restored.
Reclamation act, first form, John Day project	Apr. 25, 1906	24,960	.....
Reclamation act, first form, Umatilla project	June 25, 1906	13,600	.....
Reclamation act, Deschutes and Metolius rivers, power purposes	Oct. 24, 1908	34,735	.....
Temporary power site withdrawal No. 26, Deschutes River, Oreg.	June 30, 1909	6,716	.....
Temporary power site withdrawal No. 62, White River, Oreg.	Nov. 16, 1909	2,682	.....
Temporary power site withdrawal No. 63, Crooked River, Oreg.	.....do.....	20,820	.....
Temporary power site withdrawal No. 68, upper Deschutes River, Oreg.	Nov. 20, 1909	3,262	.....
Temporary power site withdrawal No. 66, Deschutes and Metolius rivers, Oreg.	Dec. 30, 1909	14,139	20,596
Temporary power site withdrawal No. 125, Deschutes River No. 2	Mar. 18, 1910	2,240	.....
Power site restoration No. 24, upper Deschutes River	Oct. 27, 1910	.....	1,990
Indian power site reserve No. 2, Deschutes and Metolius rivers	Nov. 1, 1910	12,534	.....
Power site restoration No. 25, Crooked River	Dec. 1, 1910	.....	18,740
Power site reserve No. 288, Deschutes River	Sept. 23, 1912	80	.....
Modification of power site reserve No. 66, Deschutes River	Oct. 8, 1912	.....	106
Power site reserve No. 334, Deschutes River No. 4	Jan. 27, 1913	41	.....
Modification of power site reserves Nos. 66 and 125, Deschutes River.	Feb. 21, 1913	.....	160
Reclamation act, first form, Columbia southern project	July 23, 1913	45,120	.....
Power site reserve No. 294, Deschutes River and tributaries (Indian reservation)	Oct. 8, 1913	61,840	.....
Power site reserve No. 412, Deschutes River and tributaries (No. 6)	Jan. 2, 1914	1,960	.....
Modification of power site reserve No. 66, Deschutes River, Oreg.	Jan. 13, 1914	.....	16
Power site reserve No. 425, Crooked River	Mar. 9, 1914	1,400	.....

Withdrawals in force under reclamation act of June 17, 1902	83,680
Withdrawals in force under general withdrawal act of June 25, 1910 (36 Stat., 847)	45,067
Withdrawals in force under Indian withdrawal act of June 25, 1910 (36 Stat., 855, 858)	74,374
Total withdrawals in force for reservation of water power	203,121

Power site withdrawals outstanding on March 1, 1914,[1] are indicated on Plates XXVI, XXVII, XXVIII.

The areas shown are the gross areas withdrawn and no attempt has been made to indicate the status of the withdrawn lands. It is known that the withdrawals included some areas of entered land and a few tracts have doubtless passed to patent since the orders were issued, under the special provisions of the withdrawal act. By far the greater part of the lands included in power-site reserves are, however, still in public ownership.

RAILROAD RIGHTS OF WAY.

The lower section of the canyon of Deschutes River is occupied by two constructed railroads—the Deschutes Railroad, leased by the Oregon-Washington Railroad & Navigation Co., a subsidiary of the Union Pacific, and the Oregon Trunk Railway, which is associated with the Spokane, Portland & Seattle Railroad and controlled by the Hill interests. The Oregon Trunk Railway crosses Columbia River near the mouth of the Deschutes and closely parallels the west bank south to North Junction, where it crosses to the east side of the river, which it follows to the mouth of Willow Creek. It ascends Willow Creek to the plateau north of Crooked River and thence continues southward, crossing Crooked River by a high bridge west of Prineville. The line then passes over the plateau south of Crooked River, terminating at Bend. Its total length is 156.9 miles.

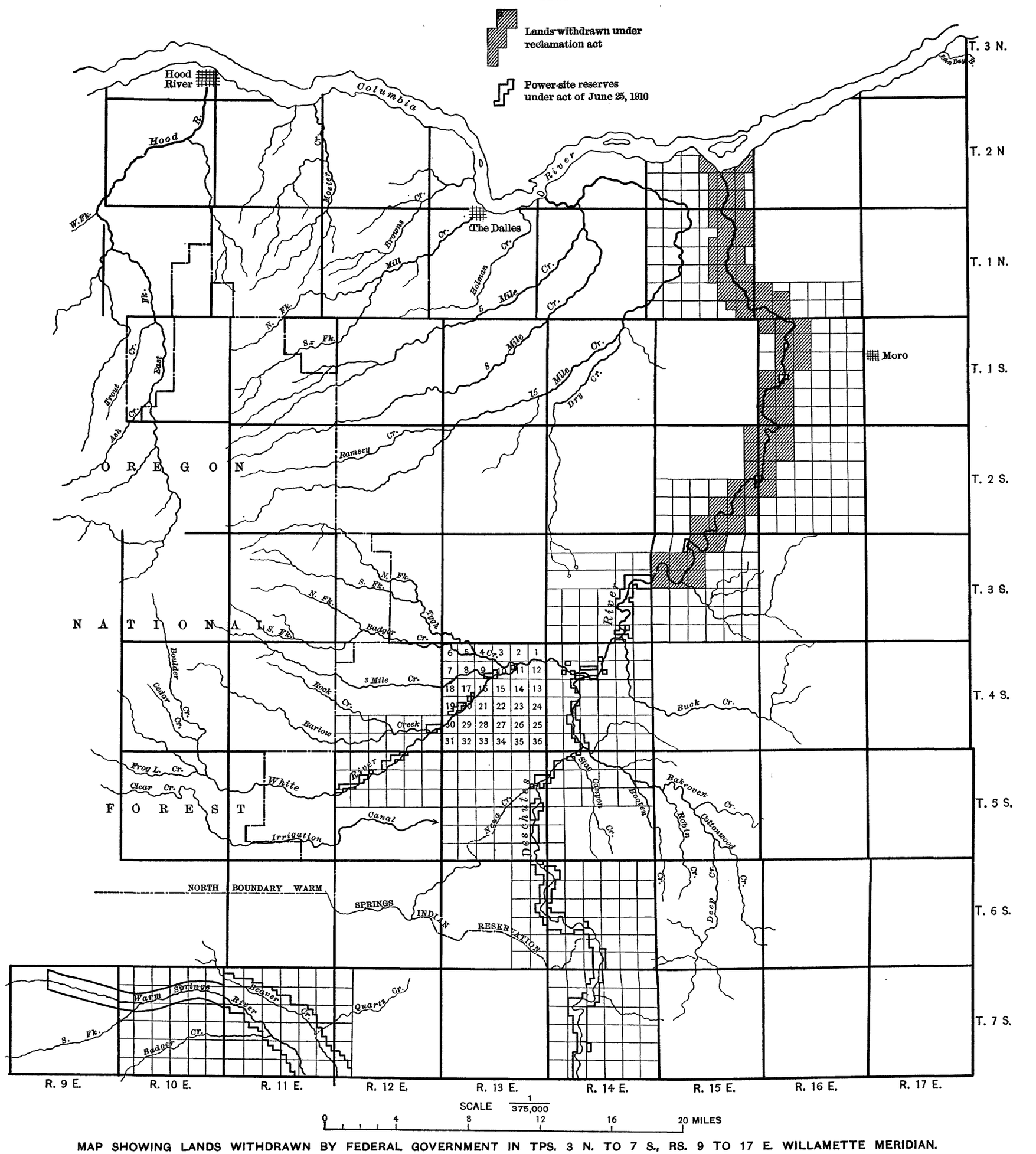
The Deschutes Railroad leaves the main line of the Oregon-Washington Railroad & Navigation Co. at Deschutes Junction, near The Dalles, and follows the east bank of the Deschutes south to the mouth of Trout Creek, using the valley of this stream as a means of exit from the Deschutes canyon to the plateau. Between North Junction and South Junction and between Metolius and Bend the Deschutes Railroad uses the tracks of the Oregon Trunk Railway. From the mouth of the Deschutes southward to T. 7 S., R. 14 E., the river is thus paralleled by two railroad lines, one on each bank, and thence to the mouth of Willow Creek by a single line on the east bank.

Surveys for these railroads were made in 1908 and 1909. Applications for rights of way under the act of March 3, 1875 (18 Stat., 482),

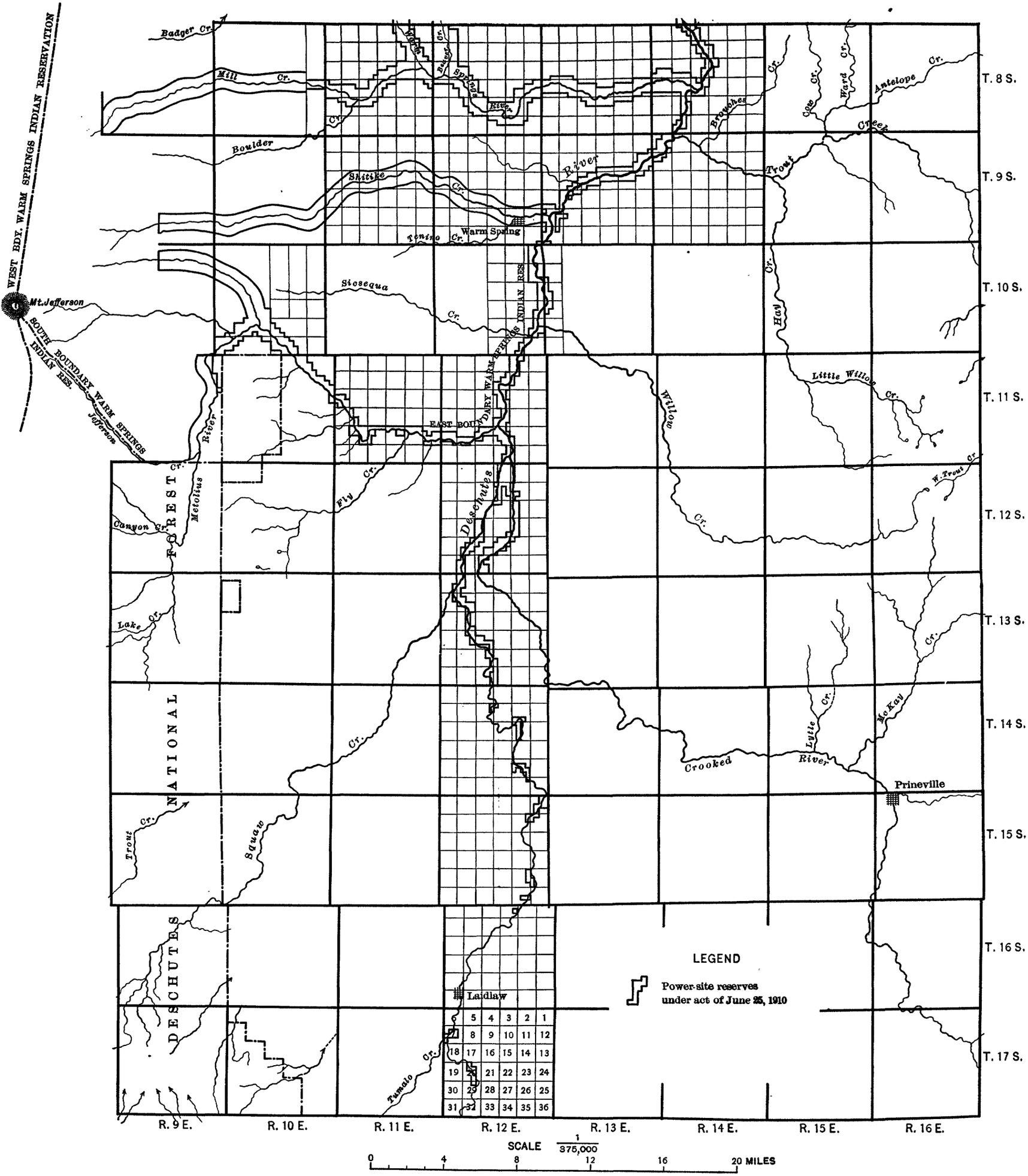
[1] Power-site reserve No. 425, approved March 9, 1914, was created after the preparation of Plate XXVII and is not shown thereon. It includes the following areas:

Willamette meridian.

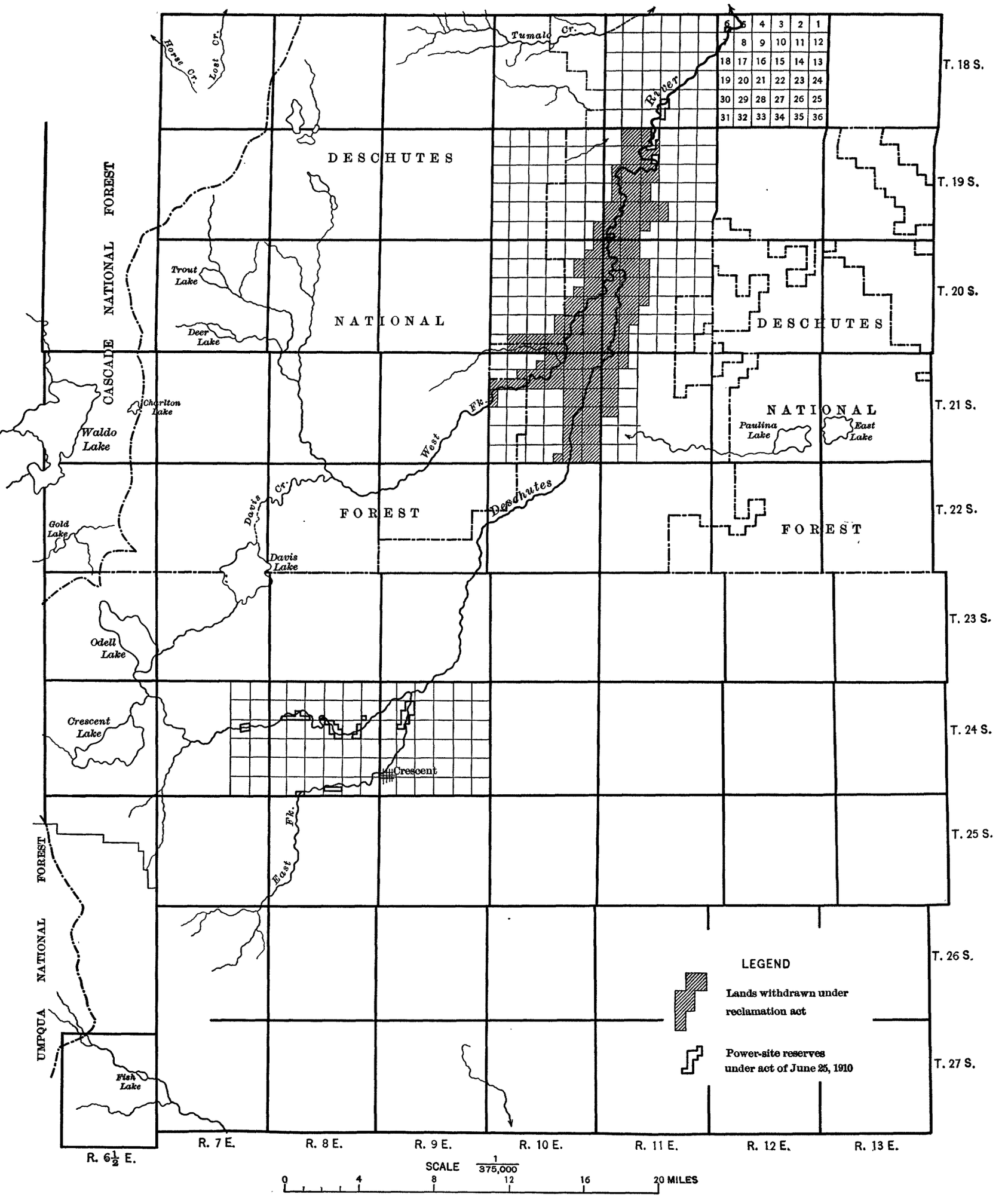
T. 12 S., R. 12 E., sec. 33, SW. ¼ of NE. ¼.
T. 13 S., R. 12 E., sec. 3, lots 7, 8, and 9.
sec. 4, lots 2, 3, 6, and 7, SW. ¼ of NE. ¼, SE. ¼ of NW. ¼, W. ½ of SE. ¼.
sec. 9, NE. ¼ of NE. ¼.
sec. 10, NE. ¼, N. ½ of NW. ¼, N. ½ of SE. ¼, SE. ¼ of SE. ¼.
sec. 11, SW. ¼ of SW. ¼.
sec. 13, lots 12, 13, and 14.
sec. 14, lots 3, 5, 6, and 12, NW. ¼.
sec. 24, SW. ¼ of NE. ¼.



MAP SHOWING LANDS WITHDRAWN BY FEDERAL GOVERNMENT IN TPS. 3 N. TO 7 S., RS. 9 TO 17 E. WILLAMETTE MERIDIAN.



MAP SHOWING LANDS WITHDRAWN BY FEDERAL GOVERNMENT IN TPS. 8 TO 17 S., RS. 9 TO 16 E. WILLAMETTE MERIDIAN.



MAP SHOWING LANDS WITHDRAWN BY FEDERAL GOVERNMENT IN TPS. 18 TO 27 S., RS. 6½ TO 13 E. WILLAMETTE MERIDIAN.

were promptly filed by both companies and construction work was pushed forward with great rapidity, so that by the summer of 1910 it had practically been completed throughout the canyon. The road was completed to Bend in 1911.

From time to time the right of way applications filed by the companies for various sections of their roads have been approved by the Secretary of the Interior, the last maps having been approved January 20, 1914. Some of the maps were approved subject to a stipulation on the part of the railway that it would "elevate its tracks * * * in such manner as may be deemed necessary by the Secretary of the Interior for the purpose of utilizing to the best advantage any public lands * * * for the conservation or use of power, power sites, or power purposes." The greater portion of the rights of way was, however, granted without stipulations or agreements on the part of the railroad companies to make provision for the development of water power from Deschutes River.

The relation of the Oregon Trunk Railway or the Oregon Trunk Line, as it was first incorporated, to Deschutes River, is essentially the same as that of the Deschutes Railroad. The Oregon Trunk Railway is at first but a few feet above the Deschutes, but at the west line of sec. 21, T. 2 N., R. 15 E., the railroad begins to climb, and on the south line of sec. 35 of this township it passes the Moody dam site with the subgrade at approximately 332 feet, United States Geological Survey datum. In this 5 miles the average gradient is about 0.54 per cent. From the Moody dam site southward the grade is level to near the east line of sec. 31, T. 1 N., R. 16 E., at which point the subgrade is about 45 feet above low water in Deschutes River. The railroad then rises approximately with the river to sec. 5, T. 1 S., R. 16 E., where the subgrade is 33 feet above low water. A second elevation of the tracks relative to the river then begins, culminating at the dam site in secs. 5 and 6, T. 2 S., R. 16 E., where the railroad is 120 feet above low water. Having passed this point, the railroad continues at the same elevation and in consequence is only 25 feet above low water in sec. 27, T. 2 S., R. 15 E. The railroad then ascends with the river to sec. 26, T. 3 S., R. 24 E. Here the railroad begins a third rise with relation to the river, which reaches its maximum in lot 2, sec. 3, T. 4 S., R. 14 E., where clearance has been provided for a 70-foot dam. The gradient then again becomes flat, and in sec. 8, T. 4 S., R. 14 E., the subgrade is 20 feet above low water and probably not over 5 feet above high water. A line just a few feet above high water is then followed until the railroad leaves the river at the mouth of Willow Creek.

Provision has thus been made by the railroads for the construction of only three high-power dams on the lower Deschutes—at the Moody,

the Reclamation, and Sherar Falls power sites. At only one site does the present location of the railroads permit the complete utilization of the water power as outlined by Mr. McCaustland in another part of this report (pp. 124–132). At the Moody site the railroads are 150 feet above the river—30 feet less than the proposed height of the dam at that site. To secure this additional head at the present time would require the relocation of about 16 miles of railroad if present grades are not exceeded. No provision has been made for a dam at the Lockit site, the railroads at this point being but slightly above high water. Full provision was made for the dam at the Reclamation power site, and no relocation would be necessary at this point The Sinamox and Oak Brook sites would, if developed, require the relocation of both roads, or about 15 miles of line.

The railroads at the Sherar Falls power site are 70 feet above low water as compared with the 88 feet considered necessary, and 6 miles of each road would have to be relocated to clear a dam of this height, providing that the present maximum gradient were not exceeded. At the Oak Springs, Maupin, and Frieda sites both railroads are at low elevations. Farther up the river at the White Horse Rapids and Coleman sites there is only one track to be relocated. The railroads leave the canyon below the Mecca, Pelton, and Metolius sites.

It thus appears that of the 14 sites on Deschutes River only four can be constructed as outlined by Mr. McCaustland without interference from the railroads. Provision for partial development has been made at two others. At eight sites there is an absolute conflict between the railroads and the power developments proposed, and such development must await the time when the power becomes of sufficient value to warrant the heavy cost of the reconstruction of the railroads. The cost of the Deschutes Railroad alone, in that portion along the river, was about $60,000 per mile.[1] The situation is further aggravated by the fact that through railroad rivalries rather than because of the needs of the country two parallel and competing lines were constructed up the Deschutes, either of which would doubtless serve the territory for years to come. Not only must the public in the long run pay for the second and superfluous line of road, but it is also saddled with the economic loss resulting from the impairment of water-power values. It is probable that one line of road so located as to allow for the fullest development of the water powers and equal in efficiency to either of the present lines could have been constructed for a sum much less than was expended for the existing roads.

[1] Eng. News, vol. 64, p. 139, 1910.

GOVERNMENT PERMITS FOR POWER AND RESERVOIR SITES.

By N. C. GROVER.

CLASSIFICATION OF LANDS.

Except as Congress has made special grants of land, no general provision has been made for the alienation of lands of the United States unless valuable for agriculture or for minerals. Land valuable in connection with water-power development, which have passed from the control of the Government, have been patented, therefore, either as a grant—generally as the result of the use of some form of script—or under the guise of mineral or agricultural lands. Until recent years no classification of the public lands, except as regards minerals, has been attempted. The withdrawal act of June 25, 1910 (36 Stat., 847), authorized the President to withdraw for certain purposes public lands valuable for water power or reservoir sites. The classification of lands valuable as power and reservoir sites, which had been progressing during the two or three preceding years, was continued under this new law.

RIGHTS OF WAY.

Land so withdrawn, or other public land desired for use in connection with the development of water power, may be utilized by private parties or corporations under one of several right-of-way acts which provide different forms of tenure in accordance with the use that is to be made of the developed power. Rights of way "for the construction and maintenance of dams, reservoirs, water plants, ditches, flumes, pipes, tunnels, and canals" for municipal, mining, and milling purposes within or across national forests are granted by the act of February 1, 1905 (33 Stat., 628), under general regulations to be prescribed by the Secretary of the Interior, while the act of February 15, 1901 (31 Stat., 790), authorizes the issuance of revocable permits for the use of rights of way for power and other purposes on public lands, both inside and outside of national forests. Rights of way for the development of power as subsidiary to the main purpose of irrigation are granted under the act of March 3, 1891 (26 Stat., 1095), as amended by the act of May 11, 1898 (30 Stat., 404). The Secretary of the Interior, by amendment dated January 15, 1913, of the regulations approved June 6, 1908, concerning rights of way through public lands and reservations for canals, ditches, and reservoirs for irrigation, under the act of March 3, 1891, and under the act of May 11, 1898, has defined the meaning of "subsidiary to the main purpose of irrigation" as follows:

The words "for the development of power as subsidiary to the main purpose of irrigation," as used in section 2 of the said act of May 11, 1898, are not to be construed as

authorizing a power use which is merely incidental to the irrigation use. An incidental feature of an irrigation project may not be subsidiary; for "subsidiary" implies not only that the feature is subordinate and inferior to the main purpose, but that it is "in aid of" that purpose and a part of it, although in an inferior and tributary capacity. The development of power under section 2 of the said act of 1898 is restricted to the development of power exclusively for such use as does in fact aid irrigation, as the pumping of irrigation water. Any other use of power developed under said section 2 is prohibited.

REVOCABLE PERMITS.

The law under which developments of hydroelectric power must generally be made, however, is the act of February 15, 1901 (31 Stat., 790), which provides for a revocable permit in the following terms:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of rights of way through the public lands, forest, and other reservations of the United States, and the Yosemite, Sequoia, and General Grant national parks, California, for electrical plants, poles, and lines for the generation and distribution of electrical power, and for telephone and telegraph purposes, and for canals, ditches, pipes and pipe lines, flumes, tunnels, or other water conduits, and for water plants, dams, and reservoirs used to promote irrigation or mining or quarrying, or the manufacturing or cutting of timber or lumber, or the supplying of water for domestic, public, or any other beneficial uses to the extent of the ground occupied by such canals, ditches, flumes, tunnels, reservoirs, or other water conduits or water plants, or electrical or other works permitted hereunder, and not to exceed fifty feet on each side of the marginal limits thereof, or not to exceed fifty feet on each side of the center line of such pipes and pipe lines, electrical, telegraph, and telephone lines and poles, by any citizen, association, or corporation of the United States, where it is intended by such to exercise the use permitted hereunder or any one or more of the purposes herein named: *Provided*, That such permits shall be allowed within or through any of the said parks or any forest, military, Indian, or other reservation only upon the approval of the chief officer of the department under whose supervision such park or reservation falls and upon a finding by him that the same is not incompatible with the public interest: *Provided further*, That all permits given hereunder for telegraph and telephone purposes shall be subject to the provision of title sixty-five of the Revised Statutes of the United States, and amendments thereto, regulating rights of way for telegraph companies over the public domain: *And provided further*, That any permission given by the Secretary of the Interior under the provisions of this act may be revoked by him or his successor in his discretion, and shall not be held to confer any right, or easement, or interest in, to, or over any public land, reservation, or park.

This law applies to rights of way for power on all public lands outside of the national forests unless used for the main purpose of irrigation, and for all rights of way for power on lands within national forests unless used for the main purpose of irrigation or for municipal purposes, mining, or milling.

DEPARTMENTAL REGULATIONS RELATING TO PERMITS.

The administration of the act outside of the national forests is under the control of the Secretary of the Interior, whereas within the national forests it is under the control of the Secretary of Agriculture. Each of these secretaries has promulgated regulations pro-

viding for the issuance of permits under the act. These regulations (see 41 L. D., 532, for regulations of the Interior Department, and 42 L. D., 348, for amendment to these regulations) are essentially the same for the two departments and cover the following topics:

1. Preliminary permits for the purpose of obtaining the data required for an application for final permit. Final permits for the construction, maintenance, and operation of power plants.
2. Method and place of filing applications.
3. Priority of applications.
4. Protection of the most beneficial utilization of the site and of prior permittees.
5. Evidence of right to divert and use the water for the power purposes contemplated by the applicant.
6. Tenure for 50 years unless sooner revoked by the Secretary.
7. Definition of terms.
8. Rates of compensation for the public lands involved.
9. Evidence of citizenship of the applicant or, if a corporation, evidence of incorporation and of authority to construct and operate the proposed power plant in the State in which it is located.
10. Maps and technical information which must accompany an application for a preliminary permit for a power plant of more than 100-horsepower capacity.
11. Maps and technical information which must accompany an application for a final permit for a power plant of more than 100-horsepower capacity.
12. Maps and technical information which must accompany an application for a preliminary permit for a power plant of 100 horsepower or less.
13. Requirements for an application for a final permit for a power plant of 100 horsepower or less.
14. Obligations which must be assumed by an applicant for a final permit for a power plant of more than 100 horsepower.
15. Amendments to maps and plans under certain conditions.
16. Extensions of time under certain conditions.
17. Transfer of final permit under certain conditions.
18. Action to be taken in case of an engineer's false affidavit.
19. Action to be taken in case of the violation by a final permittee of any of the provisions of the regulations or conditions of the permit.
20. Abandonment of a power project under permit or any part thereof.
21. Procedure in the department from the time of filing of an application for a power permit to the issuance of the permit.

FINAL PERMITS.

FORMS USED.

The form of final permit now followed by the Department of the Interior is in general that used in the joint permit of the Secretaries of the Interior and Agriculture to the International Power & Manufacturing Co. for the development of a power site on Clark Fork in Washington. This permit, which has been published as Senate Document No. 147, Sixty-third Congress, first session, is reproduced in full below. It shows the essential requirements of the regulations, so far as the obligations of the permittee are concerned, but does not describe the details of the maps and documents which must accompany the application.

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By act of March 4, 1911 (36 Stat., 1253), Congress provided for grants, for periods not exceeding 50 years, of rights of way for transmission for electric power as follows:

That the head of the department having jurisdiction over the lands be, and he hereby is, authorized and empowered, under general regulations to be fixed by him, to grant an easement for rights of way, for a period not exceeding fifty years from the date of the issuance of such grant, over, across, and upon the public lands, national forests, and reservations of the United States for electrical poles and lines for the transmission and distribution of electrical power, and for poles and lines for telephone and telegraph purposes to the extent of twenty feet on each side of the center line of such electrical, telephone, and telegraph lines and poles, to any citizen, association, or corporation of the United States, where it is intended by such to exercise the right of way herein granted for any one or more of the purposes herein named: *Provided,* That such right of way shall be allowed within or through any national park, national forest, military, Indian, or any other reservation only upon the approval of the chief officer of the department under whose supervision or control such reservation falls, and upon a finding by him that the same is not incompatible with the public interest: *Provided,* That all or any part of such right of way may be forfeited and annulled by declaration of the head of the department having jurisdiction over the lands for nonuse for a period of two years or for abandonment.

That any citizen, association, or corporation of the United States to whom there has heretofore been issued a permit for any of the purposes specified herein under any existing law may obtain the benefit of this act upon the same terms and conditions as shall be required of citizens, associations, or corporations hereafter making application under the provisions of this statute.

The Secretary of the Interior administers this law on public lands outside of national forests, and the Secretary of Agriculture administers it within national forests. The regulations of the Secretary of the Interior thereunder, dated January 6, 1913 (41 L. D., 454), specify that the application shall be presented and considered, except as otherwise provided, in the form and manner prescribed by the regulations of August 24, 1912 (41 L. D., 150), under the act of February 15, 1901 (31 Stat., 790). The conditions imposed on the grantee by these regulations are set forth in the grant of right of way to the Great Falls Power Co. (41 L. D., 460, 62d Cong., 3d sess.), which is followed in other grants under this act.

PERMIT GRANTED THE GREAT FALLS POWER CO., MONTANA.[1]

On this 6th day of January, 1913, the Great Falls Power Co., a corporation organized under the laws of the State of Montana, and having its office and principal place of business in Butte, in said State, hereinafter called "the power company," having heretofore filed under the act of Congress approved March 4, 1911, chapter 238 (36 Stat., 1253–1254), in the United States land offices at Helena and Great Falls, in said State, its applications (designated as Helena 05776, 05777, 05778, 05779, 05780, and 05781, and Great Falls 05707) for right of way to the extent therein set forth for two transmission lines, and for a telephone line between said transmission lines, all substantially parallel, and shown on five maps filed in the said land office at Helena, and designated Helena 05777, 05778, 05779, 05780, and 05781, and on the three maps filed in the said land office at Great Falls as a part of the application designated Great Falls

[1] 62d Cong., 3d sess., Senate Doc. No. 1008.

05707, and all heretofore constructed over, across, and upon certain public lands and reservations of the United States under the jurisdiction of the Department of the Interior, which applications are now pending in the Department of the Interior, hereby renews and confirms its said applications, amending the same, however, so as to ask for such right of way for a period of 50 years over, across, and upon the said public lands and reservations to the extent of 20 feet on each side of the center of each of said lines shown on said maps, the said public lands and reservations to such extent being hereinafter called "the servient lands," and by way of further amendment the power company, in addition to the matters set forth in its said application, does, in consideration of the granting of the right of way hereby sought, hereby promise and agree for itself and its successors that upon and after such grant it will comply with the terms and conditions, and will fulfill and perform the promises hereinafter expressed.

1. The power company will, during said period of 50 years, maintain and continuously operate for the transmission of electrical power and for telephone purposes, respectively, the lines for which right of way is hereby sought, except in so far as this promise and condition may be temporarily waived by the Secretary of the Interior upon a full showing to his satisfaction that such continuous operation is prevented by inevitable accidents or contingencies.

2. The power company will, within 30 days after the granting of the right of way hereby sought, enter into and thereafter fully perform all its obligations under a contract with the Chicago, Milwaukee & Puget Sound Railway Co., a corporation organized under the laws of the State of Washington, and hereinafter called "the railway company," for the sale and delivery of electric power to the railway company, in form and substance as follows:

"This agreement, made and entered into this —— day of ———, 1912, between the Great Falls Power Co., a corporation organized under the laws of the State of Montana, party of the first part, hereinafter for convenience referred to as the power company, and the Chicago, Milwaukee & Puget Sound Railway Co., a corporation organized under the laws of the State of Washington, for convenience hereinafter referred to as the railway company, party of the second part, witnesseth:

"Whereas the said power company is engaged in the business of generating electric power or energy from certain hydroelectric works within the State of Montana and selling and disposing of said power or energy; and

"Whereas the said railway company is engaged in operating a line of railway which lies partly within the State of Montana, and said railway company is desirous of installing equipment and apparatus which will enable the said railway company to operate certain portions of its said railway, hereinafter more particularly referred to, by means of electric power: Now, therefore, it is agreed between the parties hereto:

"First. That the said railway company will, as soon as it is expedient for it so to do, begin, and that it will prior to the 1st day of January, 1918, complete, the installation and equipment of such apparatus, machinery, and motive power as may be necessary to enable the said railway company to operate its said line or railway from that certain station situated on said line of railway, in Musselshell County, known and designated as Harlowton, to that certain other station on said line of railway known as Deer Lodge, situated in Powell County, Mont., and that the said railway company will, on or before the 1st day of January, 1918, receive and take from the said power company, and that the said power company will, as soon as said railway company shall be ready to receive and use said power, and thereafter continuously during the term of this contract, sell and deliver to the said railway company, in such manner and quantities and upon such terms and conditions as may be hereinafter stipulated, the electric power herein contracted for.

"It is agreed that the railway company will give the power company two years' notice in writing of the date when the railway company will begin to use the power aforesaid, but it is understood and agreed that the said date when said power shall so begin to be used will not in any event be later than January 1, 1918.

"Second. Subject to the reservations and in accordance with the provisions of this agreement as hereinafter stated, the power company hereby sells and agrees to deliver to the railway company and the railway company hereby buys and agrees to receive from the power company, electric power or energy for operating its railway equal to but not at any one time exceeding, except as provided for in articles 9, 10, 11, and 12, 10,000 kilowatts, for the full period of this agreement.

"Third. The said power shall be delivered by the power company at its own sole cost, to the stations to be established and designated by the railway company between Deer Lodge and Harlowton, not exceeding 5 in number, in such amounts as may be required by the said railway company for the operation of its said line of railway during the term of this contract. Said power to be delivered in the form of 3-phase 60-cycle alternating electric current at a potential of approximately 50,000 or 100,000 volts, as may be jointly agreed upon; provided, however, that the voltage at which said current shall be so delivered when once fixed shall not thereafter be changed during the life of this contract, except by mutual agreement of the parties hereto.

"Fourth. The power company agrees that it will construct such suitable transmission lines as may be necessary in order to enable it to deliver, and that it will deliver, the power herein contracted for at its own cost, to the points, not exceeding five in number, as aforesaid, which points shall be located and designated by the said railway company between the points aforesaid. The said railway company shall receive the current at the points so designated by it at the terminals of air brake, high-tension line switches, to be provided by the power company, and shall transform (by such apparatus as if may prefer) and conduct it along its said line of railway according to its requirements, in such manner as it may see fit.

"Fifth. It is agreed that the power herein contracted for shall be measured at each agreed point of delivery by curve-writing wattmeters operated synchronously and integrating watt-hour meters, or such approved instruments for the measurement of electric current as may be agreed upon by the parties hereto.

"It is agreed that the measurement of the said power shall at all times be under the control and direction of the said power company, but that the said railway company and its duly designated agents shall, at all times, possess the right to make full inspection of the methods employed and the instruments and apparatus used for recording such measurements and to make any tests or examinations which may be necessary to enable the said railway company and its agents to determine the accuracy and reliability of such methods as may be pursued and such instruments and apparatus as may be used for the recording and measuring of the electric power furnished.

"It is agreed that the railway company shall install in its substations such transforming or converting apparatus as, in its judgment, will best meet the requirements of its railway operations, provided that such apparatus shall comprise sufficient synchronous machines or other equivalent means to secure 80 per cent lagging or 80 per cent leading power factor of the apparatus affected. The railway company hereby grants to the power company the right to install and maintain at the sole cost of the power company, in the substations that may be established by the railway company, Tirrell ragulators, or such other equivalent device as will operate the railway company's synchronous apparatus at any power factor between 80 per cent lagging and 80 per cent leading of the apparatus affected.

"Sixth. It is agreed that the railway company will, and it does hereby, bind itself to give the power company 12 months' notice in writing of the location of the delivery points hereinbefore referred to. The power company agrees that it will, upon the date so fixed in said notice by the said railway company, and thereafter during the term of this contract, continue to either deliver, or hold in readiness for delivery, to said railway company such an amount of electric power as the said railway company shall be under obligation to receive and use under the terms of this contract.

"Seventh. It is agreed that the railway company shall, and it does hereby, bind itself to pay to the power company, on the basis of measurements made at such points of delivery as are designated by the railway company, for the power or energy delivered to it under the terms and provisions of this contract at the rate of $0.00536 (five hundred thirty-six thousandths of a cent) per kilowatt-hour, as shown by the instruments provided for in the fifth clause hereof; said payments to be made not later than the 15th day of each calendar month for all power or energy received and used by the railway company, or which the said company was under obligation to receive and use during the previous calendar month.

"Eighth. It is agreed that, after a period terminating one year from the date when delivery of electric power shall begin under the terms of this contract, and during the remaining term of this contract, from the expiration of said period of one year, the said railway company shall be obliged, and does hereby agree, to pay to the said power company a minimum amount in monthly periods as aforesaid equivalent to 60 per cent of the amount which the said railway company would pay to the said power company, provided the full amount of power which the said railway company is under obligation to take and which the power company is under obligation to deliver had been actually delivered by the said power company to and received and used continuously by the said railway company, upon the basis of the rate above provided for.

"Ninth. It is agreed that the railway company shall have the right, to be exercised at its option, such option to be exercised by it giving the power company written notice thereof, to receive in additon to the amount of power above provided for, an additional amount of not less than 4,000 kilowatts, nor more than 8,000 kilowatts, provided that said option to take and receive such additional amount of power is exercised by the railway company prior to January 1, 1923. It being understood and agreed that in the event of the said railway company so exercising said option that the amount of power which it will call for in addition to the original amount of 10,000 kilowatts shall become fixed, and thereafter the said railway company will be under obligation to take and receive, and the power company will be under obligation to sell and deliver, during the remaining term of this contract, the amount of power which shall be represented by the sum of 10,000 kilowatts plus the additional amount which the railway company shall have called for under the provisions of its said option.

"Tenth. It is further agreed that at any time subsequent to January 1, 1923, and prior to January 1, 1928, the railway company shall have, and it is hereby given, the right, to be exercised at its option, in writing as aforesaid, to take and receive from the power company, and the power company shall be under obligation to sell and deliver to the said railway company an amount of power, in addition to the amounts previously provided for, of not less than 3,500 nor more than 7,000 kilowatts: *Provided*, That if the said railway company shall at any time during the period between January 1, 1923, and January 1, 1928, so exercise its option for additional power, then in such event the railway company shall be under obligation to take and receive, during the remainder of the entire term of this contract, the amount of power represented by the amount which the railway company had been under obligation to take and receive, plus the amount of power which it shall have called for under the provisions of this option.

"Eleventh. In the event of the railway company having failed to exercise its option for additional power provided for in article ninth hereof, it is understood and agreed that the railway company will hereafter possess no right to call for or receive additional power except as hereinafter provided for in article twelfth.

"Twelfth. It is agreed that the railway company shall have, and it is hereby given, the right, to be exercised at its option, in writing as aforesaid, of taking power in addition to the 10,000 kilowatts herein contracted for, up to the full amount of 25,000 kilowatts at any time subsequent to January 1, 1918, and prior to January 1, 1928, provided it shall have called for under the provisions of this option at least 6,300 additional kilowatts prior to January 1, 1923.

"It is agreed that the provisions set forth in article eighth hereof, with reference to the minimum payments which shall be made for power delivered under this contract, shall apply in like proportion to the amount which the railway company shall be under obligation to take after having exercised its right with reference to any of the options herein expressed, the same as said provision covers the rate of payment to be made upon the original amount herein contracted for.

"Thirteenth. If the railway company shall be unable, on account of strikes, fires, floods, or other causes beyond its control, to receive or use the power herein provided for, or some part thereof, then it is understood and agreed that the railway company shall pay for so much power only as can be received and used by it during said period. If the power company, by reason of any unavoidable cause or accident, or because of strikes, floods, or fires, shall be unable at any time during this contract to make delivery of power as herein agreed, then the said power company shall not be liable in any sum for such failure so caused to deliver power during such period.

"In the event of this contract being suspended on account of any of the reasons hereinbefore enumerated, it is agreed that the period of such suspension shall be added to the term of the contract herein provided for, and the contract and all of its provisions shall be extended for such period equal to the period of suspension.

"It is further understood and agreed that if the power company shall at any time be permanently enjoined, restrained, or prevented by Federal or State interference, or by final judgment or decree of any court of competent jurisdiction, from maintaining transmission lines or other works necessary to enable it to perform its engagements hereunder, the power company shall thereupon be relieved from any obligation thereafter to furnish or deliver power under the terms hereof, and the railway company shall likewise be relieved from any obligation thereafter to take or pay for such power.

"Fourteenth. It is agreed that the railway company shall have a preferential right to receive power from the power company, and that up to the full amount which it shall have contracted to receive and use the power company will sell and deliver said power before filling any other contract.

"It is agreed that the power company shall hold itself in readiness to furnish all of the power herein contracted for up to the maximum amount that the railway company shall be entitled to receive continuously so that the railway company shall during the full period of this contract, except as otherwise herein provided for, be able to draw upon said power company for the full amount of power which it shall be entitled to receive at such times as may be necessary to meet the requirements of its business.

"Fifteenth. It is agreed that the power company shall have, and it is hereby granted, subject to the right of the railway company to prescribe such reasonable limitations as may be deemed by it advisable to insure the safety of its business and to provide for the safe conduct of the current or energy transmitted, as hereinafter provided, the right to construct transmission lines over, across, along, and upon the right of way of the said railway company wherever it may see fit, for the purpose of transmitting and conducting electrical power or energy, for purposes other than to supply said railway company with power, provided, however, that the location of poles and wires shall be designated by the railway company, and that notwithstanding such designation, if the railway company afterwards requires the use of the right of way or station grounds, or any part thereof, for any purpose, the power company will remove, at its own sole expense, on 60 days' notice, its poles and wires to another location on the railway company's property, if such location can be furnished by the railway company, or if not, to a location outside and off the railway company's property, and that the said power company shall so conduct such electrical power or energy as will cause no interference, damage, or injury to the said railway company or interfere in any manner with any of the operations of said railway company, or the telegraph or telephone service along its line of railway. In case the power company extends its transmission lines along or parallel to the railway company's right of way, then in that event the power company

will deliver power and hereby agrees to deliver power at such other points along the railway line as best serves the purpose of the railway company. The power company further agrees to purchase at a mutually agreed upon price and operate at its own expense such transmission lines as may have been built by the railway company on its right of way as come within the area of such extension of the power company's transmission lines.

"Sixteenth. It is agreed that the railway company shall have the right to receive and use the power or current herein provided for in the operation of its railway and for such other purposes as it may require electric power or current incidental to the operation of its said railway; but that it shall have no right, and it hereby agrees that it will not sell or dispose of any of the electric power which it is entitled to receive and use under the terms of this contract to any other person or persons or corporations whatsoever, and that it will not, during the life of this contract, use or apply the said electric power or current to any use or purpose other than in connection with the operation of its said line of railway, shops, stations, coaling stations, ice houses, and other railway uses, either power or lighting.

"Seventeenth. Any and all questions which shall or may arise touching this agreement or the construction or performance of any provision thereof shall be submitted to the decision of three disinterested persons to be chosen as follows:

"The railway company shall select one and the power company shall select one, and the two thus chosen shall select the third, and the persons thus chosen, after a full hearing to both parties and full examination of the matter in dispute, shall determine the same in writing, and the decision of the majority of the three persons thus chosen shall be final. If either party shall neglect or refuse to appoint an arbitrator on its own part, then 10 days after receiving written notice from the other of its appointment of an arbitrator on its part, the arbitrator so appointed by the party giving such notice may select a disinterested person to act as an arbitrator for and on account of the party so notified and refusing or neglecting to appoint an arbitrator on its part, and the two thus chosen shall select a third. If the two so chosen in either of the methods above provided shall be unable to agree upon a third arbitrator, or shall fail to agree upon a third arbitrator, and such inability shall continue for a period of 15 days, then in that event the parties hereto shall and may notify the chief justice of the Supreme Court of the State of Montana of such fact, and he shall and may appoint said third arbitrator. The decision and award of the arbitrators as herein provided, or any two of them, shall be binding and conclusive upon the parties hereto with respect to the matters so submitted to and decided by said arbitrators.

"If any arbitrator appointed by either of the parties hereto shall neglect or fail to act, notice of such failure shall be served upon the party appointing such arbitrator by the other party, and in case such party shall fail to appoint another arbitrator, or shall fail to cause the arbitrator first appointed to act, and such failure shall continue for a period of 10 days, then the arbitrator appointed by the other party may select a disinterested person to act as an arbitrator for and on account of the other party, and the two thus chosen shall select a third, and the decision and award of such arbitrators or any two of them, shall be binding and conclusive upon said parties hereto with respect to the matter so submitted and decided by said arbitrators.

"The award and decision of the arbitrators under the provisions hereof shall be served by them, or some one for them, upon the parties within 15 days after the time when such arbitrators shall make their award.

"It is further mutually agreed that any difference which may arise as to the construction of or the transaction of any business under this agreement by the parties hereto shall not interrupt the transaction of such business nor the operation of trains, nor the delivery of power, but all said business of either party and operations of trains and the delivery of power shall continue in the same manner in which the same shall have been transacted prior to the arising of such difference until the matter of difference

shall have been fully determined by the arbitrators as aforesaid, and thereupon such payments or restoration shall be made by the respective parties to the other as may be required by the decision or award of said arbitrators.

"In case any charge made or item embraced in any statement rendered by either party to the other shall be contested and submitted to arbitration under the terms hereof, and an award shall be made by said arbitrators requiring payment thereof or any part thereof, or in case any failure to comply with any other covenant or agreement in this contract is alleged by either party against the other, and the same is submitted to arbitration as herein provided and decided by said board of arbitration, then the losing party shall pay the amount of such award or comply with the terms and requirements thereof; and if it fails so to do, and such failure shall continue for a period of 30 days after the service of the award, then and in that event the prevailing party shall have the right to terminate this agreement according to the terms and provisions thereof for and on account of such failure and default.

"Eighteenth. It is agreed that this contract shall be, and it is hereby made, for the full term and period of 99 years from and after this date.

"Nineteenth. It is agreed that the terms and provisions of this contract shall inure to the benefit of and its obligations shall be binding upon the successors, grantees, or assigns of the respective parties hereto.

"In witness whereof, the respective parties have caused these presents to be executed in duplicate by their proper officers, thereunto duly authorized, the day and year first above written.

"GREAT FALLS POWER CO.,
"By ——— ———,
"*Its* —— *President.*
"Attest:
"——— ———,
"*Its* —— *Secretary.*
"CHICAGO, MILWAUKEE & PUGET SOUND RY. CO.,
"By ——— ———,
"*Its* —— *President.*
"Attest:
"——— ———,
"*Its* —— *Secretary.*"

Said contract having been heretofore tentatively agreed upon by the two said companies: *Provided*, First. That nothing contained either in this application, or in the grant hereby sought, or in said contract, and especially the section thereof designated "eighteenth," shall be construed to give to the power company any right, easement, claim, license, or permission to hold, occupy, or use the servient lands for the operation or maintenance of electrical transmission lines or for any other purpose whatsoever after the expiration of 50 years from the date of the grant hereby sought; and the power company shall and will, upon the expiration of said 50 years, be deemed and taken to be permanently prevented by Federal interference from maintaining transmission lines on the servient lands and thereby relieved under the last paragraph of the section of said contract designated "thirteenth" from any obligation to furnish and deliver power under the terms of said contract unless and until it shall have obtained from the United States the right to occupy the servient lands for the maintenance of such lines: *Provided*, Second. That nothing in this application or in the grant hereby sought, or in said contract and especially the section thereof designated "fifteenth," shall be construed to give to the power company or the railway company any right whatsoever to occupy or use lands of the United States within the railway right of way for any other than railway purposes nor as expressing the acquiescence or consent of the United States or of the Secretary of the Interior in or to any such occupancy or use; but the power company shall and will make due application to the Secretary of the Interior, or other proper officer or agent of the United States, for the right to occupy and use such lands for other than railway purposes, and especially for any purpose other than to supply

the railway company with power, and the power company will abide by the decision and action of the said Secretary or other officer upon such application.

3. The power company will never, by reason of or in connection with the right of way hereby sought or otherwise, have, exercise, or claim any greater or other rights under said contract, with respect to prices to be paid for power by said railway company, than it could have rightfully had, exercised, or claimed if the right of way hereby sought had been sought and granted without any mention of or reference to said contract.

4. The power company will pay annually, on or before February 1 in each year, by certified check to the order of the Secretary of the Interior, a rental charge at the rate of 5 mills ($0.005) per thousand kilowatt hours for all energy delivered by it over the lines for which right of way is hereby sought during the preceding calendar year of the decade beginning on January 1, 1913, whether said delivery is made to the railway company under the said contract or otherwise or to other takers; and during each decade thereafter a rental charge at such reasonable rate per thousand kilowatt hours so delivered to said railway company and to said other takers as the Secretary of the Interior may fix before the beginning of each decade for such deliveries, respectively: *Provided*, That the burden of proving that any rate fixed by the said Secretary under this paragraph is unreasonable shall be and remain upon the power company: *Provided further*, That if no rate is so fixed for any particular decade, then the rental charge to be paid for each year of such decade shall be calculated upon all energy delivered during the preceding calendar year over the lines for which right of way is hereby sought at the rate per thousand kilowatt hours fixed for the preceding decade: *Provided further*, That any payment duly made by the power company to the head or other officer of any department of the Federal Government having jurisdiction over national forests or other reservations of the United States occupied or used by any portion of the lines for which right of way is hereby sought, such payment having been made as or on account of a rental charge for such occupancy and use for any calendar year during the said period of 50 years for which right of way is hereby asked, shall be credited upon the rental charge imposed under this paragraph for the same year, but such credit shall in no case exceed the total of the rental charge so imposed for such year.

5. The power company will install at such places and maintain in good operating condition in such manner as shall be approved by the said Secretary accurate meters, or other devices approved by the said Secretary, adequate for the determination of the amount of electric energy delivered over the lines for which right of way is hereby sought, or any part thereof, to the said railway company, and to all other takers, respectively, and will keep accurate and sufficient record of the foregoing determinations to the satisfaction of the Secretary, and will make a return during January of each year, under oath, of such of the records of measurements for the year ending on December 31 preceding, made by or in the possession of the power company as may be required by the said Secretary.

6. The books and records of the power company will be open at all times to the inspection and examination of the said Secretary, or other officer or agent of the United States duly authorized to make such inspection and examination.

7. The lines constructed, maintained, and operated on the servient lands will not be owned, leased, trusteed, possessed, or controlled by any device or in any manner so that they form part of or in any way effect any combination in the form of an unlawful trust, or form the subject of any unlawful contract or conspiracy to limit the output of electric energy, or in unlawful restraint of trade with foreign nations or between two or more States, or within any one State in the generation, sale, or distribution of electric energy or in the transmission of communications by telephone.

8. The power company will protect in a workmanlike manner, according to the usual standards of safety for construction, operation, and maintenance in such cases, all Government and other telephone, telegraph, and power transmission lines at

crossings of and at all places in proximity to the power company's transmission lines, and will maintain its transmission and telephone lines in such manner as not to menace life or property.

9. The power company will clear and keep clear all lands owned or controlled by the United States along the lines for which right of way is hereby sought to such width and in such manner as the officer of the United States having supervision of such lands may direct.

10. The power company will, to the satisfaction of the officer last above described, dispose of all brush, refuse, or unused timber on lands owned or controlled by the United States caused by or left from the construction and maintenance of its lines for which right of way is hereby sought.

11. The power company will pay the full value as fixed by the said Secretary for all timber cut, injured, or destroyed on lands owned or controlled by the United States in the construction, maintenance, and operation of the lines for which right of way is hereby sought.

12. The power company will sell and deliver power to the United States and to the State of Montana and to any or all municipal corporations of said State, when requested, at as low a rate as is given to any other purchaser for a like use at the same time and under similar conditions: *Provided*, That the power company can furnish the same without diminishing the quantity of power sold before such request to any other customer by a binding contract of sale: *Provided further*, That nothing in this clause shall be construed to require the power company to increase permanent works or install additional generating machinery or construct any transmission line or connection beyond the limits of the servient lands.

13. The power company will do everything reasonably within its power, both independently and on request of the Secretary of the Interior or other duly authorized officer or agent of the United States, to prevent and suppress fires on or near the servient lands.

14. The power company will maintain a system of accounting of its entire power business in such form as the Secreatry of the Interior may prescribe and will render annually such reports of the power business as the said Secretary may direct.

15. The power company will indemnify the United States against any liability for damages to life or property arising from its occupancy or use of the servient lands.

16. The power company with respect to service rendered and power delivered to other takers than the railway company over its lines for which right of way is hereby sought and with respect to the prices charged and to be charged therefor will comply with all such just and reasonable regulations as may be imposed by any duly constituted Federal, State, or other governmental authority having jurisdiction in the premises: *Provided*, That if, as to any matters promised by the power company in this paragraph, the regulations prescribed by the Federal Government, its officers or agents, are in conflict with the regulations prescribed by the State or any duly authorized agency thereof, compliance with the Federal regulations shall be deemed and taken to be a fulfillment of the promises of this paragraph in so far as such conflict extends and no further.

17. The power company will not assign or transfer the right of way hereby sought to any other person or corporation whatsoever, except with approval in writing first obtained from the Secretary of the Interior or other proper officer of the United States, and upon conditions prescribed in said written approval by him. The assignee or transferee under any such approval shall take and use the right of way subject to all the terms, conditions, and promises in this application set forth, and subject to such additional terms, conditions, and promises as may be imposed and exacted by such written approval.

18. In respect to the regulation, by any competent public authority, of the services to be rendered by the power company or of the prices to be charged therefor, and in respect to any purchase or taking over of the works or business of the power company

or any part thereof by the United States or by the State of Montana, or by any municipal corporation of said State, no value whatsoever shall at any time be assigned to or claimed for the right of way hereby sought, nor shall said right of way or the grant hereby applied for ever be estimated or considered as property upon which the power company shall be entitled to earn or receive any return, income, price, or compensation whatsoever.

19. Upon breach by the power company of any of the terms, conditions, or promises in this application set forth the United States may have and enforce appropriate remedy therefor by specific performance, injunction, action for damages, or otherwise in a suit instituted by the Attorney General for that purpose in any court of competent jurisdiction. And if any such breach shall be continued or repeated after 30 days' notice thereof given in behalf of the United States to the power company, the right of way hereby sought, together with all rights thereunder and all moneys paid thereon, may be forfeited to the United States by a suit brought on request of the Secretary of the Interior by the Attorney General for that purpose in any court of competent jurisdiction.

In witness whereof said Great Falls Power Co. has caused these presents to be executed, in duplicate, by its president and agent and its corporate seal to be hereto affixed by its secretary, both thereunto duly authorized, the day and year first above written.

GREAT FALLS POWER CO.,
By JOHN D. RYAN, *President.*

Attest:

P. E. BISLAND,
Secretary of the Great Falls Power Co.

(Corporate seal.)

In pursuance of the provisions of the act of Congress approved March 4, 1911, chapter 238 (vol. 36, Stat. L., pp. 1253 and 1254), and in pursuance of general regulations thereunder fixed by the Secretary of the Interior, and in consideration of the promises by the said Great Falls Power Co. made and set forth in the foregoing application, the rights of way over, upon, and across the public lands and reservations of the United States under the jurisdiction of the Department of the Interior, sought by and described in the foregoing application, are hereby granted for the period of 50 years from this 7th day of January, 1913, subject, however, to the general regulations under the said act fixed by the Secretary of the Interior and to the terms and conditions in said application set forth, such grant, subject to said regulations, terms, and conditions, having been found by me to be not incompatible with the public interest. This grant does not affect national forests or other reservations not under the jurisdiction of the Department of the Interior.

In witness whereof I have subscribed these presents, in duplicate, the day and year last above written.

WALTER L. FISHER,
Secretary of the Interior and
Head of the Department of the Interior.

FINAL PERMIT TO INTERNATIONAL POWER & MANUFACTURING CO., OF SPOKANE, WASH.[1]

FINAL PERMIT INVOLVING POWER.

[Act of Feb. 15, 1901 (31 Stat., 790). Regulations of Mar. 1, 1913.]

DEPARTMENT OF THE INTERIOR,
Washington.

Applicant: International Power & Manufacturing Co., Spokane, Wash.

Principal works: Dam and power plant.

Location: Tps. 39 and 40 N., R., 43 E., Willamette meridian, Washington, on Clark Fork or Pend d'Oreille River.

[1] 63d Cong., 1st sess., Senate Doc. No. 147, 1913.

Purpose of occupation and use of public lands: Construction, operation, and maintenance of works for the generation, distribution, and use of electrical power.

Date of initiation of priority: July 22, 1913.

Date of initiation of valid rights as against other claimants: July 22, 1913.

AGREEMENT.

The International Power & Manufacturing Co., hereinafter called the permittee, a corporation organized and existing under and by virtue of the laws of the State of Washington, the office and principal place of business of said permittee being at Spokane, Wash., being the successor in interest of the Pend d'Oreille Development Co., a corporation organized under the laws of the State of Washington and authorized by act of Congress approved February 25, 1907 (34 Stat., 931), extended by act of Congress, May 20, 1912 (37 Stat., 115), to construct a dam across Clark Fork or Pend d'Oreille River, in the State of Washington, for the development of water power, electrical power, and for other purposes, which said dam was to be constructed, maintained, and operated in accordance with and subject to the provisions of the act of Congress approved June 23, 1910 (36 Stat., 593), entitled "An act to amend an act entitled 'An act to regulate the construction of dams across navigable waters,' " approved June 21, 1906; and the said permittee in accordance with the provisions of the said act of Congress approved June 23, 1910, has submitted, under date of June 3, 1912, to the Secretary of War and the Chief of Engineers of the United States Army, plans and specifications and maps showing the location of such dam and necessary works, and the said permittee having heretofore filed in the Department of the Interior an application, designated as Spokane .08319, and including the following-described map of location: Map of location of reservoir site and power plant, marked Exhibit J1, bearing affidavit of M. H. Gerry, jr., engineer, and certificate of International Power & Manufacturing Co., by Wilbur S. Yearsley vice president, under corporate seal of said company, filed in the General Land Office, Washington, D. C., on July 22, 1913; and said permittee having filed an application in the Department of Agriculture, including a duplicate of said map of location, said applications filed in the Department of the Interior and the Department of Agriculture, hereinafter called the final application, having been made for the purpose of obtaining permission to occupy and use certain lands under the jurisdiction of the said departments for the purposes of the act of Congress approved February 15, 1901 (31 Stat., 790), for the construction, operation, and maintenance of certain works, said lands and works being more particularly described in and located and shown by the final application, does hereby amend said final application to include this agreement, and furthermore does hereby covenant and agree, in consideration of and as a prerequisite to the giving of the permission applied for in the final application as thus amended, such permission being hereinafter called the permit, that the conditions of the permit, each and every one of which shall at all times be binding on the permittee, are as follows:

SECTION 1. The following terms, wherever used in this agreement, shall have the respective meanings in this section assigned to them:

(*a*) "Interior Department lands" means lands under the jurisdiction of the Department of the Interior for the purposes of the act of Congress approved February 15, 1901 (31 Stat., 790), and "national forest lands" means lands under the jurisdiction of the Forest Service of the Department of Agriculture for said purposes.

(*b*) "Secretaries" means the Secretary of the Interior and the Secretary of Agriculture.

(*c*) "Power business" means the entire business of the applicant or permittee in the generation, distribution, and delivery of power by means of any one power system, together with all works and tangible property involved therein, including freeholds and leaseholds in real property.

(*d*) "Power system" means all interconnected plants and works for the generation, distribution, and delivery of power.

(*e*) "Power project" means a complete unit of power development, consisting of a power house, conduit or conduits conducting water thereto, all storage or diverting or fore-bay reservoirs used in connection therewith, the transmission line delivering power therefrom, any other miscellaneous structures used in connection with said unit or any part thereof, and all lands the occupancy and use of which are necessary or appropriate in the development of power in said unit.

(*f*) "Project works" means the physical structures of a power project.

(*g*) "Construction of the project works" means the actual construction of dams, water conduits, power houses, transmission lines, or some permanent structure necessary to the operation of the complete power project, and does not include surveys or the building of roads and trails, or the clearing of reservoir sites or other lands to be occupied, or the performance of any work preliminary to the actual construction of the permanent project works.

(*h*) "Customer" means the purchaser of electric current for redistribution and sale.

(*i*) "Consumer" means the user of current at the point of its final conversion into light, heat, or power.

(*j*) "Nominal stream flow" means the sum of (*a*) the average of the values estimated for the mean natural flow for the two-month (calendar) minimum-flow period in each successive five-year cycle or major fraction thereof, and (*b*) the increase in such average due to artificial means other than the project works.

(*k*) "Project storage flow" means the estimated increase in nominal stream flow made practicable by the project works.

(*l*) "Available stream flow" means the sum of nominal stream flow and project storage flow.

(*m*) "Load factor" means the ratio of average power output to maximum power output.

(*n*) "Total capacity of the power site" means the power estimated to be available for transmission, and is determined as the continued product of (1) the factor 0.08; (2) the average effective head, in feet; (3) the available stream flow at the intake (in second-feet and in amount not to exceed the maximum hydraulic capacity of the project works); and (4) a factor, not less than the average load factor of the power system, representing the degree of practicable utilization of the available stream flow, and based on the extent of practicable forebay storage and the load factor of the power system.

SEC. 2. The permit shall be subject to and the permittee shall be governed by the provisions of the act of Congress approved February 15, 1901 (31 Stat., 790), and to the regulations thereunder fixed by the secretaries.

SEC. 3. The permit shall relate solely to the occupancy and use of the Interior Department lands and national forest lands necessary for the construction, operation, and maintenance of such works contemplated by the act of Congress approved February 15, 1901 (31 Stat., 790), as are described in the final application, to the extent of the ground occupied by such works and not to exceed 50 feet on each side of the marginal limits of works other than pipe lines and electrical transmission lines and not to exceed 50 feet on each side of the center of each pipe line or electrical transmission line, in conformity with the location of such works on said lands as shown by the maps of location hereinbefore described.

SEC. 4. The permittee shall construct the project works on the location shown upon and in accordance with said maps and plans submitted with the final application, and shall make no material deviation from said location unless and until maps and plans showing such deviation shall have been submitted and approved by the secretaries.

SEC. 5. Any approval of any alteration or amendment, or of any map or plan, or of any extension of time, shall affect only the portions specifically covered by such

approval; and no approval of any such alteration, amendment, or extension shall operate to alter or amend, or in any way whatsoever be a waiver of any other part, condition, or provision of the permit.

SEC. 6. The permittee shall begin the construction of the project works and of the several parts thereof and shall thereafter diligently and continuously prosecute such construction to completion unless temporarily interrupted by climatic conditions or by some special or peculiar cause beyond the control of the permittee, within the respective periods, dating from the issuance of the permit, specified for such beginning and for such completion in the following schedule:

1. Project works as a whole, excepting installation of hydraulic and electric machinery, shall be begun within one year and completed within three years.

2. Installation of hydraulic and electric machinery: Machinery of 50,000 horsepower rated capacity shall be installed within three years; and additional machinery shall be installed as the conditions of the market will warrant or as the secretaries or any duly authorized State agency may direct.

SEC. 7. The permittee shall, after their completion, operate the project works continuously for the development and transmission of electric energy for sale or other disposal, unless upon a full and satisfactory showing that such operation is prevented by unavoidable accidents or contingencies, this requirement is temporarily waived by the written consent of the secretaries.

SEC. 8. No compensation for the permission given will be required prior to the year 1923; but on or before the first day of February in each year, beginning with 1924, the permittee shall pay, by certified check to the order of the Secretary of the Interior, or in such other manner as the secretaries may direct, an amount calculated from the total capacity of the power site at rates per horsepower per year varying directly as the square of the average price for electric energy charged to customers and consumers of the permittee as determined in subsection (*c*) hereof and varying inversely as the square of the proportional development of the power site, as shown by the following table:

When the average price in cents per kilowatt-hour charged by the permittee is as shown by this column.	If the percentage of development of power site is—						
	Over 90.	90 and over 80.	80 and over 70.	70 and over 60.	60 and over 50.	50 and over 40.	40 or less.
	Then the rates of compensation to the United States per horsepower per year will be as shown below.						
0.2 and less	$0.05	$0.06	$0.08	$0.10	$0.14	$0.20	$0.31
0.3 and over 0.2	.11	.14	.18	.23	.31	.45	.70
0.4 and over 0.3	.20	.25	.31	.41	.56	.80	1.25
0.5 and over 0.4	.31	.39	.49	.64	.87	1.25	1.95
0.6 and over 0.5	.45	.56	.70	.92	1.25	1.80	2.81
0.7 and over 0.6	.61	.76	.96	1.25	1.70	2.45	3.82
0.8 and over 0.7	.80	.99	1.25	1.63	2.22	3.20	5.00
0.9 and over 0.8	1.01	1.25	1.58	2.06	2.81	4.05	6.33
1.0 and over 0.9	1.25	1.54	1.95	2.55	3.47	5.00	7.81
1.2 and over 1	1.80	2.22	2.81	3.67	5.00	7.20	11.25
1.5 and over 1.2	2.81	3.47	4.40	5.74	7.82	11.25	17.60
2 and over 1.5	5.00	6.17	7.82	10.00	13.80	20.00	31.25
3 and over 2	11.25	13.87	17.58	22.95	31.25	45.00	70.40
4 and over 3	20.00	24.70	31.25	40.80	55.60	80.00	125.00
5 and over 4	31.25	38.60	48.80	63.80	86.80	125.00	250.00
6 and over 5	45.00	55.60	70.40	91.80	125.00	180.00	281.25

It is expressly understood and agreed, however, that—

(*a*) At any time not less than 10 years after the date for the first payment under this section or after the last revision of the rates of compensation the secretaries may review such rates after application by or notice to the permittee and impose such new rates of compensation, under a rule which shall be uniform for all permittees under like con-

ditions, as they may decide to be reasonable and proper: *Provided*, That such rates shall not be so increased as to result in reducing the margin of income (including appreciation in land values) from the project over proper, actual, and estimated expenses (including reasonable allowance for renewals and sinking-fund charges) to an amount which, in view of all the circumstances (including fair development expenses and working capital) and risks of the enterprise (including obsolescence, inadequacy, and supersession), is unreasonably small; but the burden of proving such unreasonableness shall rest upon the permittee.

(*b*) For the purposes of this section complete development of the power site shall mean the construction of such permanent project works and the installation of such generating equipment as will provide for the full utilization of the total capacity of the power site.

(*c*) The average price for electric energy charged to customers and consumers of the permittee shall be determined by dividing the total actual and estimated annual receipts from the sale and disposition of electric energy by the total number of kilowatt hours generated: *Provided*, That in determining said total annual receipts there shall be included estimated receipts for any electric energy used by the permittee at a price which shall not be less than 2 cents per kilowatt hour, nor less than the cost per kilowatt hour of generating, transmitting, and delivering such energy to the point of use, taking into account proper operating and maintenance expenses, fixed charges and reasonable allowances for renewals and sinking fund: *And provided further*, That if the permittee shall sell or dispose of electric energy to any consumer, said consumer being an association or corporation which the permittee owns or controls in whole or in part, or in which the permittee may have, hold, or control any interest, direct or indirect, by stock ownership or otherwise, the sale price per kilowatt hour at which the aforesaid annual receipts from such energy so sold or disposed of shall be computed shall not be less than as herein provided for in the computation of estimated receipts for energy used by the permittee: *And provided further*, That if the permittee shall sell or dispose of electric energy to any customer, said customer being an association or corporation which the permittee owns or controls in whole or in part, or in which the permittee may have, hold, or control any interest, direct or indirect, by stock ownership or otherwise, the sale price per kilowatt hour at which the aforesaid annual receipts from such energy so sold and disposed of shall be computed shall not be less than the price paid for such energy by the consumers thereof, nor less than as herein provided for in the computation of estimated receipts for energy used by the permittee.

(*d*) Unless otherwise authorized by the secretaries, the maximum price at which electric energy developed by or transmitted from the power project may be disposed of to customers or consumers shall not exceed 6 cents per kilowatt hour, and the maximum price at which such electric energy in excess of 2,000 kilowatt hours per annum with an average annual delivery of more than 35 per cent of the connected installation within the year may be disposed of to customers or consumers shall not exceed 2 cents per kilowatt hour, said maximum price being determined by dividing the total annual charge to the purchaser by the corresponding total annual delivery to him of electric energy. In contracts with its customers the permittee shall specify the maximum price of final sale or resale and shall reserve the right to cancel any contract or agreement for sale or resale of electric energy that provides for a price in excess of such maximum. Complaint by any customer or consumer of a price paid by him in excess of such maximum price will be received by the secretaries in case of and after the failure of his attempts to obtain satisfaction from the permittee or other parties selling electric energy under the power system, and thereupon, after notice to all interested parties, with opportunity for hearing, the secretaries will determine whether this condition has been violated.

(*e*) The permittee shall at no time contract for the delivery to any one customer of electric energy in excess of 50 per cent of the total deliverable capacity of the power

site; nor shall the permittee deliver to any customer or consumer or use in its own manufacturing or other operations any amount of energy in excess of 50 per cent of said deliverable capacity if and when there are pending unfilled applications for energy from other customers or consumers.

SEC. 9. The total capacity of the power site shall be deemed and taken to be 112,000 horsepower.

It is expressly understood and agreed, however, that said total capacity of the power site may be adjusted by the secretaries annually to provide for increase or decrease, by storage or otherwise, of available stream flow to an amount of 10 per cent or more, or for increase or decrease of 10 per cent or more in average effective head, or in degree of practicable utilization, and that the decision of the secretaries shall be final as to all matters of fact upon which the calculation of the capacity or compensation depends.

SEC. 10. The permittee shall pay the full value as fixed by the secretaries for all timber cut, injured, or destroyed on Interior Department lands and on national forest lands in the construction, maintenance, and operation of the project works.

SEC. 11. The permittee shall pay the United States full value for all damages to the lands or other property of the United States resulting from the breaking of or the overflowing, leaking, or seeping of water from the project works, and for all other damage to the lands or other property of the United States caused by the neglect of the permittee or of the employees, contractors, or employees of the contractors of the permittee.

SEC. 12. The permittee shall install at such places and maintain in good operating condition in such manner as shall be approved or required by the secretaries accurate meters, measuring weirs, gages, or other devices approved by the secretaries and adequate for the determination of the amount of electric energy generated by the project works and delivered under the power system and of the flow of the stream or streams from which the water is to be diverted for the operation of the project works and of the amount of water used in the operation of the project works and of the amounts of water held in and drawn from storage; and shall keep accurate and sufficient records of the foregoing determinations to the satisfaction of the secretaries; and shall make a return during January of each year under oath of such of the records of measurements for the year ended on December 31 preceding made by or in the possession of the permittee as may be required by the secretaries.

SEC. 13. The books and records of the permittee shall be open at all times to the inspection and examination of the secretaries, or other officer or agent of the United States duly authorized to make such inspection and examination.

SEC. 14. On demand of the secretaries the permittee shall install a system of accounting for the entire power business in such form as the secretaries may prescribe, which system, as far as is practicable, will be uniform for all permittees, and shall render annually such reports of its power business as the secretaries may direct: *Provided, however*, That if the laws of the State in which the power business or any part thereof is transacted require periodical reports from public utility corporations under a uniform system of accounting, copies of such reports so made will be accepted as fulfilling the requirements of this clause in so far as they contain the information that may be required by the secretaries.

SEC. 15. The permittee shall protect all Government and other telephone, telegraph, and power transmission lines at crossings of and at all places of proximity to the permittee's transmission lines in a workmanlike manner according to the usual standards of safety for construction, operation, and maintenance in such cases, and shall maintain the transmission lines of the project in such manner as not to menace life or property.

SEC. 16. The permittee shall clear and keep clear the Interior Department lands and national forest lands along the transmission lines for such width and in such manner as the officer of the United States having supervision of such lands may direct.

SEC. 17. The permittee shall dispose of all brush, refuse, or unused timber on Interior Department lands and national forest lands resulting from the construction and maintenance of the project works to the satisfaction of the officer last aforesaid.

SEC. 18. The permittee shall build and repair such roads and trails as may be destroyed or injured by construction work or flooding under the permit and shall build and maintain necessary and suitable crossings for all roads and trails that intersect the water conduit constructed, maintained, or operated under the permit.

SEC. 19. The permittee shall do everything reasonably within the power of the permittee, both independently and on request of the secretaries or other duly authorized officers or agents of the United States to prevent and suppress fires on or near the lands to be occupied under the permit.

SEC. 20. The permittee shall indemnify the United States against any liability for damages to life or property arising from the occupancy or use of Interior Department lands and national forest lands by the permittee.

SEC. 21. The permittee shall sell power to the United States, when requested, at as low a price as is given to any other purchaser for a like use at the same time, and under similar conditions, if the permittee can furnish the same to the United States without diminishing the quantity of power sold before such request to any other customer by a binding contract of sale: *Provided*, That nothing in this clause shall be construed to require the permittee to increase permanent works or install additional generating machinery.

SEC. 22. The permittee shall abide by such reasonable regulation of the service rendered and to be rendered by the permittee to consumers of power furnished or transmitted by the permittee, and of prices to be paid therefor as may from time to time be prescribed by the State or any designated agency of the State in which the service is rendered: *Provided*, That for the purposes of this section any such regulation shall be deemed to be suspended pending proceedings in the courts of such State, or in the Supreme Court of the United States on appeal from said State courts where such proceedings are in the nature of an appeal taken direct from the officer, commission, or board prescribing such regulation to said State courts: *And provided further*, That in the absence of regulation of service and prescribing of prices by any State agency, jurisdiction in the premises will, in their discretion, be exercised by the secretaries.

SEC. 23. Upon demand in writing by the secretaries to surrender the permit to the United States or to transfer the same to such State or municipal corporation as the secretaries may designate, and to give, grant, bargain, sell, and transfer with the permit all works, equipment, structures, and property then owned or held by the permittee on lands of the United States occupied or used under the permit and then valuable or serviceable in the generation, transmission, and distribution of power: *Provided*, (*a*) That such surrender or transfer shall not be demanded in the case of a municipal corporation unless by condemnation such corporation shall have acquired, or unless by proceedings in a court of competent jurisdiction it shall have been determined that such a municipal corporation has the right to acquire the property of the permittee situated elsewhere than on public land, or unless such municipal corporation has the power to acquire the property and rights of the permittee in accordance with the following conditions: (*b*) That such surrender or transfer shall be on condition precedent that the United States shall pay or the transferee shall first pay to the permittee the reasonable value of all such works, equipment, structures, and property to be surrendered or transferred; (*c*) That such reasonable value shall not include any sum for any permit, right, franchise, or property granted by any public authority in excess of the sum paid to such public authority as a purchase price therefor; and (*d*) That such reasonable value shall be determined by mutual agreement of the parties in interest, and in case they can not agree, by the secretaries under a rule which, except as modified by the requirements of this section, shall be the then existing rule

of valuation for power properties in condemnation proceedings in the State in which the properties to be surrendered or transferred are located. But nothing herein shall prevent the United States or any State or municipal corporation from acquiring by any other lawful means the permit or the works, equipment, structures, or property then owned or held by the permittee on lands of the United States occupied or used under the permit.

SEC. 24. In respect to the regulation, by any competent public authority, of the services to be rendered by the permittee or of the prices to be charged therefor, and in respect to any purchase or taking over of the properties or business of the permittee or any part thereof by the United States or by any State within which the works are situated or business is carried on in whole or in part, or by any municipal corporation in such State, no value whatsoever shall at any time be assigned to or claimed for the permit or for the occupancy or use of Interior Department lands or national forest lands thereunder, nor shall the permit or such occupancy or use ever be estimated or considered as property upon which the permittee shall be entitled to earn or receive any return, income, price, or compensation whatsoever.

SEC. 25. The works to be constructed, maintained, and operated under the permit shall not be owned, leased, trusteed, possessed, or controlled by any device or in any manner so that they form part of, or in any way effect any combination in the form of an unlawful trust, or form the subject of any unlawful contract or conspiracy to limit the output of electric energy, or in restraint of trade with foreign nations or between two or more States, or within any one State in the generation, sale, or distribution of electric energy. Except as in this agreement specifically provided, the permittee shall not agree or arrange in any manner whatsoever with any other party generating or disposing of electric energy with a view to the avoidance of competition or the fixing, maintenance, or increase of prices for electric energy or service.

SEC. 26. This permit shall be indeterminate as to time during compliance with the conditions of this agreement by the permittee, or until the United States or any State or municipal corporation shall exercise its option to purchase as provided in section 23. It is expressly understood and agreed, however, that the permit may be revoked by the secretaries, after due notice to the permittee with opportunity for hearing, on a finding by them that any part of the amounts due for the compensation or the charges herein provided for, after due notice has been given, are in arrears for six months; or on a finding by the secretaries that any of the provisions of this agreement or any of the regulations of the secretaries or the provisions of the act of Congress to which the permit is subject as provided in section 2 hereof have been violated by the permittee.

It is further understood and agreed that under the terms of said act of Congress "any permission given by the Secretary of the Interior under the provisions of this act may be revoked by him or by his successor in his discretion."

It is further understood and agreed that at intervals of not less than 20 years, on application of the permittee or on demand of the secretaries, this agreement and the permit shall be modified to conform to the then subsisting regulations fixed by the secretaries under said act of February 15, 1901, or amendments thereto.

SEC. 27. The permittee shall in the exercise of the permission given by the permit, at all times conform to and abide by such rules and regulations subserving the purpose of any reserved lands of the United States through which right of way is sought as may be prescribed by the officer having jurisdiction over such lands.

SEC. 28. The permit does not affect the rights to the occupancy of lands granted by the State of Washington or any rights, privileges, or franchises conferred upon the permittee by virtue of the act of Congress approved February 25, 1907 (34 Stat., 931), as amended by the act of Congress approved May 20, 1912 (37 Stat., 115), entitled "An act to extend the time for the construction of a dam across the Pend d'Oreille River, Washington," or impair or affect the rights conferred upon the said permittee by compliance with the provisions of the act of Congress approved June 23, 1910 (36

Stat., 593), entitled "An act to regulate the construction of dams across navigable waters."

SEC. 29. On proper application by the permittee under subsisting regulations fixed by the secretaries, the permit may be amended to provide for the construction, operation, and maintenance of additional project works and the use of additional rights of way for the power project. Any application for such amendment and approval thereof shall be in the form of a supplemental agreement and permit so drawn as to become a part of the original agreement and permit.

SEC. 30. The permit and the right of way thereby afforded shall be subject to all prior valid rights and to a reservation of right of way for canals or ditches constructed by authority of the United States.

In witness whereof the permittee has caused these presents to be executed, in triplicate, by its vice president and agent and its corporate seal to be hereto affixed by its vice president, both thereunto duly authorized, this 28th day of July, 1913.

[SEAL.] INTERNATIONAL POWER & MANUFACTURING CO.,
By WILBUR S. YEARSLEY, *Vice President.*

Attest:
N. S. COMBS, JR.
M. T. BUNCH.

ACKNOWLEDGMENT.

DISTRICT OF COLUMBIA, *ss:*

On this 28th day of July, 1913, before me, a notary public in and for said county, duly commissioned and sworn, my commission expiring November 6, 1913, personally came Wilbur S. Yearsley, to me personally known, who being by me duly sworn, did depose and say that he resides in Spokane, Wash.; that he is the vice president of the International Power & Manufacturing Co.; that said company is the corporation that is described in and that executed the foregoing agreement; that he knows the seal of said corporation; that the seal affixed to the foregoing agreement is such corporate seal and was affixed to such instrument by order of the board of directors of said corporation, and that he signed his name thereto by like order; and the said Wilbur S. Yearsley acknowledged the foregoing agreement to be the free act and deed of said corporation.

Witness my hand and official seal the day and year first hereinbefore written.

[Notarial seal.] E. C. OWEN,
Notary Public.

My commission expires November 6, 1913.

PERMIT.

In pursuance of the act of Congress approved February 15, 1901 (c. 372; 31 Stat., 790), and in pursuance of the general regulations thereunder fixed, respectively, by the Secretary of the Interior and the Secretary of Agriculture, and in consideration of the conditions made and accepted in the foregoing agreement, permission to use the right of way through the public lands and reservations of the United States under the jurisdiction of the Department of the Interior and the Department of Agriculture sought by and described in the application identified in the foregoing agreement is hereby given to the said International Power & Manufacturing Co., subject, however, to the said general regulations and to the conditions in said agreement, such permission, subject to such regulations and conditions, having been found by us to be not incompatible with the public interest.

In witness whereof we have subscribed these presents, in triplicate, on this 29th day of July, 1913.

ANDRIEUS A. JONES
Acting Secretary of the Interior.
D. F. HOUSTON,
Secretary of Agriculture.

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