UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT DIRECTOR

TWENTY-SECOND
ANNUAL REPORT
1900-1901
PART IV
HYDROGRAPHY



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TWENTY-SECOND ANNUAL REPORT

OF THE

United States Geological Survey

TO THE

SECRETARY OF THE INTERIOR

1900-1901

CHARLES D. WALCOTT

IN FOUR PARTS

PART IV.—HYDROGRAPHY
F. H. Newell, Chief of Division



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TWENTY-SECOND ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART IV.-HYDROGRAPHY

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 30, 1901.

SIR: I have the honor to transmit herewith the manuscript for a volume on hydrography, prepared for publication as Part IV of the Twenty-second Annual Report of the Survey. The data presented relate to the investigations carried on during the calendar year 1900.

The first part of the report discusses the results of measurements of streams in different parts of the United States, the facts being presented in diagrammatic form as well as by statistical tables. The arrangement adopted is that of preceding reports of this series, being a geographic order, beginning in the extreme northeastern part of the United States and ending in the southwestern portion. A number of papers, prepared independently, have been incorporated in this part of the report, with such modification as was necessary to bring them into accord with the general arrangement.

Following the report of stream measurements is a paper by Mr. Arthur Powell Davis, giving conclusions based upon his work while detailed to the Nicaraguan and Isthmian canal commissions. The original data have been incorporated in the reports of those bodies; but since this important investigation has been conducted by one of the members of the United States Geological Survey it is particularly appropriate that a brief recapitulation of the principal facts should appear in this volume. The résumé here given contains the facts of chief interest to students of hydrography, thus rendering them available for consideration in connection with similar data obtained for the United States.

The last paper, "The High Plains and their utilization," by Mr. Willard D. Johnson, is a continuation of that in the Twenty-first Annual Report, Part IV, the completion of which was unfortunately interrupted. Although this break in the sequence involves some inconvenience for reference, it will not detract from the value of the material.

Very respectfully,

F. H. NEWELL, Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,

Director United States Geological Survey.

REPORT OF PROGRESS OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1900

BY

F. H. NEWELL

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REPORT OF PROGRESS OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1900.

By F. H. NEWELL.

FIELD OF OPERATIONS.

During the year 1900 rivers have been measured in various parts of the United States, from Maine to California, and related investigations have been carried on embracing a variety of questions pertaining to the country's resources in water above and under ground. The operations leading up to the estimates of daily flow of streams have occupied most time and attention, for these form to a large extent the foundation upon which rest all matters relating to the hydrography of the country. Consideration has, however, also been given to underground waters, especially to those reached by deep borings; surveys of reservoir sites have been continued, particularly in California, in cooperation with a State organization; the matter of the diversion of large rivers has also been taken up, and various projects relating to the utilization of water for irrigation, power, and other industrial purposes have been investigated. The locations of the principal gaging stations are shown in figs. 1 and 2 by the heavy dots upon branching lines of river systems.a

The industrial application of the results obtained is extremely wide, but for convenience of administration it has been found desirable to classify the data somewhat arbitrarily by geographic divisions. For example, taking the eastern coast and the Appalachian region, the data obtained from stream measurements have the largest use in con-

^{*}The results obtained in preceding years have been described in earlier volumes, notably in Part IV of the Eighteenth, Nineteenth, Twentieth, and Twenty-first Annual Reports. The operations at the river stations during the year 1900 have been given in detail in Water-Supply Papers Nos. 47 to 52, inclusive, to which reference should be made for the data upon which are based the computations of stream flow herein contained. This duplicate form of publication has been adopted, as explained in previous reports, on account of the necessity for making available at the earliest possible date the results of the field work. This has been found possible by publishing the original results of the field operations, without illustrations, in the series of Water-Supply Papers, and holding the computations arising from them until all can be completed and the illustrations can be prepared. A brief statement of the plans and operations of the hydrographic branch of the Survey is also given in the administrative report of the Director, which forms a portion of Part I of the Twenty-second Annual Report.

nection with the development of water power, and therefore this section of the work has been termed the water-power division. West of this, in the great valley of the Ohio, where in the prairie States the streams have relatively slight fall and sluggish flow, sanitary questions are foremost, since the pollution of rivers produces a more immediate

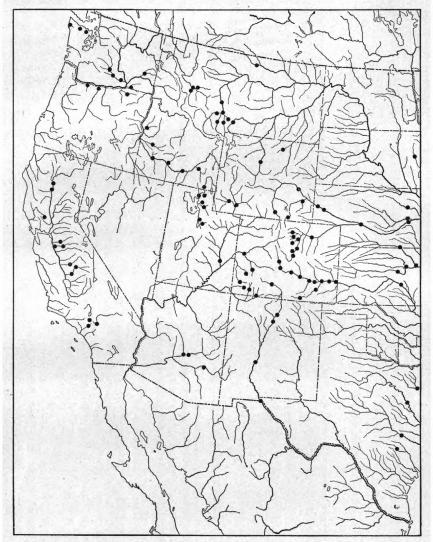


Fig. 1.—Map showing location of river stations in western half of United States in 1900.

and notable effect than in mountainous or hilly areas. This branch of the work is, from the chief factor, designated the sanitary division, although as a matter of fact sanitary problems are also pressing in the eastern or water-power area. In the drainage basins of Missouri River and its tributaries, particularly in that portion known as the Great Plains, the streams are for the most part small and a considerable distance apart. There water from under ground, especially that from artesian sources, has great value, and the investigation has consisted principally of a complete study of the geology, so conducted

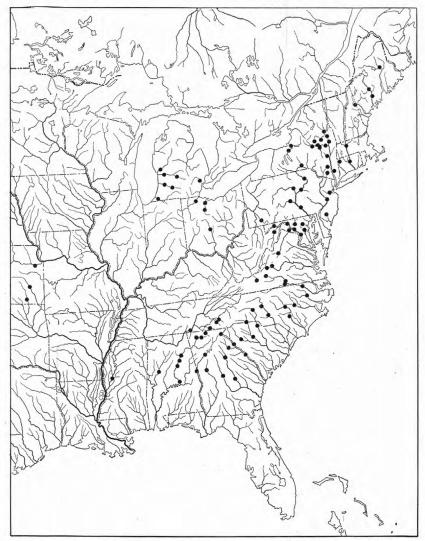


Fig. 2.—Map showing location of river stations in eastern half of United States in 1900.

as to yield facts concerning the depth to the water and the possibility of obtaining it. Stream measurements are made in this region wherever practicable, but as they are subordinate to the problem of obtaining water from deep wells, this section has been designated the artesian division.

In the northwestern part of the United States, embracing the northern half of the arid region, the rivers, coming from high mountains, are of larger volume than those of the southern portion of the arid region. The utilization and development of the vast extent of public land there rest to a considerable degree upon the diversion of these streams. The expense of the work is prohibitory as a speculative enterprise. If the streams are to be diverted, therefore, it is evident that the work must be done with public funds. The examination of this great area has been systematically entered upon, and since the work for the most part deals with the taking out of the water of large rivers it has been designated the diversion survey.

In the southern half of the arid region, or the southwestern part of the United States, the question of making homes upon the public lands is largely one of reservoir construction, since the rivers are usually small, with intermittent flow. There the cost and capacity of reservoirs, and especially the depth at which suitable foundations for dams can be obtained, are of special importance, and the work therefore falls mainly under the head of reservoir surveys.

In each of these divisions or sections of the country the leading feature just described is by no means the only important one, but all of the other problems enter to a greater or less extent. For example, in the Southwest there are streams to be diverted, there is considerable water power to be developed, and sanitary questions are involved, necessitating consultation along all these lines; but, nevertheless, the main feature is water storage. The same is true of the other sections; each has important considerations beyond the central or predominant investigation.

With these conditions in view the administration of the hydrographic work has been divided among experts, each of whom has prominently in mind the leading feature of his work, and who from time to time consults with engineers familiar with the numerous details. In this way it is possible to expand the work and to adjust it to the varying conditions which arise. The principal object in view, however, is the procurement of data which shall show the extent to which the arid lands can be redeemed by irrigation.

ARID REGIONS.

The arid regions of the United States include about two-fifths of its entire area, and extend from about the middle of the continent westerly nearly to the Pacific Ocean. There are no sharply marked lines or divisions between the arid and the humid areas, but there is, especially near the center of the United States, a broad intermediate belt neither distinctly arid nor distinctly humid, which is called the subhumid or semiarid region. This belt extends over North Dakota, South Dakota, western Nebraska, and western Kansas, into Oklahoma

and the panhandle of Texas. In years of excessive moisture the subhumid region sometimes creeps up toward the foothills of the Rocky Mountains, while during dry years the greater part of the Plains region west of the Missouri becomes semiarid. The relative extent of the regions of aridity is shown in fig. 3.

In a general way it may be said that arid regions are those where the average annual rainfall is 20 or fewer inches. The arid regions of the United States, therefore, are but a portion of those of North America, there being large tracts of arid lands in Mexico on the south and in Canada on the north. Modern civilization has developed largely in humid regions, and thus we have come to regard aridity as exceptional. As a matter of fact, however, a great part of the countries of the Old World have less than 20 inches annual rainfall, and

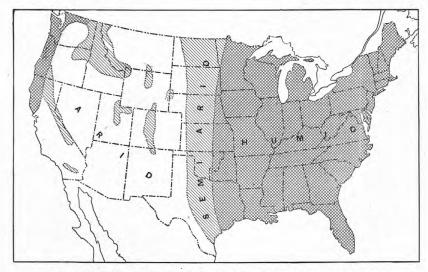


Fig. 3.-Map showing arid, semiarid and humid regions of the United States.

therefore according to our standards must be considered arid. The civilization of former times, however, grew up in those arid regions, and we can not fully appreciate the writings of the ancients and the true meaning of many familiar phrases handed down to us without bearing in mind the fact that the writers lived in an arid climate, where agriculture was successful only through irrigation. The accompanying map (fig. 4) illustrates the great extent of aridity throughout the world, and shows that the Mediterranean countries (including Egypt) and India, the latter the seat of ancient civilization, are in large part arid and desertlike in character. The dense foliage of the forests of the eastern part of the United States and of Europe and the verdant covering of turf so common in our modern towns and villages were practically unknown to the races who produced the

sacred books of the East, and their frequent references to the lifegiving qualities of water show the high value which they placed on it.

Aridity, or, rather, the unequal distribution of moisture, is largely the result of topography or of inequalities of land surface. If the globe were entirely flat it is probable that the winds, meeting with no obstructions, would distribute the rains with considerable uniformity in broad bands approximately parallel to the equator; but the relatively thin layer of dense atmosphere surrounding the globe is disturbed in its uniform movement by the lofty mountain masses which traverse the continents. The atmosphere enveloping the earth extends outward for many miles, but it is the thin layer a mile or two in thickness resting immediately upon the surface within which occur the

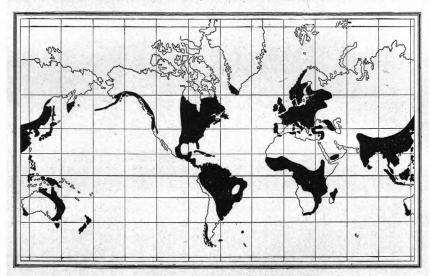


Fig. 4.-Map showing arid regions of the world.

changes or disturbances that make up what we know as weather. The movements of the air above this thin layer concern us little; it is the clouds and winds near the surface that bring success or failure to the farmer, and affect, more or less directly, other industries, and even health.

Taking the United States as a whole, the general movement of the atmosphere is from west to east. The moisture-laden winds from the Pacific encountering the mountain masses which extend along or parallel to the coast are forced upward and cooled. In winter they deposit much of their moisture on the mountains, and then pass eastward as dry winds, leaving the broad plains east of the Sierra Nevada dry, sterile, and desertlike in character. In the summer, however, when the mountains have become relatively warm, the winds from the

Pacific pass over them without leaving their moisture, and thus there results the summer drought characteristic of the Pacific coast. Passing onward the winds, not deprived of humidity, give up from time to time portions of their precious fluid, and thus in the interior there are the occasional summer rains, which tend to make amends for the deficient precipitation of the winter season. East of the Sierra Nevada and Coast ranges and the plains and deserts at their bases are scattered irregular mountain ranges and the great Cordillera or Rocky Mountain system, whose high summits intercept the rain-bearing winds. These mountain ranges are for the most part well watered, while the lowlands are parched with drought. From the east face of the Rocky Mountains the High Plains stretch out toward the Mississippi Valley, decreasing gradually in altitude to the rolling plains and prairies of the East-Central States.

The mean monthly precipitation in the western part of the United States is shown in the following table and illustrated by the accompanying diagram, fig. 5, which illustrates graphically the contrast between the distribution of precipitation on the western coast and in the interior.

Normal monthly precipitation, in inches, at various localities in the Western States.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Length of record.
Walla Walla.													Years.
Wash	2.28	1,54	1.81	1.90	1.70	1.23	0.30	0.43	0.91	1.63	2.02	2.07	15
Fort Bidwell, Cal.	3.58	2.37	2.25	1.58	1.39	1.12	0.31	0.17	0.43	1.02	2.16	3.26	27
San Francisco, Cal	4.60	3.31	3.14	1.89	0.76	0.22	0.02	0.01	0.30	1.34	2.70	4.56	30
San Diego, Cal	1.99	1.98	1.51	0.70	0.39	0.06	0.01	0.11	0.05	0.42	0.77	1.91	29
Boise, Idaho	2.24	1.61	1.72	1.19	1.66	0.78	0.18	0.23	0.45	1.11	1.31	1.83	29
Promontory, Utah	1.03	0.85	0.79	0.69	0.81	0.53	0.23	0.36	0.65	0.58	0.55	0.90	27
Beowawe, Nev	0.78	0.69	0.63	0.60	0.76	0.42	0.22	0.11	0.23	0.38	0.54	0.88	30
Yuma, Ariz	0.48	0.42	0.27	0.08	0.03	T.	0.13	0.33	0.15	0.23	0.26	0.45	25
Fort Ellis, Mont	0.87	0.91	1.39	1.76	4.31	3.45	1.03	1.18	1.49	1.23	0.75	1.33	15
Cheyenne, Wyo	0.41	0.46	0.83	1.55	2.28	1.51	2.04	1.53	0.90	0.70	0.36	0.31	30
Santa Fe, N. Mex.	0.60	0.79	0.69	0.80	1.11	0.97	2.88	2.46	1.52	1.08	0.70	0.76	28
Fort Stanton, N. Mex	0.64	0.75	0.96	0.57	0.96	1.71	3.17	3.73	2.06	1.37	0.76	1.04	22
Fort Totten, N. Dak	0.49	0.53	0.92	1.40	2, 32	3.69	2, 37	2, 49	0.99	1,20	0.83	0.55	21
North Platte, Nebr	0.45	0.41	0.73	2, 20	2.57	3.17	2, 61	2.33	1, 25	1.04	0.41	0.51	26
Fort Reno, Okla	1.02	1.38	1.53	2.49	3.90	3.92	2.66	3.10	2.45	2.95	1.31	1.42	16
Waco, Tex	2.92	1.87	2.88	4.22	4.56	3.33	1.78	3.05	2.78	2.13	2.40	2.03	a13 to 21

^aThe length of records for the various months varies, the average for some months extending over a period of thirteen years, while the average for other months extends over a period of twenty and twenty-one years.

The average annual precipitation at the foregoing places is given in the following table:

Average annual	precipitation at	various	localities in	the	Western States.
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Station.	Length of record.	Average rainfall.
	Years.	Inches.
Walla Walla, Wash	15	17.82
Fort Bidwell, Cal	27	19.64
San Francisco, Cal	30	22.85
San Diego, Cal	29	9.90
Boise, Idaho	29	14.31
Promontory, Utah	27	7.97
Beowawe, Nev	30	6.24
Yuma, Ariz	25	2.83
Fort Ellis, Mont	15	19.70
Cheyenne, Wyo	30	12.88
Santa Fe, N. Mex	28	14.36
Fort Stanton, N. Mex	22	17.72
Fort Totten, N. Dak	21	17.78
North Platte, Nebr	26	17.68
Fort Reno, Okla	16	28.18
Waco, Tex	13 to 21	33, 95

The average amount of rain falling at the places above named during each month is indicated in fig. 5. Taking, for example, San Francisco, it will be seen that the rain during January averages more than 4 inches, that the amount decreases during February, March, and April, and becomes less than an inch in May. In June, July, August, and September there is practically a drought, followed, in October, November, and December, by a sudden increase in the amount of precipitation. In contrast with this is the distribution of rainfall at Santa Fe, where the spring and winter months have comparatively little precipitation, the greatest amount occurring in July and August. Thus it may happen that although there is more than 20 inches of rainfall each year at points near the Pacific coast, yet irrigation is necessary during the latter part of the crop season, and especially in the late summer; while in other localities, where there is less annual rainfall but heavy summer precipitation, the artificial application of water is not needed.

The diagram (fig. 5) being illustrative of averages for a considerable number of years exhibits a regularity which does not occur in any one year. The monthly rainfall, while tending to follow in the long run a certain law, is from season to season extremely erratic, being in some years half as much or twice as great as in other years. To illustrate these seasonal fluctuations the following tables are given of the annual precipitation at three important points in the arid region, viz, Santa Fe, N. Mex., Salt Lake City, Utah, and Denver, Colo. The record

for Salt Lake City begins with observations made at Camp Douglas, an army post on the high ground overlooking the city, where the precipitation may be slightly in excess of that at the city station. The results are, however, sufficiently accurate for purposes of comparison. The figures from 1865 to 1874 are for Camp Douglas, those from 1875 to 1900 for Salt Lake City.

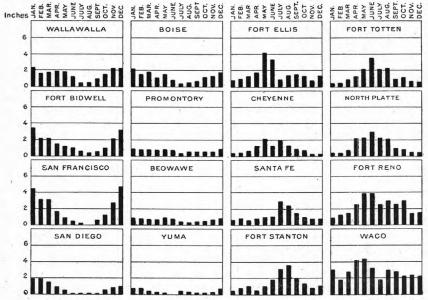


Fig. 5.—Diagram showing mean monthly precipitation at sixteen localities in the Western States.

Annual precipitation, in inches, at Santa Fe, N. Mex.

Year.	Precipi- tation.	Year.	Precipitation.	Year.	Precipitation.	Year.	Precipi tation.
1853	21.77	1865	23.15	1877	13.15	1889	7.89
1854	24.80	1866		1878	19.52	1890	12.88
1855	24.18	1867		1879	11.44	1891	16.79
1856	23.07	1868	8.92	1880	9.89	1892	11.62
1857	8.52	1869	11.08	1881		1893	14.94
1858	11.35	1870	13.93	1882	11.37	1894	13.31
1859	9.49	1871	14.62	1883		1895	20, 24
1860	8.83	1872 в	9.87	1884		1896	14.28
1861	a 15. 79	1873	9.73	1885	14.89	1897	20.40
1862		1874	19.93	1886	15.90	1898	12.97
1863	7.75	1875	18.97	1887	13.38	1899	10.05
1864	a 20. 72	1876	15.07	1888	12.03	1900	15.89

^{*} Estimated.

b Signal Service observations.

Annual precipitation, in inches, at Camp Douglas and Salt Lake	Annual	City, Utah.	a
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Year.	Precipitation.	Year.	Precipitation.	Year.	Precipitation.	Year.	Precipi- tation.
1865	16.86	1874	19.27	1883	14.24	1892	14.08
1866	ь 17.54	1875	23.64	1884	17.52	1893	17.35
1867	28.00	1876	21.28	1885	19.69	1894	15.27
1868	16.99	1877	16.35	1886	18.89	1895	11.95
1869	b 21. 19	1878	19.75	1887	11.66	1896	18.42
1870	20.24	1879	13.11	1888	13.62	1897	16.74
1871	19.59	1880	10.94	1889	18.46	1898	16.09
1872	15.09	1881	16.88	1890	10.33	1899	17.57
1873	15. 21	1882	15.98	1891	15.92	1900	11.53

^aThe record from 1865 to 1874 is for Camp Douglas; that from 1875 to 1900 is for Salt Lake City.

Annual precipitation, in inches, at Denver, Colo.

Year.	Precipi- tation.	Year.	Precipitation.	Year.	Precipitation.	Year.	Precipi- tation.
1870	13. 29	1878	15.51	1886	15.07	1894	15.09
1871	12.09	1879	10.86	1887	12.49	1895	16.12
1872	18.05	1886	9.58	1888	9.51	1896	11.84
1873	11.81	1881	12.78	1889	14.75	1897	15.37
1874	13.46	1882	14.49	1890	9.33	1898	12.98
1875	17.25	1883	19.49	1891	21.43	1899	9.33
1876	20.12	1884	15.07	1892	15.02	1900	15.29
1877	16.38	1885	15.95	1893	8.48.		

To bring these facts more graphically to the eye fig. 6 has been prepared, showing the variations in the precipitation at the three places mentioned. Referring first to the portion of the diagram showing the fluctuations in the amount of precipitation at Salt Lake City, it will be noted that the average annual rainfall there is a little more than 15 inches. In 1890, however, the total precipitation was 10 inches, and in 1867 it was 28 inches, fluctuating, as shown by the diagram, between 10 and 28 inches. When a shortage occurs the effects of the aridity are notably increased, and a large amount of water is needed to supply, artificially, the deficiency. Similar fluctuations in rainfall occur in humid regions, but there the effects are not so marked. For example, in a country like that along the Atlantic seaboard, where the annual precipitation averages 50 inches, a deficiency of 10 inches during the year may not have an appreciable effect upon the crops and industrial conditions, but in a country where the annual rainfall is only 20 inches a deficiency of 10 inches may result in the disappearance of rivers and the destruction of the scanty vegetation so valuable in the cattle and sheep industries.

In the humid East the impression is rather general that aridity implies desert conditions—i. e., absence of vegetation, with naked rocks

b Estimated.

and sand glistening in the brilliant sunshine. On the contrary, the area of actual desert lands in the United States is relatively small. To the west of Great Salt Lake is what may be termed a true desert of sand and alkali, destitute of vegetation except a few thorny or woody plants which occur at intervals; and in southern California, adjacent to Colorado River, is the Salton Desert, which embraces the bottom of an ancient arm of the Gulf of California, the land surface being in some places 300 feet below sea level, but shut off from the tides by the bars and ridges of mud brought down by the river. It is estimated

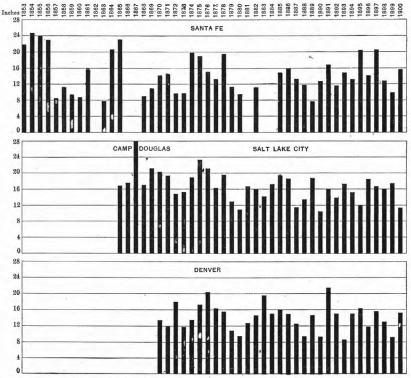


Fig. 6.—Diagram showing annual precipitation at Sante Fe, N. Mex., Camp Douglas and Salt Lake City, Utah, and Denver, Colo.

that there are 70,000,000 acres of desertlike lands in the United States, areas which do not support any plants suitable for forage. The remainder of the arid regions is covered with a more or less scanty vegetation of some value to mankind.

The distribution of rainfall throughout the United States in average years is shown by the map forming fig. 7, the quantity being indicated by the several different degrees of shading. The heavy precipitation on the east and west coasts is thus brought out, and also the deficiency of moisture in the interior. As a companion to this fig. 8

has been prepared, showing, not the amount of rain upon the surface, but the amount of water which flows off in streams. If all of the rain

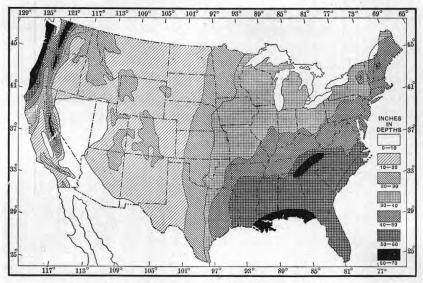


Fig. 7.—Map showing mean annual rainfall in United States.

and melted snow remained upon the ground where it fell it would cover the surface to the depth shown by the map—40 to 60 inches—and

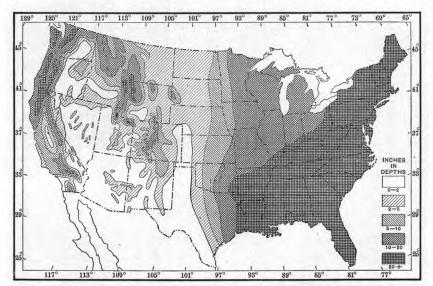


Fig. 8.—Map showing mean annual run-off in United States.

even more near the coast. Much of this, however, soaks into the ground or is evaporated from the surface, leaving about half or less

to form creeks and rivers. It is the latter amount that is indicated by the map of mean annual run-off (fig. 8). The proportion of water which runs off varies widely, but is related to the amount of precipitation in that the proportion of run-off increases with the rainfall; that is to say, where the rainfall is very light—from 15 to 20 inches a year—only 1 or 2 per cent flows into the streams; where the rainfall aggregates 60 inches, fully 50 per cent escapes to form large rivers. This matter has been discussed in the Fourteenth Annual Report, Part II, pages 149 to 152.

PUBLIC LANDS.

One-third of the United States, exclusive of Alaska and outlying possessions, consists of vacant public land. One of the great economic questions now before the people of the country is the utilization of this vast area, much of which has a rich soil and under good management would be capable of sustaining a large population. As matters are now drifting, however, these lands are not being utilized to any considerable extent for the making of homes, but are passing into the control of speculators or large landowners.

The public lands are open to entry and settlement under what is known as the homestead law, the intent and purpose of which is to provide homes for the rapidly increasing population and permit an extension of the agricultural area as rapidly as the needs of the people demand. The object of the law is, however, not being accomplished, because of the fact that the lands are for the most part within the arid region and crops can not be produced until a water supply has been obtained sufficient to moisten the soil during the growing season. There is a large amount of water that can thus be employed, but the expense of utilizing it is too great for the settler. The lands in localities where water can easily be diverted to the thirsty soil were taken up by the pioneers. In the olden days it was possible for a man with a team and ordinary farm tools to construct ditches leading from the creeks flowing out of the mountains, and thus to provide channels by which his farm could be irrigated. In this way he was able to produce crops on the lowlands along the rivers and gradually extend the system of water supply to even the adjacent terraces or bench lands. The later comers, however, find that the small streams are already fringed with farms, and that the land lying beyond, although in many cases of better quality, can not be watered except at great cost.

It is for the interest of the public at large and the nation to have all of these good agricultural lands utilized, and the question arises: Who is to make it possible for the settler to occupy them? The answer must come from the lawmakers of the country, and before they can answer it intelligently they must be in possession of the facts.

The laws governing the disposal of public lands have been drawn

almost wholly with reference to the broad prairies and plains of the Mississippi Valley, where the rainfall is sufficient to mature the crops. In that flat or gently rolling country every tract of 160 acres is practically as good as its neighbor, small differences of soil and surface erosion being excepted, and each farmer is independent as regards his method of cultivation, conducting his operations in the manner that his experience dictates. In the great arid region, however, where lies the larger part of the unoccupied public lands (see fig. 9), the value

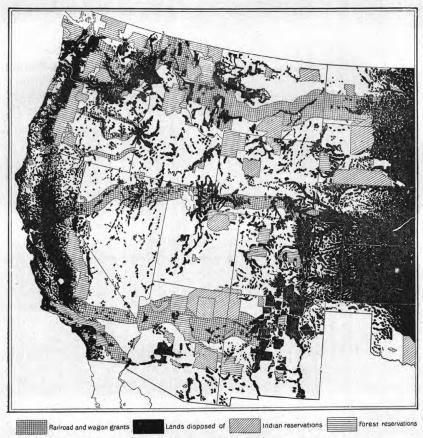


Fig. 9.—Map showing location of vacant public lands.

of the farm depends almost wholly upon the water supply, the accessibility and permanence of which far outweigh all other considerations. There the interests of the farmers are closely related, for all depend upon streams or other sources of supply used in common, and independence must give way to cooperation. While the lands may be equally good as regards soil, their value may be far different, because of the fact that one tract of land has more water than another; so that the man who controls the water virtually owns everything of value.

This fact has not been sufficiently recognized in framing laws governing the disposal of the public lands, and the result is that in many localities water monopoly is a powerful factor. In numerous instances title to a few hundred acres has virtually given possession to thousands of other acres, because the latter are rendered practically valueless by being cut off from participation in the water supply. In other words, the creation of hundreds of homes has been prevented by neglect to safely guard the right to the use of the scanty supply of water.

Without going into details it is sufficient to state that the rectangular system of subdivision of the public lands, while one of the most beneficial measures leading to the settlement of the Ohio and Mississippi valleys, has been found to be detrimental to the best growth of the western two-fifths of the United States. This has arisen from a lack of knowledge by the public, who are the owners, as to the part which irrigation plays in the utilization of the lands of the West. Attention has been concentrated upon land titles, and great care has been exercised in surveying, in the marking of boundaries, and in recording the patents or deeds, while the water, which alone gives value to the land, has scarcely been considered, and the rights to its use are in a most chaotic condition. It would have been far better, if one or the other were to be neglected, to have given first thought to the water rights and secondary consideration to the titles.

To remedy this evil so that the remaining public lands will furnish the greatest possible number of homes is an object worthy the sustained effort of enlightened and patriotic citizens. To assemble the facts upon which intelligent action can be based is a task to which the best efforts of aspiring students or investors may well be directed. These facts pertain first of all to the water supply and its limitations, since in a country where arid land is in excess the useful area is limited by the available water.

The term irrigation has been used in a double sense. In its original and narrow meaning it covers the operation of artificially supplying moisture to the soil to supplement a scanty rainfall or overcome a drought. In the wider and looser sense it has been made to include the whole question of conservation and utilization of water in the development of the arid region, and to embrace a discussion of features of social and political importance arising from the reclamation of the arid public domain. In the first instance irrigation is of prime importance to the farmer or agriculturist who is attempting to raise crops in a country of deficient rainfall. He wishes to produce the most profitable fruits or grains with the least expenditure of time and energy. To him a discussion of irrigation means a description of the methods of applying water, the amount to be given to various soils and to different crops, and the results obtained by applying or withholding water at stated periods of plant life. In the second instance

irrigation is of concern to all citizens of the United States, since they are the great landowners, and, as such, are, or should be, interested to see that their lands are put to the best uses. It is their duty also to guard these vast tracts, the heritage of their children, and prevent them from falling into the hands of persons who will treat them as a speculative commodity, regardless of the future. It is from the standpoint of the citizen that the subject is here discussed. Unquestionably it is a duty of the highest citizenship to provide a hundred homes for independent farmers, instead of permitting the land to be occupied as one or two great stock ranches, controlled by nonresidents, and furnishing employment to only a few nomadic herders. These facts should be borne in mind to appreciate fully the effect of neglect or forethought upon the future of the country.

FORESTS.

The higher mountain slopes and mesas whose abrupt rise forces upward the winds and compels them to deposit moisture have, as a consequence of the increased precipitation, a covering of trees. In places the trees are scattered, but in many localities they form dense and valuable forests. Within the arid and semiarid portions of the Western States it is estimated that nearly 120,000,000 acres are covered with woodland, the trees, though scattered, having value for firewood, fence posts, rails, and other purposes essential to the success of the pioneer and the farmer. In addition, more than 75,000,000 acres are covered with heavy forests having commercial value as timber. aggregate area of desert, woodland, and forest is a little more than half the extent of the arid and semiarid regions; the remainder, estimated at 470,000,000 acres, is grazing land. Thus, so far as area is concerned, it is evident that the grazing industry, or the raising of range stock—that is, cattle, horses, sheep, and goats—is and probably always will be the great industrial pursuit. So far as values are concerned, however, there is another aspect of the matter.

The open range of the arid region is generally stated to be capable of supporting one cow to every 20 acres. The same land when watered and put in alfalfa will frequently feed ten cows to every 20 acres, or in orchards at favorable altitudes will support a family of three, or even five, persons. The open range may have a value of 50 cents an acre, while under irrigation the selling price may jump to \$50 an acre, and if in orchards to \$500 an acre. Thus the values of the lands are directly reversed, the grazing land having the greatest extent and the least value and the irrigated land the least extent and the greatest value.

The forests of the arid region mark not only the greatest rainfall but also the localities whence come the principal streams, for the headwaters of nearly all of the rivers and creeks which give value to the lands are within forested regions. It is commonly believed that to a certain extent the forests protect and even regulate the flow of these streams, and it has been urged that the largest and best development of the country requires the conservation of the forests along the headwaters. This conservation can be accomplished by suitable regu-

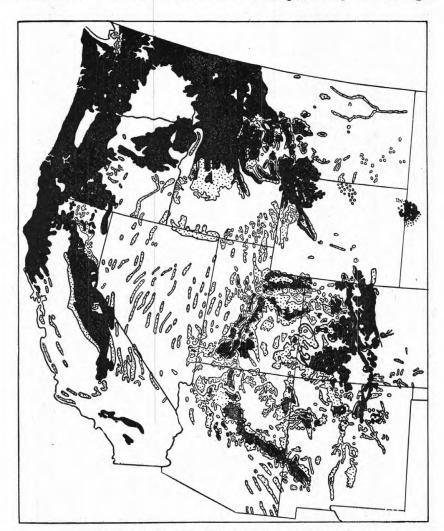


Fig. 10.—Map showing location of forests and woodlands of the West.

lations regarding the cutting of the timber. Experience has shown that the removal of the mature or ripe trees, such as are best suited for lumber, improves the general condition of the forests. In some of the wooded areas of the West the proportion of trees which have passed maturity and are dying or dead is as high as 40 per cent. It is

obvious that these trees should be removed as quickly as possible, before they have lost their value as lumber and become a source of danger to the younger growth. From the commercial standpoint, trees have first value for lumber; and, fortunately, the best use of the forests as lumber producers is not antagonistic to their preservation and to the perpetuation of favorable conditions for a permanent water supply. Public sentiment has been aroused to such an extent that steps have already been taken to preserve the forests of the headwater streams of the West, primarily for the beneficial influence which the leafy cover may have upon stream flow. The Government has already set aside more than 47,000,000 acres of forests and adjacent woodlands, and efforts are being made to preserve the remainder of the large public forests. The first step in the preservation of the forests is to protect them from their great enemy, fire; the next step is the judicious cutting of the mature trees, which should be conducted on a businesslike basis that will make the forests yield a revenue sufficient to pay the cost of patrolling and protecting them. It is believed that with systematic supervision similar to that employed in the preservation of the public forests in other parts of the world it will be possible to protect the headwaters of the streams without cost to the taxpaver.

The accompanying map (fig. 10) shows the general distribution of the forests of the West, all of which are in the mountains or highlands. The black portions indicate the areas upon which trees of commercial value are growing or have recently grown. The areas surrounded by irregular lines indicate the wooded portions of lower mountains upon which are scattered trees whose size or condition is such that they are not suitable for lumber, although they are of great value to the settler and the farmer for cheap fuel and material for fence posts, cabins, corrals, and shelter for cattle. Much of this woodland has been included in forest reservations, and under effective protection the more valuable trees will probably thrive.

The forest reserves already created do not by any means embrace all of the public lands covered with valuable timber, but each reserve has been segregated for a specific purpose, usually with reference to the protection of the headwaters of streams used for irrigation. The location of the forest reserves is shown on the map forming fig. 11, which also shows the lands still held for the use of various Indian tribes. Some of the latter lands include wooded areas. The map also shows the Yellowstone National Park, which, although not a forest reservation, is of the same general character. It is to be noted that the Indian reservations, which formerly embraced almost the entire West, have shrank to a small percentage of that vast country and are steadily diminishing in area, while the forest reserves are being increased in number and in size. Under the present system, as farms

are allotted in severalty to the heads of Indian families, the Indian reservations are gradually decreased in size, the lands in excess of those specifically allotted being sold or thrown open to homestead entry by the whites. In a few cases the wooded lands formerly embraced in the Indian reservations have been created into forest reserves.

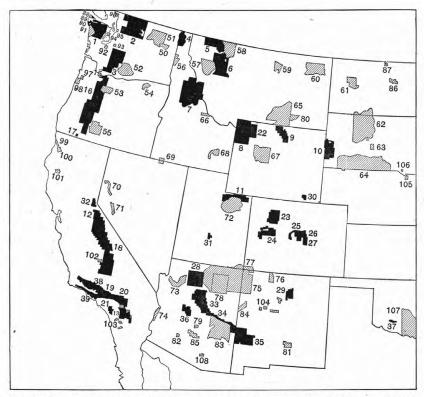


Fig. 11.—Map showing location of forest reserves and Indian reservations. Black areas are forest reserves; shaded areas are Indian reservations.

FOREST RESERVES.

- 3. Mount Rainier. 4. Priest River. 5. Flathead, 6 Lewis and Clarke. 7. Bitterroot. 8. Teton.
- 9. Bighorn. 10. Black Hills.

1. Olympic.

2. Washington.

- 11. Uinta. 12. Stanislaus.
- 13. San Jacinto.

- 15. Bull Run.
- 16. Cascade Range.
- 17. Ashland.
- 18. Sierra.
- 19. San Gabriel.
- 20. San Bernardino.
- 21. Trabuco Canvon.
- 22. Yellowstone Park.
- 23. White River Plateau.
- 24. Battlem ** Mesaa.
- 25. Sout Platte.
- 26. Plum Creek.
- 27. Pikes Peak.

- 28. Grand Canyon.
- 29. Pecos River.
- 30. Crow Creek.
- 31. Fish Lake.
- 32. Lake Tahoe.
- 33. San Francisco Mountain.
- 34. Black Mesa.
- 35. Gila River. 36. Prescott.
- 37. Wichita.
- 38. Pine Mountain and Zaca Lake.
- 39. Santa Inez.

INDIAN RESERVATIONS.

50. Spokane.	69. Duck Valley.	89. Osette.
51. Colville.	70. Pyramid Lake.	90. Hoh.
52. Yakima.	71. Walker River.	91. Quinaielt.
53. Warmsprings.	72. Uinta.	92. Nisqualli.
54. Umatilla.'	73. Walapai.	93. Puyallup.
55. Klamath.	74. Colorado River.	94. Fort Madison.
56. Cœur d'Alène.	75. Navaho.	95. Tulalip.
57. Flathead.	76. Jicarilla.	96. Lummi.
58. Blackfoot.	77. Southern Ute.	97. Grande Ronde.
59. Fort Belknap.	78. Hopi.	98. Siletz.
60. Fort Peck.	79. Salt River.	99. Klamath River.
61. Fort Berthold.	80. Northern Cheyenne.	100. Hupa Valley.
62. Standing Rock and	81. Mescalero Apache.	101. Round Valley.
Cheyenne River.	82. Gila Bend.	102. Tule River.
63. Lower Brulé.	83. White Mountain.	103. Mission.
64. Pine Ridge and Rose-	84. Zuñi.	104. Pueblo grants.
bud.	85. Gila River.	105. Niobrara.
65. Crow.	86. Devils Lake.	106. Yankton.
66. Lemhi.	87. Turtle Mountain.	107. Chickasaw.
67. Wind River.	88. Makah.	108. Papago.
68. Fort Hull.		

Three bureaus of the Government are closely identified with the forest reservations. To the General Land Office, Department of the Interior, has been intrusted the guarding and patrolling of the reservations. The survey of the regions within and adjacent to the reserves has been assigned to the Geological Survey, which bureau is preparing detailed topographic maps showing all elevations of the surface, the streams and their catchment areas, the extent of burns resulting from fires, the amount of cutting, and the location of roads, trails, houses, Upon the topographic base thus prepared there is indicated, by appropriate colors, the general character and commercial value of the standing timber. After the mapping of the forest reserves by the Geological Survey comes the systematic examination and preparation of working plans by the Bureau of Forestry of the Department of Agriculture. By an effective protection from fire and by following carefully prepared working plans it should be possible to enlarge the wooded areas upon the headwaters of streams of the arid West, and to increase the beneficial effect which the forests have upon the flow of the streams upon which the irrigators depend.

GRAZING LANDS.

By far the greater portion of the arid West consists of open grazing lands, which vary in their covering of forage plants from the extremely scanty vegetation of the deserts to the thick turf which is to be found within the mountain parks. The broad, sandy deserts are occasionally drenched by a local storm or a cloud-burst, and at once there springs up a scanty herbage, which, though apparently dry and woody, is nutritious and is eagerly sought by the cattle. The less arid plains support a variety of grasses and small plants or shrubs, which, drying under the intense heat, become in effect naturally cured

hay, and although sparsely distributed this herbage furnishes sustenance for horses, cattle, and sheep,

As summer approaches and the heat upon the deserts and plains becomes intolerable, the herds and flocks gradually move up into the mountains, and find excellent grazing upon the broad slopes and open spaces within the forested areas. Thus a considerable portion of the lands shown in fig. 10 as wooded and forested areas is also of value for grazing. The interests, however, of the stock herder (more particularly the shepherd) and of the forester are often at variance, since the stock (more particularly the sheep) browse upon the young herbage and prevent the growth and development of small trees. So great is the destruction that it is often necessary to exclude sheep and cattle from the forests, in order that the trees may reproduce themselves under natural conditions. For this reason the extension of forest reserves has frequently been opposed by the sheep and cattle interests, and their administration has been hampered by the demand for free grazing upon the public lands.

Sheep raising is one of the chief pursuits of the arid region, and the profits are notably large, so that from a commercial standpoint it is highly important that the grazing lands be as widely extended as possible, even into forest reserves. Obviously it is not good public policy to prevent the growth of wool valued at \$10 to encourage the growth of trees which are not worth \$1. It is believed, however, that, with a proper system for the preservation and development of the forests, while sheep may be excluded from certain areas they can, with a minimum amount of injury to the young growth, be permitted to graze in other areas. No general working plan has yet been adopted, but the need of one is great, for there is constant controversy between the irrigators and water users on the one hand, who are concerned in protecting their water supply, and the sheep owners on the other hand, who demand that their flocks shall graze wherever young plants can be found.

The approximate location and extent of the open or free grazing lands are shown on the accompanying map, fig. 12, the cross-lined areas indicating the lands where, for the most part, sheep, cattle, and horses graze freely. Some of these lands are in private ownership, particularly those in western Nebraska, in Kansas, and in Texas. The map is on too small a scale to exhibit deserts and mountain tops where no forage plants exist. It serves, however, to emphasize the fact that throughout nearly half of the United States grazing is the principal industry, and any plan for the reclamation and utilization of the vast arid region must take cognizance of this fact and be shaped accordingly.

From one standpoint irrigation may be regarded as an outgrowth or later development of the grazing industry, especially in the more

northern part of the arid region. In the early days, at the approach of cold weather the sheep and cattle on the open ranges were driven down into the lower valleys or sought natural shelter. During severe winters the losses were extremely large, occasionally from half to three-fourths of the stock dying during long-continued or extremely stormy weather. With the growth of the business and the overstocking of the ranges the necessity for providing winter feed for the young and less vigorous animals became evident, and the owners began to irrigate small areas at the home ranches in order to provide

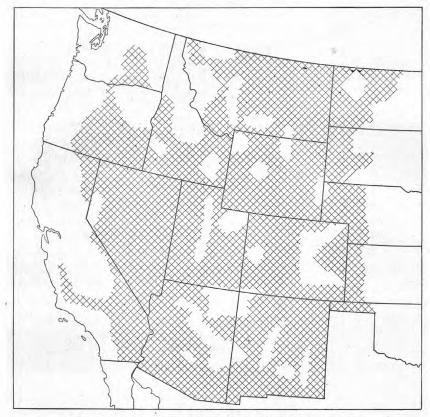


Fig. 12.—Map showing approximate location and extent of open range.

forage for them during the winter. This practice has increased to such an extent that a balance has been reached between the available summer range and the winter food supply raised by irrigation. In other words, a cattle owner can maintain as many animals as he can feed for two or three months with forage raised by irrigation, provided he can obtain sufficient summer range. If, however, his summer range is limited or is partly injured by incursions of sheep, he may find it economy to reduce the amount of feed raised by artificial watering, and consequently the size of his herd.

Owing to the competition for summer range and the necessity for providing an increased amount of winter feed, the tendency in the stock-raising business is toward an increase in the number of small owners and a diminution of great herds and flocks. Thus there is a gradual evolution from stock raising toward what is sometimes known as stock farming. That is to say, the owner of a relatively small herd is tempted to put his irrigated land into crops other than forage, or to raise an additional amount of the latter for sale in local markets. In some of the stock-raising districts, therefore, there is a gradual development toward intensive farming.

Nearly every settler upon the public domain, whether intending ultimately to raise the ordinary farm crops and fruits or to confine himself to stock raising, requires for a time a certain amount of grazing land, for in any case he must have a few draft animals and dairy cows, and as a rule he finds it profitable to own a small herd of cattle or a band of sheep. Therefore he desires and needs the use of the public land in his vicinity in order that he may close herd his cattle and bring them in each day or at frequent intervals. But under existing laws the settler who is making a home has no legal right to the use of public lands other than the right possessed in common by every citizen of the country. Often he feels the gross injustice of the laws when cattle or sheep belonging to a nonresident person or corporation come upon the land in his vicinity and destroy all of the nutritious vegetation. Naturally he feels that since he is trying to make a home and is paying taxes for the maintenance of law and order he has a superior right to the use of the unoccupied land until it is wanted for homes for other settlers, or until he is in position to raise by irrigation sufficient forage for his cattle. Thus it happens that the settler is often at war with the stock owner; and, in addition, many areas which might have been utilized for homes have been kept vacant from fear of depredations by the cattlemen, or of resort to open violence.

On the free range there is also controversy between rival stock owners, particularly between the sheep herders and the cattlemen. Sheep and cattle can not graze on the same area, and as a rule a band of the former will render the range unfit for the latter and will drive them out. With the growth of the wool industry the range devoted to cattle is being encroached upon, and many of the owners are disposing of their herds and are going into the sheep business, finding it possible to make a living on the public lands by sheep grazing when they can not do so by raising cattle.

In many localities there exists among the various interests concerned with the use of the public land what might be termed an armed neutrality. The settler and irrigator, having obtained a foothold, has been able, by combining with his fellows and by a show of force at times, to secure for himself the use of certain pieces of public land for grazing.

The cattle companies and the larger stock owners have, as a rule, found it good policy not to encroach upon the settlers who are already established, and have combined with these men to exclude sheep from the cattle ranges used by all in common. After numerous conflicts and conferences the sheep owners have agreed to confine their animals to certain other ranges, and for a time at least peace has existed and all have been fairly content. The condition, however, is an unstable one, and is likely to be upset at any moment by the gradually increasing herds of one or another of the parties to the mutual understanding, or by erratic bands of sheep.

With the uncertain conditions surrounding the use of the public lands it is but natural that practically all of the farmers and irrigators of the arid region, as well as the stockmen, ask for legislation by which temporary rights in the form of licenses can be had to the use of the forage pending complete or final settlement of the lands. It is highly essential that those concerned be able to enjoy in undisturbed possession from year to year certain lands to be used for grazing purposes. For this privilege the owners of the stock are willing to pay a suitable compensation or rent. Under present conditions there is no inducement for any person to guard or protect the range land, and as a result the valuable forage plants are eaten down so close as to be destroyed. If, however, one man or association of men had the exclusive right to the grazing on a certain area for a term of years it would be to their advantage not to overstock the range, but to treat it in such a manner that it would not deteriorate.

Should any law be enacted regulating the temporary use of the public lands for grazing, it must be framed in such a way as not to retard the development of irrigation and the settlement of the land by homesteaders. It is probable that the licenses granted for grazing could be made subject to rights of passage and to the deduction of relatively small areas for settlement without in any way reducing the value of the grazing right. The chief object is to promote the permanent settlement of the country and the making of homes.

This matter of regulating the grazing in the West has been emphasized in the preceding pages, for, being of fundamental concern in the arid region, it is constantly brought to the attention of the hydrographer, since it has an intimate relation to the development of irrigation and the complete utilization of the water resources of the public domain.

DESERT LANDS.

The actual desert lands in the United States—those upon which no grazing is possible even in winter or after the rains of early spring—are relatively small. They are mainly in the States of California, Nevada, Utah, and Wyoming and the Territory of Arizona, and they

aggregate about 70,000,000 acres. The surface of these deserts is mainly sand and barren rock, the soil often being so charged with an excess of soluble earthy salts that even when moistened plants can not grow. Such, for example, are the broad flats adjacent to Great Salt Lake, in Utah, and the lands around Humboldt, Carson, and Walker sinks, in Nevada. Other deserts, such as those of southeastern California adjacent to Colorado River, have a soil which is fertile and produces large crops when watered. Portions of these deserts are reclaimable by deep or artesian wells or by reservoirs to store the intermittent floods of the small streams which flow from the bordering mountains.

It is highly important that a thorough geologic examination of these desert areas and the surrounding country be made, in order to determine the practicability of obtaining water by deep wells. When the facts have been brought together and studied it may be possible to give general directions regarding the proper locations for wells and the probable depth to water. If, however, the structure of the country is so obscure that predictions regarding the depth to water have little value, it may be important to drill one or two wells to a depth sufficiently great to penetrate the valley deposits, and thus settle definitely for a large area the question whether an artesian flow can be obtained. Investigations of this character have been carried on in different parts of the United States, and a few maps have been prepared showing the depths to water in certain regions, and they should be extended to the truly desert areas, making wherever possible oases from which cultivation may in time extend outward.

METHODS OF INVESTIGATION.

Customary methods of the Survey have been followed in making measurements of rivers during the year. It has been found that the general method of noting the river height each day or several times during the day, with current-meter measurements as often as practicable, is of the widest application. In some cases, however, particularly on streams used for manufacturing purposes, better results can be obtained by using the dams as broad-crested weirs, noting the height of water upon the crests, and making computations of flow, employing the coefficients of discharge determined by Bazin and by the Cornell These methods are fully described in Water-Supply experiments. Paper No. 56. In special cases other means of measurement may be found more accurate and convenient, particularly in the case of small streams, conduits, or pipe lines. On large pipe lines it has been found that the Venturi meter gives reliable results, and it is likely that it will be more generally used. The Metropolitan Water Board of Massachusetts has recently installed two 48-inch meters of this type, which are shown in Pl. I. The meter itself is of very simple design, consisting of two conical-shaped pipes and arrangements by which the pressure can be recorded automatically by an electric register. The tube has no moving parts, and is not affected by water hammer, or by dirt, fish, sticks, or other substances in the water. The register, however, is rather complicated, and requires more careful handling than the meter. The loss of head is very slight.

COOPERATION.

In the extension of hydrographic investigations cooperation with State officials has become a notable feature, enabling many of the operations to be carried on with greater attention to details, thus adding to the accuracy and increasing the value of the results. aid or assistance rendered has been brought about not only by the fact that the results of the investigations are needed in carrying out the laws indicated by Congress, but because they have a local application of public importance. In general it may be said that while a systematic course of procedure may be pursued, the execution of the details can be greatly facilitated by the financial aid rendered by the States. For example, if under the funds available for water measurements only one measurement could be made at a locality during a month or a quarter, it is possible, with the aid given by the State, to make two measurements, and thus increase the accuracy of the results, adding greatly to their application in problems of development of the water resources. With a given organization and system it is possible, by an increase in the funds available for field work, to more than double the activities, and thus the money devoted by the State to the elaboration of the investigations yields far greater returns than would be possible by the creation of a State bureau or organization. This condition has been recognized and cooperation has been freely offered from many directions.

In accepting aid the understanding has been that it shall not interfere with the systematic investigations contemplated by Congress and authorized by various laws, but that while pursuing a general course the work shall be extended in the manner that experience has shown to be the most effective. All disbursements, whether ultimately paid out of the appropriation of the Geological Survey or the State treasury, pass through the same channel and are subject to the same scrutiny, precautions being taken to guard against every possible error or outlay not specifically authorized by law and custom.

The principal aid received during 1900 was from the California Water and Forest Association, an organization which has for its object the development and utilization of the arid lands of the State of California, and also the protection of the forests therein, as these have a beneficial influence upon the water supply. This association, finding



TWO 48-INCH VENTURI WATER METERS OF THE METROPOLITAN WATER BOARD OF MASSACHUSETTS.

that suitable appropriation could not be obtained at the time from the State, raised, by subscription, funds which were offered to the Geological Survey to aid in its work, under terms similar to those which might have been entered into with the State officials. In other words, the association, appreciating the emergency, was able to undertake what the State at the time could not. The object of assisting or cooperating in this work is stated as follows:

- (1) An extended record of the discharge of a stream shows the area normally irrigable with safety from that stream, as well as the power possibilities, and, in connection with reservoir surveys, indicates the volumes of winter and flood water available for storage.
- (2) The records of stream flow are an official basis for the legal adjudication of water rights.
- (3) The records are essential in considering questions of domestic water supply, navigation, and overflow.
- (4) The length of time required to establish average conditions prohibits private investigations, and the construction of reservoirs by the public is improbable without this information.
- (5) All of these data are officially distributed, either free or at the bare cost of printing.
- (6) Topographic maps are important for educational, engineering, political, administrative, statistical, and economic uses.
- (7) The Geological Survey, which is now under the civil service act, is, after twenty years of service, well equipped, with experienced men and complete outfits, to obtain the information at minimum cost.
 - (8) The State gets full value at one-half cost.

The principal features of the understanding or agreement with the California Water and Forest Association are as follows:

In the drainage basins of Kings and San Joaquin rivers a reconnaissance was to be made during the summer of 1900, for which an expenditure of not to exceed \$2,500 was to be made by the Survey and an equal sum contributed by the association, the latter including \$1,500 advanced by the canal companies deriving their supply from Kings River. The Geological Survey also agreed to maintain a gaging station on Kings River at Red Mountain and one on San Joaquin River at Herndon.

It was agreed that in the valley of Salinas River an investigation should be made by the Survey for reservoir sites, and that gaging stations should be maintained, the cost to the Survey not to exceed \$500, a like amount to be contributed by the association. Subsequently \$1,000 additional was made available by the Survey, and a like amount was contributed by Monterey County at the instance of the association.

On Yuba River an examination and gagings were planned, the sum of \$450 being agreed upon as the limit by each party.

On Cache Creek, on the western side of Sacramento Valley, a recon-

naissance was to be made, the cost not to exceed \$250 to the Survey and a like amount to the association. Subsequently the Woodland Board of Trade subscribed \$250 additional, and a like amount was expended by the Survey.

For the examination of reservoir sites on Stony Creek an estimate of \$1,000 was made. Of this the Survey expended from its appropriation \$500, and the association contributed a like amount, \$250 of which was obtained by subscription from the Willow Chamber of Commerce.

For the midsummer gaging of streams it was agreed that approximately \$300 should be expended by the Survey, and an equal amount be contributed by the association.

In the execution of the work made possible by these allotments it was agreed that the board of engineers of the association should at all times have access to the notes of the Survey, and the privilege of inspecting all work and advising as to its general character, the investigation to be discontinued in whole or in part upon due notice.

The work was carried out as contemplated by the agreement, the total expenditures being as follows:

Summary of expenditures through cooperation in Calif	Summary	ugh cooperation in Co	lifornia.
--	---------	-----------------------	-----------

Stream.	Contribu-	Total expendi- ture.
Kings and San Joaquin rivers.	\$2,500	\$6,228
Salinas River.	1,500	3,507
Yuba River	450	1,025
Cache Creek	500	1,112
Stony Creek	500	2, 231
Low-water measurements	168	336
Total	5,618	14, 439

Of the \$14,439 expended for these investigations, a little less than 39 per cent was contributed through the agreement growing out of the efforts of the California Water and Forest Association. The results are discussed further on, in connection with the stream measurements and other work in California, and the detailed reports have been published in the series of Water-Supply and Irrigation Papers, in particular in Papers Nos. 45, 46, and 58.

ACKNOWLEDGMENTS.

Most of the measurements presented in this volume have been obtained through local hydrographers, a comparatively small portion of the work having been conducted directly from the office of the Geological Survey at Washington. Acknowledgment is due to each of these persons, and thanks are extended to other persons and to cor-

porations who have assisted the local hydrographers or have cooperated in any way, either by furnishing records of the height of water or by assisting in transportation. The following list, arranged alphabetically by States, gives the names of the resident hydrographers:

California: J. B. Lippincott, civil engineer, Los Angeles.

Colorado: A. L. Fellows, civil engineer, Denver.

Georgia and Alabama: Prof. B. M. Hall, civil engineer, Atlanta; Prof. W. S. Yeates, State geologist, Atlanta; and Prof. Eugene A. Smith, State geologist, Tuscaloosa.

Idaho: N. S. Dils, civil engineer, Caldwell.

Kansas: W. G. Russell, Russell.

Maryland: Prof. W. B. Clark, State geologist, Baltimore.

Montana: Prof. Samuel Fortier, Bozeman; Prof. Fred. D. Smith, Missoula.

Nebraska: Prof. O. V. P. Stout, State University, Lincoln, assisted by Adna Dobson and Glenn E. Smith.

Nevada: L. H. Taylor, civil engineer, Carson City.

New Mexico: P. E. Harroun, civil engineer, Albuquerque.

North and South Carolina: Prof. J. A. Holmes, State geologist, Chapel Hill, N. C., assisted by E. W. Myers.

Texas: Prof. Thomas U. Taylor, State University.

Utah: Prof. George L. Swendsen, Logan.

Virginia and West Virginia: Prof. D. C. Humphreys, Washington and Lee University, Lexington, Va.

Washington: Sydney Arnold, civil engineer, North Yakima; William J. Ware, civil engineer, Port Angeles.

Wyoming: A. J. Parshall, civil engineer, Cheyenne.

In Colorado the State engineering department has cooperated, and valuable assistance has been rendered by the Denver and Rio Grande, the Union Pacific, the Colorado and Southern, the Rio Grande Southern, the Atchison, Topeka and Santa Fe, and the Burlington and Missouri River railroads. Special thanks are also due to the officers and employees of The Great Plains Water Company, one of whose engineers, Mr. C. W. Beach, has made many measurements on the Arkansas; to the Amity Land and Canal Company and its chief engineer, Mr. Thomas Berry; to the Buffalo Canal Company; to Mr. C. L. Harrison, chief engineer of the Denver Union Water Company; to Messrs. S. M. Matlock, T. J. Burrows, J. M. Wolaver, L. H. Dickson, Thomas Kneale, and W. E. Obert; to water commissioners in various parts of the State, and to many others who have furnished valuable information.

In California assistance in transportation has been rendered by Mr. William Hood, chief engineer of the Southern Pacific Company, who has also procured the assistance of bridge watchmen in observing the height of water in the rivers. Mr. Walter James, chief engineer of the Kern County Land Company, has supplied records of Kern River, and Mr. A. K. Warren, assistant engineer, has also furnished information. Mr. Burt Cole, engineer of the South Antelope Valley Irrigation Company, has furnished records of the flow of Little Rock Creek;

Mr. H. F. Parkinson, superintendent of canals taking water from San Gabriel River above Azusa, has furnished records of that stream; Mr. J. H. Carruthers, manager of the Anglo-American Canaigre Company, has furnished records of Lytle Creek; Mr. W. B. Clapp, city engineer of Pasadena, has furnished records of the Arroyo Seco; and Mr. K. Sanborn, engineer of the Riverside Water Company, rendered valuable assistance in making low-water measurements during the summer of 1900. Mr. W. G. Nevin, general manager of the Southern California Railroad, has furnished transportation over the Santa Fe lines in California. The city of Los Angeles has maintained gagings of Los Angeles River, which, through the courtesy of Mr. F. H. Olmsted, city engineer, have been furnished to the Survey without charge. Mr. H. N. Savage, chief engineer of the San Diego Land and Town Company, has contributed information concerning Sweetwater River.

In October, 1899, the California Water and Forest Association was formed, and the work which it had undertaken was vigorously pushed during the winter of 1899-1900. The funds which, through its president, Mr. William Thomas, of San Francisco, were pledged to the United States Geological Survey were all duly received and expended in the prosecution of the work outlined in the Twenty-first Annual Report. The association itself contributed \$3,000, and organizations in sympathy with it contributed a similar amount. The contributions of the affiliated organizations were as follows: Chamber of Commerce of Willow, \$250 for work on Stony Creek; Chamber of Commerce of Woodland, \$250 for work on Cache Creek; Kings River Storage Association, \$1,500 for investigations on Kings River, \$100 additional being provided for stream gaging; Monterey County, \$1,000 for investigations on Salinas River. The organizations made an effort to obtain a State appropriation for the continuance of hydrographic investigations in California, the effort being to procure \$107,000 for cooperation with the scientific departments of the Government during two fiscal years. Although this measure received but two dissenting votes in the legislature, it failed to receive the signature of the governor. The objects of this cooperation have been described on pages 50-52.

In Georgia, Alabama, Florida, Tennessee, and Mississippi Prof. B. M. Hall and Mr. Max Hall, resident hydrographers, have been assisted in their work by the following persons and corporations: Prof. W. S. Yeates, State geologist of Georgia, has paid the observers at Madison, Tallulah Falls, Juliette, Almon, and Blueridge, and for a portion of the year the observers at Carters, Canton, and Woodbury. Dr. Eugene A. Smith, State geologist of Alabama, has paid the observers at Riverside, Cordova, Milstead, Susanna, Sturdivant, Dadeville, Alexander, and Nottingham. The city of Augusta maintains the station at Augusta, Ga. The officials of the United States Weather Bureau have shown a great interest in the work, and have rendered

valuable assistance, particularly Messrs. J. B. Marbury, D. Fisher, F. P. Chaffee, L. M. Pindell, W. M. Dudley, and T. S. Collins. They have maintained stations at Calhoun Falls, S. C.; at Carlton, Dublin, Albany, West Point, and Oakdale, in Georgia; at Montgomery and Selma, in Alabama, and at Chattanooga and Knoxville, in Tennessee; and for a part of the year stations at Woodbury, Canton, Resaca, and Rome, in Georgia, and at Charleston, Tenn. Acknowledgments are also due to Messrs. R. C. McCalla, D. M. Andrews, and G. T. Nelles, United States assistant engineers, for cooperation in the work by sending records of stations at Tuscaloosa, Ala., and Lincoln, Ala., and furnishing valuable data concerning the Coosa, Cahaba, Warrior, Tennessee, and other rivers. Also to Prof. C. M. Strahan, of Georgia University; to Prof. C. S. Wilkins, of Alabama University; to Prof. W. M. Fulton, of Knoxville University; to Mr. H. S. Weems, of Carters, Ga.; and to Mr. W. M. Towers, of Rome, Ga. Transportation has been furnished through the kindness of Mr. J. S. B. Thompson, general agent of the Southern Railway; Mr. E. St. John, vice-president and general manager of the Seaboard Air Line; Mr. Thomas K. Scott, general manager of the Georgia Railroad; Mr. John M. Egan, president of the Central of Georgia Railway; Mr. James T. Wright, president and general manager of the Macon, Dublin and Savannah Railroad; Mr. John B. Newton, general manager of the Atlanta, Knoxville and Northern Railway; Mr. W. B. Denham, general superintendent of the Plant System; Mr. C. A. Wickersham, president and general manager of the Atlanta and West Point Railway and the Western Railway of Alabama; Mr. Hunter McDonald, chief engineer of the Nashville, Chattanooga and St. Louis Railway; Mr. Y. Vandenberg, vice-president of the Louisville and Nashville Railroad; and Mr. J. T. Harahan, second vice-president of the Illinois Central Railroad.

Thanks are due to the Chesapeake and Ohio Railway and to the Norfolk and Western Railway for annual passes over all lines in Virginia and West Virginia, issued to Prof. D. C. Humphreys. Thanks are also due to Mr. Decatur Axtell and Mr. F. B. Isaacs, of Richmond, Va., to Mr. Charles S. Churchill, of Roanoke, Va., and to Mr. J. Turner Morehead, of Holcomb Rock, Va., for valuable suggestions.

In Idaho the State engineer, Mr. D. W. Ross, has heartily cooperated. Transportation has also been furnished to Mr. N. S. Dils through the kindness of Mr. D. E. Burley, general passenger and ticket agent of the Oregon Short Line.

In connection with the work in Kansas the Survey is under obligations to the Missouri, Kansas and Texas Railway, the Union Pacific Railway, and the Santa Fe Railroad for transportation furnished to Mr. W. G. Russell, resident hydrographer.

In Montana assistance has been rendered by the Great Northern Railroad, by the Bitterroot Stock Farm, of Hamilton, by Prof. M. J. Elrod, of Missoula University, and by Mr. J. L. Rhead, superintendent of the Big ditch at Laurel, Mont.

In Nebraska the resident hydrographer, Prof. O. V. P. Stout, has had the benefit of the continued cooperation of various public and private organizations. Special acknowledgments are due to the agricultural experiment station and the State board of irrigation for the service of hydrographers, to the State board of agriculture for the preparation and publication of valuable data, and to the following railway officials, without whose assistance the amount of work accomplished would have been greatly lessened: Mr. G. W. Holdredge, general manager of the Burlington lines west of Missouri River; Mr. George F. Bidwell, general manager of the Fremont, Elkhorn and Missouri Valley Railroad; and Mr. E. L. Lomax, general passenger agent of the Union Pacific Railroad; also to Prof. A. B. Crane, of the South Dakota Agricultural College, for measurements of Big Sioux River.

In Nevada officials of the Southern Pacific Railroad Company, of the Nevada-California-Oregon Railway Company, and of the Lake Tahoe Railway and Transportation Company have furnished transportation to Mr. L. H. Taylor, enabling him to greatly extend his field work.

In Wyoming transportation has been furnished to Mr. A. J. Parshall by Mr. E. Dickinson, general manager of the Union Pacific Railroad; by G. W. Holdredge, general manager of the Burlington and Missouri Railroad; by George F. Bidwell, general manager of the Fremont, Elkhorn and Missouri Valley Railroad; and by Frank Trumbull, general manager of the Colorado and Southern Railway, thus greatly increasing the amount of work accomplished.

In Washington the work has been facilitated by transportation furnished to Mr. Sydney Arnold by Mr. Thomas Cooper, land agent of the Northern Pacific Railway.

NORTHERN ATLANTIC COAST DRAINAGE.

Under this heading have been included data pertaining to the rivers entering the Atlantic Ocean from Maine to Virginia, inclusive, an arbitrary line being drawn between James River and Roanoke River, the latter stream being included in the Southern Atlantic coast drainage.

KENNEBEC RIVER.

Computations of the discharge of this river at Waterville, Me., have been made by the engineers of the Hollingsworth & Whitney Company since 1892. In the Twenty-first Annual Report, Part IV, page 52, are given the monthly estimates for the years 1898 and 1899. It

has been found necessary, however, to revise the data for the latter year, and the new computations for that year, as well as the estimated discharge for 1900, are given herewith, through the courtesy of James L. Dean, engineer of the Hollingsworth & Whitney Company.

Estimated monthly discharge of Kennebec River at Waterville, Me. [Drainage area, 4,410 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
January	2,757	1, 245	2, 357	144, 926	0.53	0.61
February	3; 362	1,420	2, 363	131, 234	0.54	0.56
March	3, 773	1,960	3, 218	197, 867	0.73	0.84
April	45, 724	6,017	24,006	1, 428, 456	5.44	6.09
May	41,756	11,480	21, 303	1, 309, 871	4.83	5. 56
June	13, 044	5,673	8,821	524, 886	2,00	2, 23
July	6,509	2,500	5,077	312, 173	1.13	1.30
August	5, 195	1,089	3, 302	203, 032	0.75	0.86
September	2,370	246	1,854	110, 321	0.42	0.47
October	1,969	406	1, 274	78, 335	0.29	0.33
November	4, 109	1,390	2, 252	134,003	0.51	0.57
December	5, 223	747	2,741	168, 537	0.62	0.71
The year	45, 724	246	6, 547	4, 743, 641	1.48	22. 13
1900.						
January	6,851	656	2,384	146, 586	0.54	0. 62
February	23,971	1,615	9,050	502, 611	2.05	2.14
March	20,538	4, 373	9, 153	562, 796	2.08	2.40
April	62,291	8, 381	28, 473	1, 694, 261	6.46	7. 21
May	52, 268	14, 113	28, 272	1, 738, 377	6.41	7. 39
June	25, 091	5, 015	10,033	597, 005	2. 27	2. 53
July	12, 281	2, 344	5, 791	356, 075	1.31	1.51
August	5,601	1,016	4, 173	256, 588	0.95	1.09
September	4, 238	1,635	2,807	167, 028	0.64	0.71
October	4, 190	859	3,065	188, 459	0.70	0.81
November	17,580	1,502	6, 376	379, 398	1.45	1.62
December	6, 540	1, 895	4, 096	251, 853	0.93	1.07
The year	62, 291	656	9, 473	6, 841, 037	2.15	29. 10

Note.—Daily discharge for 1899 and 1900 is given in Water-Supply Paper No. 47, page 30.

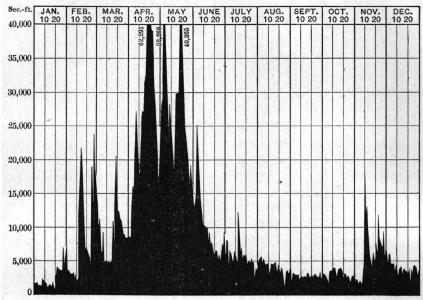


Fig. 13.—Discharge of Kennebec River at Waterville, Me., 1900

COBBOSSEECONTEE RIVER.

This river is the outlet of the Cobbosseecontee Waters in the southern part of Kennebec County, Me. It empties into Kennebec River 8 miles below Augusta. Measurements are made at the reservoir dam in Gardiner by Alexander H. Twombly, engineer of the Forestville Paper Company, of Yarmouthville, Me.

Estimated monthly discharge of Cobbosseecontee River at upper dam near Augusta, Me.

[Drainage area, 230 square miles.]

	Dischar	rge in secon	nd-feet.		Run-off.	
Month.	Max- imum.	Min- imum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	220	90	136	8, 362	0.51	0.59
February	2, 194	220	508	28, 213	1.97	2.05
March	2, 316	815	1, 365	83, 931	5.93	6.83
April	1,380	300	1,044	62, 122	4.38	4.88
May	1,422	300	562	34, 556	2.36	2.73
June	300	280	282	16, 780	1.07	1.19
July	280	260	276	16, 971	0.97	1.12
August	275	260	264	16, 233	1.00	1.15

Estimated monthly discharge of Cobbosseecontee River at upper dam near Augusta, Me.—Continued.

	Discha	rge in secon	id-feet.		Run-off.	
Month.	Max- imum,	Min- imum. Mean.		Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.		i.				
September	260	230	245	14,578	0.89	0.99
October	230	150	206	12,666	0.78	0.90
November	220	130	199	11,841	0.75	0.84
December	240	220	232	14, 265	0.81	0. 93
The year	2, 316	90	443	320, 518	1.79	24. 20

Note.—Daily discharge for 1900 is given in Water-Supply Paper No. 47, page 31.

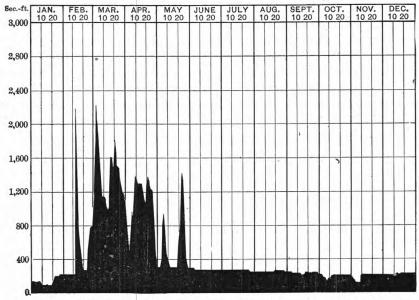


Fig. 14.—Discharge of Cobbosseecontee River at upper dam near Augusta, Me., 1900.

ANDROSCOGGIN RIVER.

This river is the outlet of the Rangeley series of lakes near the border line between Maine and New Hampshire. It flows in a general southerly direction, with a rapid fall, and possesses some of the finest water powers on the Atlantic coast. The Union Water Power Company, of Lewiston, Me., has three dams for controlling the flow of the Rangeley Lakes. The upper dam, at the outlet of Mooselookmeguntic Lake, is shown in Pl. II, B. It raises the level of the lake 18 feet.

The second or middle dam is at the outlet of Lower Richardson Lake. It raises the level of the lake 22 feet. The third dam is on the main river below the outlet of Umbagog Lake, the lowest lake of the Rangeley series, and is known as the Errol dam. A considerable portion of the spring freshet flow of Androscoggin River is thus stored, and during the low stages in the summer months is allowed to pass down the river by raising the gates of the dams, thus tending to equalize the natural fluctuations of the stream.

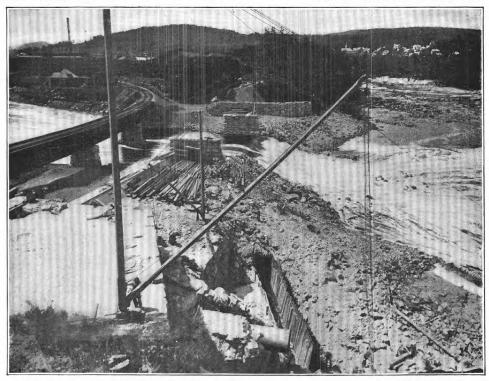
Pl. II, A, is a view of the rock-fill dam under course of construction during the summer of 1900 by the Rumford Falls Water Company, at Rumford Falls, Me. The dam is to be used as a waste weir for the canal. Its height will be 25 feet, slopes $2\frac{1}{2}$ to 1, and length 300 feet. When the dam is completed the water will flow under the three spans of the highway bridge shown. During the course of construction, as shown in the view, the water is passed under the middle span only, through a depression in the crest of the dam.

Discharge measurements at Rumford Falls have been made since 1892 by Charles A. Mixer, resident engineer of the Rumford Falls Water Company, through whose courtesy the figures are obtained.

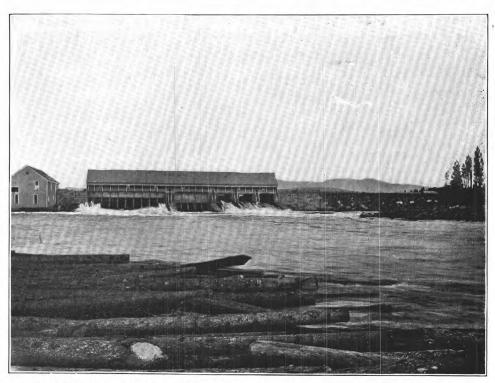
Estimated monthly discharge of Androscoggin River at Rumford Falls, Me.

[Drainage area, 2.320 square miles,]

	Dischar	ge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum. Mini- mum.		Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	3, 221	1, 115	1,408	86, 574	0.61	0.70	
February	6,009	1, 277	2, 555	141, 897	1.10	1. 15	
March	3,063	1,600	2, 109	129, 677	0.91	1.05	
April	22,025	1,830	9, 763	580, 939	4. 21	4.70	
May	24, 531	6,632	12,633	776, 773	5.45	6. 27	
June	7, 458	1,810	4, 127	245, 574	1.78	1.99	
July	3, 168	1,640	2, 201	135, 334	0.95	1.10	
August	2,009	1,318	1,574	96, 781	0.68	0.78	
September	2,025	1, 247	1,596	94, 969	0.69	0.77	
October	3, 754	1,430	2, 213	136, 072	0.95	1.10	
November	12,061	1,460	3,945	234, 744	1.70	1.90	
December	3, 264	1,764	2, 331	143, 328	1.00	1.15	
The year	24, 531	1, 115	3, 871	2, 802, 662	1. 67	22. 66	
				I a series and the series and	1	The second	



A. ROCK-FILL DAM ON ANDROSCOGGIN RIVER AT RUMFORD FALLS, ME.



B. UPPER DAM ON ANDROSCOGGIN RIVER, AT OUTLET OF MOOSELOOKMEGUNTIC LAKE.

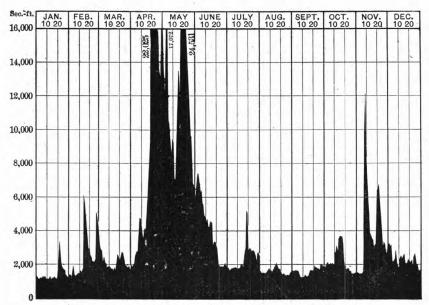


Fig. 15.—Discharge of Androscoggin River at Rumford Falls, Me., 1900.

WATER POWERS OF THE COAST STREAMS OF NEW HAMPSHIRE.

COUNTRY DRAINED.

Only four of the principal coast streams of New Hampshire will be considered in this report, viz, the Salmon Falls, the Cocheco, the Lamprey, and the Exeter, embracing a total drainage area of about 860 square miles. Of this area, 220 square miles are in Maine, while the remaining 640 embrace about three-fourths of the region in New Hampshire between the Merrimac divide and the ocean. This district has an extreme length of about 50 miles, north and south, and a width of 30 miles, east and west. It is a moderately timbered, hilly country, the hills gradually rising from low elevations near the coast to heights of from 500 to 1,000 feet along the western and northern divides. Glacial action has resulted in covering the surface with drift, and in contributing to its topography scattered drumlins, as well as numerous lakes varying in extent from several square miles downward. these the more important are artificially controlled for storage, and without them the value of the streams for power purposes would be greatly diminished. Modification of the drift is revealed along the coast, also in several inland localities, as in the extensive sand plain around Rochester and in the swampy district to the east of Pawtuckawa Pond. The soil is usually of slaty composition.

^a Report of Dwight Porter, being a continuation of the data relating to New England streams given in the Nineteenth Annual Report, Part IV, pages 34 to 111.

UTILIZATION OF THE STREAMS.

The four rivers mentioned—Salmon Falls, Cocheco, Lamprey, and Exeter—find their way to the ocean through the Piscataqua, a tidal estuary, by means of which navigation is extended from the coast a few miles up their courses; it is then interrupted by natural falls or by dams, and the streams above are utilized for power only, except Salmon Falls River, which also furnishes the city of Somersworth its public water supply. From the point at which the drainage area amounts to about 50 square miles, the developments of power on the respective streams are as follows:

Power developments on coast streams of New Hampshire.

River.	Power development.	Distance to tide water.	Total fall.	Fall developed, Sept., 1898.	Turbines installed, Sept., 1898.
		Miles.	Feet.	Feet.	Horse- power.
Salmon Falls	Below dam at Milton Three Ponds.	19	414	275	7,400
Cocheco	Below Farmington	17	(?)	170	a 1, 800
Lamprey	Below railroad crossing west of Raymond.	23	173	66	900
Exeter	Below railroad crossing at Fremont.	13	135	- 70	600

* About 300 horsepower idle.

These figures indicate that, with respect to available power and its artificial development, the streams referred to diminish in importance toward the south. Of the total horsepower utilized on the main portions of the rivers (about 10,700), more than half (about 6,200) is applied to cotton manufacturing, mills of that description being found on each river, either at tide water or near it; about 1,700 horsepower is applied to commercial electric-lighting and power plants; about 1,400 to woolen mills; about 800 to leather-board and paper mills, and the remainder to a variety of industries represented by sawmills, gristmills, machine shops, box factories, shoe factories, etc.

CHARACTERISTICS OF THE STREAMS.

The beds and banks of these rivers are generally favorable to the development of power where concentrated fall exists, the material being firm and the banks of sufficient height. Rock outcrops occur at intervals along the courses of all of them. Where the fall is pronounced it is usually accomplished either in rapids or in successive low pitches, there being no abrupt falls of large size except at Somersworth, where Salmon Falls River descends 62 feet in about a half mile, and at Dover,

on Cocheco River, where there is a fall of 36 feet, mainly a natural pitch over ledges. In characteristics of flow these streams do not differ greatly from other streams in New England. All except the Exeter have storage reservoirs, and in that feature of development they rank in about the same order as in available fall. Regarding their actual volume of flow substantially no information is at hand, although at Dover the Cocheco Manufacturing Company has for many years recorded systematic gage readings from which the flow of the Cocheco could have been computed. The data have not yet been worked up, however.

The mean rainfall for the entire area under consideration, combining, as the best available figures, the record at Newton, on the south, and at Concord, on the west, for the period 1889 to 1899, is found to be approximately 40 inches per annum, the average monthly precipitation being as follows:

Mean monthly rainfall in drainage basins of Salmon Falls, Cocheco, Lamprey, and Exeter rivers, New Hampshire, 1889–1899.

Month.	Precipitation.	Month.	Precipitation.	Month.	Precipitation.	Month.	Precipi- tation.
	Inches.		Inches.		Inches.		Inches.
January	3.4	April	2.4	July	3.8	October	3.9
February	3.0	May	3.5	August	3.4	November	3.8
March	3.4	June	3.1	September	3.3	December	2.9

SALMON FALLS RIVER AND TRIBUTARIES.

With respect to water power, this river is clearly the most important of the streams under consideration. Rising in Great East Pond, 10 miles east of Lake Winnepesaukee, it flows southerly, forming the boundary between Maine and New Hampshire, and at South Berwick reaches tide water. Two and a half miles below this point Cocheco River joins it from the west, to form the Piscatagua. The total length of Salmon Falls River, from Great East Pond to the mouth of the Cocheco is about 35 miles. The area drained amounts to about 340 square miles, a moderately wooded, hilly region, with summits increasing in elevation above the sea from 200 or 300 feet at the southern end to about 1,000 feet at the headwaters. In the lower half of its course the river approaches closely the western border of its basin, and is within about 2 miles of the divide that separates it from the Cocheco. The townships directly bordering the river have a combined population of nearly 30,000, of which 8,000 is in Maine and the remainder in New Hampshire, while more than two-fifths of the whole is probably to be found within 3 miles of the center of the city of Somersworth, where are located the principal manufactories. Navigation extends to South Berwick.

To a large extent the bed of the river is of solid rock. Its banks are generally high and permit but little overflow during freshets. In its upper reaches, which are above artificial pollution, the water of the river is of exceptional purity, and by means of large storage reservoirs its volume is usually well maintained through the dry season.

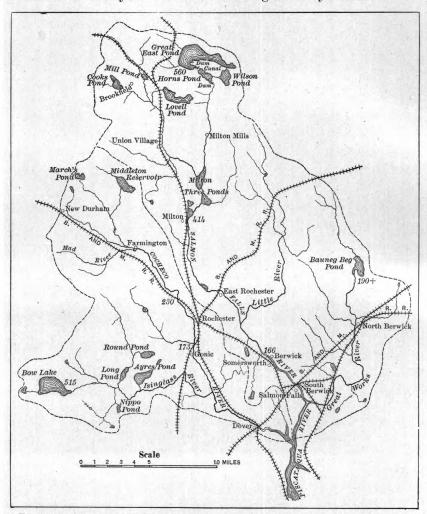


Fig. 16.—Drainage basins of Salmon Falls and Cocheco rivers. The figures indicate elevations above sea level.

Drainage areas of Salmon Falls River.	
Square m	
At Milton Mills	31
Above mouth of Branch River	38
Below mouth of Branch River	
At Milton	120
At East Rochester	152
At Somersworth	
At junction with Cocheco River.	340

On the main river, or at its headwaters, there are four storage reservoirs, which, according to the maps of the United States Geological Survey, cover a combined area of about 3,000 acres. Tributary to the upper waters of Branch River there are three other reservoirs of moderate size, the areas of which can not be definitely stated. These seven reservoirs are controlled by the Great Falls Manufacturing Company, of Somersworth. The most important of them is Great East Pond, the source of the main stream. It covers more than 1,700 acres, lies about 560 feet above tide-water level, and can be drawn down 18 feet from high-water level. It discharges through an artificial canal into Horns Pond, which covers 180 acres and can be drawn down about 6 feet, and by natural channels it also connects with that pond through Wilson Pond, a body of water covering 240 acres. Eight miles below Horns Pond are Milton Three Ponds, with a surface area of 840 acres and permitting a nominal draft of 12 or 13 feet at the dam. On Branch River are Lovell, Cooks, and Mill ponds.

From the surface of Great East Pond to tide water, a distance of 32.2 miles, the descent is about 560 feet, an average of between 17 and 18 feet to the mile. The fall is mainly concentrated, however, in two stretches—166 feet in the first 5 miles above tide water, and more than 140 feet in the $2\frac{1}{2}$ miles below Milton Three Ponds. Of the total fall of 560 feet, between 350 and 360 feet, or nearly two-thirds, has been developed between Horns Pond and the mouth of the river, leaving unimproved a fall of about 200 feet. Of this, probably from 50 to 75 feet is within a mile below the village of Milton. Perhaps half as much is near Milton Mills, and the rest is distributed along the stream.

Fall of Salmon Falls Rive	Fall.	of I	Salmon	Falls	River
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Locality.	Distance from mouth of river.	Height above mean tide level.	Fall be- tween points.	Distance between points.	Average fall per mile between points.
	Miles.	Feet.	Feet.	Miles.	Feet.
Great East Pond	35.0	a 560+	} 20±	1.5	13. 33
Horns Pond	33.5	^ь 540+		11.4	11.1
Milton Three Ponds	22.1	c 414	248	14.5	17.1
Somersworth, top of Great Falls dam.	7.6	^d 166	166	4.8	34.6
South Berwick, tide water	2.8	0)		
			1		1

^a United States Geological Survey map of Maine, new field sheet. Elevation is given as 499 in Wells's Water Power of Maine, p. 148.

^bUnited States Geological Survey map of Maine, new field sheet. Elevation is given as 479 in Wells's Water Power of Maine, p. 148.

^e Elevation adjusted to full pond (top of flashboards) from height of base of rail at B. & M. R. R. bridge, which is given by H. Bissell, chief engineer, as 422.70 feet above mean low tide at Boston. In Geology of New Hampshire, Vol. I, p. 176, the elevation of Three Ponds is given as 409 feet above mean tide.

d Geology of New Hampshire, Vol. I, p. 176.

The 356 feet, approximately, of developed fall is represented at twenty-two dams. Three of these, including one that has been rendered temporarily useless, have been maintained simply for storage; at all of the others power is actually in use, under falls varying from 6 to 31 feet. The turbines installed in the mills aggregated, in September, 1898, about 7,700 horsepower. Of this amount approximately 6,000 horsepower is utilized at Somersworth and below, where it is used mainly in cotton manufacture, although a considerable amount is used to operate a woolen mill and two electric power stations. Above Somersworth the river furnishes power to three woolen mills, two shoe factories, two leather-board mills, a paper mill, and several sawmills and gristmills.

The power of the river is very largely under the control of the Great Falls Manufacturing Company, which owns about half of the developed fall and the greater part of the available undeveloped fall, together with the various storage reservoirs at the headwaters and at Milton, and a regulating reservoir above Somersworth. As the stored water is drawn upon mainly with a view to the requirements of the company's mills at Somersworth, some irregularity exists in the supply to the mills on the upper river. On the whole, however, the flow is well maintained. July 26, 1899, a gaging, with current meter, about a mile below the village of Milton, showed a flow of 44 cubic feet per second during working hours. The 7,700 horsepower of turbines in use can not be operated at full power during low water, so that nearly all of the important mills on the river have steam plants in reserve.

Ascending the river, the first water privilege is at South Berwick, at the head of tide. It was formerly used by the cotton mill of the Portsmouth Company, but when visited in September, 1898, the plant was being remodeled to serve as a power station for the United Gas & Electric Company. The intention of the company was to use the power for operating a street railway between Somersworth and Dover, as well as for lighting Somersworth, Dover, and Berwick, it being supplementary to the power obtained at a dam above Somersworth. The nominal fall is 19 feet, measured from the crest of the dam. This can be increased about 14 inches, but, on the other hand, it is subject to temporary reductions of $2\frac{1}{2}$ or 3 feet from ordinary high tides. Turbines to the extent of 880 horsepower were being installed, in addition to which there was to be a steam engine in reserve.

Backwater from the South Berwick dam extends substantially to the lower privilege at Salmon Falls. There the Salmon Falls Manufacturing Company has two dams a short distance apart, and uses the power in the manufacture of cotton novelties, having a plant consisting of about 5,600 spindles and nearly 1,300 looms. The fall obtained is 24½ feet at the lower dam and 22 feet at the upper dam. About 450 horsepower of turbines is operated on each privilege, but the mills have outgrown

the capacity of the stream for constant power, and 220 horsepower of steam is in use most of the time. The ponds are maintained practically full, and the turbine power mentioned is obtained throughout the year.

The fourth dam is a mile or so below the city of Somersworth, at a place sometimes called New Dam. The water power there is owned by the Great Falls Company and is leased to the present users. As now developed, the fall is about 30 feet, but this could be increased to embrace several additional feet in rapids below the mills. On the New Hampshire bank 225 horsepower is used in the 9-set mill of the Great Falls Woolen Company, manufacturers of dress goods, and on the opposite, or Maine, bank the United Gas & Electric Company has 800 horsepower of turbines in its power station.

The next power, the most important on the entire river, is used by the Great Falls Manufacturing Company, at Somersworth, and includes two dams. The lower dam, which was built in 1845, is of rough stone, laid dry, and is about 24 feet high and 140 feet long. A canal 600 feet long conveys water to mill No. 3 and to the bleachery, the fall obtained being 31 feet. Turbines of 1,320 horsepower are in use, with 600 reserve horsepower of steam for low water. The upper dam, built in 1872 at a cost of \$13,000, is of cut stone laid in cement, and, like the lower dam, is built upon a ledge. It is 6 feet high and 375 feet long. A canal 7 feet deep, 36 feet wide, and 2,000 feet long leads water to mills Nos. 1 and 2. A fall of 31 feet is obtained, there being 1,840 horsepower of turbines, with 600 horsepower of steam in reserve at each mill. The company manufactures cotton goods, such as sheetings, shirtings, twills, and sateens, operating 125,000 spindles and 3,000 looms. Its mills are ordinarily run about two months in the year by water power exclusively, but during the remainder of the time steam is used to a greater or less extent.

From the upper dam at Somersworth the pond extends about 2 miles upstream, to what is known as Mast Point dam, where the Great Falls Manufacturing Company maintains a regulating reservoir. This dam is a timber structure, apparently from 100 to 125 feet long, and creates a fall of about 7 feet. The flow past the dam is controlled by sluice gates adjacent to the west bank. No power is in use here, and the value of the privilege for such employment is made doubtful by the small fall and the fluctuations due to drawing upon the pond. For five months preceding September 13, 1898, when this place was visited, no water had been wasted past the dam except as needed at the mills below; in other words, during that time complete control had been exercised over the flow of the stream. In the drier months of the year the pond surface is generally drawn down about 2 feet during the day; on the other hand, during the freshets of 1895 and 1896 water poured over the crest of the dam to a depth of 8 feet.

Between Mast Point Pond and East Rochester there is an unimproved fall of moderate amount, known as Stair Falls, owned by the Great Falls Manufacturing Company.

At East Rochester, a village of 700 or more inhabitants, the Cocheco Woolen Manufacturing Company has two dams. The lower dam is of wood, founded on rock, and gives a fall of 12 feet at mill No. 3, which is close by, and where 75 horsepower is employed. A canal 20 feet wide and 700 feet long leads water to mills Nos. 1 and 2, where 17 feet of fall and 240 horsepower of turbines are in use. These can be run at full capacity, except sometimes on Saturday, when the supply from Milton Three Ponds is shut off, in which case steam is used for A 100-horsepower engine is also kept in reserve for mills mill No. 3. Nos. 1 and 2. Ordinarily, however, water wastes over the dam day The Cocheco Company operates 18 sets of cards in the and night. manufacture of all kinds of woolen wear. A quarter of a mile above this dam is the upper dam, also of wood, forming a pond 2 miles long and giving a head of 8 feet. The power here has been used in a box shop, and when the place was visited an electric power station was being built at one end of the dam, where the Cocheco Company proposed to install about 160 horsepower of turbines to furnish light, and perhaps power, to its mills.

The next dam, the tenth above tide water, is about midway between East Rochester and Milton. It is only a rude barrier of bowlders, serving to divert part of the stream's volume into a canal, which extends about three-fourths of a mile along the river, finally giving a head of 6 feet at a small mill where 30 or 40 horsepower is used in grinding grists, making shingles, spinning yarn, and in other light work. The property is owned by Mrs. E. J. Cottle, of West Lebanon, Me.

Upstream there is no fall of consequence between this and the next dam, which is within $1\frac{1}{2}$ miles of Milton. Here a fall of 16 feet is obtained, which might be increased 2 feet by excavating in the rapids below the dam, the power being used in Spaulding's leather-board mill, which has a capacity of 3 tons a day. From 250 to 275 horsepower of turbines is employed, and steam power is not required.

Between the top of the dam last described and the top of the reservoir dam at Milton Three Ponds, a distance of from 2 to 3 miles, there is a developed fall of 63 feet, covering four water privileges, which closely succeed one another through the village of Milton. In addition to this there is probably from 50 to 75 feet of available undeveloped fall a short distance below the village. All of this water power is owned by the Great Falls Manufacturing Company, which leases it to the present users and has additional power to lease to acceptable persons. The undeveloped fall is scattered along a stretch of a half or three-fourths of a mile, from which the railroad is nowhere more

than a half mile distant. The bed of the river is of granite, and granite ledges form its banks, which rise abruptly from 5 to 15 feet above the stream on each side, and are succeeded by more gradual slopes farther back. In the lower part of this stretch are two abrupt pitches, a few hundred feet apart, at each of which there is a descent of from 10 to 15 feet in a distance of about 200 feet. Farther upstream there is a fall of about 25 feet in a distance of 200 or 300 feet, and elsewhere there is a succession of low pitches and rough water.

Of the four developed privileges the first in order is occupied by the Strafford Paper Company, manufacturing 10 or 12 tons of manila paper and newspaper stock a day. Turbines aggregating 280-horsepower are operated under a head of 17 feet, and a 75-horsepower steam engine is also in constant use. The dam is of logs, running in two sections of 50 or 75 feet each from the banks to a ledge in midstream. Next in order comes a stone dam, giving a head of 25 feet, under which from 200 to 300 horsepower is obtained by the Milton Leather Board Company. The third dam is a timber structure about 60 feet long, at each end of which N. B. Thayer & Co. has a shoe factory, the combined output of which is 7,000 60-pair cases a year of a medium grade of boys' shoes. A 50-horsepower turbine under 8 feet head is used on each side of the river, with steam in reserve. Although the water power here is regarded as relatively constant, it is subject to occasional shortage, due to the closing of gates at Three Ponds and to some interruption during extreme freshets, when the stream becomes choked in a gorge below, and backwater nearly destroys the fall at this privilege. The uppermost dam in the village of Milton, the fifteenth in order from the mouth of the river, is at the outlet of the so-called Three Ponds. With flashboards on the dam and with full pond the fall is about 13 feet, but when visited in September, 1898, the pond had been drawn down about 8 feet, reducing the fall correspondingly. A small power is used for a sawmill and a gristmill. The dam is a low dry-stone structure, with high flashboards. It creates a reservoir which is very useful to the Great Falls Company, being about midway between Great East Pond, at the headwaters, and the company's mills at Somersworth, and here the principal regulation of the supply to the lower river is effected. Although the three ponds are somewhat distinct from one another, they connect freely, stand at a common level, and form a continuous sheet of water of about 840 acres extent. Commanding a drainage area of 124 square miles, they fill rapidly in spring, but during the summer and fall they are gradually drawn down, though fluctuating more or less with rains and according to the management of the upper reservoirs. During the period of drought the gates at the dam are kept closed from Saturday night to Sunday night, no water passing downstream in the interval, except what leaks through the dam.

From this dam it is 6 or 7 miles, by river, to Milton Mills, the next settlement upstream. Backwater from Three Ponds covers the lower half of this distance, and for the remainder the stream has a flat slope.

Milton Mills is a small village on the New Hampshire side of the river, 3 miles distant from the railroad. In the village and its immediate vicinity there are five dams, covering an aggregate fall of 63 feet, at three of which power is used, while two have served for storage purposes only. This portion of the stream is above the mouth of Branch River, has a drainage area of less than 30 square miles, and is entirely dependent upon the Great East and connecting ponds. Ordinarily drought upon these begins in the latter part of July and continues until winter, and although a rather constant flow is thus assured, its absolute value is not great, and the resulting water power above Milton is but moderate. Some details of the utilized power will be found in the following table. Between Hooper and Roe dams is undeveloped fall, variously stated at 18 and 36 feet, and there is additional fall, the amount of which could not be learned, between Wiggin's mill and Horns Pond.

Water powers on Salmon Falls River above Milton, N. H.

Dam.	Location.	Fall.	Turbines.
-		Feet.	Horsepower.
No. 22 a	Outlet of Horns Pond	10-	40
	Between Horn's mill and Wiggin's mill	8	None.
No. 21	About 1 mile below Horns Pond	$8\frac{1}{2}$	45
No. 20	Roe dam, above Milton Mills	10	None.
	Jewett privilege.	(?)	None.
No. 19	Hooper dam, Milton Mills	13	None.
No. 18	Milton Mills	14	56
No. 17	do	15	90
with the second second second	do	11	80

a Above tide water.

The water power at dam No. 22 is owned by the Great Falls Manufacturing Company, which controls the pond for storage purposes. The fall is 9 or 10 feet when the pond is full, but it is subject to, say, 5 feet reduction when the water in the pond is drawn down. The power is utilized at James Horn's sawmill.

The water power between Horn's mill and Wiggin's mill is unimproved. The fall is 8 feet. It is said to have formerly been used.

Dam No. 21 is a dry-stone structure. The pond is small, and the power is used at L. P. Wiggin's sawmill.

At dam No. 20 (the Roe dam) the reservoir is used simply for storage. It forms part of the Waumbeck Woolen Company's property.

It is a narrow pond, extending about 2 miles upstream, nearly to the next dam. The dam is of dry stone, planked on top, and with full pond gives a fall of about 10 feet.

The power at Jewett's privilege is unimproved. The fall is variously stated at 18 and 36 feet.

Dam No. 19 is a dry-stone structure with plank top. It formerly served to form a reservoir for the Waumbeck Woolen Company, but within a year or two of the time it was visited a section at the right end had been carried away and the pond was empty, the river running through.

At dam No. 18 half of the power is owned by the Great Falls Manufacturing Company and half by the Gale Shoe Manufacturing Company. The latter company employs more than 100 persons and has an output of 15 or 16 cases of shoes a day.

At dam No. 17 the power is used by the Waumbeck Woolen Company in the manufacture of cheap dress goods. The mills have 10 sets of cards and 54 looms. A 60-horsepower steam engine is held in reserve.

At dam No. 16 the power is used in H. H. Townsend's blanket mills, which have 3 sets of cards and 18 looms. There are two buildings in use here, one opposite the dam, at which the fall is $8\frac{1}{2}$ feet, and another 200 or 300 feet lower down, to which water is led in a timber penstock, giving a fall of 11 feet. During ordinary low water a 45-horsepower wheel can be run at only half gate, and a steam engine is used for auxiliary power.

GREAT WORKS RIVER.

Of the tributaries of Salmon Falls River, Great Works River is the largest in point of drainage area. It has its immediate source in Bauneg Beg Pond, 9 miles northeast of Somersworth, and joins the main river near South Berwick, a short distance below the head of tide water in that stream. Its drainage area embraces 85 square miles, 44 of which are above North Berwick, including the basin of Neoutaquet River, which enters at that place. Although there are several other tributary ponds of smaller size, the principal storage is afforded by Bauneg Beg Pond, which on the United States Geological Survey map covers about 180 acres and commands the drainage from 18 square miles of territory. Its shores are steep and its surface can be drawn down about 8 feet. The storage is controlled by D. P. Morrell, who has a sawmill and gristmill at the outlet and draws upon the pond according to his needs, and if the mill owners farther downstream at any time desire more water than comes to them, they must pay for it. The stream runs very low, however, in the dry season, and at the North Berwick Company's woolen mill furnishes at that time scarcely enough water for washing purposes. Below Bauneg Beg Pond the country drained is flat, and ordinary freshets are not severe, giving a depth estimated at not more than 3 feet on a 100-foot dam at South Berwick. In March, 1896, however, a loss of \$17,000 was caused at the Newichawanick mills, at South Berwick, due to the destruction of a bridge upstream in the unusual freshet of that month, the débris lodging against the bulkhead at mill No. 1 and carrying it away. At Agamenticus, in the lower course, the stream in the dry season is about 60 feet wide, and runs 1 foot or 2 feet deep at the center, with a moderate current.

The elevation of the base of the rail at the bridge of the Boston and Maine Railroad, western division, near North Berwick, but below the dams there, is given by Mr. H. Bissell, chief engineer, as 130.7 feet above mean low tide at Boston. Adjusting this to mean tide, and deducting the distance from rail to water surface at summer level, the elevation of Great Works River is found to be about 93 feet above mean sea level, which at the same time is the fall from that point to the mouth, a distance, by river, of 10.9 miles.

From Bauneg Beg Pond to the mouth of the river, a distance of 16.3 miles, the total fall, according to the maps of the United States Geological Survey, is between 190 and 200 feet, or an average of about 12 feet to the mile. Of this fall, 78 feet is covered by the six water privileges at which power has been developed. The first of these, ascending the river, is at Seaton's mills, at South Berwick, where a small power is employed in a saw, grist, and shingle mill. By means of a frame dam a head of 13 or 14 feet is obtained, which could be increased somewhat, but which is reduced a foot or more at high tide. second and third dams belong to the Newichawanick mills, of South Berwick, at which are manufactured bed and horse blankets, each of the two mills running 6 sets of cards. Mill No. 1 is at the lower dam, and uses 150 horsepower of turbines under a head of 28 feet. At the upper dam are mills Nos. 2 and 3, the latter containing the pickers and the electric-light plant; also a sawmill. On this privilege the extreme fall obtained is 17 or 18 feet, and 120 horsepower is utilized. Steam power is held in reserve, but is seldom used.

At North Berwick, 11 or 12 miles above the mouth of Great Works River, the North Berwick Company has two water privileges, with dams a few hundred feet apart. The lower dam furnishes a head of 9 feet to a 60-horsepower turbine used in the box shop. From the pond formed by the upper dam water is carried to the main mill by a canal and is discharged below the lower dam, the head of 18 feet thus obtained covering both privileges. A 125-horsepower turbine is used, and it can be run at full capacity for perhaps four months of the year, while for about the same period during dry weather its use is entirely abandoned. The company manufactures all-wool goods, chiefly flannels, and runs 8 sets of cards.

The sixth and remaining dam on the Great Works is at Morrell's privilege, at the outlet of Bauneg Beg Pond, where the head is rated at 12 feet, and where a turbine of 150 nominal horsepower is in use.

LITTLE RIVER.

The second important tributary of Salmon Falls River is Little River, which drains an area of 53 square miles of rather sparsely settled country in Maine, and joins Salmon Falls River about midway between Somersworth and East Rochester, entering the slack water caused by the Mast Point dam. Although it has no reservoirs, it is regarded by the Great Falls Company as an important feeder of the main river, and the company owns several water privileges along its course. The only developed fall, so far as learned, is within a half mile of its mouth, where there is a small sawmill, which was shut down when visited. A dilapidated dam of dry stonework, with a plank top, makes available a head of 10 or 12 feet.

BRANCH RIVER.

The third important tributary of Salmon Falls River is Branch River, which heads in the town of Brookfield, a few miles west of Great East Pond. It has a total length of perhaps 12 miles, and flows in a southeasterly direction, joining Salmon Falls River within a mile of the head of Milton Three Ponds. Its drainage area includes about 63 square miles. The stream is fed by several ponds, and at Union Village it is utilized for power, but to what extent was not determined.

COCHECO RIVER.

The little streams which form the headwaters of Cocheco River rise from 4 to 7 miles southeast of Lake Winnepesaukee, mainly in the township of New Durham. From Marchs Pond, which forms one source, to its mouth the river is approximately 30 miles long. It flows southeasterly, and in its lower course is roughly parallel to Salmon Falls River, immediately to the eastward, the two streams joining $2\frac{1}{2}$ miles east of Dover to form the Piscataqua. Navigable tide water extends to Dover; thence throughout the important part of its course the river is within a mile of a line of the Boston and Maine Railroad running from Portsmouth to Lakeport, Wells River, and northward. Dover, with a population of 13,000 or 14,000, Rochester, with a population of 4,000 or 5,000, and the village of Farmington are the principal places along the valley.

Where running freely, the stream gradually increases in width from 20 or 30 feet at Farmington to 40 or 50 feet just below Rochester, and to perhaps 75 feet near its junction with Isinglass River. It seems to be very like the average New England stream with regard to fluctua-

tions of flow. The greatest recorded freshet depth on the 60-foot crest of the Norway Plains Manufacturing Company's dam at Rochester is about 8 feet. In the dry season the discharge runs very low, but it is materially augmented by storage reservoirs at the headwaters of the main river, and below the mouth of the Isinglass by important reservoirs tributary to that stream. So far as can be learned the principal of these reservoirs are the following: Middleton reservoir, in the upper basin of the main stream, which covers about 250 acres and can be drawn down 16 feet; Marchs Pond, which covers about 150 acres and can be drawn 11 feet; Bow Lake, in the Isinglass Basin, which covers 1,000 acres, lies 515 feet above sea level, and can be drawn down about 20 feet (this is the most important of the reservoirs); Ayres and Nippo ponds, in the same basin, which together cover about 500 acres and are controlled by dams; and Round and Long ponds, which cover about 125 acres each and are without dams. Bow Lake and Ayres and Nippo ponds are controlled by the Cocheco Manufacturing Company, The Middleton reservoir is owned by the Norway Plains Manufacturing Company, of Rochester, and is ordinarily drawn upon for a continuous period of about two months, beginning with midsummer.

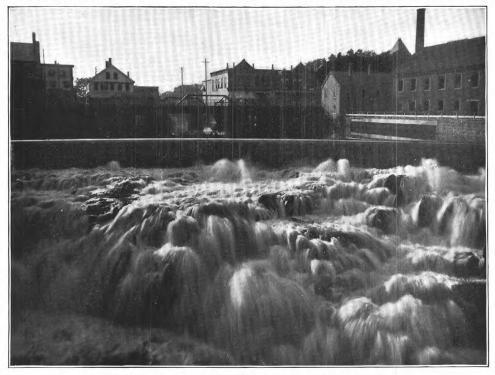
A map of the drainage basin is shown in fig. 16, page 64. The drainage areas are as follows:

Drainage areas of Cocheco River.

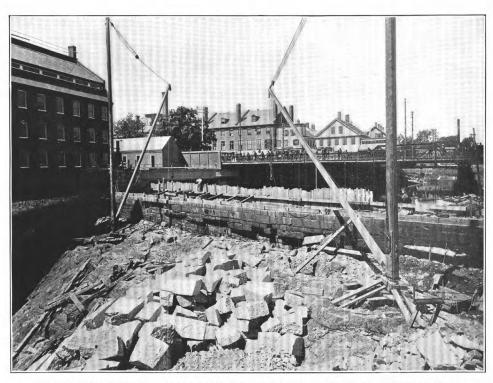
	Sq	uare miles.
At Farmington		52
At Rochester		
Above Isinglass River		97
Below Isinglass River		
At Dover		185
At mouth		192
Isinglass River above Long Pond	outlet	36
Isinglass River at mouth		73

The hills forming the northern and western divides rise to heights of from 1,000 to 1,200 feet above the sea, while those in the southern basin seldom much exceed 300 feet in elevation. From the railroad crossing 2 miles above Rochester to tide water at Dover the river descends about 230 feet in 13.3 miles, a or an average of between 17 and 18 feet to the mile. Of this amount, a total of about 130 feet has been developed by the construction of eight dams, two of which, however, serve simply to form regulating ponds for the mills at Dover. The unutilized remainder of the fall is distributed along the river. At the six privileges where power is developed the total installment of tur-

^a As indicated by contours of United States Geological Survey topographic sheet. At the railroad crossing about a mile above Gonic and 9.6 miles above tide water at Dover the elevation of the river's surface is given in Geology of New Hampshire, Vol. I, p. 267, as 173 feet.



A. NEW DAM OF COCHECO MANUFACTURING COMPANY, DOVER, N. H.



 ${\it B}$ OLD DAM OF COCHECO MANUFACTURING COMPANY, DOVER, N. H., DURING REMOVAL.

bines is about 1,800 horsepower, 1,000 of which is represented at the cotton mills at Dover, 300 or more is idle at Rochester, and most of the remainder is employed at Gonic.

The principal water power on the Cocheco is at Dover. There the river falls abruptly over a great mass of solid rock, upon which there has been built a fine masonry dam (Pl. III, A), curved in plan, of granite ashlar laid in cement. This dam replaced one of stone (Pl. III, B), which was ruined during the heavy freshet of March, 1896, when the highway bridge and buildings spanning the stream just above were carried away and swept against the structure. A head of 36 feet is obtained at this dam, and 1,000 horsepower of turbines is used for the cotton mills of the Cocheco Manufacturing Company. This power can be realized, however, only about nine months of the year, and 800 (?) horsepower of steam is maintained in reserve. During the dry season the flow of the river at this point is completely controlled, no water wasting over the dam. The pond extends about 2 miles upstream. Still farther upstream this company has two dams forming regulating ponds below the mouth of Isinglass River, and, as already stated, it also has reservoir storage to the extent of 1,500 acres, surface area, in the drainage basin of the latter stream.

The next utilized power is at the village of Gonic, 2 miles below Rochester, where the Gonic Manufacturing Company has two dams. At the lower dam there is 17 feet fall, and 190 horsepower is used at a sawmill and electric plant. A quarter of a mile or more upstream is the second dam, at which there is a fall of $19\frac{1}{2}$ feet, and 225 horsepower is employed in the company's woolen mill, which contains 12 sets of cards and 196 looms employed in the manufacture of dress goods.

At Rochester, 10 miles above Dover, there are three dams. The first of these, ascending the stream, is a wooden structure which furnishes 9 feet fall for Charles F. Trask's box factory. A water wheel of 80 nominal horsepower is in use. The two upper dams belong to the Norway Plains Manufacturing Company. They were formerly used to develop power at the mills of that company for the manufacture of flannels and blankets. The capacity of the works is 500,000 pounds a year, but for several years the mills have not been operated. The lower privilege affords a head ranging from about 16 feet at the dam to 23 feet at the end of the penstock. Turbines aggregating 275 horsepower are in place, but not more than two-thirds of that power could be obtained during ordinary low water, and steam power is held in reserve. At low stages the 24-hours' flow of the stream here can be concentrated within the usual ten working hours, with no waste over the dam. At the upper dam the fall is stated to be 8 feet.

From Rochester to Farmington, a distance of 7 miles, the bed of the river is flat and affords no important powers. Two or three miles below Farmington there is a privilege, said to belong to the Norway Plains Manufacturing Company, which was formerly used by a saw-mill, but the dam is reported to have been washed away.

At Farmington there are two privileges. The lower one gives a fall of 12 or 15 feet at the end of a canal a few hundred feet long. It was formerly used by a mill for the manufacture of underwear, but the mill was burned in 1896 or 1897. The privilege is owned by E. L. Wedgewood, of Farmington, and it is thought to be good for 20 or 25 horsepower at all times. The upper privilege is used by a sawmill and box factory. By means of a canal three-fourths of a mile long a fall of 25 feet is obtained, but the water power is used only in the fall and spring, and at other times resort is had to steam.

No power of consequence is in use above Farmington. Even at that village, below Mad River, the drainage area includes less than 50 square miles, and subdivision between the branch mentioned, Ela River, and the main stream reduces the area tributary to each above Farmington to a small amount.

ISINGLASS RIVER.

The only important tributary of the Cocheco is Isinglass River, which enters it from the west, 5 miles above Dover. Although draining 73 square miles (more than the Cocheco drains at Rochester), it is not, so far as could be learned, used for power, and its service is principally that of a feeder from the various reservoirs controlled by the Cocheco Manufacturing Company, as elsewhere stated. Near its mouth, where it is crossed by the highway, it is about 60 feet wide, and in September, 1898, it was discharging considerable water.

Bow Lake, the principal reservoir on the Cocheco, is stated in Geology of New Hampshire, Vol. I, page 269, to be 515 feet above mean sea level, and the same authority gives the following elevations along Isinglass River: Two-thirds of a mile below Bow Lake, 482 feet; 5 miles below Bow Lake, 233 feet; at railroad crossing between Barrington and Gonic, about 10 miles, by river, below Bow Lake and 3 miles from the Cocheco, 158 feet.

LAMPREY RIVER.

Various small streams heading in the town of Deerfield, about 15 miles northeast of the city of Manchester and 25 miles westerly from Portsmouth, unite to form Lamprey River. This stream pursues a winding easterly course. It is nearly 30 miles long, and discharges into Great Bay, a large tidal basin a little to the west of Portsmouth, and communicating with the ocean through the lower Piscataqua River. The basin of the Lamprey, which includes a total of 208 square miles, is rather regular in shape, with a length, in an east-west direction, of somewhat more than 20 miles, and a width in its central portion of

about 13 miles. (See fig. 17.) The drainage areas of the stream are as follows:

Drainage areas of Lamprey River.

Square 1	niles.
Below North Branch River	54
Above Pawtuckawa River	
At Wadleys Falls	155
At Newmarket	204
At mouth	208

In the vicinity of Epping the normal width of the stream appears to

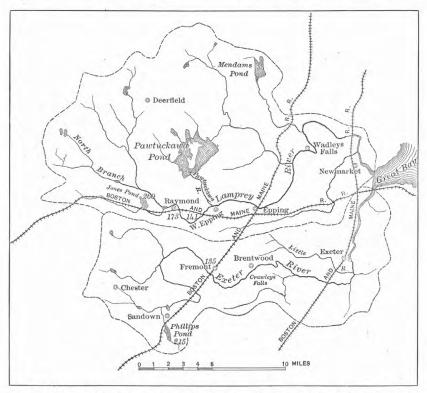


Fig. 17.—Drainage basins of Lamprey and Exeter rivers. The figures indicate elevation above sea level.

be from 75 to 100 feet. Tide water and navigation extend between 1 and 2 miles up the river from Great Bay to the manufacturing village of Newmarket, where the first dam is located. The water powers on the stream are confined to substantially the 18 or 19 miles between Newmarket and the mouth of Pawtuckawa River. Including the dam at Newmarket and the one just above the Pawtuckawa, there are five dams at which power is used, but only at Newmarket is the power of much importance. On these five privileges an aggregate of more than 900 horsepower of turbines have been installed, and of the

244 feet of natural fall which occur in the stream from the railroad crossing three-fourths of a mile above West Epping to tide water 66 feet has been developed. Above the mouth of Pawtuckawa River there are no tributary storage reservoirs; the drainage area is less than 75 square miles, the dry-weather flow is small, and the river is not utilized, so far as could be learned. It is believed, however, that a fair amount of storage could easily be developed in the upper waters, at Jones Pond, for example, said to cover 160 acres and to be about 260 feet above sea level.

Fall of Lamprey River.

Locality.	Distance from mouth of river.	Height above mean tide level.	Fall between points.	Distance between points.	Average fall per mile be- tween points.
Della da	Miles.	Feet.	Feet.	Miles.	Feet.
Railroad crossing at outlet of Jones Pond, town of Raymond	26.1	a 258	85	2.8	30. 4
Railroad crossing near Raymond station	23.3	a173	32	2.5	12.8
Railroad crossing near West Epping station	20.8	a 141	38	4.3	8.8
Railroad crossing near Epping station.	16.5	b103	103	14.7	7.0
Newmarket, tide water	1.8	0	103	14.7	1.0

^a Geology of New Hampshire, Vol. I, p. 257.

bIbid., p. 267.

The only reservoirs in the basin of Lamprey River which appear to be of value for storage purposes are Mendams and Pawtuckawa ponds, both controlled by the Newmarket Manufacturing Company. Mendams Pond covers 250 acres and can be drawn down 26 feet, but it has a small drainage area and seldom fills. Pawtuckawa Pond covers about 3,000 acres. It has two outlets; one, by a short course, reaches the main river in the western part of the town of Epping, while the other, by a more circuitous route, joins it 8 miles below, in the northeastern corner of Epping. Each of the outlets is controlled by a stone dam, the southern dam being 20 feet high and the eastern dam 10 feet high. The southern dam is somewhat out of repair, in consequence of which the reservoir is not filled to within 5 feet of the crest of the dam, and the available draft is restricted to 15 feet. As the reservoir is drawn down it divides into two ponds, which originally existed here, but which were made one by the construction of the dams. As it requires two days for the water from Pawtuckawa Pond to reach Newmarket, the gates at the pond are closed on Friday morning and are opened on Saturday morning, in order to prevent waste at Newmarket on Sunday and to provide the needed supply for Monday.

The first water power above the mouth of Lamprey River is that

utilized by the Newmarket Manufacturing Company, which runs 65,000 spindles and 1,700 looms, mainly on cotton sheetings and shirtings, but to some extent on silk goods also. By means of a wooden dam 20 feet high and 115 feet long, with a short canal on each side of the river, a head varying with the tide from 22 to 26 feet is obtained. Turbines aggregating 700 horsepower are installed, but from the middle of August to the middle of October not more than about 200 horsepower can be obtained. This company also has installed an aggregate of 1,200 horsepower of steam, a considerable portion of which is in use all of the time.

Backwater from this privilege extends upstream about 2 miles, and is succeeded by about 18 feet of unimproved fall belonging to the Newmarket Manufacturing Company and said to have formerly been used in part by a paper mill.

Next in order, and about 3 miles by road from Newmarket, is a privilege with 10 feet fall, owned by T. H. Wiswall and formerly occupied by a paper mill, which burned in 1883. Little remains of the works except a portion of the wooden dam.

The second utilized power is at Dame's sawmill, 2 miles by road below Wadleys Falls. A frame dam, perhaps 200 feet long, rests upon the rock which composes the river bed, the rapids extending a short distance downstream. A 50-horsepower wheel is in use under a head of 8 feet.

At Wadleys Falls, about 4 miles west of Newmarket, the river is full of outcropping rock, with strata steeply inclined. Upon this has been built a long frame dam, from the crest of which to smooth water below there is a fall of 15 feet. The water privilege is equally divided in ownership between the two sides of the stream, and is utilized by a machine shop, a shoe factory employing 50 persons, a small gristmill, and other works.

Above this point there is no dam until Epping is reached. At that place there is a fall of 7 feet, which furnishes power to Atwood & Quinby's shoe factory, a plant turning out ten 60-pair cases of shoes a day, as well as to a smaller shoe shop and a sawmill.

Two miles above Epping there is an unimproved privilege owned by L. A. Clough, of Manchester, and at West Epping, a short distance above the mouth of Pawtuckawa River, is the fifth and last dam at which power is used. A fall of 9 or 10 feet furnishes power for a box mill and a sawmill, but during low water steam also has to be used for several weeks. Half of this privilege is unemployed.

EXETER RIVER.

The sources of this stream are principally in the towns of Raymond, Chester, and Sandown, 10 or 15 miles east of the city of Manchester.

It takes a circuitous easterly course to Exeter, where it reaches tide water, and then runs northerly for 61 miles to Great Bay, which it enters within a mile of the mouth of Lamprey River. Its drainage basin, which comprises 124 square miles, is about 20 miles long and in the main from 5 to 7 miles wide. (See fig. 17, p. 77.) The western line of the watershed reaches, on certain summits, an altitude of about 500 feet above the sea, while the actual fall of the stream from Phillips Pond, one of the sources, in the town of Sandown, to tide water, a distance of 27 miles, is 215 feet, an average of about 8 feet to the mile. Although in its lower and central portions the basin is crossed by north-and-south lines of the Boston and Maine Railroad, there is no railroad along the river above Exeter, the only place of importance on the stream. The population of that township probably does not exceed 5,000. Having only a limited watershed (105 square miles at Exeter), and being without storage reservoirs, the river is poorly sustained and has but an insignificant volume during the dry season. On July 25, 1899, a current-meter gaging 2 miles southwest of Exeter, where the drainage area is 77 square miles, showed a discharge of only 14 or 15 cubic feet per second during working hours. At the railroad bridge near Fremont Station the surface of the stream is 135 feet above mean tide level, b corresponding to an average fall of about 10 feet to the mile in the 13½ miles thence to Exeter. A total fall of about 70 feet has been developed at seven dams, at which turbines are installed to the extent of, approximately, 600 horsepower.

Drainage areas of Exeter River.

Square n	niles.
At Fremont.	55
At Crawleys Falls	63
At Exeter	105
At mouth	124

Ascending the river, the first dam on the stream, and the only one at which important manufacturing is conducted, is at Exeter. It is a wooden structure 11 feet high, below which the river descends over outcropping ledges. A raceway extends about 800 feet down the bank, and at its foot a head is obtained varying from 17 to 21 feet, according to the state of the tide. The power is employed in the cotton mill of the Exeter Manufacturing Company, which operates 25,000 spindles and 600 looms on sheetings and shirtings. Water power to the extent of 400 horsepower is obtained for about eight months of the year, but during the remaining time it sinks to a very low point, and reliance is placed upon steam engines, 700 horsepower of which are installed.

In the $4\frac{1}{2}$ miles of the river's course lying above tide water within

the township of Exeter there appears to be nearly 100 feet of fall. About 20 feet of this has already been mentioned. There is reported to be a small fall belonging to the Exeter Manufacturing Company at what is known as Hunnewells Mill, and at Pickpocket, in the southwestern corner of the township, there is about 20 feet of unutilized fall, in two privileges, formerly used by paper mills. The upper privilege at Pickpocket, which has a dam and an available fall of 10 or 15 feet, is stated to be owned by the Portsmouth Savings Bank, while the lower privilege, with a fall of 9 feet, which could be combined with the upper fall, is owned by Nathaniel Gordon, of Exeter.

From the Pickpocket dam backwater extends several miles upstream, through the township of Brentwood, to Robinson's sawmill. A mile above this there formerly was a dam, and a mile farther, at Crawleys Falls, there are now three dams, with falls, in order upstream, of 6, 7, and 9 feet, respectively. The total horsepower of wheels installed at these three dams is perhaps 125, the power being used for a machine shop, a grist and shingle mill, a sawmill, and a shop for making carriage woodwork. The tributary drainage area at this point is 63 square miles, but the stream furnishes very little power during low stages.

At West Brentwood, 1 mile above Crawleys Falls, there are two dams, the lower one giving a head of 7 or 8 feet and the upper one a head of about 11 feet. The power is used by R. H. Fellows, in the manufacture of lumber and boxes, about 1,500,000 feet of lumber being worked up during the nine months' sawing season.

The next dam is at the village of Fremont, 9 miles west of Exeter, where a fall of 10 feet is used by a sawmill, a gristmill, and for other small machinery. Where flowing over riffles in this vicinity the stream during low water is only about 20 feet wide and is very shallow, with low banks succeeded by rather wide meadows. A mile above there is a lumber and box mill, but the tributary area is only about 50 square miles, and the flow and power are unimportant. It is said that there have been other mills farther upstream, but that all have been abandoned except one at Sandown.

NEW YORK STATE STREAMS.

Measurements of streams in New York State have been made with the cooperation of the State engineer and surveyor, Edward A. Bond, and the deputy State engineer and surveyor, William Pierson Judson, under the immediate supervision of Robert E. Horton. The stations established during the year are chiefly current-meter stations, although records are still kept of the flow over a number of dams. In addition, examinations have been made of various streams, notably those flowing from the northern slope of the Adirondack region, to

determine favorable localities for establishing gaging stations, and a number of records have been obtained which are not yet ready for

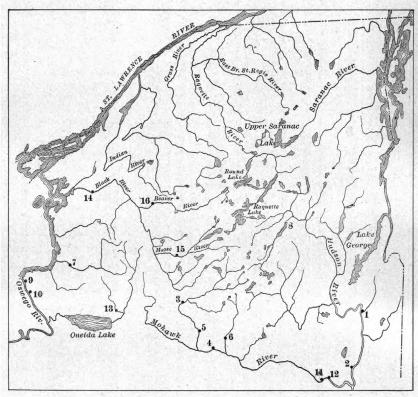


Fig. 18.—Map of Adirondack region, showing location of gaging stations.

- 1. Fort Edward.
- 2. Mechanicsville.
 3. Twin Rock Bridge.
 4. Little Falls.
 5. Middleville.

- 6. Dolgeville.

- Pulaski.
 Indian Lake dam.
 High dam near Oswego.
 Above Minetto.
 Schenectady.
 Rexford Flats.

- 13. McConnellsville. 14. Huntingtonville. 15. Moose River. 16. Belfort.

publication. Fig. 18 shows the location of the gaging stations established, and the following table gives data regarding them:

Location of gaging stations on New York streams.

Stream.	Location.	Kind of station.	Duration of record.	Gage reader.
Mohawk River	Ridge Mills	Dam and water- works.	Oct. 1, 1898, to Nov. 28, 1900.	Daniel Brown.
Oriskany Creek	Oriskany	Dam and feeder.	Oct. 16, 1898, to Jan. 31, 1901.	Frank Baker.
Sauquoit Creek	New York Mills (No. 3).	Dam and mill	Sept. 20, 1898, to Sept. 30, 1900.	Robert Hughes.
West Canada Creek	Twin Rock Bridge.	Bridge	Sept. 9, 1900—Cont'd	Utica Elec. Lt. and Power Co.
Do	Middleville	Dam and mill	Oct. 7, 1898-Cont'd. a .	E. J. Nelson,

a No record February 1 to May 9, 1900, inclusive.



A. FRONT FACE OF PLATTSBURG PAPER COMPANY'S NEW DAM AT CODYVILLE, N. Y., DURING CONSTRUCTION.



B. NEW DAM OF PLATTSBURG PAPER COMPANY, SHOWING EFFECT OF CURVED FACE.

Location of gaging stations on New York streams-Continued.

Stream.	Location.	Kind of station.	Duration of record.	Gage reader.
Mohawk River	Little Falls	Dam and mills	Sept. 23, 1898—Cont'd .	J. J. Gilbert and Wm. Hoffman.
East Canada Creek.	Dolgeville	Dam and power plant.	Sept. 23, 1898—Cont'd .	Henry Meyer.
Cayadutta Creek	Below Johnstown	do	Oct. 1, 1898—Cont'd	A. N. Terry.
Schoharie Creek	Fort Hunter	Dam and feeder.	Sept. 23, 1898, to July 31, 1900. a	H. J. Wittemeier.
Do	Erie Canal aqueduct.	Bridge	May 2, 1900, to Oct. 13, 1900.	James Shutts.
Do	Mill Point	do	July 6, 1900—Cont'd	Henry Peters.
Do	Schoharie Falls	Dam and plant	June, 1900—Cont'd	Empire State Power Co.
Mohawk River	Near Schenec- tady.	Bridge	Feb. 1, 1899—Cont'd. b.	L. Diggins.
Do	Rexford Flats	Dam and feeder.	Dec. 8, 1898—Cont'd	H. R. Betts.
Do	Dunsbach Ferry	Dam	Mar. 12, 1898—Cont'd. o	Kept for D. J. Howell, C. E.
Indian River	Indian Lake dam	Storage dam	July 22, 1900—Cont'd	Frank Pelon.
Schroon River	Below Warrens- burg.	Dam and mill	Nov. 1, 1895—Cont'd	Joseph Goodfel- low.
Hudson River	Fort Edward	Dam and mills	Dec. 1, 1895—Cont'd	B. A. Carr.
Do	Mechanicsville	do	Dec. 1, 1887—Cont'd	The Duncan Co.
Seneca River	Baldwinsville	do	Nov. 12, 1898—Cont'd .	Chas. Brannock.
Chittenango Creek	Bridgeport	do	Sept. 16, 1898—Cont'd .	Jefferson Downs.
Oneida Creek	Kenwood	Dam and mill	Oct. 4, 1898, to Dec. 31, 1900. d	Wm. Padgham.
Fish Creek, West Branch.	McConnellsville	Dam and mills	Sept. 13, 1898—'Cont'd. •	Frank S. Harden.
Oswego River	High dam	do	Apr. 1, 1897—Cont'd	Oswego Water Works Co.
Do	Above Minetto	Cable	Sept. 14, 1900—Cont'd .	H. L. Woodcock.
Salmon River	Above Pulaski	Bridge	Sept. 4, 1900—Cont'd	H. A. Walker.
Moose River	Moose River	Cable	June 5, 1900—Cont'd	Frank W. Smith.
Black River	Huntington ville dam.	Waterworksdam	Feb. 22, 1897—Cont'd	Alonzo Dressor.

No record December, 1899, and February, 1900.

No record August, 1899, to April, 1900.

A number of companies are being organized in the State for the purpose of utilizing the flow of streams for water power. Several of them intend to manufacture pulp and paper, the conditions being highly favorable for that industry. The Plattsburg Paper Company has recently constructed a dam across Saranac River at Codyville, views of which are shown in Pl. IV, A being a view of the dam under construction, after the rubble masonry was laid and the facing of concrete was being placed, and B showing the completed dam at the time of high water, and illustrating the effect of the curved face.

There are in the State a number of waterfalls available for development, especially on streams flowing from the Adirondack region. Raquette and Grass rivers and other streams flowing to the north into the St. Lawrence are of large volume and have considerable fall throughout their courses. The greatest obstacles to development are

No record October 3, 1899, to April 7, 1900, inclusive.
 No record April 1, 1899, to August 31, 1900, inclusive.
 No record August and September, 1899, and February and May, 1900.

lack of transportation and inaccessibility. Pl. V shows the Rainbow Falls, in the chasm of Ausable River, a stream of considerable volume flowing into Lake Champlain. For many miles its course is through a rocky and precipitous gorge with vertical banks several hundred feet in height. Besides its economic value as a possible source of water power, Ausable River is a popular resort for summer tourists, who enjoy the wild scenery and the many small waterfalls. Ausable Chasm is without doubt the deepest gorge in northeastern United States.

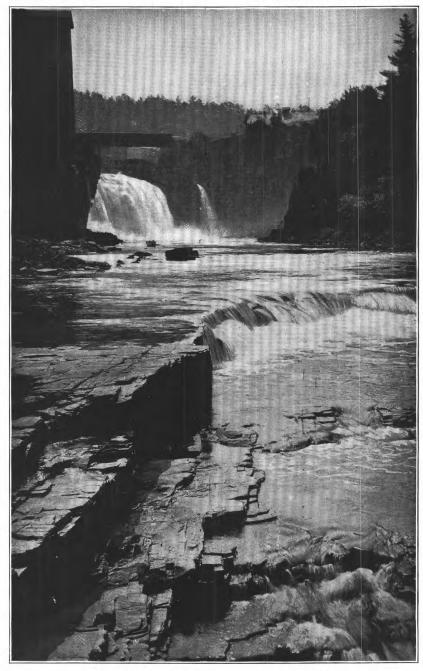
HUDSON AND MOHAWK RIVERS AND TRIBUTARIES.

The Hudson receives the principal part of its water supply from the eastern slope of the Adirondack Mountains, in the northern part of the State of New York. It flows in a general southerly direction, and receives from the west, as its largest tributary, Mohawk River, which enters near the head of tide water. From that point south the river is practically a navigable estuary of the ocean. The upper drainage basin is largely forest covered, but the timber is being rapidly cut for lumber and for use in the manufacture of pulp and paper, many saw-mills and pulp mills being located upon the river. The trees are felled during the summer and fall, and during the winter months are drawn to the banks of the stream and are floated down to the mills. Pl. VII, A, shows a log jam in the Adirondacks, and illustrates one of the great difficulties encountered in log driving.

Computations have been made of the discharge of Hudson River over the dams at Fort Edward and Mechanicsville, and also of Schroon River, a large tributary from the north. Records of flow of Hudson River at Fort Edward for the years 1899 and 1900 are published on pages 107 and 108. Records at this dam have been kept for several years, but the earlier data are not yet available for publication. Back records will be published in a later report. Records of the discharge at Mechanicsville for the years 1898, 1899, and 1900 are given on pages 109 to 111.

The results of measurements of Schroon River from 1895 to 1900 are published on pages 104 to 106. The figures differ slightly from those published in the Twenty-first Annual Report, Part IV, for the reason that when the earlier computations were made doubt existed in regard to certain features of the dam, especially the amount of leakage. This has recently been determined and more careful measurements of the discharge have been made, which have changed slightly the previous computations.

About 5 miles below Mechanicsville is the large water-power plant of the Hudson River Power Transmission Company, which has built a dam across the river and installed wheels for the development of electric power. Pl. VII, B, shows the waste gates of this plant, with the



RAINBOW FALLS OF AUSABLE RIVER, NEW YORK.

entire discharge of the stream (about 4,500 cubic feet per second) passing through them.

The tables on pages 86 to 103 give results at the gaging stations on Mohawk River and its tributaries, namely, Mohawk River at Ridge Mills, Oriskany Creek at Oriskany, Sauguoit Creek at New York Mills, West Canada Creek at Middleville, Mohawk River at Little Falls, East Canada Creek at Dolgeville, Cavadutta Creek near Johnstown, Schoharie Creek at Fort Hunter, and Mohawk River at Rexford Flats. At a number of these stations measurement of flow of the rivers is made by considering the dams as broad-crested weirs. Mohawk River and a number of its tributaries are so frequently dammed along their courses that it has been found advisable to employ this method instead of the current meter. Pl. VI, A, shows the State dam at Fort Hunter, on Schoharie Creek, which has been used for the purpose of measuring flow. On the right bank, just above the dam, are the gates of the Erie Canal feeder. The flow through this feeder has greatly complicated the computation of the discharge of Schoharie Creek. For that reason, and also because of the fact that the State dam at the time of high water becomes almost completely submerged, a meter station was established at Mill Point, N. Y. Later the Empire State Power Company, of Amsterdam, N. Y., built a dam across the creek at Schoharie Falls, where records of the flow are now being kept, the Fort Hunter station having been abandoned. Occasional current-meter measurements have been made from the railroad bridge shown in the background of Pl. VI, B.

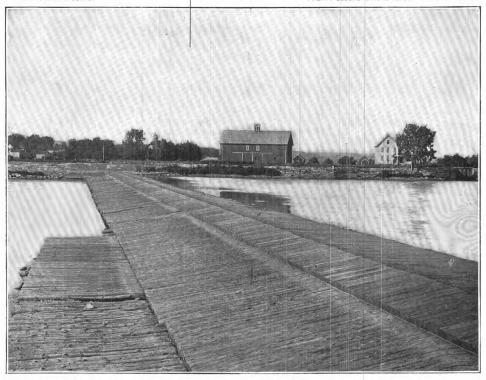
Estimated monthly discharge of Mohawk River at Ridge Mills, N. Y.

[Drainage area, 153 square miles.]

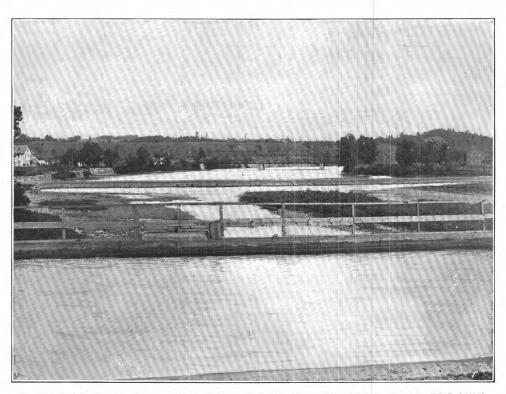
	Dischar	ge in secon	d-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.
1898.						
October	1, 251	127	369	22, 689	2.41	2.78
November	2, 134	104	401	23, 861	2.62	2. 92
December	974	121	261	16,048	1.71	1.97
1899.						
January	2, 373	153	377	23, 181	2.46	2. 83
February	697	123	244	13, 551	1.59	1.65
March	1, 211	176	467	28, 715	3.05	3. 52
April	2, 226	254	997	59, 326	6.52	7. 27
May	1, 136	94	320	19,676	2.09	2. 41
June	402	214	281	16, 721	1.84	2.05
July	669	127	310	19,061	2.03	2.34
August	315	121	226	13, 896	1.48	1.71
September 9 to 30			81	3, 535	0.53	0.43
October	540	93	278	17,093	1.82	2.10
November	515	205	291	17, 316	1.90	2. 12
December	3, 625	75	532	32, 711	3.48	4. 01
1900.						
January	1,535	265	160	9, 838	1.05	1. 21
February	3, 162	100	581	32, 267	3.80	3. 95
March	815	112	336	20, 660	2. 20	2.54
April	3, 375	225	1,062	63, 193	6.94	7.74
May	210	100	126	7,747	0.82	0.95
June	285	123	180	10, 711	1.18	1. 32
July	515	100	160	9, 838	1.05	1. 21
August	458	80	140	8,608	0.92	1.06
September	625	85	198	11,782	1.29	1.44
October	895	90	212	13, 035	1.39	1.60
November 1 to 26 a			971	50, 075	6. 35	6. 14

^a Gage carried away by high water.

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 44 and 45.



A. SCHOHARIE CREEK AT FORT HUNTER, N. Y., LOOKING ACROSS THE STATE DAM.



 $\it B$. GENERAL VIEW OF SCHOHARIE CREEK AT FORT HUNTER, N. Y., GAGING STATION; ERIE CANAL IN FOREGROUND.

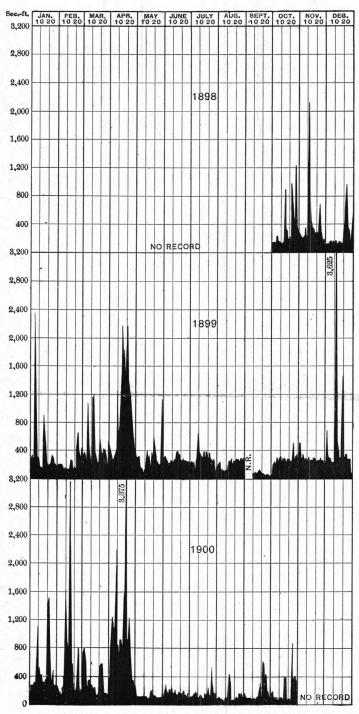


Fig. 19.—Discharge of Mohawk River at Ridge Mills, N. Y., 1898 to 1900.

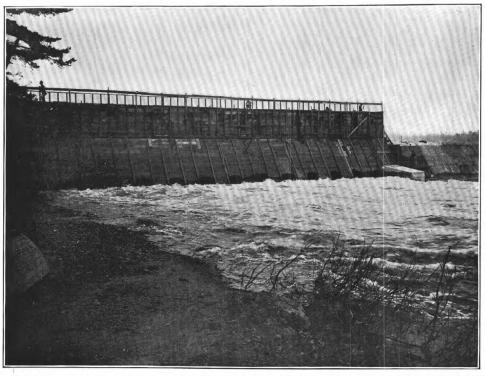
Estimated monthly discharge of Oriskany Creek at Oriskany, N. Y. [Drainage area, 144 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
October 16 to 31			325	10, 314	2, 26	1.54
November	740	236	327	19, 458	2. 27	2.53
December	825	100	327	20, 106	2. 27	2. 62
1899.						
January	550	180	295	18, 139	2.05	2.36
February	410	150	291	16, 161	2.02	2. 10
March	910	175	342	21, 029	2.37	2. 73
April	1,440	50	466	27, 729	3. 24	3. 62
May	238	25	119	7, 317	0.83	0.95
June	118	80	99	5, 891	0.69	0.77
July	270	104	180	11,068	1.25	1.44
August	206	98	186	11, 437	1.29	1.49
September	222	10	126	7, 498	0.87	0.97
October	180	26	91	5, 595	0.63	0.72
November	789	53	360	21, 421	2.50	2.79
December	340	10	89	5,472	0.62	0.71
The year	1, 440	10	220	158, 757	1.53	20.65
1900.						. J.
January	1, 376	41	199	12, 236	1.38	1.59
February	3, 116	60	378	20, 993	2.62	2.73
March	876	76	386	23, 734	2.68	3.09
April	1,391	194	488	29, 038	3. 39	3. 78
May	238	70	136	8, 362	0.94	1.08
June	97	95	95	5, 653	0.66	0.74
July	140	30	100	6, 149	0.69	0.79
August	132	100	103	6, 333	0.72	0.83
September	85	61	73	4, 344	0.51	0.57
October	191	63	`85	5, 226	0.59	0.68
November	2, 592	35	255	15, 174	1.77	1, 98
December	1, 172	112	272	16, 725	1.89	2. 18
The year	3, 116	30	214	153, 967	1, 49	20.04

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 46 and 47.



 $m{A}_{\star}$ LOG JAM IN THE ADIRONDACKS, NEW YORK, ILLUSTRATING DIFFICULTIES ENCOUNTERED IN LOG DRIVING.



B. WASTE GATES OF HUDSON RIVER POWER TRANSMISSION COMPANY, NEAR MECHANICSVILLE, N. Y., TAKING ENTIRE FLOW OF STREAM, ABOUT 4,500 CUBIC FEET PER SECOND.

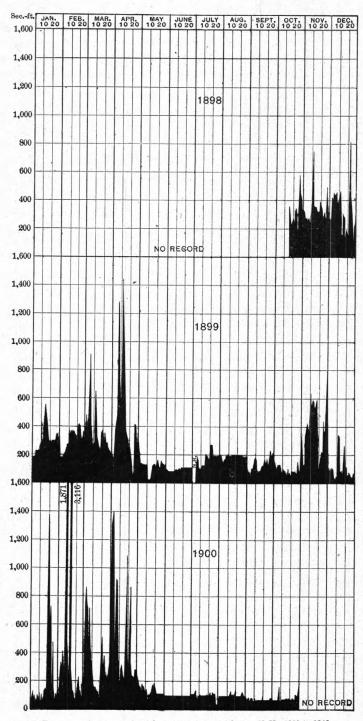


Fig. 20.—Discharge of Oriskany Creek at Oriskany, N.Y., 1898 to 1900.

Estimated monthly discharge of Sauquoit Creek at New York Mills, N. Y. [Drainage area, 52 square miles.]

Mum. Mum. Mum. Mum. Square mile. Mum.	Month.	Dischar	ge in secon	nd-feet.		Run-off.	
September 20 to 30				Mean.		feet per square	Depth in inches.
October 144 7 56 3, 443 1.08 November 140 32 57 3, 392 1.10 December 288 22 57 3, 505 1.10 1899. January 185 13 58 3, 566 1.12 February 409 6 58 3, 221 1.12 March 480 42 111 6, 825 2.13 April 585 40 127 7, 557 2.44 May 56 9 38 2, 337 0.73 June 56 7 23 1, 369 0.44 July 31 3 20 1, 230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1, 045 0.33 November 53	1898.						
November 140 32 57 3,392 1.10 December 288 22 57 3,505 1.10 1899. 185 13 58 3,566 1.12 February 409 6 58 3,221 1.12 March 480 42 111 6,825 2.13 April 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86	September 20 to 30			27	589	0.52	0. 21
December 288 22 57 3,505 1.10 1899. January 185 13 58 3,566 1.12 February 409 6 58 3,221 1.12 March 480 42 111 6,825 2.13 April 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45	October	144	7	56	3, 443	1.08	1, 24
January 185 13 58 3,566 1.12 February 409 6 58 3,221 1.12 March 480 42 111 6,825 2.13 April 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 337 49 138 8,108 2.81 March 371 13 84 5,165 1.61	November	140	32	57	3, 392	1.10	1. 23
January 185 13 58 3,566 1.12 February 409 6 58 3,221 1.12 March 480 42 111 6,825 2.13 April 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 January 306 9 72 4,427	December	288	22	57	3, 505	1.10	1. 26
February 409 6 58 3, 221 1.12 March 480 42 111 6, 825 2.13 April 585 40 127 7, 557 2.44 May 56 9 38 2, 337 0.73 June 56 7 23 1, 369 0.44 July 31 3 20 1, 230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1, 045 0.33 November 53 18 26 1, 547 0.50 December 72 12 29 1, 783 0.56 The year 585 3 45 32, 297 0.86 1900. 33 45 32, 297 0.86 4 427 1.38 32 32 32	1899.					Salar	
March 480 42 111 6,825 2.13 April 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65	January	185	13	58	3, 566	1.12	1. 29
April. 585 40 127 7,557 2.44 May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 37 5 49 3,013 0.94 </td <td>February</td> <td>409</td> <td>6</td> <td>58</td> <td>3, 221</td> <td>1.12</td> <td>1.17</td>	February	409	6	58	3, 221	1.12	1.17
May 56 9 38 2,337 0.73 June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62	March	480	42	111	6, 825	2.13	2.46
June 56 7 23 1,369 0.44 July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. January 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 87 5 49 3,013 0.94 June 57 5	April	585	40	127	7, 557	2.44	2.72
July 31 3 20 1,230 0.39 August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. January 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5	May	56	9	38	2, 337	0.73	0.84
August 43 5 16 984 0.31 September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	June	56	7	23	1, 369	0.44	0.49
September 33 5 14 833 0.27 October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	July	31	3	20	1, 230	0.39	0.45
October 32 7 17 1,045 0.33 November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	August	43		16	984	0.31	0.36
November 53 18 26 1,547 0.50 December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	September	33	5	14	833	0. 27	0.30
December 72 12 29 1,783 0.56 The year 585 3 45 32,297 0.86 1900. 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	October	32	7	17	1,045	0.33	0.38
The year	November	53	18	26	1,547	0.50	0.56
1900. January 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	December	72	12	29	1, 783	0.56	0.64
January 306 9 72 4,427 1.38 February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	The year	585	3	45	32, 297	0.86	11.66
February 1,413 13 146 8,108 2.81 March 371 13 84 5,165 1.61 April 337 49 138 8,212 2.65 May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	1900.	1.00					
March 371 13 84 5, 165 1. 61 April 337 49 138 8, 212 2. 65 May 87 5 49 3, 013 0. 94 June 57 5 32 1, 904 0. 62 July 65 5 32 1, 968 0. 62 August 37 5 22 1, 353 0. 42	January	306	9	72	4, 427	1.38	1.59
April 337 49 138 8, 212 2. 65 May 57 5 49 3, 013 0. 94 June 57 5 32 1, 904 0. 62 July 65 5 32 1, 968 0. 62 August 37 5 22 1, 353 0. 42	February	1,413	13	146	8, 108	2.81	2.93
May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	March	371	13	84	5, 165	1.61	1.86
May 3 87 5 49 3,013 0.94 June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	April	337	49	138	8, 212	2.65	2.96
June 57 5 32 1,904 0.62 July 65 5 32 1,968 0.62 August 37 5 22 1,353 0.42	, , , , , , , , , , , , , , , , , , ,	87	5	49	3, 013	0.94	1.08
August		57	5	32	1,904	0.62	0.69
	July	65	5	32	1,968	0.62	0.71
September	August	37	5	22	1,353	0.42	0.48
SEAN TO A SOUTH A SANDER STORE OF THE SEAR	September	37	5	15	893	0.29	0.32

 ${\tt Note.-Daily\ discharge\ for\ 1898,\ 1899,\ and\ 1900\ is\ given\ in\ Water-Supply\ Paper\ No.\ 47,\ pages\ 48\ and\ 49.}$

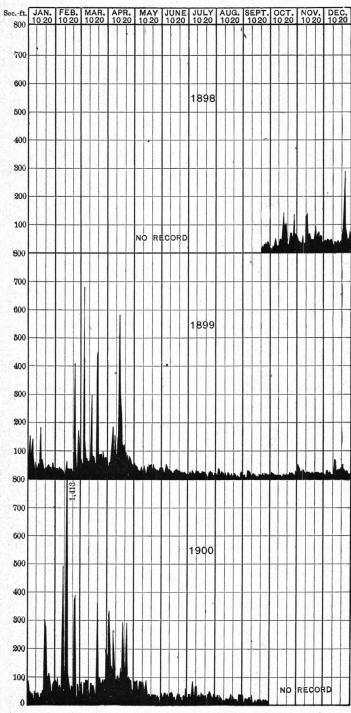


Fig. 21.—Discharge of Sauquoit Creek at New York Mills, N. Y., 1898 to 1900.

Estimated monthly discharge of West Canada Creek at Middleville, N. Y.

[Drainage area, 519 square miles.]

Month.	Dischar	ge in seco	nd-feet.		Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
October 7 to 31	2,554	398	1, 161	71, 387	2. 24	2.58
November	4, 240	450	1, 110	66,050	2.14	2. 38
December	2,083	465	1,024	62, 963	1.98	2. 28
1899.						
January	3,500	462	1, 150	70, 711	2. 22	2.56
February	2,640	937	1,594	88, 526	3.08	3. 21
March	1,835	685	1,176	72, 309	2. 27	2. 62
April	6, 994	523	3, 365	200, 231	6.50	7. 25
May	4, 760	728	1, 456	89, 526	2.81	3. 24
June	1, 114	130	397	23, 623	0.77	0.86
July	993	115	324	19, 922	0.63	0.73
August	345	110	235	14, 450	0.45	0. 52
September	476	145	221	13, 150	0.43	0.48
October	1,040	140	324	19,922	0.63	0.73
November	2,867	220	577	34, 334	1.11	1. 24
December	4,710	330	1, 259	77, 413	2.43	2.80
The year.	6, 994	110	1,007	724, 117	1.94	26. 24
1900.						
January	2,874	530	1,366	83, 992	2.64	3.04
May 10 to 31			924	40, 320	1.78	1.45
June	676	219	406	24, 159	0.78	0.87
July	636	289	451	27, 731	0.87	1.00
August	1,516	168	463	28, 469	0.89	1.03
September	947	136	419	24, 932	0.81	0.90
October	958	170	448	27, 546	0.86	0.99
November	5,920	270	1,536	91, 398	2.97	3. 31
December	1,517	390	800	49, 190	1.54	1.78

 ${\tt Note.-Daily\ discharge\ for\ 1898,\ 1899,\ and\ 1900\ is\ given\ in\ Water-Supply\ Paper\ No.\ 47,\ pages\ 51\ and\ 52.}$

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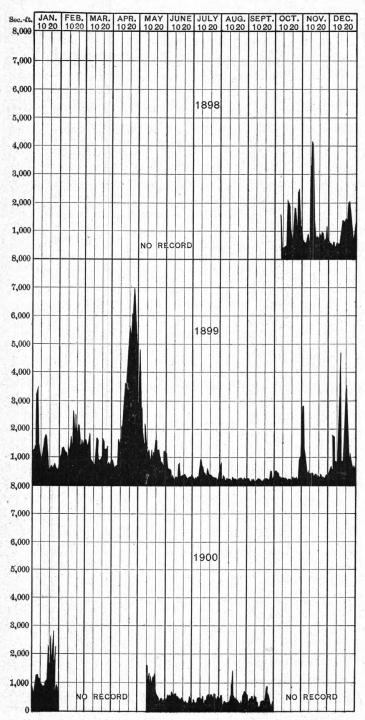


Fig. 22.—Discharge of West Canada Creek at Middleville, N. Y., 1898 to 1900.

Estimated monthly discharge of Mohawk River at Little Falls, N. Y.

[Drainage area, 1,306 square miles.]

	Dischar	rge in secon	id-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.
1898.						
September 23 to 30			2, 378			
October	6, 290	849	2, 493	153, 289	1.91	2. 20
November	9, 433	1, 137	2, 891	172, 026	2. 21	2.46
December	5, 279	969	2,036	125, 189	1.56	1.80
1899.						
January	7, 440	1, 126	2,753	169, 275	2.11	2.43
February	4,506	646	1,510	83, 861	1.16	1. 21
March	6,614	2, 129	3, 757	231,009	2.88	3. 32
April	12,649	2, 329	8, 102	482, 103	6. 20	6. 92
May	6,708	1, 290	2,651	163, 004	2.03	2. 34
June	1,957	535	1,014	60, 337	0.78	0.87
July	2, 593	50	803	49, 374	0.61	0.70
August	506	0	223	13, 712	0.17	0. 20
September	920	7	298	17, 732	0. 23	0.26
October	2, 293	142	509	31, 297	0.39	0.45
November	6,600	717	1,699	101,098	1.30	1.45
December	10,996	932	3, 360	206, 598	2.57	2.96
The year	12,649	0	1,890	1,609,400	1.70	23. 11
1900.						
January	7,736	180	2, 523	155, 133	1.93	2. 23
February	11,642	421	3, 862	214, 484	2.96	3.08
March	5,024	1,001	2, 469	151, 813	1.89	2. 18
April	15, 242	4, 202	8, 142	484, 483	6. 24	6. 96
May	4,673	723	2,063	126, 849	1.58	1.82
June	1,643	72	801	47, 663	0.61	0.68
July	2, 109	311	943	57, 983	0.72	0.83
August	2,370	93	694	42, 672	0.53	0.61
September	1,777	200	630	37, 487	0.48	0.54
October	2, 137	282	899	55, 277	0.69	0.80
November	14,551	885	3, 854	229, 329	2.95	3, 29
December	6, 316	1,586	3, 240	199, 220	2.48	2.86
The year	15, 242	72	2, 510	1, 802, 393	1.92	25. 88

 ${\tt Note.-Daily\ discharge\ for\ 1898,1899, and\ 1900\ is\ given\ in\ Water-Supply\ Paper\ No.\ 47, pages\ 54\ and\ 55.}$

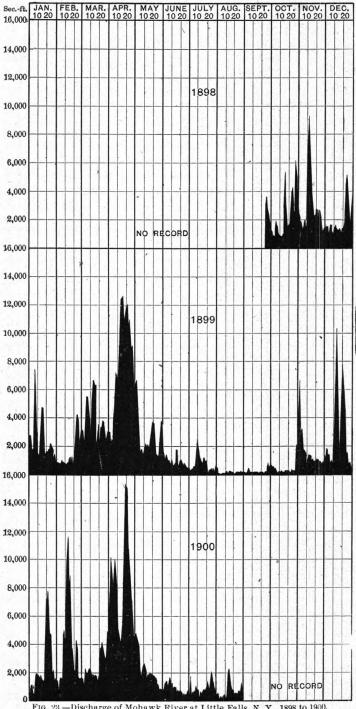


Fig. 23.—Discharge of Mohawk River at Little Falls, N. Y., 1898 to 1900.

Estimated monthly discharge of East Canada Creek at Dolgeville, N. Y. $[\text{Drainage_area, 256 square miles.}]$

	Dischar	rge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1898.							
September 23 to 30			638	10, 124	2.49	0.74	
October	1,422	213	581	35, 724	2.27	2.61	
November	1,937	235	689	40, 998	2.69	3.00	
December, 18 days	1, 275	372	564	34, 679	2, 20	2.54	
1899.							
January	1,942	342	816	50, 174	3. 19	3. 67	
February	992	348	439	24, 381	1.71	1.78	
March	852	372	519	31, 912	2.03	2.34	
April	4, 472	355	1,978	117, 699	7.73	8. 63	
May	1,701	324	633	38, 922	2.47	2. 84	
June	384	112	196	11,663	0.77	0.86	
July	394	79	166	10, 207	0.65	0.75	
August	210	44	97	5, 964	0.38	0.44	
September	192	67	92	5, 474	0.36	0.40	
October	372	74	112	6, 887	0.44	0.51	
November	1,674	134	377	22, 433	1.47	1. 64	
December	3, 029	132	706	43, 410	2.76	3. 18	
The year	4, 472	44	511	369, 126	2.00	27. 04	
1900.		A. Jan					
January	1,704	240	531	32, 650	2.07	2. 39	
February	4, 320	264	879	48, 817	3. 43	3. 57	
March	468	152	276	16, 971	1.08	1. 25	
April	5, 335	631	2,086	124, 126	8. 15	9.09	
May 1 to 26	1,476	240	486	29, 883	1.90	2. 19	
June 5 to 30	827	149	370	22, 017	1.45	1.62	
July	767	110	221	13, 589	0.86	0.96	
August	396	77	144	8, 854	0.56	0.65	
September 1 to 25	196	73	133	7,914	0.52	0.58	
October	582	81	195	11,990	0.76	0.88	
November, 22 days	3, 802	194	957	56, 945	3.74	4.17	
December 5 to 31	1, 192	63	368	22, 689	1.44	1.66	

 ${\tt Note.-Daily\ discharge\ for\ 1898,\ 1899,\ and\ 1900\ is\ given\ in\ Water-Supply\ Paper\ No.\ 47,\ pages\ 57\ and\ 58.}$

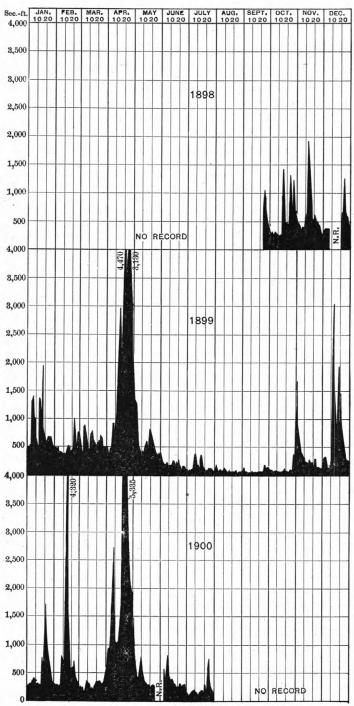


Fig. 24.—Discharge of East Canada Creek at Dolgeville, N. Y., 1898 to 1900. 22 GEOL, PT IV—01——7

Estimated monthly discharge of Cayadutta Creek near Johnstown, N. Y. [Drainage area, 40 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
October	290	10	64	3, 935	1.60	1.84
November	734	12	91	5, 415	2. 27	2.53
December	98	23	44	2, 705	1.10	1. 27
1899.						
January	125	13	39	2, 398	0.97	1.12
February	91	14	31	1,722	0.77	0.80
March	282	35	74	4, 550	1.85	2. 13
April	811	31	251	14, 936	6. 27	7.00
May	57	12	31	1,906	0.77	0.89
June	37	17	26	1,547	0.65	0.72
July	34	8	20	1, 230	0.50	0.58
August	32	8	18	1, 107	0.45	0.52
September	36	11	20	1,190	0.50	0.56
October	33	9	21	1, 291	0.52	0.60
November	48	6	26	1,547	0.65	0.72
December	238	11	49	3,013	1. 22	1.41
The year	811	6	51	36, 437	1. 26	17.05
1900.						
January	705	14	71	4, 366	1.77	2.04
February	1,404	20	119	6,609	2.97	3.09
March	296	19	62	3,812	1.55	1.79
April	314	22	137	8, 152	3.42	3. 82
May	81	19	27	1,660	0.67	0.77
June	36	8	21	1, 249	0.52	0.58
July	31	6	17	1,045	0.42	0.48
August	35	4	20	1, 230	0.50	0.58
September	32	6	18	1,071	0.45	0.50

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 59 and 60.

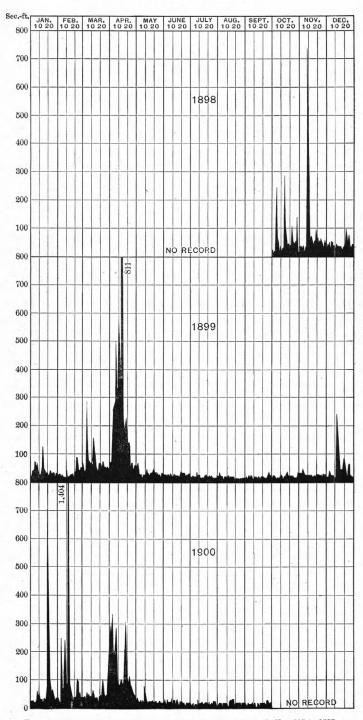


Fig. 25.—Discharge of Cayadutta Creek near Johnstown, N. Y., 1898 to 1900.

Estimated monthly discharge of Schoharie Creek at Fort Hunter, N. Y. [Drainage area, 947 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum,	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
September 24 to 30			129			
October	3, 211	161	1, 142	70, 219	1. 21	1.40
November	9, 517	667	2, 148	127, 815	2. 27	2.53
December	3, 864	689	1,573	96, 720	1.66	1.91
1899.						
January	5, 791	941	2,307	141, 852	2.44	2.81
February	6,035	657	1,944	107, 964	2.05	2.13
March	13, 635	1, 335	3, 792	233, 161	4.00	4. 61
April	9, 335	1,335	4, 100	243, 967	4. 33	4. 83
May	1,560	260	579	35, 601	0.61	0.70
June	295	195	226	13, 448	0. 24	0. 27
July	202	165	187	11, 498	0.20	0. 23
August	152	132	142	8, 731	0.15	0.17
September	6, 984	138	916	54, 506	0.97	1.08
October	3, 867	587	1,603	98, 565	1.69	1.95
November	1, 835	295	875	52,066	0.92	1.03
1900.						
January	8, 235	315	1, 313	80, 733	1.39	1.60
March	7, 515	1,755	3, 137	192, 887	3.31	3.81
April	6, 615	1, 325	3,530	210,050	3.73	4. 16
May	1,550	250	561	34, 495	0.59	0.68
June	515	105	219	13, 031	0.23	0. 26
July	144	72	115	7, 071	0.12	0.14

Note.—Station abandoned July 31, 1900. Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 62 and 63.

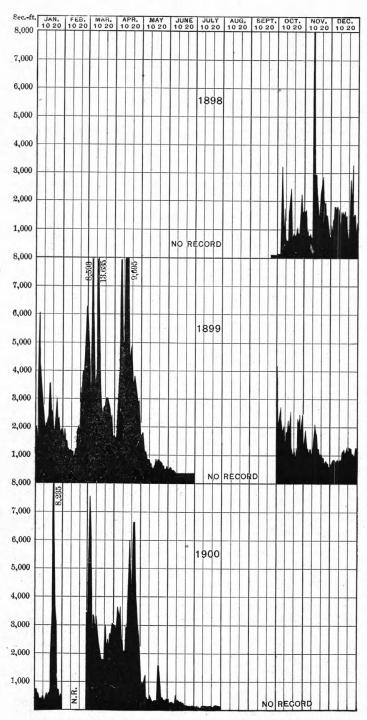


Fig. 26.—Discharge of Schoharie Creek at Fort Hunter, N. Y., 1898 to 1900.

Estimated monthly discharge of Mohawk River at Rexford Flats, N. Y.

[Drainage area, 3, 385 square miles.]

	Dischar	rge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
December 8 to 31	11,550	1,800	4, 471	274, 911	1. 32	1. 52
1899.		1 75				
January	16, 850	2,750	5, 739	352, 877	1.70	1.96
February	10, 150	2, 100	3, 935	218, 539	1.16	1. 21
March	25, 700	4,750	9,004	553, 634	2.66	3.06
April	30,630	5, 270	17,057	1,014,962	5.04	5. 62
May	9,828	1,678	4,084	251, 115	1. 21	1.40
June	5, 128	928	2,014	119, 841	0.59	0.66
July	928	288	498	30, 621	0.15	0.17
August	608	208	294	18,077	0.09	0.10
September	9, 178	228	980	58, 314	0. 29	0. 32
October	2,928	728	1,608	98, 872	0.48	0.55
November	9,028	1, 128	2,824	168, 040	0.83	0. 92
December	21, 358	1, 328	7,001	430, 475	2.07	2.38
The year	30, 630	208	4,586	3, 315, 367	1.36	18. 35
1900.		S - North				
January	45, 750	1, 260	7,860	483, 293	2. 32	2.67
February	45,050	1,860	9,032	501, 612	2.67	2.78
March	8, 750	1,160	4, 235	260, 400	1.25	1.44
April	28, 370	7, 250	14, 996	892, 324	4. 43	4.94
May	5,500	1, 425	2,857	175, 670	0.84	0.97
June	2,910	910	1,503	89, 435	0, 44	0.49
July	2, 490	750	1,447	88, 973	0.43	0.49
August	5,020	920	1,746	107, 357	0.52	0.60
September	1,920	430	981	58, 374	0.29	0. 32

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 68 and 69.

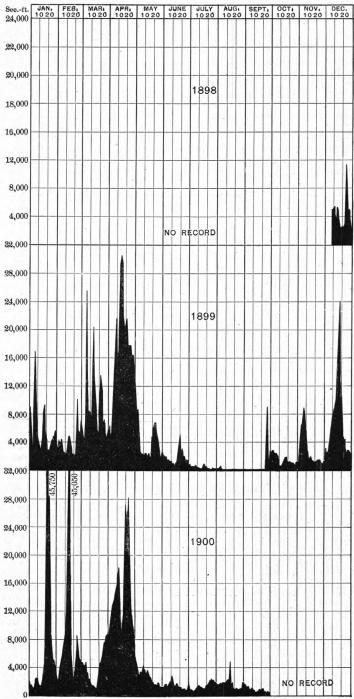


Fig. 27.—Discharge of Mohawk River at Rexford Flats, N. Y., 1898 to 1900.

Estimated monthly discharge of Schroon River near Warrensburg, N. Y. [Drainage area, 562.5 square miles.]

			Run-off.		
Month.	Mean dis- charge in second- feet.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1895.					
November	478	27, 443	0.85	0.94	
December	1, 233	75, 814	2. 19	2.53	
1896.					
January	2,779	170, 874	4.94	5. 70	
February	516	28, 657	0.92	0.96	
March	1,664	102, 315	2.96	3.41	
April	3, 280	195, 174	5. 83	6. 51	
May	728	44, 763	1. 29	1.49	
June	827	49, 210	1.47	1.64	
July	276	16, 971	0.49	0.56	
August	265	16, 294	0.47	0.54	
September	215	12, 793	0.38	0.42	
October	330	20, 290	0.59	0.68	
November	1,089	64, 800	1.94	2.17	
December	243	14, 941	0.43	0.50	
The year	1,018	737, 082	1.81	24. 58	
1897.					
January	337	20, 721	0.60	0.69	
February	188	10, 441	0.33	0.34	
March	738	45, 378	1.31	1.51	
April	3, 164	188, 271	5. 62	6. 27	
May	1,822	112,030	3. 24	3. 73	
June	2, 384	141, 859	4. 24	4.73	
July	1,426	87, 681	2.54	2.93	
August	1,377	84, 668	2.45	2. 82	
September	281	16, 721	0.50	0.56	
October	166	10, 207	0.30	0. 35	
November	2,077	123, 590	3.69	4. 12	
December	2,776	170, 690	4. 93	5. 69	
The year	1, 395	1, 012, 257	2.48	33. 74	

Estimated monthly discharge of Schroon River near Warrensburg, N. Y.—Continued.

	Dischar	rge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1898.							
January			852	52, 387	1.51	1.74	
February			416	23, 103	0.74	0.77	
March			3, 194	196, 391	5. 68	6. 55	
April			2,853	169, 765	5.07	5. 66	
May			2,203	135, 457	3.92	4. 52	
June			568	33, 798	1.01	1.18	
July			216	13, 281	0.38	0.44	
August			223	13, 712	0.40	0.46	
September			166	9,878	0.30	0.33	
October			263	16, 171	0.47	0.54	
November			464	27, 610	0.82	0. 92	
December			783	48, 145	1.39	1,60	
The year			1,017	739, 698	1.81	24. 66	
1899.							
January	641	575	606	37, 261	1.08	1. 25	
February	478	478	478	26,547	0.85	0.89	
March	718	478	564	34, 679	1.00	1. 15	
April	5, 103	708	2,877	171, 193	5, 11	5. 70	
May	4,854	1, 391	3, 150	193, 686	5. 60	6.46	
June	1,506	381	1,093	65, 038	1.94	2. 17	
July	304	150	210	12, 912	0.37	0.43	
August	150	150	150	9, 223	0. 27	0. 31	
September	381	150	234	13, 924	0.42	0.47	
October	478	381	462	28, 407	0.82	0.95	
November	1,468	708	1,047	62, 301	1.86	2.08	
December	1, 153	708	948	58, 290	1.69	1.95	
The year	5, 103	150	985	713, 461	1.75	23. 81	
1900.							
January	810	810	810	49,805	1.44	1.66	
February	2,035	810	1,380	76, 641	2.45	2.55	
March	1,360	1,085	1, 140	70, 096	2.02	2. 33	
April	7, 745	1, 162	3, 688	219,451	6. 56	7. 32	
May	3,965	1,025	1,688	103, 791	3.00	3.46	
June	1,990	963	1, 280	76, 165	2. 28	2. 54	
July	885	285	528	32, 465	0.94	1.08	

Note.—Daily discharge for 1899 and 1900 is given in Water-Supply Paper No. 47, page 74.

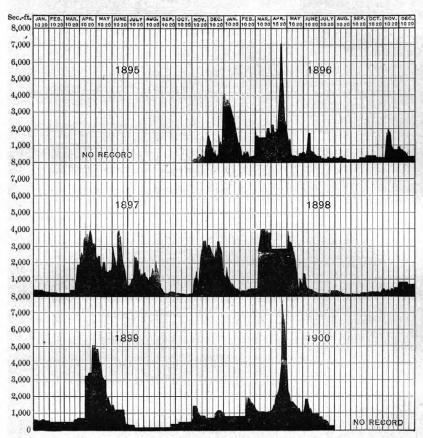


Fig. 28.—Discharge of Schroon River near Warrensburg, N. Y., 1895 to 1900.

Estimated monthly discharge of Hudson River at Fort Edward, N. Y. [Drainage area, 2,800 square miles.]

4	Dischar	rge in seco	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
January	5, 388	925	3, 527	216, 867	1. 26	1.45
February	2,853	942	1,902	105, 632	0.68	0.71
March	6, 229	2, 415	5,005	307, 745	1.79	2.06
April	32, 159	1,560	16, 811	1,000,324	6, 00	6, 69
May	23, 033	700	9, 561	587, 883	3.41	3. 98
June	3, 106	583	1,617	96, 218	0.58	0. 65
July	1,817	20	1, 150	70, 711	0.41	0.47
August, 23 days	1,176	20	714	43, 902	0. 26	0. 30
September	4, 889	20	1, 347	80, 152	0.48	0. 54
October	2, 181	20	1,033	63, 517	0.37	0. 43
November	14, 930	20	5,098	303, 352	1. 82	2. 03
December	11, 410	20	5, 157	317, 092	1.84	2. 12
1900.						
January	7, 577	1,401	3, 211	197, 437	1.15	1.38
February	18, 975	1,810	7, 181	392, 870	2.53	2. 63
March	4,942	1,302	3,934	241, 892	1.40	1.61
April	43,900	3, 237	16, 914	1,006,453	6.04	6. 74
May	12, 486	415	6, 358	390, 938	2. 27	2. 61
June	5,094	20	2,834	168, 635	1.01	1. 13
July	3, 441	30	1,248	76, 737	0.45	0. 52
August	3, 347	95	1,652	101, 578	0.59	0.68
September	1,661	190	1,110	66, 050	0.40	0.45
October	2,703	20	1, 243	76, 429	0.44	0.51
November	10, 213	302	2,670	158, 876	0.95	1.06
December	7, 697	965	3, 198	196, 637	1.14	1. 31
The year	43, 900	20	4, 294	3, 074, 532	1.53	20. 58

Note.—Daily discharge for 1899 and 1900 is given in Water-Supply Paper No. 47, page 76.

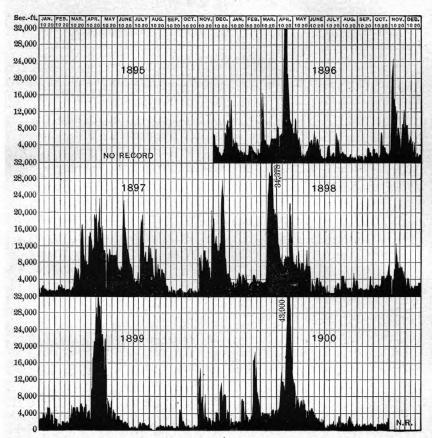


Fig. 29.—Discharge of Hudson River at Fort Edward, N. Y., 1895 to 1900.

Estimated monthly discharge of Hudson River at Mechanicsville, N. Y. [Drainage area, 4,500 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum-	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1898.							
January	14,053	4,822	8, 173	502, 538	1.82	2. 10	
February	9,732	3,956	6,038	335, 333	1.34	1.39	
March	39, 231	4, 791	19,617	1, 206, 202	4.36	5. 02	
April	24, 338	7,646	13, 047	776, 351	2, 90	3. 23	
May	15, 327	7,875	10, 525	647, 157	2.34	2.69	
June	9,490	3, 238	5, 069	301, 626	1.13	1. 26	
July	4,665	1, 163	2, 751	169, 152	0.61	0.70	
August	11, 167	3,005	5, 029	309, 221	1.12	1. 29	
September	6,878	2, 487	3, 810	226, 710	0.85	0.95	
October	20, 089	2,780	7, 516	462, 141	1.67	1.92	
November	20, 256	5, 503	8,978	534, 228	1.99	2. 22	
December	8, 369	3,540	5, 291	325, 331	1.18	1.36	
The year	39, 231	1, 163	7, 987	5, 795, 990	1.78	24. 13	
1899.					Ž.		
January	10, 155	4,066	6, 437	395, 796	1.43	1.65	
February	10, 326	3, 448	5, 141	285, 517	1.14	1.18	
March	16, 501	6, 403	9,316	572, 819	2.07	2.38	
April	41, 475	6, 955	24, 607	1, 464, 218	5.47	6.11	
May	27,617	3, 787	9,591	589, 728	2.13	2.46	
June	3,990	304	2,539	151, 081	0.56	0. 62	
July	3, 533	1,047	2, 402	147, 693	0.53	0.61	
August	2,460	484	1,417	87, 128	0.31	0.36	
September	6,000	711	2,054	122, 222	0.46	0.51	
October	4,042	1,798	2,616	160, 852	0.58	0.67	
November	12,020	3, 318	6,066	360, 950	1.35	1.5	
December	14, 979	2, 585	7, 303	449, 044	1.62	1.87	
The year	41, 475	304	6, 624	4, 787, 048	1.47	19. 93	
1900.							
January	18, 307	3,000	5, 841	359, 149	1.30	1.50	
February	41, 285	3, 349	12, 484	693, 326	2.77	2.88	
March	15, 344	3,675	7,740	475, 914	1.72	1.98	
April	43, 546	10,088	22, 614	1, 345, 627	5.02	5.60	
May	16, 713	3,857	8,992	552, 896	2.00	2. 3	
June	7,644	1,877	4,093	243, 550	0.91	1.02	

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Estimated monthly discharge of Hudson River at Mechanicsville, N. Y.—Continued.

	Discharge in second-feet.				Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
GE "IKE							
1900.							
July	4,082	1,342	2, 352	144, 619	0.52	0.60	
August	5,773	1,702	2,703	166, 201	0.60	0.69	
September	2,519	713	1,886	112, 225	0.42	0.47	
October	3, 287	1,692	2, 128	130, 846	0.47	0.54	
November	11,694	1,576	5, 077	302, 103	1.13	1.26	
December	10,694	3, 763	5, 331	327, 790	1.18	1.36	
The year	43, 546	713	6,770	4, 854, 246	1.50	20. 21	
						100	

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 47, pages 78 and 79

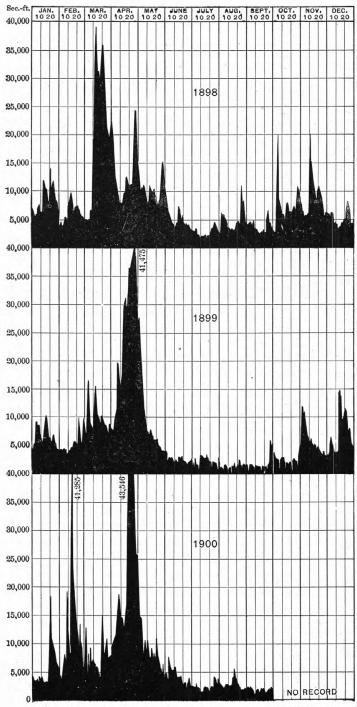


Fig. 30.—Discharge of Hudson River at Mechanicsville, N. Y., 1898 to 1900.

DELAWARE RIVER AND TRIBUTARIES NEAR PHILADELPHIA.

The gaging station on this river was established July 23, 1897, at Lambertville, N. J. Since its establishment continuous records have been kept of the flow of the river, which have been published in the various annual reports since that year. The record for 1900 is published herewith. Measurements of the flow of Perkiomen, Wissahickon, Tohickon, and Neshaminy creeks, all tributaries of Delaware River near Philadelphia, have been continued during the year by Mr. John E. Codman, in charge of the hydrographic work of the bureau of water of the city of Philadelphia. The location of these creeks and the points of measurement are shown in fig. 16 of the Twentieth Annual Report, Part IV, page 89. On the following pages are given records of the flow of Perkiomen Creek from 1884 (the year the station was established) to 1900, inclusive; of Tohickon Creek from 1883 (the year the station was established) to 1900, inclusive; of Neshaminy Creek from 1884 (the year the station was established) to 1900, inclusive; and of Wissahickon Creek for 1900, the latter being a continuation of the records published in former annual reports.

Estimated monthly discharge of Delaware River at Lambertville, N. J.

[Drainage area, 6,855 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Max- imum.	Min- imum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January 12 to 27	43, 475	6, 100	17, 527	1,077,693	2.56	2.96
February 4 to 28	81,070	15, 900	33, 100	1, 838, 281	4.83	5.03
March	87, 250	9, 250	23, 478	1, 443, 606	3.42	3.95
April	37,295	10,000	16,660	991, 339	2.43	2.71
May	20, 300	5, 300	9, 553	587, 391	1. 39	1.60
June	8, 225	2, 300	5, 260	312, 992	0.77	0.86
July	11,225	1,900	5, 186	318, 875	0.76	0.88
August	5,050	2,000	3,066	188, 521	0.45	0.52
September	5, 300	2,000	2, 975	177, 025	0.43	0.48
October	3, 900	1,525	2, 341	143, 942	0.34	0.39
November	14, 625	2,000	4, 281	254, 737	0.62	0.69
December, 21 days	20, 300	5,050	10, 126	622, 623	1.48	1.71

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 47, page 80; rating table in Paper No. 52, page 511. The above figures include the flow of the Delaware and Raritan Canal feeder.

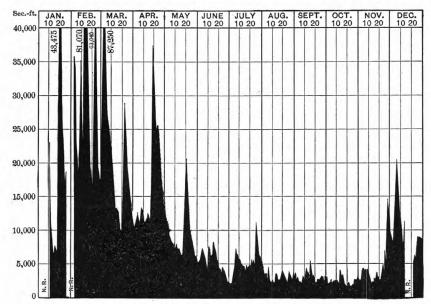


Fig. 31.—Discharge of Delaware River at Lambertville, N. J., 1900.

Estimated monthly discharge of Tohickon Creek at Point Pleasant, Pa.

[Drainage area, 102.2 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1883.						
October	687	3	77	4, 735	0.75	0.86
November	220	15	53	3, 154	0.52	0.58
December	260	31	86	5, 288	0.84	0.97
1884.	`					
January	3, 492	331	703	43, 226	6.88	7. 93
February	2, 412	392	990	56, 945	9.69	10.45
March	1,871	306	580	35, 663	5. 68	6.55
April	408	15	175	10, 413	1.71	1.91
May	349	9	57	3,505	0.56	0.65
June	4, 379	4	314	18, 684	3.07	3.54
July	2,309	5	242	14, 880	2.37	2.73
August	103	3	25	1,537	0. 24	0. 28
September	29	2	7	417	0.07	0.08
October	250	0	12	738	0.12	0.14
November	859	. 10	108	6,426	1.06	1.18
December	2,372	44	353	21,705	3. 45	3. 98
The year	4, 379	0	297	214, 139	2. 91	39. 42

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114 PROGRESS OF STREAM MEASUREMENTS FOR 1900.

Estimated monthly discharge of Tohickon Creek at Point Pleasant, Pa.—Continued.

	Dischar	ge in secon	d-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1885.		1. 8					
January	2,614	82	401	24,656	3.92	4. 52	
February	1,885	58	340	18, 883	3. 33	3. 47	
March	1,027	51	265	16, 294	2.59	2.99	
April	3,664	29	415	24, 694	4.06	4.58	
May	186	12	44	2,705	0.43	0.50	
June	15	1	7	417	0.07	0.08	
July	325	0	20	1,230	0.20	0. 23	
August	1,489	1	112	6, 887	1.10	1.27	
September	8	1	3	179	0.03	0.03	
October	244	1	31	1,906	0.30	0. 35	
November	1, 137	23	236	14,043	2.31	2.58	
December	809	30	158	9, 715	1.55	1.79	
The year	3, 664	0	169	121, 609	1.66	22. 34	
1886.							
January	3, 352	83	388	23, 857	3.80	4. 38	
February	5, 404	87	910	50, 539	8.90	9. 27	
March	2,598	35	382	23, 488	3.74	4. 31	
April	3,692	24	438	26,063	4. 29	4.78	
May	2, 121	17	304	18, 692	2.97	3. 42	
June	1,030	18	129	7,676	1. 26	1.41	
July	378	9	69	4, 243	0.68	0.78	
August	22	2	9	553	0.09	0.10	
September	5	1	2	119	0.02	0.05	
October	17	1	4	246	0.04	0.08	
November	2,064	7	180	10, 711	1.76	1.96	
December	1,016	23	212	13, 035	2.07	2. 39	
The year	5, 404	1	252	179, 222	2.47	32. 8	
1887.		7-11-19		1			
January	2,544	100	449	27, 608	4. 39	5.0	
February	2, 357	107	517	28,713	5.06	5. 2	
March	1,538	48	342	21, 029	3. 35	3.8	
April	312	24	93	5, 534	0.91	1.0	
May	669	15	87	5, 349	0.85	0.9	
June	1,483	9	110	6, 545	1.08	1. 20	
July	1,858	10	145	8,916	1.42	1.6	

Estimated monthly discharge of Tohickon Creek at Point Pleasant, Pa.—Continued.

L.	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1887.						
August	1,883	16	173	10, 637	1.69	1.95
September	349	10	38	2, 261	0.37	0.41
October	90	7	23	1, 414	0. 23	0. 27
November	79	9	24	1,428	0.23	0. 26
December	1, 201	20	283	17, 401	2.77	3. 20
The year	2, 544	7	190	136, 835	1.86	25. 11
1888.						
January	3, 492	86	571	35, 109	5.59	6. 44
February	2,768	104	637	36, 640	6.23	6. 72
March	2,659	79	556	34, 187	5.44	6. 28
April	2,019	32	393	23, 385	3.85	4. 28
May	92	28	46	2,828	0.45	0.52
June	43	3	15	893	0.15	0.17
July	11	2	7	430	0.07	0.08
August	3, 489	4	157	9,654	1.54	1.78
September	5,546	9	499	29, 693	4.88	5, 44
October	993	32	138	8, 485	1.35	1.56
November	1, 130	49	286	17,018	2.80	3. 12
December	2,689	63	310	19,061	3.03	3.49
The year	5, 546	2	301	217, 383	2.95	39. 88
1899.						
January	1,530	72	389	23, 919	3. 81	4. 39
February	819	37	149	8, 275	1.46	1.52
March	2, 567	36	341	20, 967	3. 34	3.85
April	2, 126	29	264	15, 709	2.58	2.87
May	911	16	151	9, 285	1.48	1.71
June	807	28	189	11, 246	1.85	2.06
July	4,714	38	570	35, 048	5.58	6.43
August	2,602	19	334	20, 537	3. 27	3.77
September	3,028	9	317	18, 863	3. 10	3.46
October	2,958	31	207	12, 728	2.03	2.34
November	3, 394	102	733	43, 617	7. 17	8.00
December	606	55	172	10, 576	1.68	1.94
The year	4, 714	9	318	230, 770	3. 11	42.34

Estimated monthly discharge of Tohickon Creek at Point Pleasant, Pa.—Continued.

	Dischar	rge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum,	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January			219	13, 466	2.14	2.47
February			500	27, 769	4.89	5. 09
March			248	15, 249	2.43	2.81
April			116	6,902	1.14	1. 27
May			79	4,858	0.77	0.89
June			31	1,845	0.30	0. 33
July			61	3, 751	0.60	0.69
August			17	1,045	0.17	0.20
September			. 8	476	0.08	0.09
October			13	799	0.13	0.15
November			35	2,083	0.34	0.38
December			62	3, 812	0.61	0.70
The year			116	82, 055	1.13	15.07

NOTE.—Daily discharge for 1883 to 1899, inclusive, is given in Water-Supply Paper No. 47, pages 81 to 89; monthly discharge for 1890 to 1898, inclusive, in Twentieth Annual Report, Part IV, pages 98 to 103, and for 1899 in Twenty-first Annual Report, Part IV, page 83.

Estimated monthly discharge of Neshaminy Creek, Pennsylvania, below the forks.

[Drainage area, 139.3 square miles.]

	Dischar	ge in secon	nd-feet.	Total in acrefect.	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1884.						
June	2, 271	5	139	8, 271	0.99	1.10
July	905	13	62	3, 812	0.45	0.52
August	462	10	61	3, 751	0.44	0.51
September	15	3	6	357	0.04	0.04
October	12	3	5	307	0.04	0.05
November	441	3	39	2, 321	0.28	0.31
December	2, 354	20	534	32, 834	3.83	4.41
				-	-	

Estimated monthly discharge of Neshaminy Creek, Pennsylvania, below the forks—Cont'd.

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1885.						
January	1,886	120	382	23, 488	2.74	3. 16
February	4, 484	33	. 589	32, 711	4. 23	4.40
March	1,053	42	203	12, 482	1.46	1.68
April	1,761	42	171	10, 175	1.23	1. 37
May	474	20	65	3,997	0.47	0. 54
June	22	4	9	536	0.06	0.07
July	41	2	6	369	0.04	0.05
August	2, 377	3	112	6, 887	0.80	0. 92
September	9	1	4	238	0.03	0.03
October	103	1	21	1, 291	0.15	0.17
November	746	23	185	11,008	1. 33	1.48
December	1,803	63	200	12, 298	1.44	1.66
The year	4, 484	1	162	115, 480	1.16	15. 53
1886.						
January	3, 735	83	609	37, 446	4. 37	5. 04
February	5, 767	122	843	46, 818	6.05	6. 30
March	1,870	66	266	16, 356	1.91	2. 20
April	4, 734	65	431	25, 646	3. 09	3. 45
May	2, 346	41	244	15,003	1.75	2. 02
June	732	29	110	6, 545	0.79	0.88
July	598	19	92	5, 657	0.66	0.76
August	46	4	17	1,045	0.12	0.14
September	10	2	5	298	0.04	0.04
October	38	2	6	369	0.04	0.05
November	770	7	67	3, 988	0.48	0. 54
December	2, 228	46	272	16, 725	0. 20	0, 23
The year	5, 767	2	247	175, 896	1.63	21.65
1887.						
January	2, 891	130	490	30, 129	3. 52	4.06
February	1,703	156	507	28, 157	3. 64	3.79
March	2, 185	109	380	23, 365	2, 73	3, 15
April	663	69	176	10, 473	1.26	1.41
May	310	25	82	5,042	0, 59	0.68
June	3, 159	23	199	11, 841	1.43	1, 60
July	1,570	30	226	13, 896	1.62	1.87

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Estimated monthly discharge of Neshaminy Creek, Pennsylvania, below the forks-Cont'd.

	Dischar	ge in seco	nd-feet	111 35	Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1887.	1617					
August	379	30	93	5, 718	0.67	0.77
September	492	14	51	3,035	0.37	0.41
October	398	13	42	2, 582	0.30	0.38
November	61	18	32	1,904	0.23	0.20
December	1,648	23	334	20, 537	2.40	2.77
The year	3, 159	14	218	156, 679	1.56	21. 12
1888.						
January	4,890	151	558	34, 310	4.01	4. 62
February	3, 619	191	709	40, 782	5.09	5. 49
March	3, 126	. 77	592	36, 401	4. 25	4.9
April	2, 227	68	350	20, 826	2.51	2.8
May	130	36	64	3, 935	0.46	0.5
June	65	8	25	1, 488	0.18	0. 20
July	. 125	8	18	1, 107	0.13	0.1
August	1,500	6	80	4,919	0.57	0.6
September	3,099	9	327	19, 458	2.35	2.6
October	688	47	129	7,932	0.93	1.0
November	1,821	84	291	17, 316	2.09	2. 3
December	3, 759	80	380	23, 365	2.73	3. 1
The year	4, 890	6	294	211, 839	2. 11	28. 52
1889.						
January	1, 130	116	356	21, 890	2.56	2.98
February	1, 116	87	208	11,552	1.49	1.5
March	3, 197	89	348	21, 398	2.50	2.89
April	2,258	48	257	15, 293	1.84	2.0
May	822	41	214	13, 158	1.54	1.78
June	562	40	145	8,628	1.04	1.10
July	5, 531	94	658	40,459	4.72	5.4
August	2,046	49	410	25, 210	2.94	3. 39
September	2,947	38	443	26, 360	3. 18	3.58
October	3, 749	87	304	18, 692	2.18	2.55
November	3, 528	180	783	46, 592	5. 62	6. 2
December	443	109	228	14,019	1.64	1.89
The year	5, 531	38	363	263, 251	2. 60	35. 44

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NESHAMINY CREEK.

Estimated monthly discharge of Neshaminy Creek, Pennsylvania, below the forks.—Cont'd.

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	2,588	48	327	20, 106	2.35	2.71
February	3, 163	142	696	38, 654	5.00	5. 21
March	2,675	101	378	23, 242	2.71	3. 13
April	860	64	153	9, 104	1.10	1. 23
May	3,990	26	279	17, 155	2.00	2. 31
June	1, 221	19	102	6,069	0.73	0.81
July	250	10	47	2,890	0.34	0.39
August	88	9	23	1,414	0.17	0. 20
September	58	5	11	655	0.08	0.09
October	118	8	18	1, 107	0.13	0.15
November	840	8	50	2, 975	0.36	0.40
December	711	15	91	5, 595	0.65	0.75
The year	3, 990	5	181	128, 966	1.30	17. 38

Note.—Daily discharge for 1884 to 1900, inclusive, is given in Water-Supply Paper No. 47, pages 90 to 98; monthly discharge for 1890 to 1898, inclusive, in Twentieth Annual Report, Part IV, pages 104 to 107, and for 1899 in Twenty-first Annual Report, Part IV, page 86.

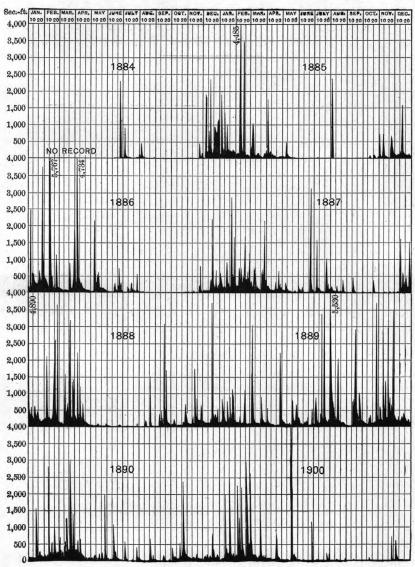


Fig. 32.—Discharge of Neshaminy Creek, Pennsylvania, below the 40rks, 1884 to 1890, and 1900. For hydrograph of years 1891 to 1898, inclusive, see Twentieth Annual Report, Part IV, page 108; for 1899 see Twenty-first Annual Report, Part IV, page 86.

Estimated monthly discharge of Perkiomen Creek at Frederick, Pa. [Drainage area, 152 square miles.]

	Dischar	ge in secor	id-feet.		Ru	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1884.				1		
September	100	23	45	2,678	0.30	0.33
October	238	16	51	3, 136	0.34	0.39
November	768	47	124	7,378	0.82	0.9
December	3,425	64	491	30, 190	3. 23	3. 72
1885.						-1
January	2,600	113	431	26, 501	2.84	3. 28
February	2, 107	98	313	17, 383	2.06	2. 15
March	992	67	330	20, 291	2.17	2. 51
April	3, 192	92	373	22, 195	2.45	2. 73
May	805	58	142	8, 731	0.93	1.0
June	85	16	37	2, 202	0. 24	0. 27
July	35	9	23	1, 414	0.15	0.17
August	1,673	19	163	10,022	1.07	1. 23
September	36	8	22	1, 309	0.14	0.16
October	243	8	56	3, 443	0.37	0.48
November	862	46	240	14, 281	1.58	1.76
December	2, 546	67	320	19,676	2.11	2. 44
The year	3, 192	8	204	147, 448	1.34	18. 20
1886.						
January	3,044	143	400	24,595	2. 63	3.03
February	4, 395	135	818	45, 429	5.38	5.60
March	1,827	134	336	20, 660	2. 21	2. 55
April	4,020	106	462	27,491	3.04	• 3.39
May	3,094	79	343	21,090	2. 26	2.61
June	1,967	72	256	15, 233	1.68	1.87
July	400	42	145	8, 916	0.95	1.09
August	95	23	45	2, 767	0.30	0.35
September	44	22	31	1, 845	0. 20	0. 22
October	114	16	33	2,029	0. 22	0. 25
November	1,597	30	210	12, 496	1.38	1.54
December	820	44	190	11, 683	1.25	1.44
The year	4, 395	16	272	194, 234	1.79	23. 94

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Estimated monthly discharge of Perkiomen Creek at Frederick, Pa.—Continued.

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1887.							
January	4,098	76	523	32, 158	3.44	3.97	
February	2, 369	184	615	34, 155	4.05	4. 22	
March	1, 156	149	397	24, 411	2.61	3. 01	
April	322	98	171	10, 175	1.13	1. 26	
May	286	41	96	5,903	0.63	0.72	
June	887	36	103	6, 129	0.68	0.75	
July	1,474	29	272	16, 725	1.79	2.06	
August	1,416	54	189	11,621	1.24	1.43	
September	559	25	83	4,879	0.54	0.60	
October	136	30	58	3,566	0.38	0.44	
November	126	22	54	3, 213	0.36	0.40	
December	1, 250	40	277	17, 032	1.82	2.10	
The year	4, 098	22	236	169, 967	1.56	20.96	
1888.							
January	4, 305	99	478	29, 391	3. 14	3. 62	
February	3, 284	95	620	35, 663	4.08	4.40	
March	3, 539	152	676	41,566	4. 45	5. 13	
April	2,750	118	470	27, 967	3.09	3. 45	
May	313	75	122	7,501	0.80	0. 92	
June	147	24	53	3, 154	0.35	0.39	
July	84	13	33	2,029	0.22	0. 25	
August	3, 336	24	201	12, 359	1.32	1.52	
September	5, 305	33	500	29, 752	3. 29	3. 67	
October	833	69	165	10, 145	1.09	1.26	
November	1, 344	100	338	20, 112	2. 22	2.47	
December	4, 786	80	378	23, 242	2.49	2.87	
The year	5, 305	13	336	242, 881	2. 21	29. 95	
1889.	10						
January	1,553	159	436	26, 809	2.87	3.31	
February	1, 182	82	216	11, 996	1.42	1.48	
March	4, 235	75	395	24, 288	2.60	3.00	
April	1,894	62	284	16, 899	1.87	2.09	
May	745	60	208	12, 789	1.37	1.58	
June	2, 187	90	361	21, 481	2.38	2.66	
July	5, 567	96	640	39, 352	4. 21	4.85	
August	1,648	67	326	20, 045	2.15	2.48	

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PERKIOMEN CREEK.

Estimated monthly discharge of Perkiomen Creek at Frederick, Pa.—Continued.

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
September	3, 130	60	383	22, 790	2.52	2, 81
October	3, 356	87	311	19, 123	2.05	2, 36
November	5, 389	224	920	54, 744	6.05	6. 75
December	616	161	298	18, 323	1.96	2. 26
The year	5, 567	60	398	288, 639	2. 62	35. 63
1900.						
January	2, 342	30	299	18,385	1.97	2. 27
February	3,606	146	741	41, 153	4.87	5. 07
March	1,648	118	321	19, 737	2. 11	2.44
April	1, 212	84	178	10, 592	1.17	1.31
May	693	52	117	7, 194	0.77	0.89
June	63	23	47	2,797	0.31	0.35
July	1,505	18	127	7,809	0.84	0.97
August	198	24	54	3, 320	0.36	0.42
September	58	14	33	1,964	0. 22	0. 25
October	67	26	38	2, 337	0. 25	0. 29
November	222	20	50	2,975	0.33	0.37
December	565	36	84	5, 165	0.55	0.63
The year	3,606	14	174	123, 428	1.14	15. 26

 $\label{eq:Note:Monthly discharge for 1890 to 1898, inclusive, is given in Twentieth Annual Report, Part IV, pages 90 to 93; for 1899 in Twenty-first Annual Report, Part IV, page 78.$

Estimated monthly discharge of Wissahickon Creek near Philadelphia, Pa.

[Drainage area, 64.6 square miles.]

Month.	Dischar	ge in secon	nd-feet.	Total in acrefect.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.	no de					
July	219	9	42	2, 582	0.65	0.75
August	152	12	35	2, 152	0.54	0. 62
September	278	8	26	1,547	0.40	0.45
October	274	12	34	2,091	0.53	0.61
November	367	10	29	1,726	0.45	0.50
December	247	20	42	2,582	0.65	0.75

NOTE.—Daily discharge for 1897 to 1900, inclusive, is given in Water-Supply Paper No. 48, pages 107 to 109.

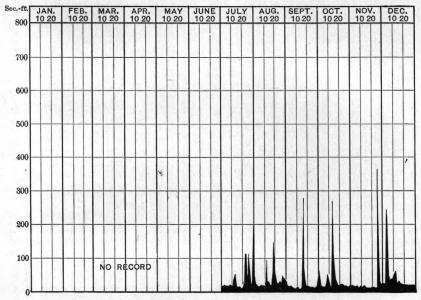


Fig. 33.—Discharge of Wissahickon Creek near Philadelphia, Pa., 1900.

SUSQUEHANNA RIVER AND TRIBUTARIES.

During 1900, as in former years, measurements have been made of Susquehanna River and a number of its tributaries, as follows, in geographic order: North Branch of Susquehanna at Wilkesbarre, Pa., and at Danville, Pa.; West Branch of Susquehanna at Allenwood, Pa.; Juniata River at Newport, Pa.; and Susquehanna River at Harrisburg, Pa. The results are given in the following tables:

Estimated monthly discharge of North Branch of Susquehanna River at Wilkesbarre, Pa.

[Drainage area, 9,810 square miles.]

A	Dischar	ge in seco	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	68, 760	5, 450	17, 251	1,060,722	1.76	2.03
February	64, 560	9,740	28, 972	1,609,023	2.95	3.07
March	73, 800	7, 180	23, 710	1, 457, 871	2.42	2.79
April	44, 120	10,800	27, 115	1, 613, 455	2.76	3.08
May	8,770	2,850	4, 884	300, 305	0.50	0.58
June	4,760	1,990	2,817	167, 623	0.29	0. 32
July	3, 300	1,500	2,060	126, 664	0.21	0. 24
August	2, 120	1,200	1,608	98, 872	0.16	0.18
September	1,990	900	1, 318	78, 426	0.13	0. 15
October	1,730	900	1,233	75, 814	0.13	0. 15
November	90,600	1,300	10, 399	618, 783	1.06	1.18
December	53, 920	8,770	28, 067	1, 725, 773	2.86	3. 30
The year	90,600	900	12, 453	8, 933, 331	1. 27	17.07

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 110; rating table in Paper No. 52, page 511.

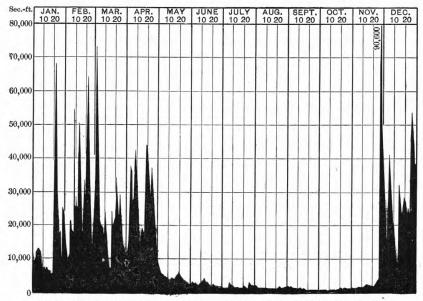


Fig. 34.—Discharge of North Branch of Susquehanna River at Wilkesbarre, Pa., 1900.

Estimated monthly discharge of North Branch of Susquehanna River at Danville, Pa.

[Drainage area, 11,070 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January 21 to 30			35, 150	697, 190	3. 18	1.18
February 9 to 28	72, 800	11,000	37, 128	2, 061, 984	3. 35	3.48
March	85, 400	11,000	28, 183	1, 732, 905	2.55	2.94
April	51, 560	16, 100	31, 459	1, 871, 940	2.84	3. 17
May	14,605	3,900	7, 787	478, 804	0.70	0.81
June	7, 200	2, 250	3, 817	227, 127	0.34	0.38
July	3,900	1,600	2, 321	142, 713	0.21	0. 24
August	2,500	1,100	1,545	94, 998	0.14	0.16
September	1,800	825	1, 182	70, 334	0.11	0. 12
October	2,000	950	1, 163	71, 510	0.11	0.13
November	95, 120	1,400	10, 169	605, 097	0.92	1.03
December	45, 080	12, 550	25, 684	1, 579, 247	2. 32	2.68

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 111; rating table in Paper No. 52, page 511.

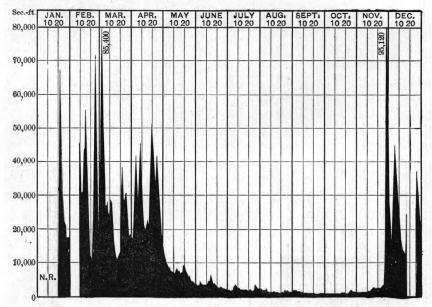


Fig. 35.—Discharge of North Branch of Susquehanna River at Danville, Pa., 1900.

Estimated monthly discharge of West Branch of Susquehanna River at Allenwood, Pa.

[Drainage area, 6,538 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maximum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	166, 750	5, 200	41, 289	2, 538, 762	6. 32	7. 29
February	117, 188	5, 200	41,635	2, 312, 290	6. 37	6. 63
March	108, 250	12,375	46, 421	2, 854, 316	7.10	8. 19
April	70, 875	23, 750	44, 171	2, 628, 357	6.76	7.54
May	22, 125	4,000	8,031	493, 807	1.23	1.42
June	18,875	1,500	6, 337	377, 078	0.97	1.08
July	3,600	1,200	1,931	118, 733	0.30	0.35
August	1,900	500	1,038	63, 824	0.16	0.18
September	1, 350	400	638	37, 964	0.10	0.11
October	2,650	300	1, 332	81, 902	0. 20	0. 23
November	208, 188	900	20, 416	1, 214, 837	3. 12	3.48
December	61, 125	4,000	19,808	1, 217, 946	3.03	, 3, 49
The year	208, 188	300	19, 421	13, 939, 816	2.97	39.99

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 112, discharge measurements page 111; rating table in Paper No. 52, page 511.

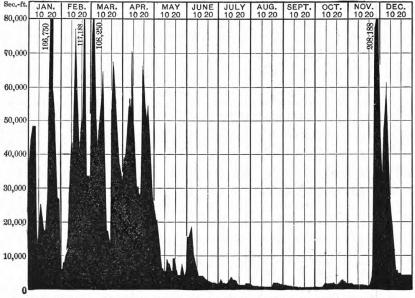


Fig. 36.—Discharge of West Branch of Susquehanna River at Allenwood, Pa., 1900.

Estimated monthly discharge of Juniata River at Newport, Pa.

[Drainage area, 3,476 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	33,000	2,040	6,779	416, 824	1.95	2. 25
February	38, 500	1,820	9,062	503, 278	2.61	2.72
March	44, 500	3,500	8,872	545, 518	2.55	2.94
April	5, 200	3, 250	4, 337	258, 069	1.25	1.39
May	3,500	1,400	2, 286	140, 561	0.66	0.76
June	2,500	1,400	1,720	102, 347	0.49	0.55
July	1,600	800	1, 113	68, 436	0.32	0.37
August	2,500	600	1,009	62,041	0.29	0. 33
September	1,600	600	727	43, 259	0.21	0. 23
October	2,500	600	1,075	66, 099	0.31	0.36
November	38,000	800	3,682	219, 094	1.06	1.18
December	15,000	1,400	3,666	225, 414	1.05	1. 21
The year	44, 500	600	3, 694	2, 650, 940	1.06	14. 29

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 113, discharge measurements, page 112; rating table in Paper No. 52, page 511.

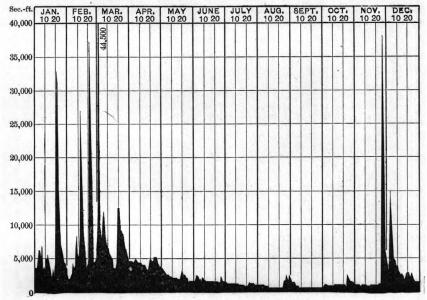


Fig. 37.—Discharge of Juniata River at Newport, Pa., 1900.

 ${\it Estimated monthly discharge of Susquehanna\ River\ at\ Harrisburg,\ Pa.}$

[Drainage area, 24,030 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.					- Q	
January	177,050	11, 125	57, 229	3, 518, 874	2.38	2.75
February	161, 835	12,700	64, 337	3, 573, 095	2.68	2.79
March	196, 740	23, 400	68, 044	4, 183, 862	2.83	3. 27
April	93, 815	35, 400	58, 380	3, 473, 852	2.43	2.71
May	35, 400	13, 100	19, 466	1, 196, 917	0.81	0.93
June	19,800	7,830	13,629	810, 982	0.57	0.64
July	10, 100	5, 475	7,550	464, 231	0.31	0.36
August	10, 100	3,035	5, 394	331, 664	0. 22	0. 25
September	7,830	2, 364	3,931	233, 911	0.16	0.18
October	8,475	2,670	4, 554	280, 015	0.19	0. 22
November	195, 845	4, 420	24,005	1, 428, 397	1.00	1.12
December	94, 710	13, 900	37, 041	2, 277, 562	1.54	1.78
The year	196, 740	2, 364	30, 297	21, 773, 362	1.26	17.00

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 114, discharge measurements, page, 113; rating table in Paper No. 52, page 511. The above figures include the flow of the Pennsylvania canal.

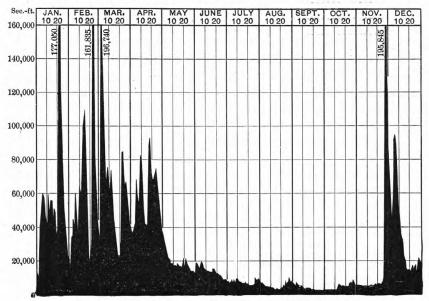


Fig. 38.—Discharge of Susquehanna River at Harrisburg, Pa., 1900.

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PATAPSCO RIVER.

This river rises in the north-central part of Maryland and empties into Chesapeake Bay about 13 miles below Baltimore. Its watershed is a hilly country, largely under cultivation. The station at Woodstock, Md., was established August 6, 1896, since which time continuous records have been kept, which have been published in former annual reports. The record for 1900 is given herewith.

Estimated monthly discharge of Patapsco River at Woodstock, Md.

[Drainage area, 251 square miles.]

	Dischar	rge in secon	nd-feet.		Run-off.	
Month.	Max- imum.	Min- imum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	1,600	235	366	22, 504	1.46	1.68
February	4, 767	122	681	37, 821	2.71	2.82
March	2,615	310	620	38, 122	2.47	2.85
April	485	235	368	21, 897	1.47	1.64
May	450	111	279	17, 155	1.11	1.28
June 1 to 15	310	100	190	11, 306	0.76	0.85
July	3, 180	50	425	26, 132	1.69	1.95
August	2, 102	50	650	39, 967	2.59	2.99
September	1,550	148	1,138	67, 716	4.53	5.05
October	218	92	140	8,608	0.56	0.65
November	252	100	139	8, 271	0.55	0.61
				9		- A

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 115 rating table in Paper No. 52, page 511.

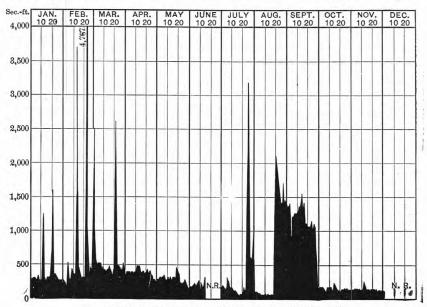


Fig. 39.—Discharge of Patapsco River at Woodstock, Md., 1900.

POTOMAC RIVER AND TRIBUTARIES.

Potomac River is formed by the junction of the North and South branches about 15 miles below Cumberland, Md. Measurements in its drainage basin have been made on the North Branch at Piedmont, W. Va., on Antietam Creek near Sharpsburg, Md., on the North Branch of Shenandoah River near Riverton, Va., on Shenandoah River at Millville, W. Va., on Potomac River at Point of Rocks, Md., and on Monocacy River near Frederick, Md. The stations on the North Branch of the Potomac and on the North Branch of the Shenandoah were established during the year 1899, and complete records are published herein. Owing to the stretching of the wire gage at the Point of Rocks station, it was found necessary to recompute the back records for Potomac River at that place. The revised figures for the years 1895, 1898, 1899, and 1900 are published herein; the records for 1896 and 1897 were found to be so uncertain that they will not be republished.

During the year 1899 a canoe survey was made of the South Branch of Shenandoah River from Port Republic, Va., to Riverton, Va., a report of which appears herein, pages 140 to 144.

Estimated monthly discharge of North Branch of Potomac River at Piedmont, W. Va.

[Drainage area, 407 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
June 27 to 30			515			
July	410	112	228	14, 019	0.56	0.65
August	352	55	132	8, 116	0.32	0.37
September	525	77	174	10, 354	0.43	0.48
October	124	77	104	6, 395	0. 26	0.30
November	845	124	287	. 17,078	0.71	0.79
December	1,880	162	419	25, 763	1.03	1.19
1900.			- COAL			Da E
January	2, 360	259	799	49, 129	1.96	2. 26
February	2, 440	352	961	53, 371	2.36	2.45
March	2, 480	705	1, 237	76, 060	3.04	3.50
April	1,560	452	808	48,079	1.99	2. 22
May	883	259	393	24, 165	0.96	1.11
June	3, 760	259	691	41, 117	1.70	1.90
July	1,240	136	321	19,737	0.79	0.91
August	336	77	154	9, 469	0.38	0.44
September	259	34	58	3, 451	0.14	0.16
October	430	77	158	9,715	0.39	0.45
November	4,080	100	483	28, 740	1.19	1.33
December	2, 360	320	648	39, 844	1.59	1.83
The year	4,080	34	558	402, 877	1. 37	18. 56

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 116, discharge measurements, page 115; rating table in Paper No. 52, page 511.

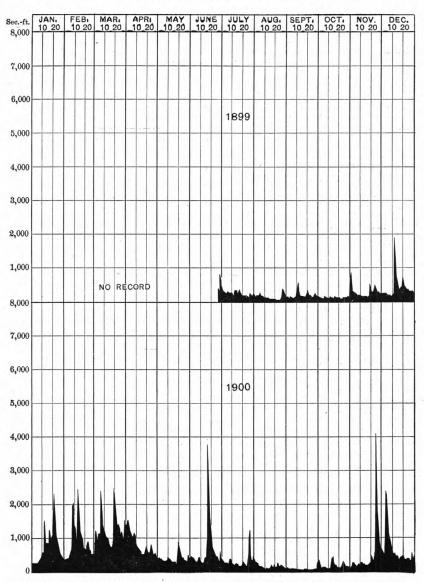


Fig. 40.—Discharge of North Branch of Potomac River at Piedmont, W. Va., 1899 and 1900.

Estimated monthly discharge of Antietam Creek near Sharpsburg, Md.

[Drainage area, 293 square miles.]

	Dischar	ge in secor	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	382	75	156	9, 592	0.53	0.61
February	1,300	75	374	20,770	1.28	1. 33
March	1,001	298	449	27,608	1.53	1.76
April	450	217	311	18,506	1.06	1.18
May	610	154	235	14, 450	0.80	0.92
June	399	123	187	11, 127	0.64	0.71
July	217	60	104	6, 395	0.35	0.40
August	217	60	103	6, 333	0.35	0.40
September	154	48	77	4, 582	0. 26	0. 29
October	233	48	87	5, 349	0.30	0.35
November	382	60	102	6,069	0.35	0.39
December	348	48	99	6, 087	0.34	0.39
The year	1, 300	48	190	136, 868	0.65	8. 73

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 118, discharge measurements, page 117; rating table in Paper No. 52, page 511.

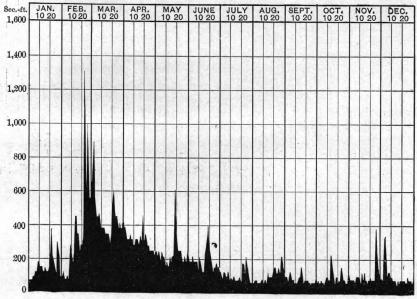


Fig. 41.—Discharge of Antietam Creek near Sharpsburg, Md., 1900.

Estimated monthly discharge of North Branch of Shenandoah River near Riverton, Va.

[Drainage area, 1, 034 square miles.]

	Dischar	ge in secon	id-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefect.	Second- feet per square mile.	Depth in inches.
1899.						
June 26 to 30			282			
July	530	140	224	13, 773	0. 22	0.25
August	380	165	218	13, 404	0. 21	0. 24
September	340	190	214	12,734	0.21	0. 23
October	215	140	182	11, 191	0.18	0. 21
November	580	165	231	13, 745	0. 22	0. 25
December	380	140	248	15, 249	0. 24	0. 28
1900.						
January	4, 140	240	732	45,009	0.71	0.82
February	3, 795	340	1,247	69, 255	1.21	1.26
March	5, 175	635	1,710	105, 144	1.65	1.90
April	1,955	480	864	51, 412	0.84	0.94
May	635	215	318	19, 553	0.31	0.36
June	2, 357	190	529	31, 478	0.51	0.57
July	1,840	140	305	18, 754	0.30	0.35
August	215	100	131	8, 055	0.13	0.15
September	340	140	157	9, 343	0.15	0.17
October	300	165	213	13, 096	0.21	0. 24
November	3, 795	140	460	27, 372	0.44	0.49
December	2,760	140	579	35, 601	0.56	064
The year	5, 175	100	604	434, 072	0.59	7.89

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 119, discharge measurements, page 118; rating table in Paper No. 52, page 511.

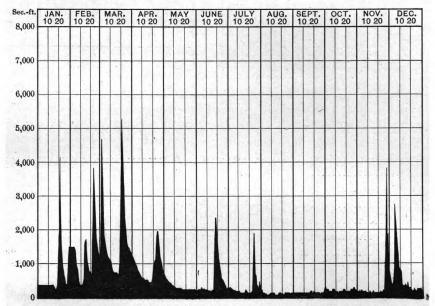


Fig. 42.—Discharge of North Branch of Shenandoah River near Riverton, Va., 1900.

Estimated monthly discharge of Shenandoah River at Millville, W. Va.

[Drainage area, 2, 995 square miles.]

	Dischar	rge in secon	nd-feet.	1	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900:						
January	13, 520	1, 250	2, 895	178, 007	0.97	1.12
February	13, 200	1,370	3, 451	192, 159	1.15	1.20
March	15, 120	2,600	5, 642	346, 913	1.88	2.17
April	4,600	1,875	2,809	167, 147	0.94	1.05
May	2,430	1, 250	1,716	105, 513	0.57	0.66
June	8,720	1,040	2, 297	136, 681	0.77	0.86
July	4, 160	740	1,391	85, 529	0.46	0.53
August	1,310	690	844	51, 895	0.28	0.32
September	1, 250	540	684	40, 701	0. 23	0. 26
October	2,780	640	922	56, 691	0.31	0.36
November	8,720	740	1, 461	86, 936	0.49	0.55
December	9,680	1,040	2, 231	137, 180	0.74	0.85
The year	15, 120	540	2, 195	1, 585, 352	0.73	9.93

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 121, discharge measurements, page 120; rating table in Paper No. 52, page 511.

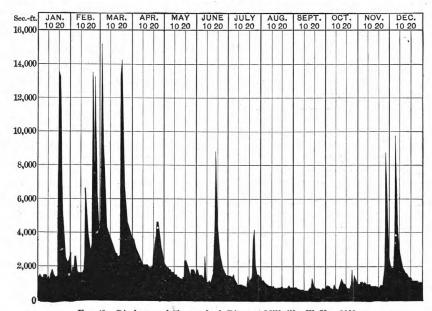


Fig. 43.—Discharge of Shenandoah River at Millville, W. Va., 1900.

Estimated monthly discharge of Potomac River at Point of Rocks, Md. [Drainage area, 9,654 square miles.]

4)	Dischar	ge in secon	d-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1895.						
February 17 to 28			7,278	173, 228	0.75	0.33
March	68, 410	11,410	24, 945	1, 533, 808	2.58	2.98
April	70,230	6,020	14, 567	866, 797	1.51	1.68
May	29, 490	7,000	12,531	770, 501	1.30	1.50
June	7,490	2, 360	3,823	227, 484	0.40	0.45
July	10, 430	2,630	4, 368	268, 578	0.45	0. 52
August	3,250	1,400	2,063	126, 849	0.21	0. 24
September	2,630	1, 200	1,640	97, 587	0.17	0. 19
October	1,400	1,000	1, 181	72, 617	0.12	0.14
November	1,620	1, 200	1,382	82, 235	0.14	0.16
December	4, 300	1, 200	2, 176	133, 797	0. 23	0. 27
1898.						
January	57, 490	11,410	23, 155	1, 423, 746	2.40	2.77
February	18,510	5, 550	8, 245	457, 904	0.85	0.88
March	67,500	4, 300	15,362	944, 572	1.59	1.83
April	53,850	8,960	16,087	957, 243	1.67	1.86

Estimated monthly discharge of Potomac River at Point of Rocks, Md.—Continued.

		er ipe legger	APR.			
	Dischar	ge in secor	nd-feet.	99 OT 1 (8)	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefect.	Second- feet per square mile.	Depth in inches.
1898.				4 4		
May	72, 505	6,020	18, 290	1, 124, 608	1.89	2.18
June	7,980	2,630	4,074	242, 420	0.42	0.47
July	5, 550	1,620	2, 463	151, 444	0.26	0.30
August	118,005	3,600	22, 575	1, 388, 082	2.34	2.70
September	3,600	2, 110	2, 541	151, 200	0.26	0. 29
October	91, 160	2, 110	13, 980-	859, 597	1.45	1.67
November	15, 460	5, 100	8, 446	502, 572	0.87	0.97
December	55,670	6,020	15, 403	947, 093	1.60	1.84
The year	118, 005.	1,620	12, 553	9, 150, 481	1.30	17. 76
1899.						
January	45, 750	8, 470	18, 863	1, 159, 841	1.95	2. 25
February	106, 630	7,000	28, 932	1,606,635	3.00	3. 12
March	122, 555	14, 240	35, 942	2, 209, 987	3.72	4. 29
April	25, 830	5,550	11,772	700, 482	1.22	1.36
May	49, 755	5, 100	11,569	711, 350	1.20	1.38
June	16,680	2,900	5, 200	309, 422	0.54	0.60
July	7,000	1,620	2, 562	157, 531	0.27	0. 3
August	3,600	1,620	2,375	146, 033	0.25	0. 29
September	3,600	1,860	2, 405	143, 107	0.25	0. 28
October	2, 110	1,620	1,761	108, 280	0.18	0. 2
November	9, 450	2, 110	3, 187	189, 640	0.33	0.33
December	11,900	2, 110	4,017	246, 996	0. 42	0.48
The year	122,555	1,620	10, 715	7, 689, 304	1.11	14. 94
1900.						
January	35, 150	3,600	8,056	495, 344	0.83	0.96
February	37, 700	2,900	13, 339	740, 810	1.38	1.48
March	51, 120	8, 470	18,657	1, 147, 174	1.93	2. 23
April	22, 780	5, 100	9, 223	548, 807	0.96	1.07
May	7,000	2,900	4, 346	267, 225	0.45	0. 52
June	49,300	2,630	8, 328	495, 550	0.86	0.96
July	7,000	1,400	2,988	183, 725	0.31	0.36
August	3,600	1,400	1,970	121, 130	0.20	0. 28
September	2, 110	1,000	1, 388	82, 592	0.14	0.16
October	2,630	1, 200	1,380	84, 853	0.14	0.16
November	46,600	1,000	4,637	275, 921	0.48	0.54
December	29, 490	2, 360	6, 188	380, 485	0.64	0.74
The year	51, 120	1,000	6, 708	4, 823, 616	0.69	9. 36
		A contract of the contract of				

Note.—Gage heights for 1895, 1898, 1899, and 1900 are given in Water-Supply Paper No. 48, pages 123 and 124; discharge measurements for 1900 are given in Paper No. 48, page 122; rating table in Paper No. 52, page 511.

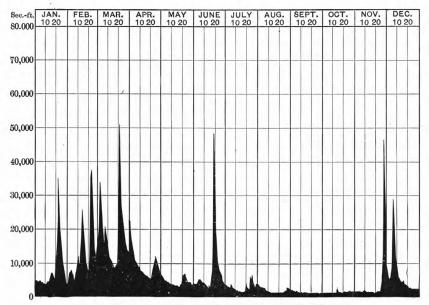
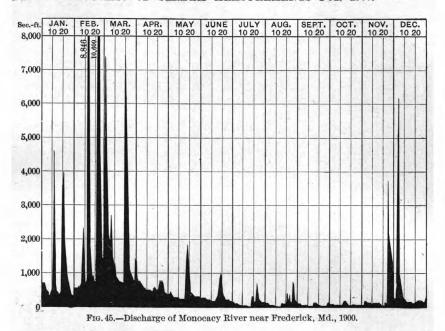


Fig. 44.—Discharge of Potomac River at Point of Rocks, Md., 1900.
Estimated monthly discharge of Monocacy River near Frederick, Md.

[Drainage area, 665 square miles.]

	Dischar	ge in secon	d-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	4,632	305	1,044	64, 193	1.57	1.81
February	10,609	550	2, 394	132, 956	3.60	3. 75
March	7,470	700	2, 158	132, 690	3. 25	3. 75
April	1,364	380	599	35, 643	0.90	1.00
May	1,880	240	462	28, 407	0.69	0.80
June	1,020	150	305	18, 149	0.46	0.51
July	750	45	154	9, 469	0.23	0. 27
August	750	27	- 159	7,776	0. 24	0.28
September	150	27	70	4, 165	0.11	0.12
October	180	65	88	5, 411	0.13	0.15
November	3,772	65	461	27, 431	0.69	0.77
December	6,266	120	518	31, 851	0.78	0.90
The year	10, 609	27	701	500, 141	1.05	14. 11

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 125; rating table in Paper No. 52, page 512. For hydrograph see page 140.



CANOE SURVEY OF SOUTH BRANCH OF SHENANDOAH RIVER FROM PORT REPUBLIC, VA., TO RIVERTON, VA.

In August, 1899, a canoe survey or reconnaissance of the South Branch of Shenandoah River was made by Mr. F. H. Anschutz, under the direction of D. C. Humphreys, resident hydrographer, for the purpose of obtaining an accurate profile of the river and a map showing the location of the mills, the unused falls, and the localities where water power might possibly be developed. Acknowledgment is due to the Norfolk and Western Railway, which furnished transportation to both men and boats in going to and returning from the river. The following facts are taken from Mr. Humphreys's report:

The reconnaissance was so complete that it may properly be called a preliminary survey. It consisted of a stadia line down the river, with a few side shots, and a level line run simultaneously, the elevation being ascertained at every change of slope of the stream.

The field party consisted of F. H. Anschutz, instrument man, Ewing D. Sloan, rodman, and William Allan, forager and general utility man, all students of Washington and Lee University. Before entering the university Mr. Anschutz and had about twelve years' experience in engineering work. The party reached the starting point, Port Republic, on July 29. Here an additional boat was procured, the outfit was completed, and the start down the river was made on August 2. Mr. Humphreys accompanied the party until August 3, when Mr. Anschutz was placed in charge.

Each man had a canoe, which he traveled in during the day and slept in at night. The canoes were of canvas, 16 feet long and 32 inches beam, and weighed about 80 pounds each. They were decked over, and in the center there was a cockpit 8 feet long and 22 inches wide, the distance from the top of the cockpit to the bottom of the boat being about 14 inches. The hatches that covered the cockpit could easily be removed for loading and unloading and to make room for a bed. At night each canoe was lifted out on the bank, a tent was erected over the cockpit, the boat was wiped out with a sponge, the large oiled canvas bag in which the bed and bedding were carried was spread in the bottom, and on top of this the mattress was laid, making a comfortable and dry bed. The construction of the canoes was as follows: First, a framework was built, over it the heaviest duck canvas was stretched, and on the outside strips were placed to protect the canvas from rocks. The canvas was very tough and hard to snag, and when a hole was made in it it was an easy matter to patch it with a piece of canvas, melted rosin and lard being used as a cement. canoes were constructed from designs by Prof. S. R. Webb, of Staunton, Va., commodore of the Shenandoah Canoe Club. When under way down the river the hatches were kept down, only a small hole being left, in which the single occupant sat. In running rapids the canoeman pulled the oiled apron up around him, thus preventing the water from entering the boat. A rubber coat, the skirts of which were spread out on the deck, afforded complete protection from rain. All equipments were carried in oiled canvas bags. The large bag containing the mattress was folded and used as a seat. An illustration of the canoes and the camp equipment, which was the same as that used in a similar reconnaissance of James River in 1897, will be found in the Nineteenth Annual Report, Part IV, Pl. XXII.

The instruments carried were a large Haskell meter attached to a light wooden rod, which was graduated for the purpose of making soundings, a tight folding rod, a complete engineer's transit, and steel tapes. The rod used was 12 feet long, hinged in the middle, graduated on one side as a self-reading level rod and on the other side as a stadia board. The wire interval of the instrument was such that 1 foot corresponded to 100 feet. The two sides could therefore be used interchangeably, and the coarser graduation of the stadia board was used in taking long sights.

It was thought that time might be saved by having the instrument man and the rodman advance simultaneously, the rodman so marking the place where he held his rod that the instrument man could find it, the elevation of the instrument being determined by direct measurement. This method was found, however, to be unsatisfactory, and the following order of operations was adopted and used for the entire survey: With instrument at station A, a backsight was taken on 1, the



Fig. 46.—Map of South Branch of Shenandoah River.

level being read from the middle wire in the instrument, the stadia distance from the top and the bottom wires on a scale on the other side of the rod; the magnetic bearing was read; the rodman then advanced, holding the rod at one or more points, 2, 3, etc., until a suitable place for a turning point was found, at, say, 4; this point was held by the rodman while the instrument man advanced. passed the rodman, and proceeded to station B. During the time thus occupied in moving the instrument the rodman made a sketch of the river. The instrument was frequently set up on the river, owing to dense brush and trees on the bank, and the rod was sometimes held on a solid snag projecting out of the water. The third man of the party went ahead in the afternoon, picked out a camping place, and prepared supper. In the morning, after cleaning up, he foraged for supplies.

The discharge of all tributary streams was measured, as was that of the main stream occasionally. The instrument used was an English meter belonging to the Washington and Lee University. The wheel that counted the revolutions was thrown in gear by pulling a string.a The measurements were usually made by wading, but where the water was too deep the meter was run from a boat; and the distances from the initial point were determined by reading the stadia board, held in the canoe, with the transit located on shore. For small creeks surface floats were used, being run over a short base line and timed with a stop watch.

Although the meter worked well there was reason to believe that the friction in the gearing varied somewhat, and that for this work a small acoustic meter would have been better.

a Rating table for this meter is given in Bull. U. S. Geol. Survey No. 140, p. 340, No. 77 of the list.

The program of operations and the outfit were entirely satisfactory. The only thing lacking to make the latter complete was a camera, which was not taken for the reason that no suitable instrument was available and not one of the party was an expert amateur photog-

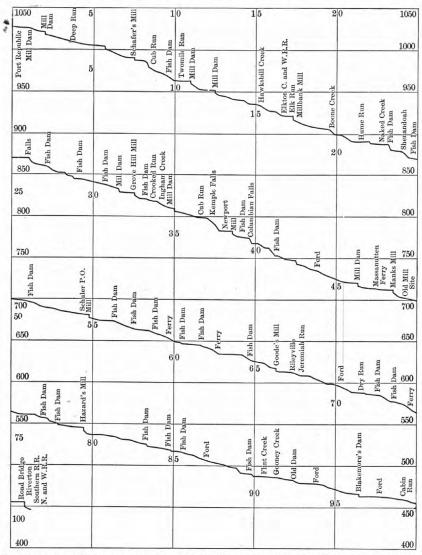


Fig. 47.—Profile of South Branch of Shenandoah River. Vertical distance in feet; horizontal in miles.

rapher. The third or general utility man could have used the camera, had he been able, without delaying the progress of the survey.

In the first 10 miles, from Port Republic to Island Ford, there was an error of -4.3 feet, which could not be located and was distributed. In the remaining 91 miles the error was only 0.89 foot.

The results of the work are shown by the map (fig. 46) and the profile (fig. 47). The distances along the profile and map are measured along the center line of the stream, the initial point being the forks of the river at Port Republic.

The developed and undeveloped power of the river is, briefly stated, as follows:

At Port Republic a combined sawmill and gristmill utilizes a fall of 10 feet in South River, which is obtained by a dam about a quarter of a mile above the mouth.

On North River, in the first 1,500 feet above the forks, there is a fall of 6 feet which was once used for power and which could easily be developed again.

At Shendun, 4 miles above Port Republic, on South River, an excellent power was partially developed during what is known as "boom times," in 1890. The fall is said to be about 20 feet.

Two miles downstream from the forks there is a gristmill utilizing about 6 feet fall, obtained by a brush dam and a long race.

At 6 miles there is a fall of 4.5 feet, but the banks are low.

At $7\frac{1}{2}$ miles there is a small gristmill with a 3-foot timber dam.

Between the $7\frac{1}{2}$ -mile point and the next mill, at 11 miles, there is a total fall of 25 feet, but the river banks are much broken and generally are low.

At 11 miles there is a small gristmill using about 6 feet fall.

At $12\frac{1}{2}$ miles there is a gristmill using $5\frac{1}{2}$ feet fall.

At 17 miles, opposite Elkton, there is a combined gristmill and sawmill, with a 4-foot dam, using 6 feet fall.

In the neighborhood of Shenandoah the fall is rapid but the banks are low.

At 31½ miles there is an old mill and a timber dam 4 feet high, the first course of timbers of which is missing.

At $32\frac{1}{2}$ miles, Grove Hill, there is a gristmill and a good dam of timber and loose rocks, 4 feet high.

At $37\frac{1}{2}$ miles, Kemple Falls, there is a fall of 15 feet in three-fourths of a mile. The bank on the left side is fairly good, but on the right side of the main group of channels the river spreads out over and runs through a large area of bowlders, and the bank for a considerable distance back is but little above the surface of the stream.

At 38 miles, Newport, there is a combined sawmill and gristmill that uses about 6 feet fall. The dam is about 4 feet high, loosely made of timber and stonework.

At 41 miles is Mank's mill, a gristmill with a dam 3½ feet high, rudely constructed of brush and loose stone. The fall below the mill is good and about 7 feet are utilized.

At 50 miles there is an old mill site, nothing being left except the foundation of the dam.

At 55 miles, Schuler, there is a gristmill, with a dam $3\frac{1}{2}$ feet high.

At 66½ miles is Goode's mill, the dam for which is 3 feet high, of timber and planking backed by loose rock. The mill uses a fall of about 6 feet.

At $79\frac{1}{2}$ miles is Hazard's mill, on the left bank of the stream, at a point where the river splits and runs around a large island. The dam is in the left branch and is substantially constructed of timber; it is $4\frac{1}{2}$ feet high.

At $97\frac{1}{2}$ miles is Blackmore's dam. It was a stoutly built dam of timber and dry masonry, but it is broken at each end and part of the upper course is missing at the middle. The mill is no longer standing.

At 101 miles, Riverton, are the Riverton mills. The dam is 6 feet high, of timber, and is well constructed.

The work ended at Riverton and the party returned to Lexington, Va. The distance run was 101.2 miles.

JAMES RIVER AND TRIBUTARIES.

James River rises in the Allegheny Mountains, on the western border of Virginia, and flows in an easterly direction across the State, emptying into Chesapeake Bay. Records of measurements are kept on North (of James) River at Glasgow, Va., and on James River at Buchanan, Va., and at Cartersville, Va. Records of gage heights are also kept on the main river at Holcomb Rock, Va., but no discharge measurements are made there.

 $Estimated\ monthly\ discharge\ of\ North\ (of\ James)\ River\ at\ Glasgow,\ Va.$

[Drainage area, 831 squ	are miles.]
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	Dischar	ge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6,910	310	1,010	62, 102	1. 22	1.41
February	7,670	375	1,854	102, 966	2. 23	2. 32
March	7,570	760	2,093	128, 694	2. 52	2.91
April	2, 240	480	960	57, 124	1.16	1. 29
May	1,630	330	594	36, 524	0.71	0.82
June	4, 190	330	1,011	60, 159	1. 22	1.36
July	650	250	350	21, 521	0.42	0.48
August	280	215	226	13, 896	0. 27	0.31
September	1,520	200	275	16, 364	0.33	0.37
October	3,020	210	405	24, 902	0.49	0.56
November	7,570	250	762	45, 342	0.92	1.03
December	4, 040	310	882	54, 232	1.06	1. 22
The year	7,570	210	869	623, 826	1.05	26. 63

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 127; rating table in Paper No. 52, page 512. For hydrograph see page 146.

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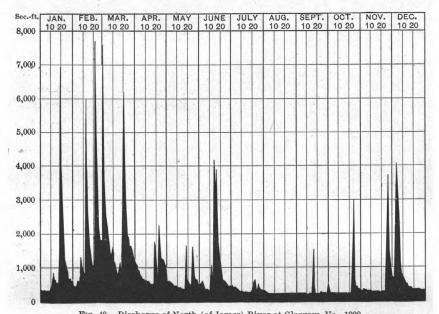


Fig. 48.—Discharge of North (of James) River at Glasgow, Va., 1900.

Estimated monthly discharge of James River at Buchanan, Va.

[Drainage area, 2,058 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum,	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	15,570	430	2, 273	139, 761	1.10	1. 27
February	15, 310	600	4, 156	230, 813	2.02	2. 10
March	18, 230	1,980	5, 717	351, 525	2.78	3. 21
April	5, 995	1,050	2,667	158, 698	1. 29	1.44
May	4,040	570	1,174	72, 186	0.57	0.66
June	9, 410	750	2, 166	128, 886	1.05	1.17
July	1,810	430	741	45, 562	0.36	0.42
August	670	330	415	25, 517	0.20	0. 23
September	1,895	330	598	35, 583	0.29	0.32
October	18, 635	480	1,501	92, 293	0.73	0.84
November	41, 410	600	3,700	220, 165	1.80	2.01
December	15, 570	1,050	2,942	180, 876	1.43	1.65
The year	41, 410	330	2, 337	1, 681, 865	1.13	15. 32
						1

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 128; rating table in Paper No. 52, page 512. For hydrograph see page 147.

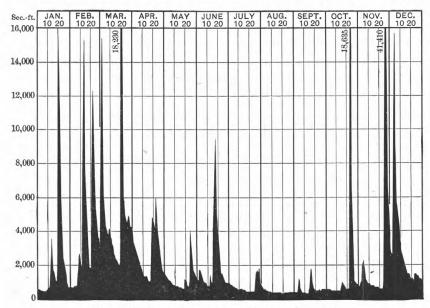


Fig. 49.—Discharge of James River at Buchanan, Va., 1900.

Estimated monthly discharge of James River at Cartersville, Va.

[Drainage area, 6,232 square miles.]

	Discha	rge in seco	nd-feet.		Run-off	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
January	49, 130	6, 140	24, 636	1, 514, 808	3. 95	4.55
February	40, 490	5,700	20,054	1, 113, 743	3. 22	3, 35
March	63, 170	10, 730	24,611	1, 513, 271	3. 95	4.55
April	22,265	5, 370	9,346	556, 126	1.50	1.67
May	16, 190	3, 300	7,007	430, 844	1.12	1. 29
June	6, 250	2,060	3,510	208, 860	0.56	0.62
July	3,800	1,030	1,771	108,895	0. 28	0.32
August	15, 380	970	2,958	181, 880	0.47	0.54
September	11, 120	1, 215	2,909	173, 098	0.47	0.52
October	3, 300	1,350	1,705	104, 836	0. 27	0.31
November	10,860	1,730	3, 286	195, 531	0.53	0.59
December	5, 590	1,420	2, 741	168, 537	0.44	0.51
The year	63, 170	970	8, 711	6, 270, 429	1.40	18. 82
		1				

148 PROGRESS OF STREAM MEASUREMENTS FOR 1900.

Estimated monthly discharge of James River at Cartersville, Va.—Continued.

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	31, 850	2, 420	8, 278	508, 994	1.33	1.53
February	29, 420	2, 240	11,764	653, 339	1.89	1.96
March	38, 735	6, 140	13,800	848, 529	2.21	2.55
April	26, 585	4, 200	10,088	600, 277	1.62	1.81
May	8,520	3, 100	4,812	295, 878	0.77	0.89
June	25, 100	2,515	7,688	457, 468	1.23	1. 37
July	4,830	1,495	2, 545	156, 486	0.41	0.47
August	2,705	970	1, 393	85, 652	0.22	0. 25
September	5, 810	585	1,684	100, 205	0.27	0.30
October	25, 910	1, 280	3, 615	222, 278	0.58	0.67
November	45, 350	1,890	6, 317	375, 888	1.01	1.13
December	26, 990	3, 200	7,949	488, 765	1.28	1.48
The year	45, 350	585	6, 661	4, 793, 759	1.07	14. 41

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 129; rating table in Paper No. 52, page 512.

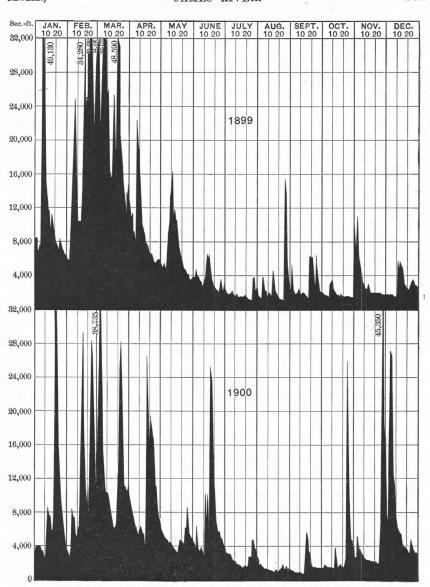


Fig. 50.—Discharge of James River at Cartersville, Va., 1899 and 1900.

SOUTHERN ATLANTIC COAST DRAINAGE.

Systematic measurements of discharge of many of the larger rivers of the Southern Atlantic States have been made during the year. The drainage areas of the rivers in that region are in general quite similar. Most of the streams rise in the southern Appalachian Mountains or their foothills. In the upper part of their courses they are rapid, with considerable fall. Across the Piedmont Plain their valleys are wide and their flow in general is sluggish, with occasional falls over rocky beds. Many of them have falls that could be utilized for water power, and it is largely to that end that data of the flow are being collected. In the study of water power it is important to know the flow and the The fall can readily be determined by an engineer, but the variations in flow often require long and careful study. Gaging stations, to determine the latter, have been established on nearly all of the larger streams in the region, and it is hoped that in the near future our information of their fall will be extended. A profile of Ocmulgee River (see figs. 67 and 68, pages 168 and 169) was run during the year 1900, also one of the South Branch of Shenandoah River (see fig. 47, page 143), and the work will be extended as rapidly as time and appropriations will permit.

Stations have been maintained by the Survey on the following rivers in this basin: Roanoke River, at Roanoke, Va., and at Neal, N. C.; Tar River, at Tarboro, N. C.; Neuse River, at Selma, N. C.; Cape Fear River, at Fayetteville, N. C.; Yadkin River, at Salisbury, N. C.; Catawba River, at Rockhill, S. C.; Broad River (of the Carolinas), near Alston, S. C.; Saluda River, at Waterloo, S. C.; Tallulah River, at Tallulah Falls, Ga.; Tugaloo River, near Madison, S. C.; Savannah River, near Calhoun Falls, S. C., and at Augusta, Ga.; Broad River (of Georgia), near Carlton, Ga.; Oconee River, near Dublin, Ga.; Yellow River, at Almon, Ga.; Towaliga River, near Juliette, Ga.; and Ocmulgee River, at Macon, Ga. The results for the year 1900 are given on the following pages. In addition to these so-called permanent stations, many temporary stations are being maintained on streams in the Southern Appalachian region, the results for which will be found in the Water-Supply Papers.

Estimated monthly discharge of Roanoke River at Roanoke, Va. [Drainage area, 388 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	4, 170	110	436	26, 809	1.12	1. 29
February	5, 195	187	763	42, 375	1.97	2.05
March	4, 887	480	1,044	64, 193	2.69	3. 11
April	3,452	260	667	39, 689	1.72	1.92
May	1,010	187	313	19, 246	0.81	0.93
June	1,240	187	411	24, 456	1.06	1.18
July	570	130	220	13, 527	0.57	0.66
August	140	85	100	6, 149	0.26	0.30
September	670	85	134	7, 974	0.35	0.39
October	5, 502	120	435	26, 747	1.12	1. 29
November	12,575	155	733	43, 617	1.89	2. 11
December	4,887	240	630	38, 737	1.62	1.87
The year	12, 575	85	491	353, 519	1. 26	17. 10

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 131, discharge measurements, page 130; rating table in Paper No. 52, page 512.

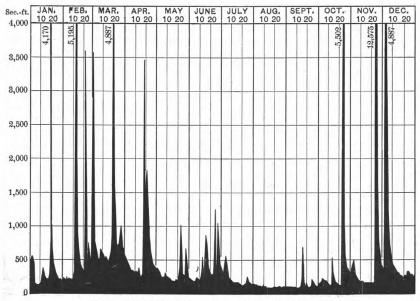


Fig. 51.—Discharge of Roanoke River at Roanoke, Va., 1900.

Estimated monthly discharge of Roanoke River at Neal, N. C. [Drainage area, 8,717 square miles.]

	Discha	rge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	31, 750	2,580	11, 940	734, 162	1.37	1.58
February	33, 550	4, 190	16, 449	913, 531	1.89	1.97
March	37, 747	11,645	17,575	1,080,644	2.02	2. 33
April	49, 140	6, 150	16, 222	965, 276	1.86	2.08
May	14,643	4, 470	7, 166	440, 620	0.82	0.95
June	17,930	3,980	7, 561	449, 911	0.87	0.97
July	13, 370	2, 180	5, 124	315, 063	0.59	0.68
August	6,610	1,560	2, 311	142, 098	0.27	0.31
September	11,990	1,380	2, 766	164, 588	0.32	0.36
October	15, 480	2,050	3, 693	227, 074	0.42	0.48
November	11,070	2,720	4, 362	259, 557	0.50	0.56
December	23,500	3,770	7, 119	437, 730	0.82	0.95
The year	49, 140	1,380	8, 524	6, 130, 254	0.98	13, 22

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 132; rating table in Paper No. 52, page 512.

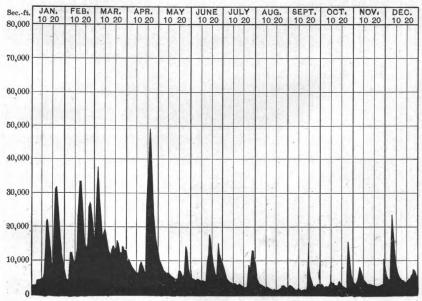


Fig. 52.—Discharge of Roanoke River at Neal, N. C., 1900.

Estimated monthly discharge of Tar River at Tarboro, N. C. [Drainage area, 2,290 square miles.]

	Dischar	ge in secon	nd-feet.		Ru	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6, 405	1, 120	2,864	176, 101	1.25	1.44
February	12,970	1,520	5,952	330, 557	2.60	2.70
March	9,640	2,865	5, 445	334, 800	2.38	2.75
April	10,540	1,995	4,802	285, 739	2.10	2. 34
May	2,805	920	1,664	102, 315	0.73	0.84
June	3, 805	550	1,376	81,878	0.60	0. 67
July	1,995	230	552	33, 941	0. 24	0. 28
August	840	230	384	23, 611	0.17	0. 20
September	550	134	233	13, 864	0.10	0.11
October	620	87	210	12, 912	0.09	0.10
November	2, 325	87	659	39, 213	0.29	0.32
December	2,045	410	880	54, 109	0.38	0.44
The year	12, 970	87	2,085	1, 489, 040	0.91	12, 19

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 135, discharge measurements, page 134; rating table in Paper No. 52, page 512.

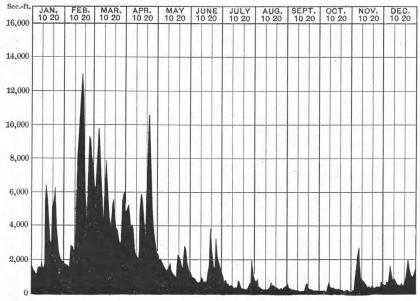


Fig. 53.—Discharge of Tar River at Tarboro, N. C., 1900.

Estimated monthly discharge of Neuse River at Selma, N. C. [Drainage area, 1,175 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	4, 435	290	2,002	123, 098	1.70	1.96
February	9, 544	390	3,061	169, 999	2.61	2. 72
March	5, 775	770	2, 314	142, 282	1.97	2. 27
April	9,876	770	2,906	172, 919	2.47	2. 75
May	2,645	436	906	55, 708	0.77	0.89
June	1,820	330	630	37, 488	0.54	0.60
July	4, 965	218	787	48, 391	0.67	0.77
August	1,075	184	325	19, 983	0.28	0.32
September	1,590	184	328	19, 517	0.28	0. 31
October	252	135	196	12,052	0.17	0. 20
November	1,780	135	479	28, 502	0.41	0.46
December	2,235	271	646	39, 721	0.55	0.63
The year	9,876	135	1, 215	869, 660	1.03	13. 88

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 136, discharge measurements, page 135; rating table in Paper No. 52, page 512.

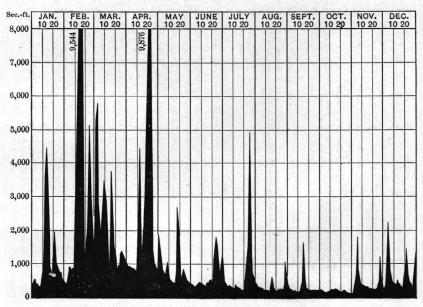


Fig. 54.—Discharge of Neuse River at Selma, N. C., 1900.

Estimated monthly discharge of Cape Fear River at Fayetteville, N. C. [Drainage area, 4,493 square miles.]

	Dischar	ge in seco	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	13, 336	1,620	4,001	246, 012	0.89	1.03
February	35,600	1,890	10,058	558, 593	2. 24	2. 33
March	31,060	3, 280	8, 649	531, 806	1.92	2, 21
April	52, 400	2,524	11,848	705, 004	2.64	2. 94
May	9,781	1,467	2, 969	182, 557	0.66	0.76
June	9, 409	984	2,688	159, 947	0.60	0.67
July	6, 133	459	1,472	90, 510	0.33	0.38
August	1,940	350	736	45,255	0.16	0.18
September	5, 187	310	1,010	60, 099	0. 22	0. 25
October	1, 145	375	526	32,342	0.12	0.14
November	6, 433	350	1, 258	74, 856	0, 28	0. 31
December	8, 541	843	2,816	173, 149	0.63	0.73
The year	52, 400	310	4,003	2, 860, 130	0.89	11.93

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 138, discharge measurements, page 137; rating table in Paper No. 52, page 512.

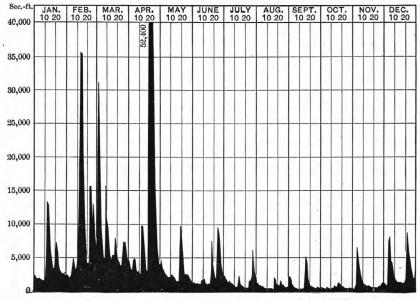


Fig. 55.—Discharge of Cape Fear River at Fayetteville, N. C., 1900.

Estimated monthly discharge of Yadkin River at Salisbury, N. C. [Drainage area, 3,399 square miles.]

	Dischar	ge in secon	id-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.		1			* 1764	
January	15, 250	1,430	4, 257	261, 753	1. 25	1.44
February	37,800	1, 430	7,029	390, 371	2.07	2. 15
March	40,500	4,080	9, 182	564, 579	2.70	3. 12
April	48, 298	2, 250	8,679	516, 436	2.55	2.84
May	8, 450	2,500	3, 331	204, 815	0.98	1.13
June	24,060	3,000	6, 190	368, 331	1.82	2.03
July	5,945	2,060	3, 332	204, 877	0.98	1.13
August	5, 112	1,870	2, 415	148, 493	0.71	0. 82
September	12,570	1,625	2,769	164, 767	0.81	0.90
October	22, 830	2,060	3, 750	230, 578	1.10	1. 27
November	29, 435	2,625	4, 417	262, 830	1.30	1.45
December	21, 915	3, 125	5, 138	315, 923	1.51	1.74
The year	48, 298	1, 430	5, 041	3, 633, 753	1.48	20. 02

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 140; rating table in Paper No. 52, page 512.

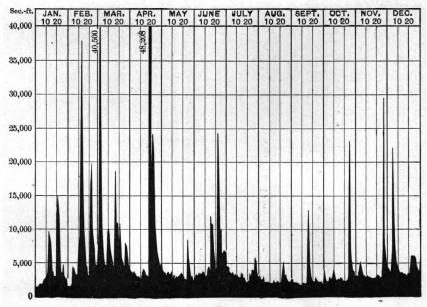


Fig. 56.—Discharge of Yadkin River at Salisbury, N. C., 1900.

Estimated monthly discharge of Catawba River at Rockhill, S. C. [Drainage area, 2,987 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.					-	
January	13, 262	2,030	3, 979	244, 659	1.33	1.53
February	46, 854	2, 390	8, 707	483, 562	2. 91	3.03
March	45,086	3,090	10, 425	641,008	3.49	4. 02
April 1 to 19			5, 734	216, 091	1.92	1.36
May 12 to 31			4, 278	263, 044	1.43	1.65
June	22, 323	2,830	7,617	453, 243	2.55	2.84
July	5, 750	2, 200	3, 291	202, 356	1.10	1. 27
August	3,090	1,750	2, 169	133, 367	0.73	0.84
September	6,632	1,460	2,037	121, 210	0.68	0.76
October	42, 434	1,505	4, 220	259, 478	1.41	1.63
November	19, 450	1,880	3, 317	197, 375	1.11	1. 24
December	11,052	2,030	4, 379	269, 254	1.47	1.69

Note —Gage heights for 1900 are given in Water-Supply Paper No. 48, page 145, discharge measurements, page 144; rating table in Paper No. 52, page 512.

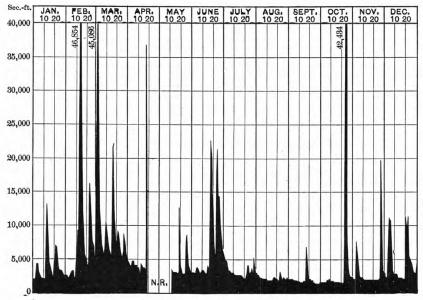


Fig. 57.—Discharge of Catawba River at Rockhill, S. C., 1900.

Estimated monthly discharge of Broad River (of the Carolinas) near Alston, S. C. [Drainage area, 4,609 square miles.]

* 1908	Dischar	rge in seco	nd-feet.		Rui	n-off.
Month, 9	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January 8 to 31			4, 886	300, 428	1.06	1. 22
February	73, 045	2,500	16, 210	900, 258	3. 52	3.66
March	47, 170	6, 410	16, 884	1, 038, 157	3.66	4. 22
April	88, 570	4,770	18,666	1, 110, 704	4.05	4. 52
May	13, 120	3, 735	5, 877	361, 363	1.28	1.48
June	46, 270	3,850	12,602	749, 871	2.73	3.04
July	9, 380	3, 160	5, 448	334, 984	1.18	1.36
August	5, 460	1,940	3, 148	193, 563	0.68	0.78
September	11, 400	1,535	3, 021	179, 762	0.66	0.74
October	21, 310	1,870	4, 231	260, 154	0.92	1.06
November	28, 945	2,500	5, 817	346, 136	1. 26	1.41
December	24, 790	3, 275	7, 823	481, 018	1.70	1,96

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 147, discharge measurements, page 146; rating table in Paper No. 52, page 512.

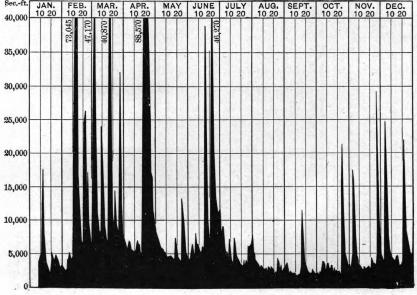


Fig. 58.-Discharge of Broad River (of the Carolinas) near Alston, S. C., 1900.

Estimated monthly discharge of Saluda River at Waterloo, S. C. [Drainage area, 1,056 square miles.]

	Dischar	rge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	5, 140	510	1,445	88,850	1.37	1.58
February	15, 100	817	3,487	193, 658	3.30	3, 43
March	7,060	2,020	3,647	224,245	3.45	3.98
April	11,900	1,077	3, 382	201, 243	3. 20	3. 57
May	4,300	1,110	1,848	113, 629	1.75	2.02
June	6,940	980	3, 371	200, 588	3, 19	3. 56
July	3,420	980	1,692	104, 037	1.60	1.84
August	1,622	480	1,023	62, 902	0.97	1.12
September	4,500	405	1, 161	69, 084	1.10	1.23
October	4, 140	415	1,343	82, 578	1.27	1.46
November	5,660	530	1,828	108, 774	1.73	1.93
December	3, 820	980	1,762	108, 341	1.67	1.93
The year	15, 100	405	2, 166	1, 557, 929	2.05	27.65

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 148, discharge measurements, page 147; rating table in Paper No. 52, page 513.

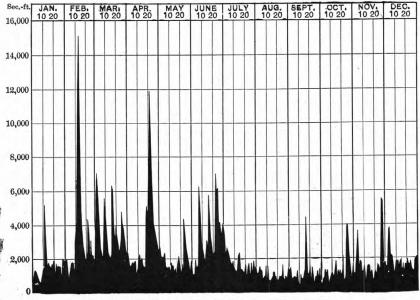


Fig. 59.—Discharge of Saluda River at Waterloo, S. C., 1900.

Estimated monthly discharge of Tugaloo River near Madison, S. C. [Drainage area, 598 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	4, 380	705	1, 223	75, 199	2.06	2.38
February	14,820	845	2,508	139, 287	4. 23	4. 40
March	6, 380	1,745	2,505	154, 026	4. 22	4.86
April	9,580	1, 475	2,751	163, 696	4.64	5. 17
May	2, 300	1, 135	1,562	96, 044	2, 63	3.04
June	9, 260	1, 135	2, 931	174, 407	4.94	5. 51
July	3, 340	1, 325	1,884	115, 843	3.18	3.66
August	1,525	880	1,095	67, 329	1.85	2. 13
September	5, 340	775	1, 305	77, 653	2.20	2.45
October	4,780	775	1, 290	79, 319	2.18	2. 52
November	6, 380	880	1, 322	78, 664	2. 23	2.49
December	3, 340	1,000	1, 491	91,678	2, 51	2.90
The year	14, 820	705	1,822	1, 313, 145	3.07	41.51

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 149; rating table in Paper No. 52, page 513.

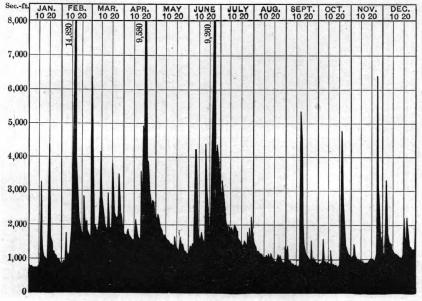


Fig. 60.-Discharge of Tugaloo River near Madison, S. C., 1900.

Estimated monthly discharge of Savannah River near Cathoun Falls, S. C. [Drainage area, 2,712 square miles.]

	Dischar	ge in seco	nd-feet.	4	Rur	ı-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	8, 250	3,500	3, 961	243,552	1.46	1.68
February	75, 240	2,910	13, 362	803, 179	4.93	5.14
March	19, 125	5,205	9, 485	583, 210	3.50	4.04
April	36,090	5,205	10,048	597, 897	3.70	4. 13
May	12, 165	3,150	5, 235	321, 888	1.93	2. 23
June	46, 095	2,910	11, 427	679, 953	4. 21	4. 69
July	6,510	1,760	3,019	185, 631	1.11	1. 28
August	4,770	1,660	2,700	166, 017	1.00	1.15
September	20, 865	1,760	4, 230	251, 702	1.56	1.74
October	12,600	1,760	3, 819	234, 821	1.41	1.63
November	9,555	2,690	4, 531	269, 613	1.67	1.86
December	7, 815	3,150	5, 659	347, 958	2.09	2.41
The year	75, 240	1,660	6, 456	4, 685, 421	2.38	31.98

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 150; rating table in Paper No. 52, page 513.

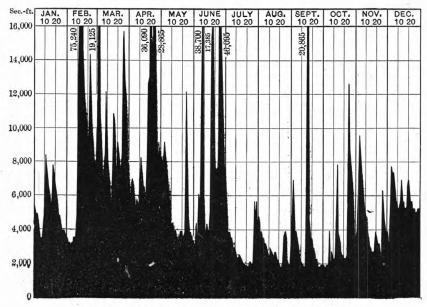


Fig. 61.—Discharge of Savannah River near Calhoun Falls, S. C., 1900.

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Estimated monthly discharge of Savannah River at Augusta, Ga.

[Drainage area, 7,294 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	20, 100	4, 490	7, 267	446, 830	1.00	1.15
February	124, 240	4, 555	26, 261	1, 458, 462	3. 60	3.74
March	46, 420	10, 280	18, 322	1, 126, 576	2.51	2.90
April	75, 400	8,000	9,695	576, 892	1.33	1.48
May	15, 800	6,500	9, 264	569, 621	1.27	1.46
June	96, 960	6,050	22, 702	1, 350, 863	3.11	3. 47
July	18,890	5,900	9,590	589, 666	1.31	1.51
August	12, 470	4,620	5,776	355, 152	0.79	0.91
September	19,000	3,880	6, 199	368, 866	0.85	0.95
October	24,080	3, 940	6, 681	410, 799	0.92	1.06
November	19,880	4,620	7, 431	442, 175	1.02	1.14
December	20, 790	5, 975	9, 704	596, 676	1.33	1.53
The year	124, 240	3, 880	11,574	8, 292, 578	1.59	21. 30

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 151, discharge measurements, page 150; rating table in Paper No. 52, page 513.

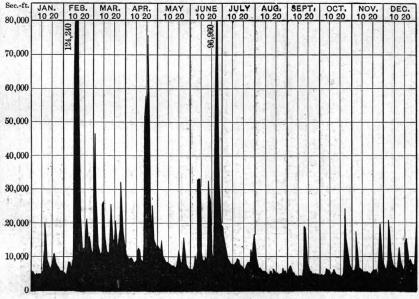


Fig. 62.—Discharge of Savannah River at Augusta, Ga., 1900.

Estimated monthly discharge of Broad River (of Georgia) near Carlton, Ga.

[Drainage area, 762 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	3, 965	730	1, 146	70, 465	1.50	1.73
February	26, 020	730	3, 468	192, 603	4.55	4.74
March	5, 230	1,220	2, 171	133, 490	2.85	3. 29
April	12,520	1,010	2,651	157, 745	3.48	3. 88
May	2,650	940	1, 168	71, 818	1. 53	1. 76
June	13,600	870	2,994	178, 155	3. 93	4. 38
July	1,920	870	1,227	75, 445	1.61	1.86
August	2,000	660	958	58, 905	1. 26	1.45
September	3,510	540	908	54, 030	1.19	1.33
October	2,950	600	1,001	61, 549	1.31	1.51
November	4, 825	730	1,043	62, 063	1.37	1.53
December	2,950	800	1,155	71,018	1.52	1.75
The year	26, 020	540	1,658	1, 187, 286	2. 18	29. 21

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 152, discharge measurements, page 151; rating table in Paper No. 52, page 513.

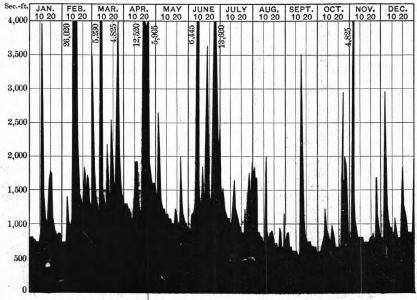


Fig. 63.—Discharge of Broad River (of Georgia) near Carlton Ga., 1900.

Estimated monthly discharge of Oconee River near Dublin, Ga.

[Drainage area, 4,182 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6, 358	2, 218	3, 506	215, 576	0.84	0. 97
February	28, 246	2,500	12,002	666, 557	2.87	2.99
March	13, 198	6, 472	9,874	607, 129	2.36	2.73
April	19,924	3, 805	9,512	566, 003	2. 27	2.53
May	9, 322	2,717	4, 754	292, 312	1.14	1.31
June	23, 572	2, 218	8, 371	498, 109	2.00	2. 23
July	21,520	2,080	6, 396	393, 275	1.53	1.76
August	5, 560	1,488	2, 314	142, 282	0.55	0.63
September	6, 700	1, 242	2, 371	141, 084	0.57	0.64
October	6, 244	1, 242	2, 233	137, 302	0.53	0. 61
November	7, 384	1,878	3, 220	191, 603	0.77	0.86
December	9, 436	2,500	5, 846	359, 457	1.40	1.61
The year	28, 246	1, 242	5, 867	4, 210, 689	1.40	18. 87

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 153, discharge measurements, page 152; rating table in Paper No. 52, page 513.

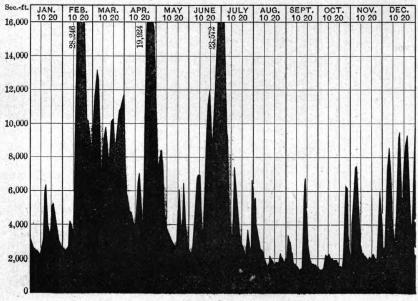


Fig. 64.—Discharge of Oconee River near Dublin, Ga., 1900.

Estimated monthly discharge of Yellow River at Almon, Ga.

[Drainage area, 379 square miles.]

Month.	Discharge in second-feet.			1	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	920	275	427	26, 255	1.13	1.30
February	9, 225	290	1,493	82, 917	3.94	4. 10
March	3, 837	505	963	59, 213	2. 54	2. 93
April	4, 912	290	1,432	85, 210	3.78	4. 21
May	2, 333	370	622	38, 245	1.64	1.89
June	4, 912	370	1,390	82, 711	3. 67	4.09
July	1, 175	290	570	35, 048	1.50	1.73
August	1, 175	275	358	22, 013	0.94	1.08
September	2, 763	290	492	29, 276	1.30	1. 45
October	780	290	373	22, 935	0.98	1.13
November	955	290	379	22, 552	1.00	1.12
December	2, 492	350	806	49, 559	2.13	2.46
The year	9, 225	. 275	775	555, 934	2.05	27. 49

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 154, discharge measurements, page 153; rating table in Paper No. 52, page 513. The figures in the above table relating to flood flow are unreliable.

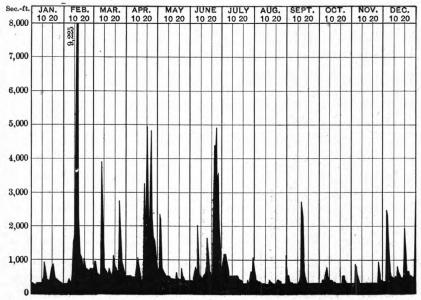


Fig. 65.—Discharge of Yellow River at Almon, Ga., 1900.

Estimated monthly discharge of Towaliga River near Juliette, Ga.
[Drainage area, 350 square miles.]

	Discharg	ge in secon	d-feet.		Run-off.			
Month.	Maximum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.		
1899.								
November	480	127	170.	10, 116	0.49	0.55		
December	597	127	248	15, 249	0.71	0.82		
1900.								
January	453	220	274	16, 848	0.78	0.90		
February	2,847	154	1,449	80, 473	4.14	4. 31		
March	597	120	354	21, 767	1.01	1.16		
April	3,081	177	751	44, 688	2.15	2.40		
May	759	255	422	25, 948	1.21	1.40		
June	1,821	220	595	35, 405	1.70	1.90		
July	795	120	408	25, 087	1.17	1.35		
August	867	109	222	13,650	0.63	0.73		
September	1, 317	109	271	16, 126	0.77	0.86		
October	579	114	243	14, 941	0.69	0.80		
November	1,353	144	357	21, 243	1.02	1.14		
December	1, 497	220	526	32, 342	1.50	1.73		
The year	3, 081	109	489	348, 518	1.40	18. 68		

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 155, discharge measurements, page 154; rating table in Paper No. 52, page 513.

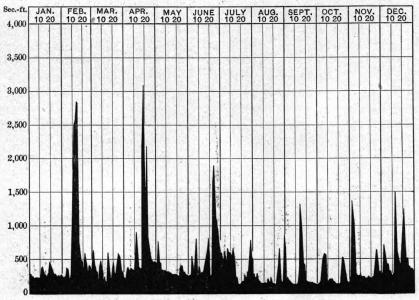


Fig. 66.—Discharge of Towaliga River near Juliette, Ga., 1900.

Estimated monthly	discharge o	of Tallulah	River at	Tallulah	Falls,	Ga.
	[Drainage a	rea, 191 squa	re miles.]			

	Dischar	rge in seco	nd-feet.		Run-off.				
Month.	Maxi- mum. Mini- mum		Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.			
1900.	3,080	200	450	26, 777	2, 36	2, 63			
September	5,080	733	400			1 1 1 1 1 1			
October 1 to 19	266	252	255	15, 679	1.34	1.54			

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 148; rating table in Paper No. 52, page 513.

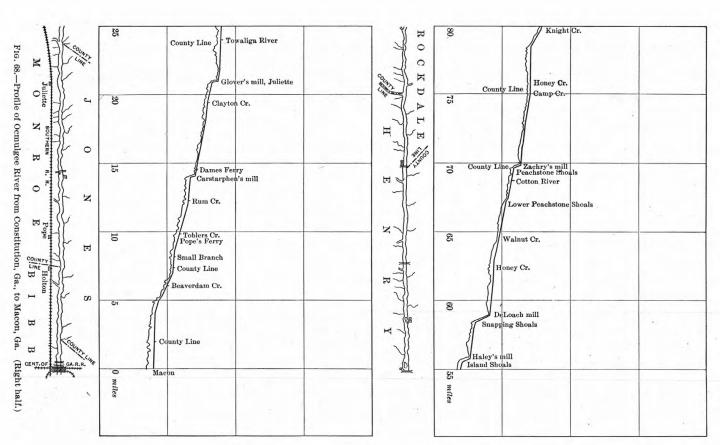
OCMULGEE RIVER.

From May 7 to June 23, 1900, a survey of Ocmulgee River from Constitution, Ga., to Macon, Ga., was made under the supervision of B. M. Hall, resident hydrographer, by a small field party with light outfit. The results of the survey are shown in the profile forming figs. 67 and 68. The distance run was 105 miles, the fall 527 feet. The methods pursued in making the survey were as follows: The chainmen in front set the stakes 100 feet apart, the levelman followed and procured the profile, and the topographer brought up the rear, making a continuous sketch of the river, with bluffs, shoals, mills, bridges, mouths of tributaries, and land lines of property owners along it, all being sketched with reference to the number of stakes. The survey began at the Southern Railway bridge near Constitution, 6 miles southeast of Atlanta, over the south prong of Ocmulgee River, known as South River, and extended down the west bank of the river to Macon, a distance of 105 miles.

In making the map and the profile it was thought best to begin at the navigable water at Macon and run up the river with mile and half-mile stations horizontally, using a vertical scale showing 2 feet elevation for each of the smallest divisions on "Plate A" profile paper, the elevations being above sea level.

For the first 25 miles above Macon the distances were not chained but were approximated from the mileposts of the Southern Railway, which runs along the west bank of the river. The fall line, or foot of the shoals, is about 4 miles above Macon. The mouth of Beaverdam Creek, which is the foot of the Holton Shoals, is 19 feet above the water level at Macon.

At Carstarphen's mill, a large merchant mill about 14 miles above Macon, there is a fall of 8 feet which is utilized, but above and below

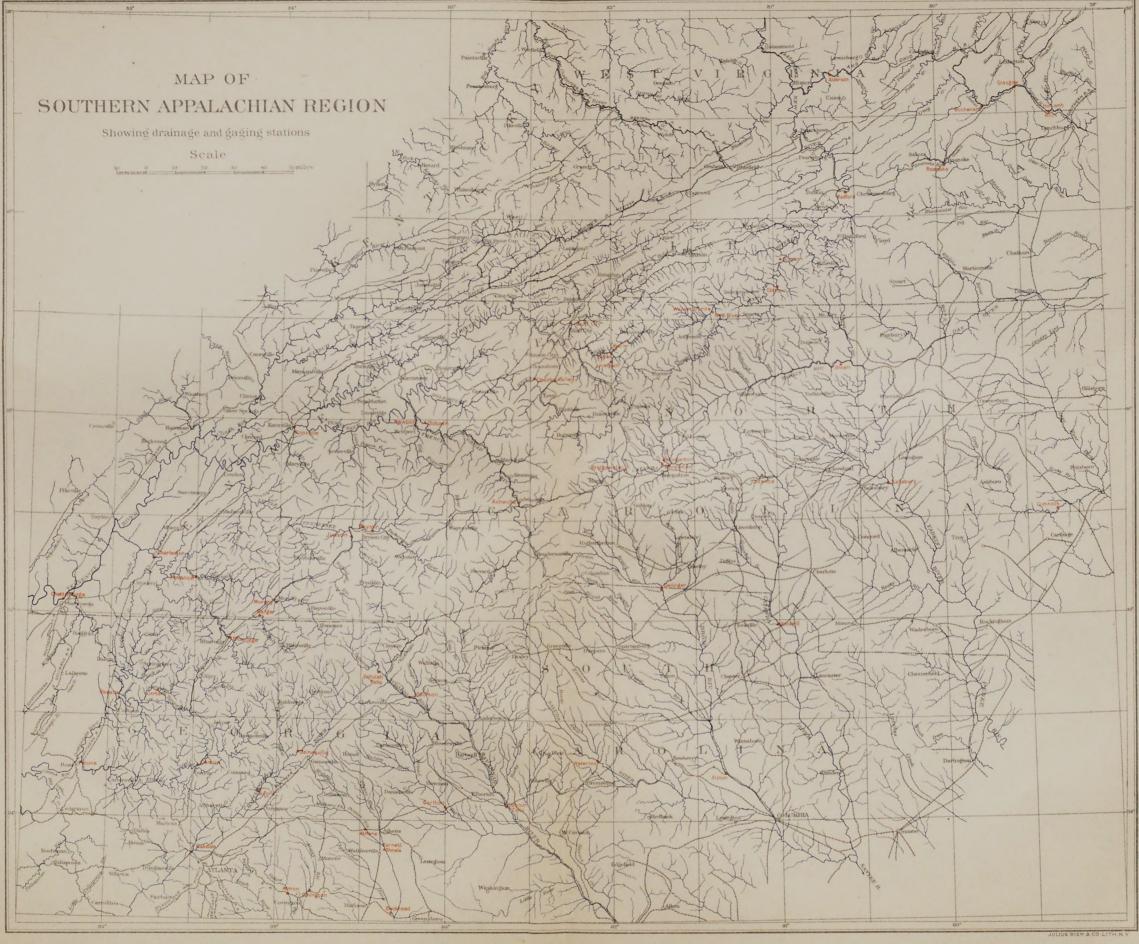


that point there is a continuous slope that gives a total fall of 60 feet from the tailwater of Glover's mill, 20 miles above Macon, down to the foot of the Holton Shoals, at the mouth of Beaverdam Creek. Macon capitalists have had elaborate surveys made for a development of this entire fall of 60 feet by a proposed organization to be known as the Ocmulgee Light, Water and Power Company. Such a development would flood the present line of the Southern Railway in that vicinity, but the railroad company could easily change its track and put it on ground above high-water mark.

The next power is at Juliette, Ga., 23 miles above Macon. This is partially developed by wing dams, which produce about 10 feet head, the power being used to operate Glover's large gristmill on the west bank and Glover's cotton factory on the east bank, but these mills use only a small part of the water, and the head could easily be increased. A head of 30 feet could be obtained here by building a dam at the top of the shoals to back the water to Goodman's ferry, and such a dam would not interfere with any water power above. The water supply here would be practically the same as that at Macon, as shown by the hydrographic station at the latter place.

The next power above is at Lamar's mill, a large merchant mill for grinding corn and wheat, located 35 miles above Macon, and operated by power developed by a wing dam and canal on the west side of the river, a small portion of the water and the fall being utilized. The Lamar property covers a fall of 25 feet, 20 feet of which can easily be developed by extending the dam entirely across the river, increasing its height 4 feet, and enlarging the present short canal. The head can be increased 17 feet by raising the dam 17 feet higher and backing the water over the Carnes and the Smith shoals to Giles's ferry. A small portion of the power of these shoals is utilized by the Carnes gristmill, on the east bank of the river, through a small canal, 4,000 feet in length, which gives a head of 10 or 12 feet. These shoals could be fully developed, independently, by enlarging the Carnes canal and building a low dam to turn the water into it. The water at the Lamar Shoals, the Carnes Shoals, and Smith Shoals is estimated at about 80 per cent of that at Macon. They are 4 or 5 miles from Flovilla, Ga., a station on the Southern Railway.

The next power above is a fall of 60 feet between the mouth of Alcovy River and the foot of the Lloyd Shoals, 1 mile above Pittman Ferry, a distance of 5 miles. The continuous shoals that make up this fall of 60 feet are known locally as Capps & Lloyd, Barnes, Barnett, and Dotson shoals. The most precipitous part of this slope is a fall of 48 feet in a distance of $2\frac{1}{2}$ miles, between Dempseys Ferry and a point about 1 mile above Pittman Ferry. It is shown on the map and profile as the Lloyd Shoals and the Barnes Shoals, though the



entire fall in this $2\frac{1}{2}$ miles is better known as the Capps & Lloyd Shoals. It is about 8 miles east of Jackson, the county seat of Butts County, a flourishing town on the Southern Railway. The fall between the mouth of Alcovy River and the head of the Capps & Lloyd Shoals at Dempseys Ferry is 12 feet in a distance of about $2\frac{1}{2}$ miles. This includes Dotson Shoals and Barnett Shoals. The water running over the 60 feet of fall just described is estimated to be about 75 per cent of that at Macon.

The next shoals above the mouth of Alcovy River are the Barnes Shoals, at the mouth of Yellow River, which have a fall of 14 feet in a distance of about 4,000 feet. Any development of these shoals will include the water of Yellow River, but not that of Alcovy River, as the latter stream enters 2 miles below.

From this point upward the survey followed the south prong of the stream, known as South River, or South Ocmulgee River, which furnishes about one-third of the water that is in the Ocmulgee at Keys Ferry, just below the mouth of Alcovy River, or probably about one-fourth of the water at Macon. There are Geological Survey hydrographic stations at Covington, Ga., on Alcovy River, and at Almon, Ga., on Yellow River.

The first abrupt shoals shown on the Ocmulgee profile above the mouth of Yellow River are the Island Shoals, which have a fall of 14 feet in a distance of 2,700 feet; but the foot of these shoals is 20 feet higher than the mouth of Yellow River, and about 7 miles above it. The Island Shoals are partially utilized by Haley's mill, a new roller flour mill on the west side of the river, operated from a canal which starts at the upper end of the shoals and gives a head of 10 feet on the wheels.

The next shoals above are the Snapping Shoals, 58 miles above Macon and about $2\frac{1}{2}$ miles above the Island Shoals, the foot of the shoals being 7 feet above the water in Haley's mill pond. The Snapping Shoals have an abrupt fall of 21 feet in a distance of 2,200 feet, which is partly developed by De Loach's mill, in the town of Snapping Shoals, Ga., on the east bank of the river. This is a large woodworking establishment and a combined merchant gristmill and flouring mill, and is run from the canal which starts out at the head of the shoals and utilizes 13 feet of the fall.

In the next 10 miles the river has a fall of 32 feet, from the mouth of Cotton River to the head of De Loach's canal. A short distance above the mouth of Cotton River are the Peachstone Shoals, with a fall of 9.8 feet, utilized by Zachry's grist and cotton mill, by means of a 5-foot dam across the river and a canal 300 feet long on the west side of the stream. Only a small part of the water is used, however, as the canal is small.

The Puckett Shoals and the Albert Shoals form a continuous descent with a total fall of 58 feet in $5\frac{1}{2}$ miles, the head of the Albert Shoals being 1 mile below the mouth of Polbridge Creek, and the foot of the Puckett Shoals being $1\frac{1}{4}$ miles below the mouth of Knight Creek. The abrupt fall of the Albert Shoals is 16.8 feet in a distance of 2,100 feet. R. S. Simms has a small gristmill on the Puckett Shoals and J. S. McLendon has a similar mill on the Albert Shoals, but they utilize a small part only of the power available.

Five miles above the mouth of Polbridge Creek, in Dekalb County, are the Flat Shoals, with a fall of 14½ feet in a distance of 400 feet, partly utilized by a small gristmill belonging to Col. M. A. Candler, who also owns a large tract of land on both sides of the river along the shoals.

Four miles higher up the river, near Flake's bridge, in Dekalb County, is Flake's mill, utilizing 10.6 feet of fall and a portion of the water.

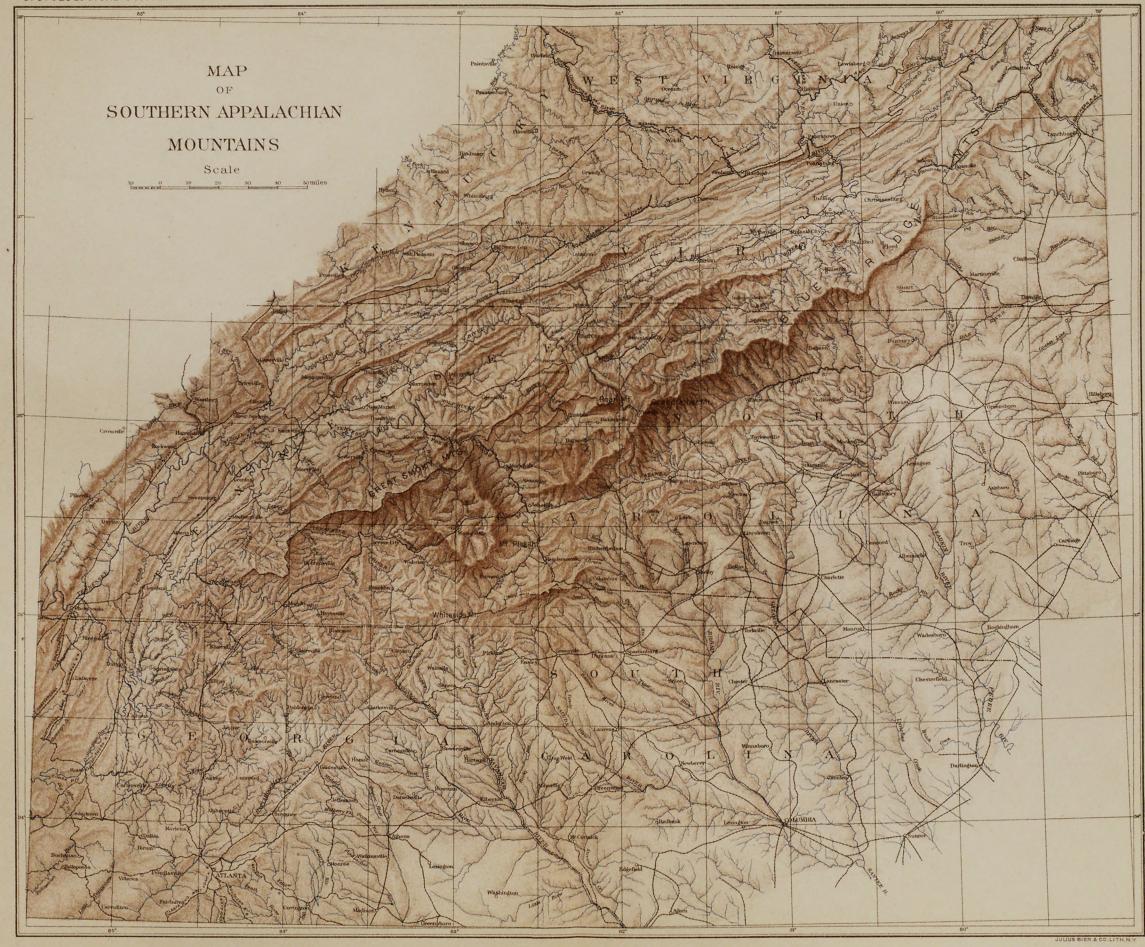
From the Southern Railway bridge near Constitution down to Flake's mill pond there is a fall of 50 feet in a distance of 11 miles. The total fall from the bridge at Constitution to Macon, a distance of 105 miles, is 527 feet, 288 feet of which is above the mouth of Yellow River.

Estimated monthly discharge of Ocmulgee River at Macon, Ga.

[Drainage area, 2,425 square miles.]

10.	Dischar	ge in secon	d-feet.		Rui	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	2, 920	940	1,530	94, 076	0.63	0.73	
February	46, 240	1,090	9,700	538, 711	4.00	1.16	
March	7,900	3, 280	4, 644	285, 548	1.92	2. 21	
April	30, 700	2,620	7,005	416, 826	2.89	3. 22	
May	5, 490	1,900	2,871	176, 531	1.18	1.36	
June	39, 940	1,900	8, 216	488, 886	3, 39	3.78	
July	11, 950	2, 140	3, 615	222, 278	1.49	1.72	
August	3,820	1,480	1,995	122, 668	0.82	0.95	
September	11,950	1, 195	2,560	152, 331	1.06	1.18	
October	5, 250	1, 195	1,876	115, 351	0.77	0.89	
November	9, 940	1,360	2, 307	137, 276	0.95	1.06	
December	10, 840	1,660	4,079	250, 808	1.68	1.94	
The year	46, 240	940	4, 200	3, 001, 290	1.73	23, 20	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 156, discharge measurements, page 155; rating table in Paper No. 52, page 518.



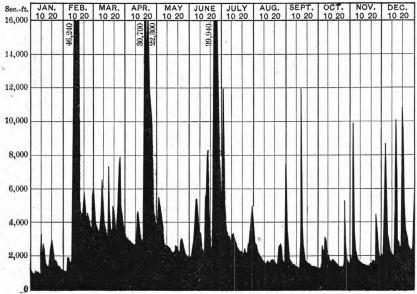


Fig. 69.—Discharge of Ocmulgee River at Macon, Ga., 1900.

PROPOSED SOUTHERN APPALACHIAN PARK.

With the growth of population and industries in the eastern part of the United States there have come a rapid destruction of the forests and an encroachment upon the mountain areas from which issue the great rivers that not only carry away the surplus water to the ocean and the Gulf of Mexico, but in their course furnish the needed supply for municipal and industrial purposes. Great interests have grown up dependent upon the preservation of the waters of these rivers both as regards quantity and quality, and the sentiment is growing in the minds of citizens that in order to preserve the rivers as nearly as possible in their natural condition or to improve them it is essential to protect the forests at the headwaters. These forests are growing upon lands which have little value except for the timber, although along the valleys and on the hillsides occasional small patches of land have been partly cleared for farms. The value of the agriculture here, however, is at best very small or doubtful, while the injury done to the whole forest is frequently very great, since each of these little isolated farms serves as a center from which originate fire and other influences destructive to the forest.

The idea is rapidly taking shape in the minds of the people of the country that these great forest areas, having principal value for the favorable influence they may exert upon water supply, should be set apart as forest reserves. It is not intended that the timber shall be allowed to mature and decay without being used, but, on the contrary, it is suggested that the larger trees shall be removed from time to time

under a systematic management that will insure a continual supply of lumber from the forest. This is in contrast with the present methods of lumbering, by which the entire forest growth is either cut or injured or is swept away by fire, which almost invariably follows careless lumbering operations.

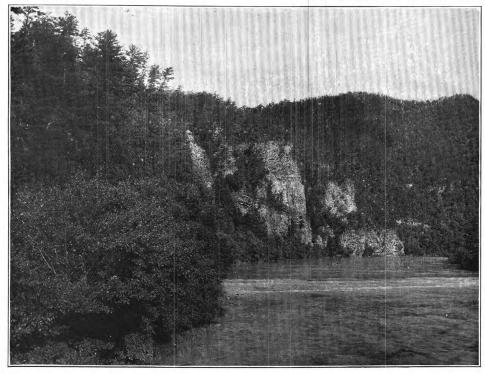
Forest reserves aggregating nearly 50,000,000 acres have already been created in Western public-land States. The importance of such reservations to the East is even greater than to the West, and owing to the rapid destruction of the forests in the Southern Appalachian region a project has been set on foot to create a forest reserve in that locality, which includes the headwaters of many of the great streams of the continent.

To procure data bearing upon the necessity of such a reserve the United States Geological Survey was requested to make a systematic investigation of the rivers issuing from the region, this being an amplification of the operations which have been carried on for a number of years within and adjacent to the area under consideration. Work was begun on June 12, 1900, under charge of Mr. H. A. Pressey, the stream measurements being made by Messrs. E. W. Myers, O. P. Hall, W. E. Hall, J. R. Hall, L. V. Branch, N. C. Curtis, Cleveland Abbe, jr., J. C. Conn, Ernest Graves, and H. G. Stokes. The various parties continued in the field with slight interruptions until November 10. As a result of this work a detailed report has been prepared by Mr. Pressey, to be published as Water-Supply Papers Nos. 62 and 63. The following extracts from this report are given herewith, since they embody the principal results accomplished.

SCOPE OF INVESTIGATION.

The drainage basins of all of the larger rivers were visited and meter measurements were made of the larger streams and their important tributaries rising in the mountains. The region is well watered. (See Pl. VIII.) From its steep slopes some of the largest rivers of the country receive their supplies. In fact, it may be considered the great mountain divide and water conservator of the southeastern part of the United States, water from its mountains flowing into the Atlantic Ocean, the Gulf of Mexico, and to the Ohio and Mississippi rivers. Flowing into the Atlantic are the Yadkin, the Catawba, the Broad, the Saluda, and the Chatooga; into the Gulf, the Chattahoochee and the Coosa. New River flows to the north and enters the Great Kanawha, whose waters finally reach the Mississippi through the Ohio, while the Tennessee, with its large tributaries, the Holston, the Nolichucky, and the French Broad, also adds its waters to the Mississippi.

Among the large streams measured were New, Yadkin, Catawba, Broad, Saluda, French Broad, Nolichucky, Watauga, Holston, Big Pigeon, Nottely, Chestatee, Toccoa, Conasauga, Coosawattee, Cartecay, Ellijay, Hiwassee, and Etowah rivers. In the study which was



A. CHEMUNG ROCK FROM RAILROAD BRIDGE NEAR PAINT ROCK, TENN., ON FRENCH BROAD RIVER.



B. MOUNTAIN VILLAGE ABOVE MARSHALL, N. C.

made of each drainage basin special attention was given to the normal flow and the yearly variations in the discharge of the streams, the developed and undeveloped water powers on them, the springs in the basin, the source and quality of the water, and the general characteristics, such as topography, rock, soil, minerals, mines, forests areas, rainfall, climate, lumbering, and transportation. The territory covered by the reconnaissance includes the high mountain plateau extending in a northeast-southwest direction from Virginia to Alabama, and also the adjacent region to the east and west of the mountains, covering large portions of the States of Virginia, North Carolina, South Carolina, Georgia, Alabama, and Tennessee.

PHYSICAL FEATURES.

The largest mountain masses and the highest peaks of the great Appalachian mountain system are in western North Carolina and eastern Tennessee, the mountains being lower both to the north and the south, but extending in practically an unbroken chain from Maine to Alabama. The region may be considered a high plateau, the Smoky Mountains forming the western boundary of the highest portions and the Blue Ridge the eastern boundary. (See Pl. IX.) The area included between these two ranges narrows to almost a point at its northern and at its southern extreme, and has a width of 55 miles at its broadest portion, with a total area of approximately 6,000 square miles.

The Blue Ridge is the divide between the rivers flowing to the Atlantic Ocean and those flowing to the Mississippi and its tributaries. The most striking characteristic of the range is the great difference in slope of its opposite sides. The rivers flowing to the west into the Tennessee and the Ohio head in the gaps upon the divide and for miles flow in broad, smoothly rounded, drift-filled valleys before entering the narrow rock-cut gorges on their lower courses, while those flowing eastward plunge downward in a series of cascades, falling several thousand feet in a distance of but a few miles. The latter can scarcely be said to have valleys, but simply V-shaped gorges, through which they tumble and foam until they reach the Piedmont Plain, which extends along the southeastern base of the Appalachian Mountains. The surface of this plain has a general eastward slope from an altitude of about 1,000 feet at the western edge to from 250 to 300 feet at the eastern edge, where it merges into the Coastal Plain.

The Smoky Mountains, on the western edge of the high mountain region, are extended to the north in the Bald and Iron mountains and to the south in the Unaka Range. These mountains and ranges are much more massive and reach far greater heights than the peaks of the Blue Ridge, many of them having elevations of more than 6,000 feet. Their slopes are equally steep on both sides, their outlines are

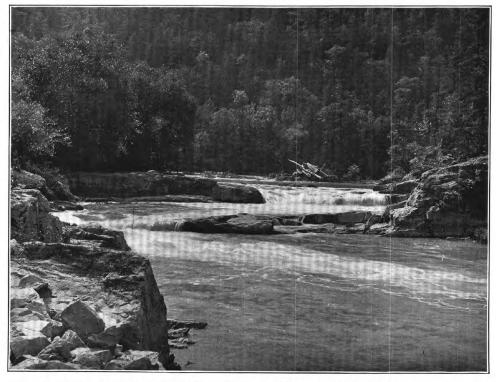
angular and rocky, and descents of 4,000 feet from the crest to the stream bed are not uncommon.

Several cross chains connect the Smoky and the Blue Ridge ranges, forming a number of smaller plateaus or basins, each nearly surrounded by mountains and having its own independent system of rivers and drainage. These connecting mountain chains divide the long valleys between the main chains so that nowhere in this region are there extended fertile valleys, as in Virginia and Tennessee; but instead in every direction high mountain ranges cut off the view and give it the appearance of a rocky and truly mountainous country. The highest and most massive of the cross chains is known as the Black Mountains, comprising 25 peaks, 20 of them more than 6,000 feet in height. Among the latter is Mount Mitchell, with an elevation of 6,712 feet, the highest mountain east of the Rockies. On the western slopes of these mountains rise the eastern tributaries of the French Broad, the valley of which separates the Black Mountains from the Pisgah and the New Found mountains, others of the cross chains. Farther to the west are the Balsam, the Cowee, the Nantahala, and the Valley River mountains, while to the east are the Linville Mountains, through which Linville River has cut its stupendous chasm.

The scenery of the Southern Appalachian region surpasses that of any other portion of the Eastern States. (Pls. X, XI, XII, XIII, and XV give characteristic views.) While in height the mountains can hardly be compared with the Rockies or the Alps, they far surpass in height, massiveness, and extent the mountains of the Northeastern States. As one ascends Roan Mountain or Grandfather Mountain or passes through Hickorynut Gap he is strongly reminded of the scenery of Switzerland, and might well imagine that he is on the Rigi or the Pilatus. The mountains and valleys are covered with a luxuriant growth of forest trees, making one continuous bank of green from the base to the summit of the highest peaks. With tireless energy the rivers have cut their ways through the massive ranges and formed stupendous gorges, with bare, rocky walls, almost vertical and hundreds of feet in height, which present views of rare grandeur and beauty. The charms of the Linville (see Pl. XV, A), the Cranberry, and the Watauga can not fail to arouse wonder and admiration in all who visit them, but, unfortunately, they are difficult of access. From Mount Mitchell six States are visible; but notwithstanding its elevation the views from that mountain are not so fine nor so extensive as can be obtained from other peaks of less elevation (notably Roan Mountain and Grandfather Mountain, which tower far above their surroundings), because it is surrounded by mountains with altitudes little less than its own. From the slopes of the mountains flow a great many pure, cold springs, forming innumerable rivulets, which flow over rocky precipices and finally unite to form one of the many rivers which rise at their base.



A. VIEW UP FRENCH BROAD RIVER NEAR BARNARD, N. C.



B. FALLS ON FRENCH BROAD RIVER ABOVE RAILROAD BRIDGE AT HOT SPRINGS; N. C.

The soil is generally deep and fertile, even on the mountain tops, so that on the steep slopes the mountaineers are able to eke out an existence, while the valleys are remarkable for their fertility. A typical mountain village is shown in Pl. X, B. Fruits and vegetables grow abundantly and to large size, and would no doubt be cultivated much more were it not for the lack of means of transportation. The entire region is well adapted to stock raising, which is one of the chief industries. The custom of turning the stock loose on the mountains about the first of April and not driving them up until November still continues. Of late considerable attention has been given to fine stock breeding.

Many varieties of shrubs and flowering plants abound, and the region should prove a Mecca for botanists.

GEOLOGY. a

The geologic formations which underlie these mountains may be divided into four large groups, each differing widely from the others in age and having also very distinct features of its own. The broad surface differences are expressed in such major topographic features as the Appalachian Valley, the Appalachian Mountains, and the Piedmont Plateau, and the minor differences appear in the variations which exist in the character of the surface in the mountain district itself.

The Appalachian Valley is underlain by a series of limestones, shales, and sandstones, mainly of Silurian and late Cambrian age, forming the youngest of the four groups of rocks of the region. Small outliers of these formations are included within the area of the mountains near the border of the Appalachian Valley.

The second group occupies the northwestern border of the mountain district, chiefly northeast of French Broad River. It consists of a series of quartzites, conglomerates, and shales of Lower Cambrian age. A second large area of these rocks occupies the Blue Ridge and adjacent territory nearly in the center of the district.

The third group of rocks is of Cambrian age. It occupies the north-western border of the mountain mass, corresponding in position to the previous group, but developed southwest of French Broad River, in the Smoky and the Unaka mountains, and consists of conglomerates, gray-wackes, sandstones, schists, and slates, and is called the Ocoee group. This and the two groups described above were composed of waste from older rocks, which was deposited under water. The thickness of the strata is approximately the same in the Ocoee group and in the formations of the Appalachian Valley. The Lower Cambrian quartzites and shales of the second group have only from one-fourth to one-third the thickness of either of the groups already described.

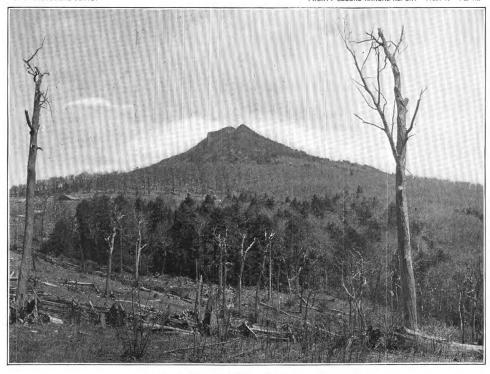
^{*} For the statements regarding the geology of the region the writer is indebted to Mr. Arthur Keitn, one of the geologists of the United States Geological Survey.

The fourth group is much the largest, both in bulk and in area. It consists chiefly of formations of the Archean or oldest known geologic age. The rocks include several kinds of granite, diorite, mica-gneiss, hornblende-gneiss, and various schists. A large number of these were of igneous origin, but the original nature of many of the gneisses and schists is unknown. Included in this group are the ancient volcanic rocks, which are developed most prominently in connection with the Cambrian quartzites in the northeastern part of the mountain district.

FORESTS AND LUMBERING.

Formerly nearly the whole region was covered with a magnificent growth of timber. Now, however, although the mountain slopes are wooded, the vast forests are gradually disappearing. Several railroads have penetrated the mountains, for transporting the lumber sawed at large mills located in the heart of the forested areas, while numerous small mills have been constructed on the lines of the railroads or within 10 or 15 miles of them. The large mills are usually steam sawmills, and they are moved deeper into the forests as the supply of timber in their immediate vicinity is exhausted, the railroads being extended to the mills. Near the rivers it is sometimes cheaper to splash the logs down the streams to the mills below, thus saving railroad transportation or long hauls over rough and steep roads. At one time there were large tracts of wild cherry and black walnut, but these have all disappeared and the mills are now sawing cheaper lumbers, such as oak, white pine, ash, and poplar. Old mountaineers tell of splitting rails from walnut logs and of burning or allowing to rot the walnut stumps which to-day would bring immense sums from veneering factories.

The unfortunate feature of this lumbering is that the ground is completely stripped of trees and then is left without cultivation. slopes are often too steep for successful working, and in many places the top soil is washed off and the hillsides become more or less gullied by the water rushing down their slopes. Usually no discrimination is made in the cutting, but all trees, large and small, are felled, and if not suitable for immediate use they are allowed to rot on the ground. This wastefulness is particularly noticeable in the case of the bark gatherers, who fell the trees for their bark and make no attempt to use the timber. Every year hundreds of cords of bark are hauled from these mountains, and each load means that a large tree has been felled and lies useless in the forest. Near the railroads it is profitable to saw the timber and haul it to the station, but the natives find that they can profitably haul the bark much farther than they can haul the timber. It is a mournful sight to see so many giants of the forest lying on the ground, of no use to anyone, simply marking the wanton wastefulness of man.



A. GRANDFATHER MOUNTAIN, NORTH CAROLINA.



B. DOE RIVER VALLEY, TENNESSEE.

MINERALS.

Besides the lumber, this region has a number of natural products of great value to the commercial world. Iron is found in many parts of the mountains, and much of it is of great purity. The Cranberry iron mines have been worked to a much greater extent than any others in North Carolina, and the product is considered as good as any in the United States. A view of the works at Cranberry is shown in Pl. XIV, B. The possibilities of this mine are very great, and it is not unlikely that in the future much iron will be mined in that locality. Corundum also is abundant, and the mica found is as good as any in the world. A number of other minerals are also mined to some extent.

HIGHWAYS.

The highways of the region are bad (see Pl. XIV, A), having steep grades and being poorly surfaced. In many localities practically no work is put on the roads, and during certain seasons of the year they become almost impassable to wagons. This is largely due to the neglect of the inhabitants, for excellent road materials occur in most parts of the mountain districts, and with proper care and intelligence good roads could be maintained at moderate expense. There are a few remarkable exceptions, however, as, for example, the toll road from Linville around Grandfather Mountain to Blowing Rock, known as the Yonahlossee road and shown in Pl. XV, B, and the road between Blowing Rock and Boone, both of which are excellent in grade and surface, and show what can be done when the materials at hand are used with proper skill.

CLIMATE.

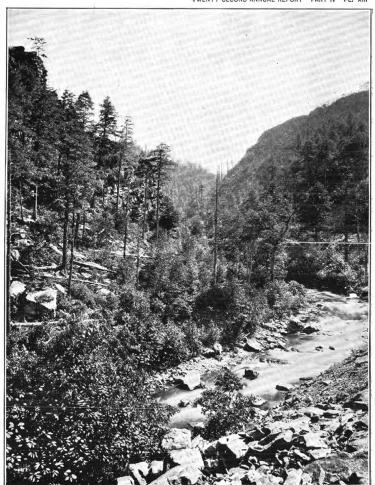
The effect of the increased altitude upon the climate is apparent. The high plateau has cooler summers and more severe winters than the lowlands adjacent, the air is drier and more salubrious, and the summer months are remarkably pleasant, the temperature varying somewhat with the altitude, but not being too cool for comfort on even the highest peaks. By choosing the proper locality one can obtain an average temperature corresponding to northern New England or to the warmer temperature of the South Atlantic States. The mean annual temperature varies from nearly 60° F. at Salisbury, east of the mountains, to 49° F. at Linville, the latter being about the mean annual temperature of Boston and Chicago. On the mountain slopes the temperature is still The seasonal temperatures of the mountain regions are approximately as follows: Spring 56 degrees, summer 73 degrees, autumn 57 degrees, and winter 40 degrees. The following table gives the average monthly and the mean annual temperature for the year 1900, also the seasonal temperatures, as observed at the United States Weather Bureau stations in the mountain regions:

Temperature observations in southern Appalachian Mountains during 1900.

					Length				Av	erage	month	ly tem	perati	ire.				Mean	Sea	sonal te	mperatu	ires.
Station. Latitude. Longitude. Elevation. of record		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	annual temper- ature.	Spring.	Sum- mer.	Au- tumn.	Win- ter.				
	0	,	0 /	Feet.	Years.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
Biltmore				2, 150	2	36.1	34.3	44.9	56.2	63.9	70.8	74.6	74.8	69.9	59.8	47.5	39.4	56.01	55.0	73.4	59.06	36.6
Charlotte	35 1	3	80 51	808	22	41.4	39.5	48.1	59.6	69.0	74.8	79.4	81.9	76.3	65, 2				58.9	78.7		
Henrietta						41.0	39.5	50.0	60.0	68.3	74.6	79.9	81.5	76.0	64.8	52.4	43.1	60.93	59.4	78.7	64.4	41.20
Hendersonville				. 2,167	1	36.6	34.6	45.1	54.4	62.4	70.2	73.4	75.4	70.4	62.6	50.0	40.5	56.30	54.0	73.0	61.0	37. 23
Highlands	35	5	83 2	3,817	15	32.8	30.6	38.4	51.0	58.4	64.1	67.5	68.1		56-2	45.3	35.8		49.3	66.6		30.06
Horse Cove	35	0	83 (2,800	6	38.4	35.5	43.6	56.0	62.8	66.6	71.6	74.4	69.4		49.6	40.6		54.1	70.9		38.16
Linville	36	5	81 5	3,800	4	30.3	29.0	36.8	48.0	55.6	64.5	67.2	67. o	63.1	54.3	43.6	34.0	49.5	46.8	66.4	53.67	31.10
Morganton	35 4	5	81 4	1,135	9						73.8		80.0	74.0			41.4					
Mount Airy	36 3	0	80 40	1,048	10	37.0			55.8	62.4	70.0	76.6	77.6	71.7	61.9	48.7	38.8			74.7	60.76	
Marion	35 3	0	82	1,425	5	38.8	36.2	46.8	57.8	66.6	72.8	78.2	80.1	75.2	63.3	51.2	41.5	59.04	57.1	77.0	63. 23	38. 83
Marshall						33.8	34.6	43.2	54.6	64.2	72.0	75,8	76.5	69.6	61.2				54.0	74.8		
Waynesville	35 2	9	82 58	2,756	4	35.2	36.1	43.6	52.6	61.0	68.5	71.8	71.4	67.2	58.4	44.0	37.5	53.94	52.4	70.6	56.53	. 36. 27



A. ELK FALLS ON ELK RIVER, NORTH CAROLINA. FALL ABOUT 40 FEET.



B. DOE RIVER GORGE, NORTH CAROLINA.

Highlands, the highest station, is 3,817 feet above sea level, while several of the mountain peaks and ranges reach elevations between 5,000 and 6,000 feet, with temperatures considerably lower than that at Highlands.

The following table, taken from Bulletin No. 8 of the North Carolina geological survey, gives the temperature extremes at a number of observation stations:

Temperature extremes in Southern Appalachian region.

Station.	on.	of rec-		est monthly mean.		est monthly mean.	High	nest observed.	Low	est observed.
	Elevation.	Length of pord.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.
	Feet.	Yrs.	Deg.		Deg.		Deg.		Deg.	
Asheville	2, 250	23	74.8	July, 1879	27. 2	Jan., 1893	95	Sept. 15, 1897	a_ 9	Jan. 16, 1893 Feb. 8, 1895
Chapel Hill	500	41	82.2	July, 1893	28.4	Jan., 1857	105	Aug. 10, 1892	- 1	Jan. 16, 1893
Greensboro	843	15	82.6	July, 1893	32.3	Dec., 1876	101	Aug. 10, 1896	6	Jan. 28, 1897
Highlands	3,817	15	70.9	July, 1878	24.4	Jan., 1893	86	June —, 1891	-17	Feb. 8, 1895
Horse Cove	2,800	6	74.4	July, 1893	28.5	Jan., 1893	93	Sept. 15, 1897	-13	Feb. 8, 1895
Lenoir	1,186	26	77.7	July, 1877	27.3	Jan., 1893	95	July 18, 1887	-16	Dec, 1880
Morganton	1,135	10	80.0	July, 1868	26.4	Jan., 1893	100	Sept. 16, 1897	- 1	Jan. 16, 1893
Mount Airy	1,048	10	77.1	July, 1872	26.2	Jan., 1893	98	Sept. 28, 1891	-15	Jan. 16, 1893
Mount Pleasant	650	12	79.1	Aug. 1896	29.9	Jan., 1893	98	June 29, 1899	- 4	Jan. 21, 1893
Murphy	1,614	12	76.9	July, 1878	28.5	Dec., 1876				
Salisbury	760	13	82.0	July, 1893	33.0	Jan., 1893	102	Aug. 10, 1896	. 5	Feb. 21, 1896

^a Minus sign (-) indicates temperatures below zero.

RAINFALL AND STREAM FLOW.

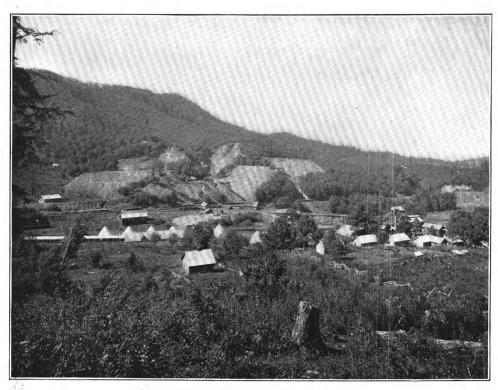
The annual rainfall is copious—larger than in the regions immediately to the east and west—owing chiefly to the great elevation. might be supposed, it varies considerably in different parts of the high regions. The warm, moist winds from the east are deflected upward by the Blue Ridge, causing a cooling and consequent precipitation. In this way the yearly rainfall is greatly increased on the slopes of those mountains. At Highlands, in Macon County, the annual normal precipitation is about 72 inches and at Horse Cove it is about 73 inches. West of the Blue Ridge the annual rainfall is much less in the valley bottoms between the mountain ranges. For instance, a long record at Asheville, N. C., gives a normal rainfall of 42 inches, the smallest of any record of the mountain regions. The normal at Waynesville, in Haywood County, is 46 inches. The average precipitation of the whole region may be considered to be approximately 53 inches. The following table gives the monthly and annual precipitation during the year 1900, as observed at the stations of the United States Weather Bureau:

Precipitation in Southern Appalachian region during 1900.

			Eleva-	Length	10.5				Month	aly pred	ipitati	on.						Sea	asonal p	recipitat	ion.
Station.	Station. tude tude tion 0	of record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual.	Spring.	Sum- mer.	Au- tumn.	Winter		
	0 ,	0 /	Feet.	Years.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Inches.	Inches.	Inches.	Inches.	Inches.
Abshers					3.35	7.50	4.92	4.89	2.93	9.28	7.43	4.14	5.46	8.73	5.15	3.35	67.13	12.74	20.85	19.34	14.2
Asheville	35 37	82 30	2,250	22	2.26	4.67	5.53	4.18	0.99	8.11	1.99	2.54	3.39	2.92	4.62	3.46	44.66	10.70	12.64	10.93	10.3
Biltmore			2,150	2	2.41	6.90	2.87	3. 31	1.37	7.91	2.10	0.52	2.51	3.67	3.34	3.80	40.71	7.55	10.53	9.52	13.1
Bryson		83 23	2,000	10	2.85	7.72	7.33	4.67	1.21	6.31	2.88	4.48	3.02	2.87	4.80	4.76	52.90	13. 21	13.67	10.69	15.3
Charlotte	35 13	80 51	808	22	2.15	5.25	5.28	5.32	2.11	7.31	3.55	3.05	0.73	3.41		4.31		12.71	13.91		11.7
Cherryville,					3.31	7.01	5.65	7.55	3.34	6.39	2.25	2.61	2.01	2.29	4.04	4.80	51.25	16.54	11.25	8.34	15. 1
Flatrock	35 15	82 25	2,214	6		13.24	5.06							8.17	3, 87	3.90					
Hendersonville			2,167	1	3.94	10.10	5.76	8.06	3.83	8.79	5.75	1.53	3.80	4.10	3.47	4.98	64.11	17.65	16.07	11.37	19.0
Henrietta	A CONTRACTOR OF THE PARTY OF TH	A Committee of the Comm	4		3.09	10.69	5. 29	6.77	2.92	6.99	2.79	1.45	1.05	4.15	5, 27	5.10	55.56	14.98	11.23	10.47	18, 8
Highlands		83 25	3,817	15	5.82	13.84	7.10	10.20	1.67	19.29	8.04	1.95		6.00	5.03	7.53		18.97	29.28		27.1
Horse Cove	35 0	83 6	2,800	6	4.28	12.98	7.10	8.86	2.28	19.92	9.43	3.36	6.74		5,94	6.67		18.24	32.71		23. 9
Linville	36 5	81 51	3,800	4	2,63	5.34	7.60	5.51	2.17	7.07	3.99	3.70	4.42	13.40	4.47	3.95	64. 25	15.28	14.76	22.29	11.9
Mana					2.13	5.17	4.06														
Marion			1,425	5	3.59	9.22	6.65	9.70	1.96	10.50	3.52	2.70	3.48	9.69	4.04	4.74	69.79	18.31	16.72	17.21	17.5
Marshall					1.26	4.07	3.69	2.62	1.46	8.33	1.49	2.69	3.63	3.51		3.09		7.77	12.51		8.4
Mount Airy	36 30	80 40	1,048	10	2.35	4.00		3.67	1.02	8.56	3.52	2.50	4.12	4.04	3.10	3.38			14.58		9.7
Mount Pleasant	35 28	80 28	650	12	2.11	6.68	3.07	4.34	2.53	4.87								9.94			
Morganton			1,135	9						5.97		1.15	2.10			4.40					
Mocksville	35 51	80 34	651	4	3.40	4.38	6.18	4.68	3.13		2.88	2.07	2.08	3.04	3.31	3.32		13.99		8.43	11.10
Murphy	35 8	84 0	1,614	20	3, 55	6.45	7.07	4.83	2.19	8.87	4.04	2.78	3.19	5.19	5.22	5.45	58.83	14.09	15.69	13.60	15.4
Salisbury	35 40	80 29	760	13	3.22	4.52	5.02	4.98	4.12	4.81	3.52	1.79	1.60	1.90	2.10	6.35	43.93	14.12	10.12	5.60	14.0
Settle				. 2	2.82	5.34	3.30	4.30	2.40	5.57	2.43	3.95	3.56	2.99	3.08	4.51	44.25	10.00	11.95	9.63	12.6
Waynesville	35 29	82 58	2,756	4	2.38	6.97	6.00	6.41	1.01	7.64	3.55	2.25	2, 49	2.12	3.57	4.08	48.47	13, 42	13, 44	8.18	13.4



A. ROAD BETWEEN MARION AND SPRUCEPINE, N. C.; A TYPICAL MOUNTAIN ROAD.



 $B_{\rm c}$ Cranberry iron works, cranberry, N. C.

Heavy rains occur at short intervals, which, with the steep slopes, cause rapid increase in the flow of streams for a day or a few hours, when the rivers as rapidly fall to their normal stage. Floods are frequently caused by these heavy rains. It is exceedingly difficult, however, to obtain measurements of the high waters, for unless the observer is near the station at the time the water rises the river falls before he can reach there. A rainfall of 7.39 inches was recorded at Salisbury on June 10, 1883, and 6.01 inches at Highlands on February 8 and 9, 1891.

There is considerable snowfall during the winter months of the year, the average annual snowfall at a few of the stations being as follows: Asheville, 16 inches; Highlands, 22 inches; Lenoir, 11 inches; and Mount Airy, 12 inches.

In some respects the season of 1900 was peculiar. Rains were abundant during June, and the streams were moderately high during the early part of the summer. Later, however, very little rain fell in all this region, and most of the rivers and their tributaries were at a low stage, as low in fact as they have been for a number of years. Measurements were made of all of the larger streams and efforts were put forth to obtain measurements at the same point at various stages of the stream. In each case a bench mark was established at the time of making the first measurement, and the relative height of the water surface was measured at each gaging, so that an idea of the relation between the rise of the stream and the discharge could be obtained. At time of floods examinations were made for the water marks, and when the yearly fluctuations of the stream could be determined they also were noted. On the larger streams gaging stations were established, as is the custom of the Survey. At these stations gages were set on which the daily height of the water surface is read and recorded by a local observer, and measurements, made as often as practicable, were referred to the same gage. It was impossible, however, to obtain a sufficient number of high-water measurements to construct rating curves for the streams, but the measurements will be continued during the spring of 1901, when an effort will be made to obtain sufficient high-water measurements for this purpose. Following is a list of the gaging stations established:

Gaging stations established in 1900 by the United States Geological Survey on rivers in the Southern Appalachian region.

Stream.	Station.	Date established.
New River	Oldtown, Va	August 5.
South Fork of New River	New River, N. C	July 29.
North Fork of New River	Weaversford, N. C	Do.
Yadkin River	Siloam, N. C.	August 3

Gaging stations established in 1900 by the United States Geologic	cal Survey on rivers in the						
Southern Appalachian region—Continued.							

Stream.	Station.	Date established
Catawba River	Morganton, N. C	June 19.
Johns River	do	Do.
Linville River	Bridgewater, N. C	July 3.
Broad River	Dellinger, S. C	August 30.
South Fork of Holston River	Bluff City, Tenn	July 17.
Watauga River	Butler, Tenn	August 11.
Roan Creek	do	Do.
Elk Creek	Lineback, Tenn	August 5.
Nolichucky River	Chucky Valley, Tenn	September 20.
Pigeon River	Newport, Tenn	September 4.
French Broad River	Oldtown, Tenn	Do.

Detailed descriptions of the various streams and their drainage basins will be found in Water-Supply and Irrigation Papers Nos. 62 and 63, and results of the gagings of the streams in Water-Supply Papers Nos. 48 and 49.

EASTERN GULF DRAINAGE.

The rivers flowing into the eastern portion of the Gulf of Mexico are for the most part of a character similar to those in the Southern Atlantic drainage, though in their lower courses their flow is usually more sluggish. A number of the rivers, however, have considerable fall in their upper courses, as shown by profiles which have been run by the Survey during the year 1900, as follows: Flint River, from Woodbury, Ga., to point opposite Knoxville, Ga.; Coosawattee River, from Ellijay, Ga., to Carters, Ga.; Tallapoosa River, from top of Griffin Shoals, Ala., to Milstead, Ala.; and Big Sandy Creek, from its mouth to the new bridge near Dadeville, Ala. These profiles, with maps of the river courses, are reproduced in figs. 70, 71, 72, 77, 78, 83, 84, 85, and 88.

FLINT RIVER.

From May 2 to May 14, 1900, a survey of Flint River from the Geological Survey gaging station, about 3 miles east of Woodbury, Ga., on the Macon and Birmingham Railroad bridge over the river, to the line of the Creek Agency Reserve near Roberta and Knoxville, a distance of 45.4 miles downstream, was made by Mr. D. L. Wardroper, under the supervision of B. M. Hall, resident hydrographer. In this 45 miles the river cuts through Pine Mountain, the western coast range of the State, and descends with a total fall of 334 feet, as shown by the resulting profile, figs. 71 and 72. The elevations are all above sea



A. LINVILLE FALLS ON LINVILLE RIVER, NORTH CAROLINA.



 ${\it B}.$ YONAHLOSSEE ROAD AROUND BASE OF GRANDFATHER MOUNTAIN, NORTH CAROLINA.

level, being taken from the track of the Atlanta and Columbus line of the Southern Railway, in front of the depot at Woodbury, which is

780 feet above sea level. From this the zero of the Woodbury River gage was found to be 659.63 feet above sea level. The map resulting from the survey is reproduced in fig. 70.

The methods pursued in making the survey were the same as those followed in the survey of Ocmulgee River, viz, the chainmen in front cut and set the stakes 100 feet apart, the levelman followed and obtained as many water levels as possible, noting bridges, ferries, mouths of tributaries, county lines, and such land lines as were pointed out to him by residents. He had with him a land-lot map (45 chains to the square) of the State survey of the region, on which he identified such localities as he could.

The country rock is vitrified sandstone or quartzite, forming fine bluffs and occasional narrow gorges suitable for dam sites. It is easily quarried, and comes out in square blocks that are excellent for building dams.

The first shoals, known as the Dripping Rock Shoals, begin near the mouth of Cane Creek, about 3,000 feet below the bridge, and fall 23.7 feet in a distance of 10,000 feet, or about 2 miles. In the next 2 miles, or to a point about 1 mile below the mouth of Pigeon Creek, the river falls only 6 feet. Then shoals begin which have a practically uniform fall of 10.5 feet per mile for a distance of $8\frac{1}{2}$ miles, or to Double Bridges (Gibson's old ferry), the total fall in that distance being 90 feet. From that point to the north boundary of the twenty-third

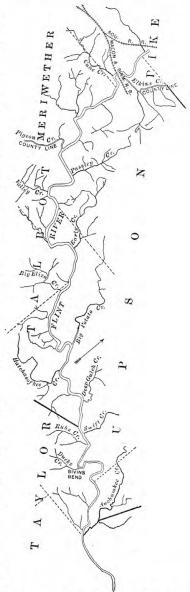


Fig. 70.—Map of Flint River from Woodbury, Ga., to point opposite Knoxville, Ga.

land district the fall is 20 feet in a distance of 4,700 feet. In the next 3 miles, or to the head of the Yellow Jacket Shoals, there is a total fall of 22 feet.

\$60000 ft. Frg. 71.—Profile of Flint River from Woodbury, Ga., to point opposite Knoxville, Ga. (Left half.) 170000 180000 190000 200000

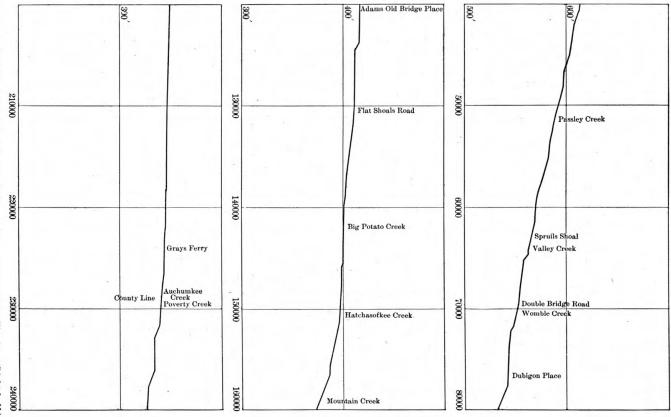


Fig. 72.—Profile of Flint River from Woodbury, Ga., to point opposite Knoxville, Ga. (Right half.)

The Yellow Jacket Shoals are the finest on the river. They are below Pigeon Creek and above Lazer Creek (sometimes called Eliza Creek), near Rowland, in Upson County, about midway between Talbotton and Thomaston, in the heart of the cotton belt of Georgia. They have a fall of 65 feet in a distance of 7,900 feet, or 1½ miles, all of which can be utilized. In fact a much larger head would be available by building a 42-foot dam at the head of the Yellow Jacket Shoals and taking the water in a canal to a point opposite the foot of the shoals. This would cover a fall of 107 feet, 7 feet of which would be sufficient for storage and canal grades, leaving a net working head of 100 feet. A dam of this height would back the water about 4 miles. There would be no trouble from flood water on the wheels, for the river is very precipitous below the foot of the Yellow Jacket Shoals, having an average fall of 6 feet to the mile in the next 10 miles, the most precipitous part being a fall of about 25 feet between Hatchasofkee Creek and Elliotts Ferry, a distance of about 2 miles. Elliotts Ferry is between the mouths of Mountain Creek and Deep Gulch Creek.

Below Elliotts Ferry the river falls 13 feet in the next 2 miles, or to Walkers Ferry, and then assumes a practically uniform grade of 1.7 feet to the mile for the next 11 miles, or to a point a half mile below the mouth of Auchumkee Creek, in Crawford County, which is the head of small shoals having a fall of 10 feet in a distance of 1 mile. This is practically the point where the river crosses the fall line and enters the younger geologic formations. The survey ended here.

Along the portion of the river surveyed there are several large tributaries which have fine shoals. The most notable of these is Big Potato Creek, near Thomaston, in Upson County, which has three shoals near its mouth, surveyed in 1891 by Mr. C. C. Anderson, assistant State geologist, and reported by him to be as follows: Rogers Shoals, 81 feet fall in a distance of 3,500 feet; Nelson Shoals, 115 feet fall in a distance of 2,700 feet; and Daniels Shoals, 13 feet fall in a distance of 150 feet.

About 10 miles above Woodbury there is a fine water power on Flint River, 1 mile from Neal, on the Southern Railway. This power is known as the Flat Shoals and has a fall of 32 feet in a distance of 3,000 feet. There is a natural storage basin just above these shoals, where it is estimated that a 2-foot dam would store the low-water flow of the river for twelve hours, and that a 4-foot dam would store it for thirty-eight hours. This power is not included in the survey described, but it was surveyed separately by B. M. Hall. It can be developed by a canal 3,000 feet long, or by a dam at the foot of the shoals, where there is a narrow shut-in.

The elevations and bench marks established are summarized in the following table:

FLINT RIVER, GEORGIA.

Elevations and bench marks along Flint River shown in figs. 71 and 72.

Sta- tion.*	Description or location.	Bench- mark eleva- tion above sea level.	Eleva- tion above sea level.
		Feet.	Feet.
0	Zero of gage at Woodbury Station		659.63
0	Water at Woodbury gaging station		661.0
0	Bench mark No. 1, top of northwest corner of bearing stone under south truss at west end of M. & B. R. R. bridge.	681.1	
31	One-fourth mile below mouth of Cane Creek		660.0
122	Two hundred feet above Melton's upper ford.		641.8
135	Nine hundred feet below Melton's upper ford		637.2
268	Bench mark No. 2, nail in leaning catalpa tree at Milton's boat landing, on		300.5
	right bank of river	638.8	
276	Five thousand feet below Brown Creek.		633.9
376	Mouth of Pigeon Creek. Bench mark No. 3, nail in pine tree on left bank, 200 feet below mouth of		620.8
378	Pigeon Creek.	628.5	
483	Six hundred feet above Passley's ford.		596.6
519	Twelve hundred feet below Passley's Creek		586.9
640	Bench mark No. 4, nail in pine tree on left bank, 100 feet below mouth of		
0.11	Valley Creek		
641	Mouth of Valley Creek.		562, 2
696 822	Double-bridge ford 800 feet above Womble Creek End of line between districts Nos. 1 and 23		552, 8 522, 0
822			322.0
022	Bench mark No. 5, white oak on top of slope on left bank, 100 feet below field, opposite line between districts Nos. 1 and 3	531.8	
836	Bench mark No. 6, sweet gum tree in field 50 feet below Talbotton and Thom-		
010	aston road, about 150 feet from river.	516.7	
912	Eight hundred feet befow mouth of Earls Creek		512.0
933 980	Talbotton and Thomaston road		507.3 499.6
1,073	Nine hundred feet above mouth of Lazer Creek		427.0
1,236	Time number feet above mouth of bazer creek		416.6
1,240			411.9
1,301	Bench mark No. 7, top of west end of wooden cap on north masonry abutment of wagon bridge at Flat Shoals road		
1,320	Twenty-three hundred feet below new bridge at Flat Shoals road		409.3
1,390	Twenty-nine hundred feet above mouth of Big Potato Creek		402.5
1,417	Bench mark No. 8, nail in water oak on right bank of Big Potato Creek, 200 feet above mouth.	413.6	
1,424	Bench mark No. 9, nail in root of sweet gum tree south of road at Parker's		
-1	Ferry	417.7	
1,454	Thirty-five hundred feet below mouth of Big Potato Creek		400.5
1,458	Thirty-nine hundred feet below mouth of Big Potato Creek		398.9
1,514	One hundred feet below Hatchasofkee Creek.		396.6
1,588	Nineteen hundred feet above Elliotts Ferry		374.0
1,707 1,984	Six hundred feet above Walkers Ferry		359. 4 349. 3
1, 904	Rench mark No. 10 nail in leaning ash tree on right bank of Swift Creek		349. 0
	Bench mark No. 10, nail in leaning ash tree on right bank of Swift Creek, 3,000 feet from its mouth, 100 feet from north end of bridge	377.1	
	Bench mark No. 11, nail in root of beech tree at south end of bridge mentioned in description of bench mark No. 10.		
2, 184	Fifty-five hundred feet above Grays Ferry.		345. 9
2, 239	Bench mark No. 12, nail in root of sweet gum opposite boat landing at Grays Ferry, left bank	353.1	
2,317	Twenty-nine hundred feet below mouth of Auchumkee Creek		339.7
2,328			335.2
2,361			334.9
2,377	Eighty-nine hundred feet below mouth of Auchumkee Creek		328.8
2,400			327.0
2,468	Bench mark No. 13, tin cap on root of red oak 20 feet west of north of the		
	north-south line on west boundary of lot No. 176, fourteenth district, of Taylor County.	352.9	
		A SELECTION	1000

Estimated monthly discharge of Flint River near Woodbury, Ga.

[Drainage area, 988 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
April	7, 380	800	2, 199	130, 850	2. 23	2. 49	
May	1,920	490	757	46, 546	0.77	0.89	
June	11,860	490	3,682	219, 094	3, 73	4. 16	
July	5, 560	490	1,676	103, 053	1.70	1.96	
August	2,760	370	611	37, 569	0.62	0.71	
September	1,500	370	557	33, 144	0.56	0.62	
October	1,780	370	641	39, 413	0.65	0.75	
November	3, 880	460	911	54, 208	0.92	1.03	
December	5, 280	490	1,922	118, 179	1.95	2. 25	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 158; rating table in Paper No. 52, page 513.

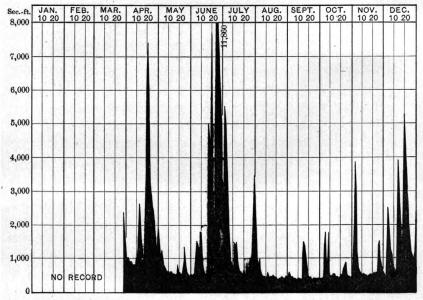


Fig. 73.—Discharge of Flint River near Woodbury, Ga., 1900.

Estimated monthly discharge of Chattahoochee River at Oakdale, Ga.

[Drainage area, 1,560 square miles.]

1	Dischar	rge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.						-	
January	6,300	1,050	2,275	139, 884	1.46	1.68	
February	28,650	1, 280	5, 929	329, 280	3.80	3. 95	
March	10,800	3,000	5, 137	315, 862	3. 29	3. 79	
April	18,000	2,630	5, 484	326, 321	3.52	3. 92	
May	5, 160	2, 450	3,295	202, 602	2.11	2.44	
June	24,600	3,000	8, 207	488, 350	5. 26	5. 87	
July	12,600	3,720	5, 847	359, 518	3. 75	4. 32	
August	5, 160	2,540	3,275	201, 372	2.10	2. 43	
September	12,900	1,700	3,277	194, 995	2.10	2.34	
October	4, 360	2, 185	3,234	198, 851	2.07	2.39	
November	6,000	1,700	2,436	144,952	1.56	1.74	
December :	4, 140	2, 100	2,753	169,275	1.76	2. 03	
The year	28,650	1,050	4, 262	3, 071, 262	2.73	36. 90	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 159, discharge measurements, page 158; rating table in Paper No. 52, page 513.

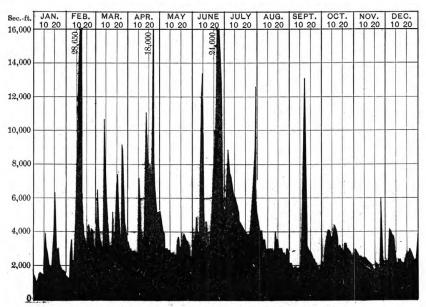


Fig. 74.—Discharge of Chattahoochee River at Oakdale, Ga., 1900.

Estimated monthly discharge of Chattahoochee River at West Point, Ga.

[Drainage area, 3,300 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	8, 316	2, 380	4, 554	280, 015	1.38	1.59	
February	63, 330	2, 380	14,652	813, 731	4. 44	4.62	
March	16,690	5, 625	8, 941	549, 761	2.71	3. 13	
April	19, 880	4, 920	9, 563	569, 038	2.90	3. 23	
May	8,040	3, 700	5, 024	308, 914	1.52	1.75	
June	55, 510	3, 890	13,-983	832, 047	4. 24	4.73	
July	31,570	4, 280	9, 277	570, 420	2.81	3. 24	
August	11,904	3,000	4, 418	271, 652	1.34	1.54	
September	31, 570	2, 100	6, 212	369, 640	1.88	2. 10	
October	8,040	2,530	4,094	251, 730	1. 24	1.43	
November	8,040	2,680	4, 054	241, 230	1. 23	1.37	
December	14, 112	3, 340	6, 571	404, 035	1.99	2, 29	
The year	63, 330	2, 100	7, 612	5, 462, 213	2. 31	31.02	
	100,000					1	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 160, discharge measurements, page 159; rating table in Paper No. 52, page 514.

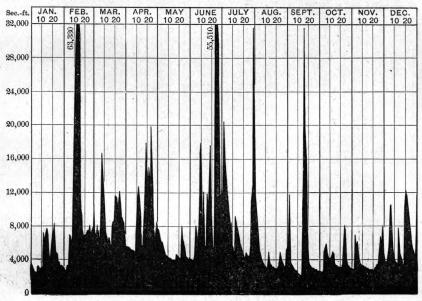


Fig. 75.—Discharge of Chattahoochee River at West Point, Ga., 1900.

Estimated monthly discharge of Etowah River at Canton, Ga.

[Drainage area, 604 square miles.]

	Discharge in second-feet.				Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	1,818	820	976	60, 012	1.62	1.87	
February	12, 276	988	2,138	118, 738	3, 54	3. 68	
March	4,972	1, 154	1,989	122,299	3. 29	3. 79	
April	4,640	1, 154	1,956	116, 390	3. 24	3. 61	
May	1,984	1, 237	1,395	85, 775	2.31	2.67	
June 1 to 9			3, 183	56, 821	5. 27	1.76	
July	3,810	1,320	1,853	113, 937	3.07	3.54	
August	2,980	988	1,371	84, 300	2. 27	2.62	
September	4,640	740	1, 347	80, 152	2. 23	2.49	
October	6, 466	665	2,038	125, 312	3.37	3. 88	
November	4, 308	1,071	1,970	117,223	3. 26	3. 63	
December	2,814	740	1,264	77, 720	2.09	2.41	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 161, discharge measurements, page 160; rating table in Paper No. 52, page 514.

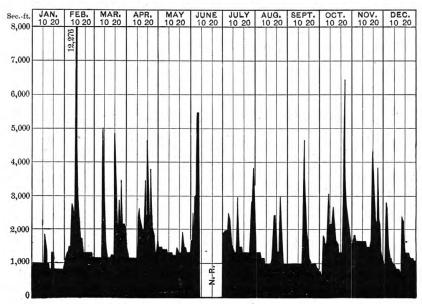


Fig. 76.—Discharge of Etowah River at Canton, Ga., 1900.

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COOSAWATTEE RIVER.

From May 29 to July 12, 1900, a survey of a part of Coosawattee River was made under the supervision of B. M. Hall, resident hydrographer, by Olin P. Hall, who was field assistant, levelman, and topographer. No camp outfit was carried. The levelman read his distances

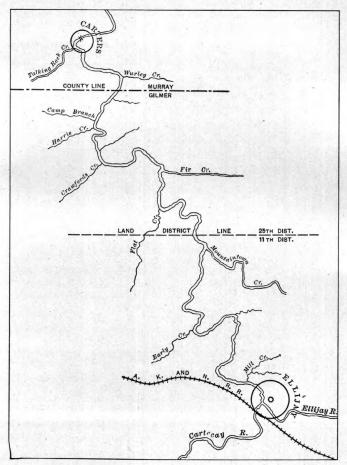


Fig. 77.-Map of Coosawattee River from Ellijay, Ga., to Carters, Ga.

with stadia and identified land lines and tributaries from a township or district map of the old State survey. This map embraces two land districts, the eleventh and the twenty-fifth. The eleventh was found to be correct, but the twenty-fifth was found to be incorrect. In plotting the map shown in fig. 77 the land lots were therefore omitted.

The survey began at the Geological Survey gaging station at Carters, Murray County, Ga., with zero of the gage as a level datum, and

extended up the river to Ellijay, Ga., a distance of 24 miles. The total fall between the two places was found to be 581.6 feet, as shown by the resulting profile, fig. 78. This 24 miles of river cuts through the Cohutta Mountains and enters the Paleozoic formation at Carters's

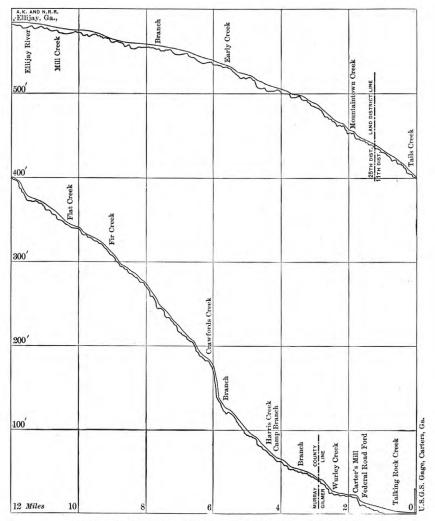


Fig. 78.—Profile of Coosawattee River from Ellijay, Ga., to Carters, Ga.

mill, about 2 miles above the gaging station, which is the head of navigation on the river. It is along a continuous shoal, and the conditions are such that water power can be developed at any point desired. The only utilized power is at Carters's mill, where there is an 8-foot dam across the river.

The following list of distances and elevations gives the fall of the river from point to point and describes the bench marks.

Elevations and bench marks along Coosawattee River above zero of gage at Carters, Ga.

Distance above Car- ters, Ga.	Description or location.	Bench- mark eleva- tion above gage datum.	Eleva- tion above gage datum.
Miles.		Feet.	Feet.
0.0	Water at gaging station May 29, 1900		1.80
0.3	Water at mouth of Talking Rock Creek.		3.50
1.75	Water below Carters's dam		17.56
1.75	Water above Carters's dam		25.73
1.75	Bench mark on small birch on right bank of river	28.40	
2.25	Water at mouth of Fishers Creek		26.00
2.50	Water at county line between Murray and Gilmer counties		49.20
3.25	Water at mouth of small branch		51.27
3.25	Bench mark on small maple 30 feet beyond branch	55. 25	
4.20	Water at mouth of Camp Branch.		69.65
4.20	Bench mark on pine root at mouth of Camp Creek	72.35	
4.40	Water at mouth of Harris Creek.		79.19
4.40	Bench mark on root of small poplar opposite mouth of Harris Creek	82.61	
5.62	Water at mouth of Wurley Creek.		129.52
5,62	Bench mark No. 8, on large basswood	135.01	
5.72	Water 1,000 feet above Wurley Creek.		139. 37
6.10	Water at mouth of Crawfords Creek, 37½ feet fall in 2,300 feet		186.89
6.10	Bench mark No. 9, on small white oak opposite Crawfords Creek	191.88	
9.00	Water opposite mouth of Tails Creek		316.84
9.00	Bench mark No. 10, on large pine 50 feet south of Tails Creek	323.44	
10.25	Water opposite mouth of Flat Creek		344.14
10.25	Bench mark on small white oak opposite Flat Creek at John Goble's boat landing	354.84	
10.50	River level		350.38
10.90	Below bend of river	Posterior and Park	363.87
11.45	Water at foot of shoals	C. C	375.09
12.25	Water at mouth of small branch from the west	5 / X X X X X X X X X X X X X X X X X X	409.18
13.25	Water at line between land districts 25 and 11	C. 20. 11.035915.	440.09
14.00	Water at mouth of Mountaintown Creek.	T 2000 1000 1000	456.87
14.00	Bench mark on small white oak on north bank of Mountaintown Creek		
16.40	Water at Gentry's boat landing, on lot No. 176		510.30
17.65	Water 260 feet below mouth of Early Creek	A CONTRACTOR OF THE PARTY OF TH	532. 21
18.18	Water at Smith's boat landing	The second second	538.91
18.22	Water at Levi Smith's ford	CONTRACTOR OF THE PARTY OF THE	547.13
18. 25	Bench mark No. 14, on root of small red oak 220 feet above ford	546.81	
19.70	Water at mouth of branch near corner of lots Nos. 103, 104, 113, and 114, in eleventh district		557.08
22.80	Water at ford 100 feet below mouth of Mill Creek	100000000000000000000000000000000000000	577.09
23.30	Water at covered wagon bridge over Coosawattee River at Ellijay, Ga		581.40
23.30	Bench mark on large oak on north bank, 50 feet above bridge		
23.60	Water at junction of Cartecay and Ellijay rivers		581. 92
24.00	Water at A. K. and N. R. R. bridge on Cartecay River	Fabruary St.	583.39
24.00	Bench mark on center of stone block on top of south pier of railroad bridge		
24.00	Base of rail on south end of railroad bridge	A STATE OF THE PARTY OF THE PAR	
24.00	Base of rail on front of A. K. and N. R. R. depot at Ellijay, Ga	613.77	

Estimated monthly discharge of Coosawattee River at Carters, Ga. [Drainage area, 531 square miles.]

Month.	Dischar	ge in secon	nd-feet.		Run-off.		
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	3, 990	365	912	56, 077	1.71	1.97	
February	13, 710	455	1,707	94, 802	3. 21	3. 34	
March	4, 350	765	1,645	101, 147	3.09	3. 56	
April	2,550	970	1,294	76, 998	2.43	2. 71	
May	1, 127	622	783	48, 145	1.47	1.69	
June	3,630	717	1,747	103,954	3.28	3.66	
July	2,694	670	1,344	82, 639	2, 53	2. 92	
August 1 to 25	1,022	495	632	38, 860	1.19	1.37	
November	2,550	455	693	41, 236	1.30	1.45	
December	2,010	495	837	51, 465	1.57	1.81	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 162, discharge measurements, page 161; rating table in Paper No. 52, page 514.

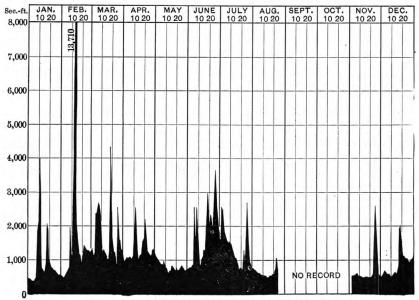


Fig. 79.—Discharge of Coosawattee River at Carters, Ga., 1900.

Estimated monthly discharge of Oostanaula River at Resaca, Ga.

[Drainage	area,	1,614	square	miles.]
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Month.	Discharge in second-feet.				Run-off.		
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January 7 to 31	9, 762	840	3, 362	206, 721	2.08	2.40	
February	19, 330	1, 100	5, 470	303, 788	3.39	3. 53	
March	13, 534	2,430	5, 760	354, 169	3.57	4. 11	
April	8,750	2,080	4,530	269, 554	2.81	3. 13	
May	3, 966	1, 280	1,760	108, 218	1.09	1.26	
June	13, 810	1,280	5, 583	332, 211	3.46	3.86	
November	10, 958	920	2, 207	131, 326	1.37	1.53	
December	7,738	1, 340	3, 059	188, 090	1.90	2. 19	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 163, discharge measurements, page 162; rating table in Paper No. 52, page 514.

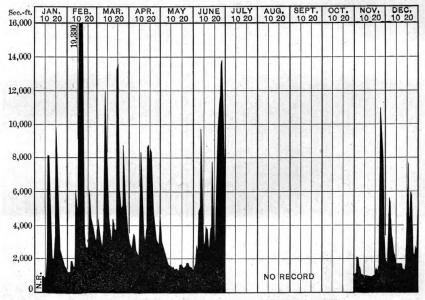


Fig. 80.—Discharge of Oostanaula River at Resaca, Ga., 1900.

Estimated monthly discharge of Coosa River at Rome, Ga.

[Drainage area, 4,006 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	21, 373	2,725	6, 854	421, 436	1.71	1.97	
February	53, 332	2,850	14, 736	818, 396	3.68	3. 83	
March	33, 835	6, 300	14, 714	904, 728	3. 67	4. 33	
April	25,996	5, 755	12,050	717, 025	3. 01	3. 36	
May	11, 122	3,850	5, 129	315, 370	1.28	1.48	
June	35,242	4,000	14, 154	842, 222	3. 53	3.94	
July	19, 765	4,000	7,589	466, 629	1.89	2. 18	
August	5, 580	2,725	3, 488	214, 469	0.87	1.00	
September	20, 971	1,930	3, 960	235, 636	0.99	1.10	
October	10, 519	2,010	3, 408	209, 550	0.85	0.98	
November	21,775	2,600	5, 438	323, 583	1.36	1.52	
December	14, 740	3, 400	7,096	436, 316	1.77	2.04	
The year	53, 332	1, 930	8, 218	5, 905, 360	2.05	27. 73	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 164, discharge measurements, page 163; rating table in Paper No. 52, page 514.

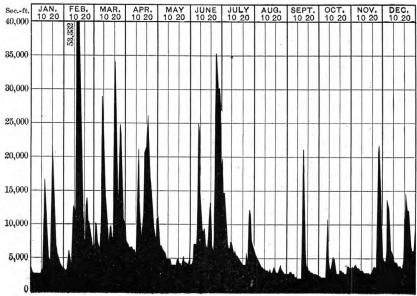


Fig. 81.—Discharge of Coosa River at Rome, Ga., 1900.

Estimated monthly discharge of Coosa River near Riverside, Ala.

[Drainage area, 7,065 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.		
Month,	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	33, 100	4, 280	13, 344	820, 491	1.89	2.18	
February	54, 300	5, 700	23, 487	1, 304, 402	3. 32	3. 45	
March	44,500	13, 450	26, 822	1, 649, 221	3. 80	4.38	
April	65,500	11, 350	29, 813	1, 773, 997	4. 22	4.71	
May	14,850	5, 970	8, 198	504, 075	1.16	1.34	
June	51,500	5, 970	22, 216	1, 321, 944	3.14	3. 51	
July	39, 500	5, 565	13,610	836, 846	1.93	2. 23	
August	12,750	4,050	5, 147	316, 477	0.73	0.84	
September	23, 100	2,760	6, 483	385, 765	0.92	1.03	
October	23, 100	3, 100	6, 910	424, 879	0.98	1.13	
November	29, 900	3, 720	7,673	456, 575	1.09	1. 22	
December	22, 300	5, 835	11,773	723, 894	1.67	1.93	
The year	65, 500	2,760	14, 623	10, 518, 566	2.07	27. 95	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 165, discharge measurements, page 164; rating table in Paper No. 52, page 514.

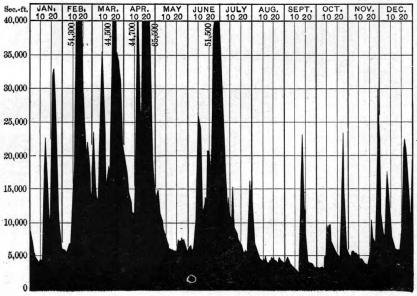


Fig. 82.—Discharge of Coosa River near Riverside, Ala., 1900.

TALLAPOOSA RIVER.

In June and July, 1900, a survey was made under the supervision of B. M. Hall, resident hydrographer, by James R. Hall, field assistant, levelman, and topographer, of 64 miles of Tallapoosa River, from

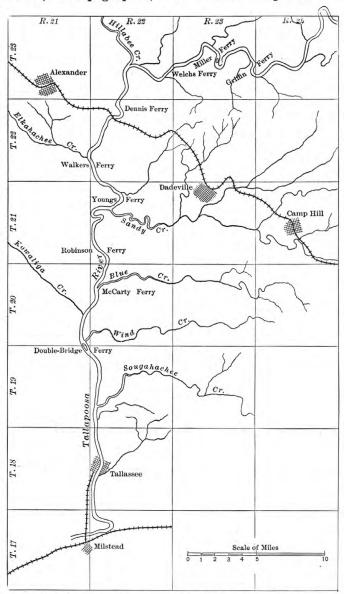


Fig. 83.-Map of Tallapoosa River from top of Griffin Shoals, Ala., to Milstead, Ala.

Milstead, Ala., to the head of the shoals above Griffins Ferry. The results of the survey are shown in the accompanying map, fig. 83, and profile, figs. 84 and 85.

The entire river above Milstead is on granitic bed rock, and has numerous bluffs along its banks forming excellent sites for dams. There are two large developed water powers on the stream, viz, the Tallassee Falls plant and the Montgomery Power Company's plant,

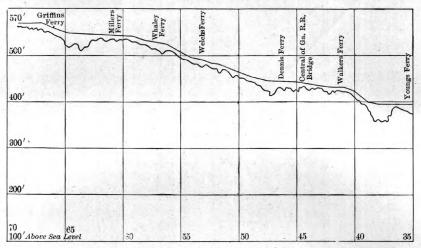


Fig. 84.—Profile of Tallapoosa River from top of Griffin Shoals, Ala., to Milstead, Ala.

both of which are near the lower end of the survey. The Tallassee Falls dam and canal, which are 6 miles above Milstead, utilize a fall of 64 feet and the entire flow of the river during low water. This

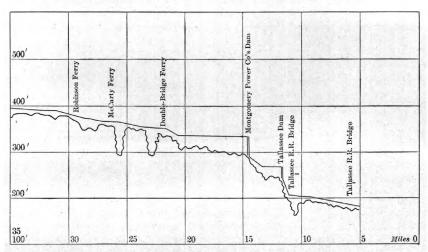


Fig. 85.—Profile of Tallapoosa River from top of Griffin Shoals, Ala., to Milstead, Ala.—Continued.

power and the large cotton-manufacturing plant recently completed are described in the Twentieth Annual Report, Part IV, pages 192 to 193. During low water of October, 1901, this power was realizing 8,900 net horsepower without storage. The Montgomery Power Com-

pany's dam is a 40-foot structure $9\frac{1}{2}$ miles above Milstead. It backs the water $6\frac{1}{2}$ miles up the river and forms an immense storage basin. It is to be completed by December 1, 1901. The water wheels, dynamos, and pole line and wires to Montgomery, a distance of about 27 miles, are installed and ready for work as soon as the dam is completed. With the river at the lowest stage it reached in 1901 the plant will develop at the wheels 5,572 net horsepower without drawing on the storage, which will add fully 25 per cent to this power and to the power at Tallassee for continuous running, without materially lowering the head at either plant.

The following list of distances and elevations of water and bench marks shows the fall of the river from point to point. The total fall in 56 of the 64 miles surveyed is 364 feet.

Elevations and bench marks along Tallapoosa River from Milstead, Ala., to Griffin Shoals.

Dis- tance from Mil- stead.	Description or location.	Bench- mark eleva- tion above sea level.	Eleva- tion above sea level.
Miles.		Feet.	Feet.
6.0	River surface of tailwater at Tallassee mills		206.3
6.2	Water above crest of Tallassee dam		
8.5	Upper end of Tallassee Pond		269.9
9.5	River below Montgomery Power Company's dam		295. 25
9.5	Crest of Montgomery Power Company's dam		335. 25
15.7	Upper end of Montgomery Power Company's pond		
16.5	Water at Double Bridge Ferry	D 4000 0 0 0	The second second
16.8	Water at mouth of Wind Creek.	4 44 7 7 7 7 7	100000000000000000000000000000000000000
16.8	Bench mark No. 7, bunch of mulberry trees at mouth of Wind Creek	0.0000000	
17.8	Bench mark No. 22, crooked willow on small branch at north end of Taylor's field $$	363.30	
17.8	Water at bench mark No. 22		.356.18
18.5	Water opposite mouth of Kowaliga Creek		357.16
18.75	Bench mark No. 33, mulberry 100 feet above old Baker field	371.73	
18.75	Water at bench mark No. 33		359.75
19.4	Bench mark No. 42, willow at Garnetts Ford	364.60	
19.4	Water at Garnetts Ford		360.55
19.7	Bench mark No. 46, pine at mouth of High Falls Branch	373.98	
19.7	Water at "blue hole" at mouth of High Falls Branch.		362.40
20.1	Water at "blue hole" at foot of Long Branch Shoals		362.40
21.0	Bench mark No. 62, mulberry 300 yards above mouth of Long Branch	365.45	
21.0	Water at bench mark No. 62, top of Long Branch Shoals		367.23
21.3	Bench mark No. 70, white hickory at McCartys Ferry, mouth of Blue Creek	376.67	
21.3	Water at McCartys Ferry, mouth of Blue Creek		367.80
23.0	Top of shoal opposite mouth of Peru Branch		
23.8	Water at mouth of Gold Mine Branch		
23.8	Bench mark No. 100, mulberry at mouth of Gold Mine Branch	386.00	
24.4	Bench mark No. 110, water oak at Robinsons Ferry	404.40	
24.4	Water at Robinsons Ferry		380. 20
25.6	Water at top of upper Robinson Shoals		389.10
25.6	Bench mark No. 124, small sycamore at mouth of small branch		
27.7	Water at mouth of small branch in Pace's field.		

Elevations and bench marks along Tallapoosa River from Milstead, Ala., to Griffin Shoals—Continued.

Distance from Mil- stead.	Description or location.	Bench- mark eleva- tion above sea level.	Eleva- tion above sea level.
Miles.		Feet.	Feet.
28.7	Bench mark No. 140, water oak at foot of Hardy Shoals, in Pace's field	414.30	
29.5	Bench mark No. 150, dead stump 100 feet below mouth of Big Sandy Creek	398.08	
29.5	Water at mouth of Big Sandy Creek		393. 80
30.0	Bench mark No. 165, big red oak at Youngs Ferry	413, 50	
30.0	Water at Youngs Ferry.		394.00
31.0	Water at Cherokee Bluff		394.60
31.2	Bench mark No. 175, big walnut 200 yards above Monowa Creek	416.75	
34.0	Bench mark No. 180, 10-inch pine tree at third bar of Seago Shoals	424.72	
34.0	Water at third bar of Seago Shoals, opposite bench mark No. 180		399.92
35.8	Bench mark No. 190, large white oak at east landing at Walkers Ferry	436.90	
35.8	Water at Walkers Ferry		429.65
37.0	Bench mark No. 210, leaning white oak at mouth of small branch at upper end of Upshaw place	438.60	
37.4	Water at bench mark No. 210.		432.00
37.6	Water at top of fish trap		436.47
38. 3	Bench mark No. 215, 16-inch white oak on small branch at upper end of Locke's old field.		
38.3	Water at bench mark No. 215.		438.00
39.3	Water under Central Railroad bridge at Sturdivant, Ala		444. 25
39.3	Bench mark on top of rail over first pier of the east end of Central Railroad bridge		
41.2	Bench mark No. 240, large water oak at east landing of Dennis Ferry	457.15	
41.2	Water at Dennis Ferry		445. 85
42.2	Water at mouth of branch on left bank of river		448.20
45.3	Water 600 feet below mouth of Hillabee Creek		
48.3	Bench mark No. 310, water oak at east landing of Welchs Ferry	504.15	
48.3	Water at Welchs Ferry		492.30
50.0	Bench mark No. 330, beech 150 feet above mouth of Freemans Branch	526.62	
50.0	Water 150 feet above mouth of Freemans Branch		521.04
52.0	Water at Whaleys Ferry		529.48
52.0	Bench mark No. 340, birch at Whaleys Ferry	539.38	
55.4	Bench mark No. 350, 10-inch birch at Millers Ferry	552.16	
55.4	Water at Millers Ferry		544.00
60.8	Water at Griffins Ferry		
60.8	Bench mark No: 380, double ash tree on left bank at Griffin Ferry	564.76	
62.0	Bench mark No. 390, 12-inch birch at head of Griffins Shoais	573.87	
62.0	Water at head of Griffins Shoal		570.30

Surveys have been made for a large dam, 35 or 40 feet in height, at or near Double Bridge Ferry, to back the water beyond Robinsons Ferry, a distance of about 8 miles up the river. There is an excellent site for a dam, and the project is entirely feasible.

Estimated monthly discharge of Tallapoosa River near Susanna, Ala.

[Drainage area, 2,610 square miles.]

	Discharge in second-feet.				Run-off.		
Month.	Maxi- mum. Mini- mum.		Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
July 27 to 31			8, 364				
August	19, 130	1,680	3, 258	200, 327	1. 25	1.44	
September	45,680	1,570	6,083	361, 964	2. 33	2.60	
October	20,030	1,570	4,776	293, 665	1.83	2. 11	
November	15,080	1,885	3,676	218, 737	1.41	1.57	
December	19, 130	2,520	6, 288	386, 634	2.41	2.78	
						1	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 167, discharge measurements, page 166; rating table in Paper No. 52, page 514.

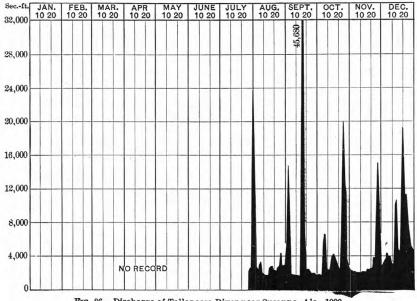


Fig. 86.—Discharge of Tallapoosa River near Susanna, Ala., 1900.

Estimated monthly discharge of Tallapoosa River near Milstead, Ala.

[Drainage area, 3,840 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum. Mini- mum.		Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	10, 335	2, 125	3, 728	229, 226	0.97	1.12	
February	48, 305	2, 237	12, 950	719, 206	3. 37	3.50	
March	17,650	5, 723	10, 208	627, 665	2.66	3, 07	
April	18,775	4,712	9,016	536, 489	2. 35	2.62	
May	6, 736	2, 462	3, 718	228, 611	0.97	1.12	
June	27, 831	2,575	8, 317	494, 896	2.17	2.42	
July	11,572	2, 462	5, 405	332, 340	1.41	1.63	
August	6,960	1,675	2,814	173, 026	0.73	0.84	
September	28, 447	1,337	4, 975	296, 033	1.30	1.45	
October	13, 262	1, 337	3, 787	232, 854	0.99	1.14	
November	11,460	2, 462	4, 224	251, 345	1.10	1. 23	
December	18, 775	2,800	6, 475	398, 132	1.69	1.95	
The year	48, 305	1, 337	6, 301	4, 519, 823	1.64	22, 09	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 168; rating table in Paper No. 52, page 514.

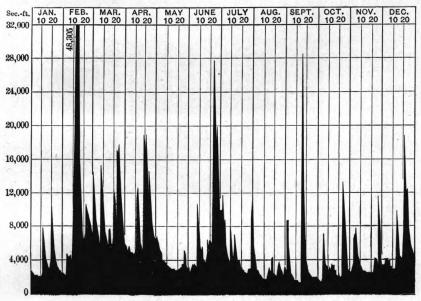


Fig. 87.—Discharge of Tallapoosa River near Milstead, Ala., 1900.

Estimated monthly discharge of Black Warrior River at Tuscaloosa, Ala.

[Drainage area, ,900 square miles.]

	Discharge in second-feet.				Run-off.		
Month.				Total in acrefeet.	Second-		
	Maxi- mum.	Mini- mum.	Mean.		feet per square mile.	Depth in inches.	
1900.							
January	29, 760	2,277	9,857	606, 083	2.01	2. 32	
February	76, 312	2,555	18, 356	1, 019, 440	3. 75	3.90	
March	87, 750	8, 280	27, 105	1, 666, 623	5.53	6. 37	
April	136, 687	5, 302	48, 426	2, 881, 547	9.88	11.02	
May	11,825	1,645	3,702	227, 627	0.76	0.88	
June	115, 312	2,138	32, 614	1, 940, 668	6.66	7. 43	
July	52,000	2,888	10,952	673, 412	2. 24	2. 59	
August	5,245	750	1,674	102, 930	0.34	0.39	
September	5, 680	512	1,580	94, 017	0.32	0.36	
October	13,000	355	3, 382	207, 951	0.69	0.80	
November	12,700	977	3,701	220, 225	0.76	0.85	
December	10, 150	2,721	5, 119	314, 755	1.05	1. 21	
The year	136, 687	355	13,872	9, 955, 278	2. 83	38. 12	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 171; rating table in Paper No. 52, page 514.

BIG SANDY CREEK.

A survey made in July, 1900, of Big Sandy Creek from its mouth to the new bridge near Dadeville, Ala., showed a total fall of 157 feet in a distance of 65,000 feet, or about 12 miles. The profile resulting from

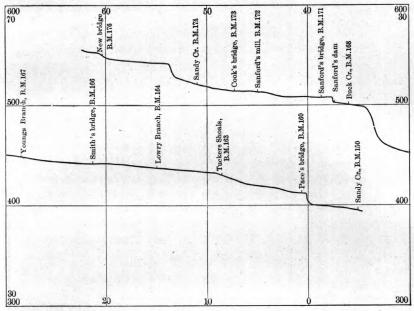


Fig. 88.—Profile of Big Sandy Creek from mouth to new bridge near Dadeville, Ala.

the survey is reproduced in fig. 88. The following list of distances and elevations of water and bench marks shows the fall of the creek from point to point:

Elevations and bench marks along Big Sandy Creek between its mouth and the new bridge near Dadeville, Ala.

Distance above mouth	Description or location.	Bench- mark eleva- tion above sea level.	Eleva- tion above level.
Feet.		Feet.	Feet.
- 0	Bench mark No. 150, dead stump at mouth of creek	398.08	
0	Water at mouth of Big Sandy Creek		393.80
5,000	Water below Pace's dam		402.00
5,000	Water above Pace's dam		412.10
5,600	Bench mark No. 160, big pine on north side, 175 feet above Pace's bridge	422.30	
8,000	Creek surface.		416.00
10,000	At point of Ivy Bend		419.00
11,700	Bench mark No. 162, large walnut at Tucker's house	503.85	
13,500	Bench mark No. 163, small oak at Tucker's fish trap	432.85	
13,500	Water above Tucker's fish trap		430.00
20,000	Bench mark No. 164, large sycamore at mouth of Lowry Branch		

Elevations and bench marks along Big Sandy Creek between its mouth and the new bridge near Dadeville, Ala.—Continued.

Distance above mouth	Description or location.	Bench- mark eleva- tion above sea level.	Eleva- tion above level.
Feet.		Feet.	Feet.
20,000	Water at mouth of Lowry Branch		436.10
26,500	Bench mark No. 166, oak post at north end of Smith's bridge		
26,500	Water at Smith's bridge.	1 1 1 1 1 1 1 1 1	441.70
26,500	Zero of U.S.G.S. gage at Dadeville.	(
33,500	Bench mark No. 167, wahoo tree at mouth of Youngs Branch	4	
33,500	Water at mouth of Youngs Branch.		446.50
35, 360	Water at Barnes Basin		
37, 930	Water at foot of Black Shoals		465.00
39, 300	Water at top of Black Shoals		Charles and the second
41,100	Water at mouth of Buck Creek		
41,100	Bench mark No. 168, small double oak at mouth of Buck Creek		
41,900	Eddy water below Sanford's dam		500, 00
42,550	Bench mark No. 169, hickory at Sanford's mill	. 522.10	
42,550	Floor of Sanford's mill .	A CONTRACTOR OF THE PARTY OF TH	
43,770	Water at Sanford bridge above dam		506.70
45,580	Water at head of Sanford Pond		506. 70
50,000	Water at second shoal above Sanford Pond		512.50
52, 340	Bench mark No. 173, large white oak near north end of Cook's bridge	I Comment	
52, 340	Water at Cook's bridge		513.80
56, 120	Water opposite mouth of Chattasofka Creek		520, 60
56, 120	Bench mark, 16-inch water oak on west bank of Chattasofka Creek, 50 feet above mouth		
58, 620	Water at top of old factory shoal		540.15
65, 350	Water at new bridge		550.80
65, 350	Bench mark on upstream end of sill on west end of new bridge	. 562.30	
65, 350	Bench mark No. 176, 6-inch maple at new bridge	563,00	

Estimated monthly discharge of Big Sandy Creek near Dadeville, Ala. [Drainage area, 195 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
August	655	80	207	12,728	1.06	1. 22
September	3, 150	80	355	21, 124	1.82	2.03
October	2,670	80	264	16, 233	1.35	1.56
November	870	110	261	15, 531	1.34	1.50
December	3,870	150	560	34, 433	2.87	3. 31

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 174; rating table in Paper No. 52, page 514. For hydrograph see page 210.

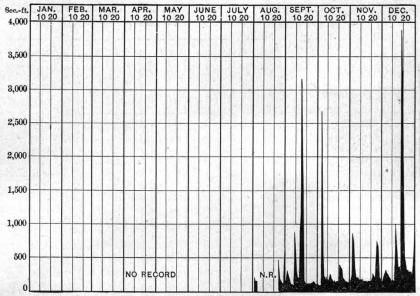


Fig. 89.—Discharge of Big Sandy Creek near Dadeville, Ala., 1900.

MISSISSIPPI RIVER DRAINAGE.

The drainage basin of the Mississippi includes so large a portion of the United States that it is found convenient to divide it, cutting off for separate description the Ohio, the Upper Missouri, the Platte, the Kansas, and the Arkansas. The results of measurements made within those basins during the year 1900 are given on the following pages, beginning on page 219. In the remaining portion of the drainage basin, including the Upper Mississippi and its tributaries, as well as the main trunk stream, comparatively few measurements of flow have been made.

The vast extent of the basin of the Mississippi is shown in Pl. XVI, on which the river and its principal tributaries have been accentuated by black lines. The Ohio, coming in from the east, is seen to be comparatively short, with small catchment area; the Upper Mississippi, in the center, is longer and has a larger drainage basin; while the Missouri reaches far to the westward and has a still greater country tributary to it. In volume of flow, however, the streams are in reverse order to their length and catchment area, the Ohio being the largest river and the Missouri the smallest.

HYDROGRAPHY OF THE MISSISSIPPI ABOVE ST. PAUL, MINN.

The hydrographic investigations of the United States Engineers on the Upper Mississippi extend over a period of thirty-two years, from 1866 to 1898, and form, according to the Report of the Chief of

Compiled by C. R. Olberg from the Annual Reports of the Chief of Engineers, United States Army.

U. S. GEOLOGICAL SURVEY

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MAP SHOWING DRAINAGE BASIN OF MISSISSIPPI RIVER.

Engineers for 1897, "the largest continuous record over large drainage areas that has been made in the United States." These investigations not only deal with the discharge of streams and their fluctuations, but also treat extensively of the meteorology of the region. Numerous records of evaporation under various conditions have been made, and considerable attention has been paid to the flow of water under ice, also to the relation of mid-depth velocity to mean velocity.

Minnesota, the State in which most of these observations have been made, is peculiar in that it is the summit divide of North America, at least so far as the United States is concerned, its watersheds draining into Hudson Bay on the north, into the Great Lakes on the east, and through the Mississippi into the Gulf of Mexico on the south, and also in that it has the largest water surface of any State or Territory of the Union, the average, exclusive of Lake Superior, being 1 square mile of water to every 15 square miles of land. The State forms part of an immense glacial plateau occupying that region of the United States, and includes within its borders most of the drainage area of the Mississippi above Lake Pepin. Almost the entire State is covered with glacial drift, the only exception being in the extreme northeastern and southeastern portions and patches in the valleys of Mississippi and Minnesota rivers, where those streams have cut down through the overlying strata to the bed rock. In general the drift consists of till, a confused mixture of sand, gravel, and clay, which lies upon the bed rock in a sheet varying in thickness from 100 to 300 feet. The surface of this drift sheet forms an immense somewhat undulating plain, the irregularities of which are very slight when compared with its thick-These irregularities, which appear to have had their origin in the accumulation of the till, form long, low swells and hollows of varying extent and direction. Many of the depressions have no outlet, and to them are due the multitude of swamps and lakes that dot the State. The general changes in altitude, however, which affect the whole country and give direction to its drainage, are doubtless due to differences in the height of the underlying rocks rather than to surface irregularities, although a great glacial moraine, in the form of low hills, extends across the drift plain, nearly coincident with the divide separating the basin of the Upper Mississippi from that of the Minnesota, and again appears near the headwaters of the Mississippi to the west of Lake Itasca. In general the drift plain rises and falls imperceptibly, its average inclination being not more than 50 feet in as many miles. To the west and southwest of Lake Itasca, however, where it is coincident with the main divide of the State, it reaches a height of 1,600 or 1,700 feet above the sea. The average elevation of the State is probably about 1,275 feet, while the lowest land in it, on the borders of Lake Superior, has an elevation of 602 feet.

By far the largest and most important of the drainage systems in

the State is that of the Mississippi, its whole area being approximately 45,566 square miles, including most of the watershed formed by the glacial deposits in the central portion of the State. The Upper Mississippi drains the timbered regions, the Minnesota the southern prairie portions. To the Falls of St. Anthony the Mississippi flows almost exclusively through the drift. From there until it leaves the State it flows in an old rocky valley excavated in pre-Glacial times. All of the tributaries below the Falls of St. Anthony enter it through deep-cut gorges. The other tributaries, however, are partly of glacial origin, and have excavated their valleys but little into the drift sheet.

The Mississippi has its source in Lake Itasca, in Beltrami County. It flows northerly in a great bend, until its waters enter Cass Lake from the northwest, 135 miles from Lake Itasca. In this distance it falls 172 feet and flows through many small lakes, its banks, which are from 10 to 20 feet high, being generally wooded. From Cass Lake to Lake Winibigoshish, a distance of 20 miles, the river falls 10 feet. After leaving Lake Winibigoshish it flows between high banks, but in about 2 miles it widens out into Little Winibigoshish Lake, a small body of water about 1.5 miles long and three-fourths of a mile broad. Lying just south of Cass and Winibigoshish lakes, and separated from them by a narrow ridge of land 30 feet high, is Leech Lake, an irregular sheet of water with a surface area of 195 square miles. Its outlet is Leech Lake River, a stream about 35 miles long with a fall of 13.6 feet, which connects the lake with the Mississippi. Leech Lake River is very tortuous, flowing back and forth through high reed and rice fields.

From Little Lake Winibigoshish to its junction with Leech Lake River, a distance of about 25 miles, the Mississippi flows through a broad savanna from 1,000 to 5,000 feet wide, and falls 11.1 feet. From Leech Lake River to Pokegama Falls, a distance of 45 miles, the river falls only 13.66 feet, is very tortuous, and flows through high reed and rice fields, except about 20 miles below Leech Lake River, where Vermilion River enters from the south, and where, just below the mouth of the latter stream, the banks are high and close together. At White Oak Point, however, the banks separate to a width of more than 2 miles, and the space not filled by the river is a vast reed field. About 3 miles above Pokegama Falls is Pokegama Lake, with a water surface of about 15.66 square miles, and about 2.6 feet higher than the water surface just above Pokegama Falls. The banks are generally high, except for about a mile at the southeast end, where the dividing ridge between it and the Mississippi is only about 8 feet above the lake. This dividing ridge is of sand. At Pokegama Falls the river runs over a ledge of sandstone, and the fall is about 14 feet in 880 feet. The whole country in the vicinity of the river and the lakes described is densely wooded, on the highest ground with Norway

pine mixed with a large amount of sugar maples, hard maples, birch, and poplar. The ridges traverse great tamarack swamps and quaking bogs. The soil is generally sandy, but clay crops out here and there on the banks.

Below Pokegama Falls the river has very different characteristics from those already described. The banks are higher, marshes are less frequent, and a true valley exists. Between Pokegama Falls and the Falls of St. Anthony the river is naturally divided into two sections—that from the town of Grand Rapids to Aitkin, a distance of 165 miles, and that from Aitkin to the Falls of St. Anthony, a distance of 208 miles.

The immediate valley of the upper reach of the river is very narrow and is bounded by low hills until the flat region bordering Sandy Lake is reached. The river is very crooked and narrow, its folds approaching quite close together in several places, and was originally obstructed by bowlders, snags, and overhanging trees, as well as by six rapids, the principal one of which—Grand Rapids—occurs at the town of that name, 3 miles below Pokegama Falls. The principal tributary streams between Pokegama Falls and Aitkin are Prairie, Wild Swan, Sandy Lake, and Mud rivers from the east and Split Hand River from the west. From Rice River to Pine Knoll, 16 miles below the mouth of Mud River, the Mississippi is a sluggish, tortuous stream flowing through low marshy ground. It has a good channel, however, and its banks are fairly high, and are covered with a growth of soft-wood trees. It is about 200 feet wide, its bottom is slightly covered with sand or mud, and it falls at the rate of 0.24 foot per Sandy Lake is in the region between Rice River and the Mississippi.

At Aitkin the character of the river and the country again changes. Sandy bluffs from 20 to 60 feet in height appear, and the river becomes more rapid and wider. From Aitkin to the Falls of St. Anthony it passes over a succession of rapids and riffles which divide it into sixteen reaches. From Mud River its general course is about due west, until it reaches the mouth of Pine River, about 20 miles below Aitkin, when it takes a sharp turn to south-by-east.

Pine River is a rapid stream, entering the Mississippi from the north. Its drainage area is 788 square miles and during the low water of 1874 it discharged 728 cubic feet per second. From the mouth of Pine River to the head of the Big Eddy Rapids, a distance of 9 miles, the average slope is 0.8 foot per mile. The adjacent country is much broken, especially on the right bank, which is considerably higher than the left. The Big Eddy Rapids are in a straight part of the river, where it is narrow and deep, with a slope for a half mile at the rapids of 5.15 feet per mile. A half mile below these rapids are the Island Rapids. There the water is very shallow and the fall 4.62 feet per

mile for 800 feet. At the foot of the latter rapids Rabbit River comes in from the east, and a little farther below are the French Rapids, with a slope of 7.4 feet per mile for 1,000 feet. At the foot of the latter rapids the river is shallow. Three-fourths of a mile below the French Rapids is French Bar, where for 500 feet the fall is 10 feet per mile and the river is broad and shallow. Three-fourths of a mile below French Bar is Brainerd, at which place the Northern Pacific Railroad crosses the river. The distance from Mud River to Brainerd is 27 miles by railroad; by river it is 55½ miles. The elevation of the low water of 1874 at Brainerd was 1,169.60 feet above the sea.

From Brainerd to Crow Wing the slope is 0.87 feet per mile. The river flows between high banks of sand, covered with Norway and Jack pines. Below Brainerd the country becomes more open, some prairie land approaching the river. Sixteen and a half miles below Brainerd Crow Wing River enters from the west. This is the largest affluent of the Mississippi above the Falls of St. Anthony. It drains a country 3,562 square miles in extent. At the time of low water in 1874 its discharge was 2,699 cubic feet per second, and its width just above the island which divides it at its mouth was 250 feet. Its waters are very clear, in strong contrast to those of the Mississippi, with which they do not really mingle for a distance of about 4 miles below their junction. The low-water discharge of 1874 of the Mississippi 3\(^2\) miles below Crow Wing was 7,099 cubic feet per second.

From Crow Wing to Fort Ripley, a distance of 9 miles, the river has a slope of 0.8 foot per mile. Fort Ripley is on a bluff 20 feet high, on the right bank of the river, nearly opposite the Nankesele. From Fort Ripley to Fort Anthony there is a notable difference in the amount of timber and in the height of the bluffs on both sides of the river, the west bank being the lower and the more heavily timbered until Sauk Rapids is reached; from there down the west bank is the higher as well as the more heavily timbered. From Fort Ripley to St. Cloud the river is a series of rapids, the intervening pools also having steep slopes. Two and a half miles below the fort is Olmstead Bar. Here the river is broad and shallow, with a slope of 4.75 feet per mile, and for the first time since leaving Pokegama Falls rock in place is seen. It is a trap dike, and extends 300 feet from the west bank into the stream. From the head of Olmstead Bar for 4 miles the average slope is 4.14 feet per mile. In this distance there are fifteen islands, all heavily timbered, which are submerged at high water.

Nine miles below Fort Ripley are the Comadis Shoals. Just above them, for a distance of 2 miles, the slope of the river is only 0.96 foot per mile. The fall of the river at the shoals is 4.74 feet in 1,500 feet. From this bar to the Little Elk Rapids the distance is 2.1 miles. Just above the Little Elk Rapids Little Elk River comes in from the west.

Here the bed of the stream is rock in place. The river now fairly enters its passage across the outcrop of the great dike of crystalline rocks, which it leaves just below St. Cloud. By river this distance is 614 miles. Generally speaking, the rock is not visible much above the water on either bank, being for the most part covered with drift. Below St. Cloud are the Elk Rapids, the Little Falls, and the Pine Rapids. The Little Falls are near the town of that name. They have a descent of 1.8 feet per mile for 3.17 miles. About 4.7 miles below the Little Falls are the Pike Rapids, with a slope of 3.4 feet per mile. Just above these rapids Swan River comes in from the west. Three more rapids occur, and then the river has a good channel for 20.8 miles. with an average slope of 1.5 feet per mile. In this distance the affluents of any importance are Two Rivers from the west and Platte River from the east. The latter drains a watershed of 110 square miles. Below it Little Rock Creek enters from the east. About 1\frac{1}{8} miles above Little Rock Creek rock appears in place. Next come the Wetab Rapids, caused by the river falling over a rocky bed on a slope of 2 feet in 800. From the foot of these rapids to the Sauk Rapids, a distance of 4 miles, the average slope is 2.5 feet per mile, the maximum slope being 5.81 feet per mile for a distance of 1.525 feet.

Just above Sauk River, which joins the Mississippi a short distance below the Wetab Rapids, the low-water discharge of the river in 1874 was 9,202 cubic feet per second. At the Sauk Rapids the river passes over a rocky bed on a slope of 17 feet in 4,000. Near the Sauk Rapids is located the town of that name. For nearly 3 miles below these rapids the river banks on both sides are 60 feet high, but their height decreases just below St. Cloud. From the latter place to the Falls of St. Anthony the river bed is in an eroded valley, seldom exceeding a mile in breadth and frequently reduced to little more than the width of the river. A cross section of the valley generally shows a terraced bench from 20 to 30 feet above the river, intermediate in elevation between the river banks and the table-lands. The river bed inclines to the right of the center line of the valley, making the western slope more precipitous than the eastern. Bottom lands are almost entirely wanting, and the river banks are strongly defined, retaining floods entirely within their lines.

Islands are of frequent occurrence. In the upper part of the river they are found in groups of from three to five; in the lower part they usually occur singly, but are of greater area. The river bed, except in the vicinity of the islands, is covered with very coarse drift, varying in size from pebbles a few inches across to bowlders several feet in diameter. Near the islands the bed is usually sandy, or of less stable material than the bed of the undivided river. The most notable of the islands are the Thousand Islands, which are a short distance below Sauk Rapids.

Numerous rapids occur in the river between Sauk Rapids and the Falls of St. Anthony. The principal ones are the Cedar Island Rapids, the Dayton Rapids, the Anoka Rapids, and the Coon Rapids. The Anoka Rapids are near the town of that name; the Dayton Rapids are 10 miles above, near Dayton; the Coon Rapids are 2.5 miles below the Anoka Rapids, and form the worst obstruction to navigation between the Falls of St. Anthony and Sauk Rapids. The fall is 6.9 feet in 3,600, and the bed of the river is thickly covered with bowlders, the worst of which, however, were removed by the United States engineers in 1874. The river widens from 675 feet above the rapids to 900 feet below them.

The principal tributaries between Sauk Rapids and the Falls of St. Anthony are Elk and Rum rivers from the east and Clearwater and Crow rivers from the west. At the mouth of Clearwater River is located the town of that name. Dayton is at the mouth of Crow River, while Anoka is at the junction of Rum River and the Missis-

sippi.

Rock in place is found at Sauk Rapids, and forms the bed of the river for a distance of 2,000 feet. Disappearing from the surface it again appears over a very limited area at the head of the Thousand Islands. Rock is next seen in place about 3 miles above the Falls of St. Anthony, where it occurs as the St. Peter sandstone. Disappearing, it again crops out at the head of Nicollet Island, with Trenton limestone superposed. In this position it forms the bed and banks of the river at the Falls of St. Anthony. The limestone forms the bed of the river immediately above the falls, and undoubtedly in the past has formed its bed for an indefinite distance below them, but the water falling over the crest of the falls rapidly wears away the fragile sandstone, and the limestone losing its support separates at its quarry face seams and falls in great blocks into the rapids below. In 1879 the crest of the falls was 1,200 feet from the northern limit of the limestone stratum. If this remnant were once broken through the falls would cease to exist as a distinct cataract, but would stretch out in a long rapid. The sandstone exposed to the full force of the current would rapidly disappear, and changes impossible to predict would occur in the bed of the river above the falls. To prevent this large sums of money were expended by the power companies and the citizens of Minneapolis, and finally the preservation of the falls passed into the hands of the Government, after which Congress from time to time appropriated sums of money, which were spent in their improvement, until in 1879 the danger of their destruction had become very slight.

At the falls the river is divided into two parts by Nicollet Island, which extends somewhat below them. A small opening occurs between the head of Hennepin Island and the foot of Nicollet Island. The direct

fall is about 45 feet. Between the foot of the falls and the head of Meekers Island the fall is 35 feet, in the next 5 miles it is 15 feet, and in the next 6½ miles it is 4 feet. One and a half miles below the falls is the Minneapolis Landing. It is claimed that during the early days 1,200 tons of freight were delivered at this landing during a single season, but the unimproved river to St. Paul, a distance of 13.5 miles, is so difficult of navigation that now all heavy freight goes by rail. The channel is divided by several islands, and is occupied by log and sheer booms, cribs, etc. The river is very swift, and at low water is quite shallow. For several miles below Minneapolis the channel is paved with water-logged slabs and edgings, refuse from the mills at Minneapolis.

The Minnesota flows into the Mississippi on its right bank, 10 miles below the Falls of St. Anthony. It is the largest tributary of the Upper Mississippi, its drainage area of 16,350 square miles and that of the Mississippi forming two distinct watersheds. The combined area of the catchment basins of the two rivers at St. Paul is 36,085 square miles.

St. Paul is the present head of navigation of the Mississippi. From there to the head of Lake Pepin the stream is winding and the current gentle, flowing over a sandy bottom, which gives rise to numerous bars. Major Mackenzie, of the United States Engineer Corps, has furnished the Board of Engineers with a valuable series of low-water measurements extending from 1868 to 1886, giving the depth of water on these bars, with the corresponding Signal Service gage reading at St. Paul. The table, with a diagram illustrating it, is given in the Report of the Chief of Engineers for 1887, page 1685. The principal of these bars are the Frenchman and Pig's Eye bars near St. Paul; then follow the Newport, Pine Bend, Hastings, Prescott Island, Smiths, Diamond Cliff, and Waconta bars.

From St. Paul to Hastings, a distance of 27 miles, the slope of the river is 0.53 foot per mile. Near Hastings St. Croix River empties into the Mississippi from the east. About 40 miles farther down, or at the foot of Lake Pepin, Chippewa River enters the Mississippi. Below this lake there is at all times sufficient water for navigation purposes, but above, between Lake Pepin and St. Paul, steamboats of ordinary draft experience great difficulty in ascending the river. To overcome this, large expenditures have been made by the Government, in the construction of contraction works, consisting of cribs, revetments, etc., designed to narrow the channel of the river, also in building dams to convert the lakes at the headwaters of the river into reservoirs.

The improvement of low-water navigation between Lake Pepin and St. Paul, as well as on the Mississippi above the Falls of St. Anthony, by means of artificial reservoirs first received attention shortly after the close of the Civil War. Surveys to obtain the needful data were begun in 1866, and were prosecuted until 1870 by General Warren. In 1874 they were continued by Major Farquhar, in connection with the examination for transportation routes to the seaboard. In 1878 Congress made appropriations for a still more elaborate investigation, and Major Allen was placed in charge of the work. Finally Congress, by act of June 14, 1880, inaugurated works of construction. The project contemplated the creation and maintenance of reservoirs upon the headwaters of the Upper Mississippi, the St. Croix, the Chippewa, and the Wisconsin, for the purpose of regulating the volume of water and improving the navigation of those rivers as well as that of the Mississippi. It was thought that the surplus water and the spring and winter precipitation would, when released systematically, be of sufficient quantity to benefit low-water navigation upon the reaches of the several streams below the dams, and ultimately, in connection with other works of improvement, benefit the main Mississippi for a considerable distance below St. Paul. Control of extended floods or freshets covering long reaches of river was, however, not expected. The works planned comprised in all forty-one reservoir dams in Minnesota and Wisconsin, of which the estimated first cost, exclusive of land and damages, was \$1,809,083. Of the seven artificial dams originally proposed for the Upper Mississippi system four are now complete, viz, one on the main stream just below Lake Winibigoshish and 170 miles below Lake Itasca, another 15 miles farther down, in a southwesterly direction, where Leech Lake River emerges from the largest natural lake of the region, another on the Mississippi about 30 miles, in a straight line, to the eastward, just above Pokegama Falls, and the fourth one on Pine River, just below Cross Lake. The water from the last reservoir discharges into the Mississippi about 190 miles below Pokegama Falls, midway between Aitkin and Brainerd. As two of the seven reservoirs originally contemplated were tributary to the reservoir at Pokegama Falls, they were dispensed with by raising the dam at the falls, the capacity of the reservoir thus formed, together with Winibigoshish and Leech lakes, being sufficient to collect the water above Grand Rapids. A third dam, originally to be located below Gull Lake, which discharges into the Mississippi through Crow Wing River, was also abandoned, as is was found that the damage to private lands would be excessive. In place of the Gull Lake reservoir, a comparatively inexpensive reservoir was constructed at Sandy Lake, 110 miles below Pokegama Falls. This reservoir was completed in 1895, and with it the system of storage reservoirs on the headwaters of the Upper Mississippi. Although the system did not have quite the desired effect, in consequence of which the construction of reservoirs upon the headwaters of the other streams has been abandoned, yet it has materially aided navigation in times of low water.

Discharge measurements of Upper Mississippi River and tributaries.

Stream.	Locality.	Date.	Area of drainage basin.	Height above mean low water.	Dis- charge.
	NAME OF THE OWNER OWNER OF THE OWNER OWNE		Sq. miles.	Feet.	Secft.
Mississippi River	Above Cass Lake	Sept. 8, 1874		(a)	517
Do	Below Cass Lake	Aug. 22, 1874		1.85	891
Do	Below Lake Winibigoshish	Oct. 14, 1878	1,442	0	541
Do	Above junction of Leech Lake River.	Oct. 16, 1878		0	548
Do	do	Oct. 21, 1878			622
Do	do	Sept. 21, 1879			308
Do	River.	Oct. 21, 1878		0	908
Do		Sept. 26, 1874		3.9	1,953
Leech Lake River	First station	Aug. 15, 1874		1.5	610
Do		Sept. 21, 1878		0	294
Do	Second station	Sept. 26, 1874		(a)	1,239
Mississippi River	Below Vermilion River	Oct. 26, 1878		0	922
Do	Above Pokegama Falls	Oct. 12, 1874	3, 298	2.5	2,474
Do	do	Dec. 24, 1883	3, 298	0	472
Do		Oct: 15, 1874		(a)	2,525
Do	do	Oct. 15, 1879		-0.4	969
	do	Oct. 13,1880		0.9	1, 367
	do	Nov. 4, 1880		1.1	1, 467
	do	Oct. 18, 1881		3.5	2,090
Do	Below Swan River	Oct. 20, 1874		(a)	2,969
	Ox Bow Portage Rapids	Oct. 22, 1881		5.0	3, 375
Do	Below Sandy Lake	Oct. 27, 1874		(a)	2,946
Do		Oct. 18, 1879		()	1,159
Do		Nov. 3, 1874		(a)	3, 784
Do		July 1, 1879	6,798	(a) 7.5	4, 362
Do		Oct. 20, 1879	6,798	0.2	1,74
Pine River		1874	5, 621	0.2	1,062
Do		Sept. 25, 1880	5, 621	0.3	15
	At Brainerd	June 3, 1875	7, 173	8.6	13, 171
Do	do	July 8, 1875	7,173	3, 3	5, 844
Do	Above Crow Wing River	Feb. 25, 1882	7, 283	3.0	1, 90
	do	May 23, 1882	7, 283	8.8	10, 837
Do	At mouth	Feb. 23, 1882	3,576	3.0	891
Do		May 13, 1882	3,576	7.7	10, 160
Gull River		Nov. 15, 1874	5,570	1.1	257
		Aug. 21, 1880		0.5	128
Do	At Sauk Rapids		19 070	7.22	27, 588
Mississippi River Do	do	June 7, 1875 Oct. 26, 1880	13,872 13,872	1.0	4, 13
Do	Friedleys Bar, 5 miles above	May 30, 1875	20,062	6.7	30, 737
Do	St. Anthony Falls.	Tule 1 1005	00 000	4.8	21,610
		July 1,1875	20, 062 20, 062	0	3, 115
Do	Minneapolis, 1,600 feet above	Mar. 9, 1881 Jan. 11, 1884	19,731	0	2, 33
	St. Anthony Falls.	- LI, 1001	20, .01		=,00.
Minnesota River	At Fort Snelling	Nov. 11, 1879	16,081	b 2.1	760
Mississippi River		Oct. 22, 1878	36, 081	b 1.8	6, 218
Do		June 9, 1880	36, 081	11.0	46, 519
st. Croix River		Jan. 25, 1882	00,001	0	2, 52
Do	dodo	May 13, 1882		7.0	35, 77
DU		may 10, 1002		1.0	00, 110

a High water.

b St. Paul gage.

OHIO RIVER DRAINAGE.

Systematic measurements have been made on a number of the larger rivers tributary to the Ohio which rise in the southern Appalachian Mountains and flow in a north or a westerly direction. The sources of these streams are in general at very high elevations, their upper courses being through narrow V-shaped valleys, with frequent falls and with high and rocky banks. A large part of their drainage areas is forest covered, and owing to the steep slopes only a small percentage of the upper basins can ever be used for farming purposes. The flow of the rivers fluctuates rapidly, and nearly all of them are subject to floods and to extreme low water.

Estimated monthly discharge of Youghiogheny River at Friendsville, Md. [Drainage area, 295 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefect.	Second- feet per square mile.	Depth in inches.	
1900.							
January	1, 942	640	1,085	66, 714	3. 68	4. 24	
February	2,512	515	1, 166	64, 756	3. 95	4.11	
March	2,740	865	1,435	88, 235	4.86	5. 60	
April	1,372	400	734	43, 676	2.49	2.78	
May	575	300	407	25, 025	1.38	1.59	
June	2,854	170	701	41,712	2.38	2.65	
July	1,050	130	327	20, 106	1.11	1.28	
August	455	130	222	13,650	0.75	0.86	
September	130	65	92	5, 474	0.31	0.35	
October	. 255	95	148	9, 100	0.50	0.58	
November	5, 590	170	743	44, 212	2.52	2.81	
December	3, 310	255	1,014	62, 348	3. 44	3.96	
The year	5, 590	65	673	485, 008	2. 28	30. 81	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 177, discharge measurements, page 176; rating table in Paper No. 52, page 514.

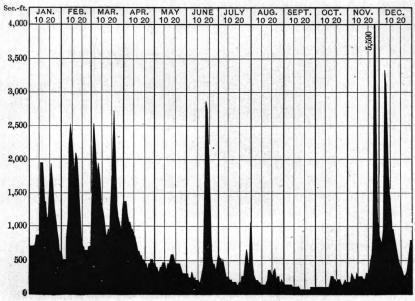


Fig. 90.—Discharge of Youghiogheny River at Friendsville, Md., 1900.

Estimated monthly discharge of Greenbrier River at Alderson, W. Va. [Drainage area, 1,344 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	9,500	387	1,692	104, 037	1.26	1.45
February	15, 260	387	3,372	187, 271	2. 51	2.61
March	16, 450	1, 205	4, 969	305, 532	3.70	4. 27
April	3,960	685	1,867	111,094	1.39	1.55
May	1,710	315	652	40,090	0.49	0.56
June	7, 350	280	1, 137	67, 656	0.85	0.95
July	4,080	120	813	49, 989	0.60	0.69
August	987	102	223	13, 712	0.17	0. 20
September	425	60	144	8, 569	0.11	0.12
October	3,480	102	388	23, 857	0.29	0. 33
November	62, 450	145	3, 795	225, 818	2.82	3. 15
December	12,500	547	1,917	117, 872	1.43	1.65
The year	62, 450	60	1, 747	1, 255, 497	1. 30	17.53

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, pages 178 and 179; rating table in Paper No. 52, page 515.

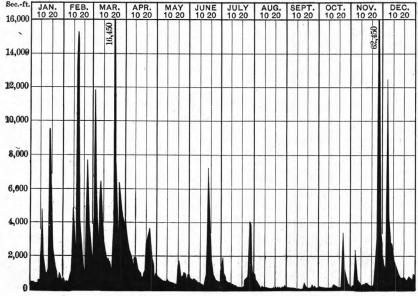


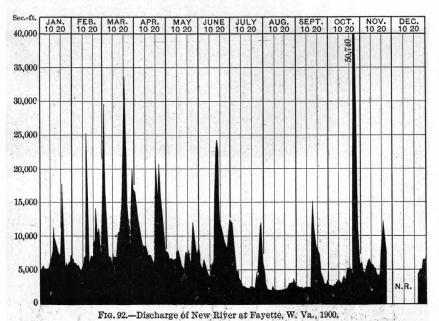
Fig. 91.—Discharge of Greenbrier River at Alderson, W. Va., 1900.

Estimated monthly discharge of New River at Fayette, W. Va.

[Drainage area, 6,200 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.		
Month.	Maxi- Mini- mum. mum.		Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	17,805	4,940	7, 263	446, 584	1.17	1.35	
February	25, 310	5,030	8,656	480, 730	1.40	1.46	
March	33, 670	5, 740	13, 420	825, 164	2.16	2.49	
April	21, 930	5,650	11, 165	664, 363	1.80	2.01	
May	12, 145	4,850	7, 235	444, 863	1.17	1.35	
June	24, 480	3,850	9,610	571, 835	1.55	1.73	
July	12, 260	2, 160	5,010	308, 053	0.81	0.93	
August	5, 030	1,840	2, 425	149, 107	0.39	0.45	
September	15, 310	1,840	4, 438	264, 079	0.72	0.80	
October	50, 740	2, 360	8, 543	525, 289	1.38	1.59	
November 1 to 25	76, 960	3,970	8, 726	519, 233	1.41	1.57	
December 24 to 31			5,636	89, 431	0.91	0. 27	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 182, discharge measurements, page 181; rating table in Paper No. 52, page 515.



Estimated monthly discharge of French Broad River near Asheville, N. C. [Drainage area, 987 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	4, 345	920	2, 221	136, 564	2.25	2.60	
February	16,325	1, 235	4, 225	234, 644	4.28	4.46	
March	14, 400	2, 110	4, 218	259, 355	4.27	4. 92	
April	14, 400	1,610	4,006	238, 374	4.06	4. 53	
May	4,620	950	1,748	107, 480	1.77	2.04	
June	13, 875	1,675	4,829	287, 345	4.89	5. 45	
July	5, 350	2, 445	3,008	184, 955	3.05	3.52	
August	2,620	1,810	2,018	124, 082	2.04	2.36	
September	6,875	. 1,280	2,074	123, 412	2.10	2.34	
October	18, 250	1, 280	3, 200	196, 760	3. 24	3.74	
November	11,075	2,030	3, 145	187, 140	3.19	3.56	
December	6, 350	2,275	3, 258	200, 327	3.30	3. 81	
The year	18, 250	920	3, 163	2, 280, 438	3. 20	43. 33	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 186; rating table in Paper No. 52, page 515.

Estimated monthly discharge of Tuckasegee River at Bryson, N. C.

[Drainage area, 662 square miles.]

	Dischar	rge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	3, 450	825	2,037	125, 250	3.08	3, 55
February	24, 925	950	4, 197	233, 090	6, 34	6.60
March	16, 012	1,850	3,577	219, 941	5.40	6. 22
April	5, 425	1,680	2,429	144, 536	3.67	4. 10
May	2,020	700	1,288	79, 196	1.95	2.25
June	6, 725	825	2, 425	144, 297	3.66	4.09
July	2, 360	950	1,565	96, 228	2.36	2, 73
August	1,350	550	764	46, 976	1.15	1.33
September	3,080	450	760	45, 223	1.15	1. 28
October	9,700	400	898	55, 216	1.36	1.57
November	8, 350	450	1,097	65, 276	1.66	1.85
December	3, 850	700	1, 257	77, 290	1.90	2.19
The year	24, 925	400	1,858	1, 332, 519	2. 81	37. 76

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 189; rating table in Paper No. 52, page 515.

Estimated monthly discharge of Little Tennessee River at Judson, N. C. [Drainage area, 675 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	3, 455	375	785	48, 268	1.16	1.34	
February	31,900	654	2,982	165, 612	4.42	4, 60	
March	7,615	2, 125	3,034	186, 553	4.49	5. 17	
April	6,500	770	1,962	116, 747	2. 91	3. 25	
May	3,650	538	1, 245	76, 552	1.84	2. 12	
June	6,500	1,595	3, 464	206, 122	5. 13	5. 73	
July	6,060	1,595	3,005	184, 770	4. 45	5. 13	
August	2, 125	1, 180	1,422	87, 435	2. 11	2.44	
September	1,380	1, 180	1,270	75, 570	1.88	2.10	
October	8, 305	480	1,429	87, 866	2.12	2. 45	
November	4, 250	828	1, 244	74, 023	1.84	2.05	
December	6, 830	1,180	2,274	139, 823	3.37	3.89	
The year	31, 900	375	2,010	1, 449, 341	2.98	40. 27	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 190; discharge measurements, page 189; rating table in Paper No. 52, page 515.

Estimated monthly discharge of Hiwassee River at Murphy, N. C. [Drainage area, 410 square miles.]

	Dischar	ge in secor	id-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.	
1900.							
January	2,375	535	858	52, 756	2.09	2.41	
February	13,080	475	1,829	101, 577	4.46	4.64	
March	3,950	1, 325	2, 141	131, 645	5. 22	6.01	
April	3, 250	1,030	1,717	102, 169	4.19	4. 67	
May	1,500	670	877	53, 925	2. 14	2.47	
June	3, 425	670	1,702	101, 276	4. 15	4.63	
July	3,075	670	1,170	71,940	2.85	3. 29	
August	1, 165	475	588	36, 155	1.43	1.65	
September	3,075	415	664	39, 511	1.62	1.81	
October	3, 250	310	596	36, 647	1.45	1. 67	
November	2,550	505	725	43, 141	1.77	1.98	
December	3, 425	600	1,043	64, 132	2.54	2.93	
The year	13,080	310	1, 159	834, 874	2. 83	38, 16	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 191; discharge measurements, page 190; rating table in Paper No. 52, page 515.

Estimated monthly discharge of Hiwassee River at Reliance, Tenn. [Drainage area, 1,180 square miles.]

	Discharge in second-feet.				Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean,	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
August 1 to 31			1, 173	34, 899	1.00	0.56	
September	5,250	970	1, 461	86, 936	1.24	1.38	
October	5, 950	970	1,431	87, 989	1.21	1.40	
November	6,825	1, 100	1,749	104,073	1.48	1.65	
December	4, 200	1, 415	2,360	145, 111	2.00	2.31	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 48, page 192; discharge measurements, page 191; rating table in Paper No. 52, page 515.

[Drainage area, 2,297 square miles.]

Estimated monthly discharge of Hiwassee River at Charleston, Tenn.

	Dischar	rge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1899.							
January	14,095	4,030	5, 621	345,622	2.45	2.83	
February	37,360	5, 515	14, 619	811, 898	6.36	6.62	
March	45,940	6, 835	18, 736	1, 152, 032	8.16	9.40	
April	18,550	6, 175	9,502	565, 408	4.14	4.62	
November	3, 205	1,050	1,664	99, 015	0.72	0.80	
December	11,950	1,580	3, 330	204, 754	1.45	1. 67	
1900.	10, 960	1,580	4,033	247, 979	1.76	2, 03	
January			,		3.50	3.64	
February	31,090	2,100	8,034	446, 186			
March	19, 375	5, 185	8, 693	534, 512	3.78	4. 36	
April	10, 960	, 5, 185	7, 104	422, 717	3.09	3. 44	
May	5, 515	2,875	3,881	238, 633	1.69	1.95	
June	13,600	2,875	6, 395	380, 529	2.78	3. 10	
July	9,970	3,040	4,780	293, 911	2.08	2.40	
August	4, 360	1,820	2,537	155, 994	1.10	1. 27	
September	11, 290	1,580	2,690	160,066	1.17	1. 31	
October	15, 250	1,695	2,882	177, 207	1.25	1.44	
November	16,900	2, 100	3, 793	225, 699	1.65	1.84	
December	11, 455	2, 875	4, 765	292, 988	2.07	2.39	
The year	31,090	1,580	4, 966	3, 576, 421	2. 16	29. 17	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 192; rating table in Paper No. 52, page 515. For hydrograph see page 226.

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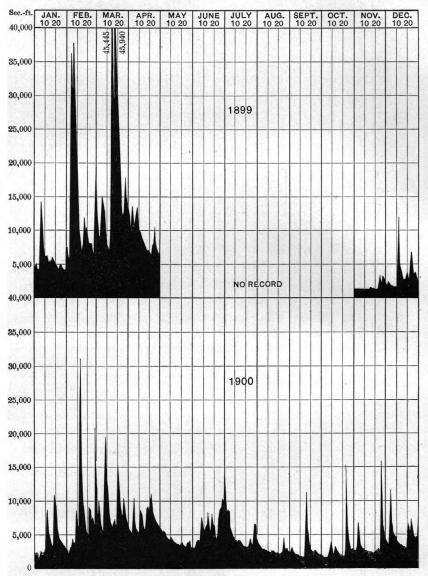


Fig. 98.—Discharge of Hiwassee River at Charleston, Tenn., 1899 and 1900.

Estimated monthly discharge of Toccoa River near Blueridge, Ga.

[Drainage area, 231 square miles.]

Month.	Dischar	ge in secon	nd-feet.		Run-off.		
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefect.	Second- feet per square mile,	Depth in inches.	
1900.							
March 23 to 31			1,035	18, 476	4.48	1.50	
April	1, 235	675	878	52, 245	3. 80	4. 24	
May 1 to 19	1, 235	460	900	55, 339	3.90	4.49	
June 27 to 30			2, 335				
July	1,935	750	1, 226	75, 384	5.31	6. 12	
August	1, 235	460	761	46, 792	3.29	3. 79	
September	1,635	423	629	37, 428	2.72	3.03	
October	6, 235	423	1,007	61, 918	4.36	5.03	
November	1,035	460	728	43, 319	3. 15	3.51	
December	1,235	460	710	43,656	3.07	3.54	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 193; rating table in Paper No. 52, page 515.

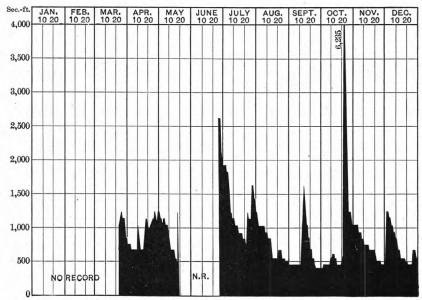


Fig. 94.—Discharge of Toccoa River near Blueridge, Ga., 1900.

Estimated monthly discharge of Tennessee River at Chattanooga, Tenn.
[Drainage area, 21,418 square miles.]

	Discharge in second-feet.				Run-off.		
Month.	Maximum,	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	54, 280	11,660	30, 807	1, 894, 248	1.44	1.66	
February	144, 800	13, 360	52,077	2, 892, 210	2.43	2. 53	
March	103, 880	42,810	66, 020	4, 059, 412	3.08	3. 55	
April	70, 400	32, 820	46, 819	2, 785, 924	2.19	2.44	
May	34, 440	15,600	21,086	1, 296, 528	0.98	1.13	
June	53, 040	14, 680	33, 295	1, 981, 190	1.55	1.73	
July	50, 870	13, 360	24, 674	1, 517, 145	1.15	1. 33	
August	34, 440	10,020	14, 602	897, 841	0.68	0.78	
September	25, 140	7,300	13, 393	796, 939	0.63	0.70	
October	42,500	8,040	14, 230	874, 968	0.66	0.76	
November	92, 720	10,840	25, 138	1, 495, 815	1.17	1.31	
December	53, 040	17,050	29,001	1, 783, 201	1.35	1.56	
The year	144, 800	7, 300	30, 928	22, 275, 421	1.44	19. 48	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 48, page 195; rating table in Paper No. 52, page 515.

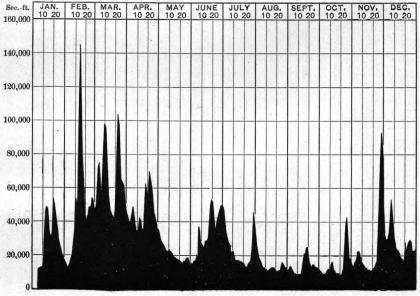


Fig. 95.—Discharge of Tennessee River at Chattanooga, Tenn., 1900.

SHOALS IN TENNESSEE RIVER NEAR FLORENCE, ALA.

In Tennessee River, in the vicinity of Florence, Ala. (see fig. 96), are several shoals capable of the development of power in large quantities. Prof. B. M. Hall has brought together the data regarding these, his intention being not to discuss the manner in which the immense water power of these shoals can be developed, but to give some idea of its magnitude and the possibility of its utilization.

The shoals are a succession of cascades amid many islands, in a river bed varying in width from a half mile to 3 miles. The numerous channels thus formed are very irregular in fall and direction. The difference between high and low water is only 5 or 6 feet, corresponding to a rise of 50 feet at Chattanooga. Beginning at Browns Ferry, 12 miles below Decatur, Ala., the river has the following falls:

From Browns Ferry to the mouth of Elk River the fall is 26 feet in 11 miles. This is known as Elk River Shoals. Its most precipitous part is at the lower end, where there is a fall of 16.5 feet in about 4 miles.

From the mouth of Elk River to the head of Muscle Shoals, a distance of 5 miles, there is a fall of only 2 feet.

From the head of Muscle Shoals to Bainbridge the fall is 85 feet in 17 miles, and is known as Big Muscle Shoals.

From Bainbridge to Florence the fall is 23 feet in 7 miles, and is known as Little Muscle Shoals.

From Florence to the head of the Colbert Shoals the fall is 3 feet in 11 miles. From the head of the Colbert Shoals to Waterloo the fall is 21 feet in 6 miles.

The total fall from Browns Ferry to Waterloo is, therefore, 160 feet in a distance of 57 miles. Sixteen miles of the distance, however, has

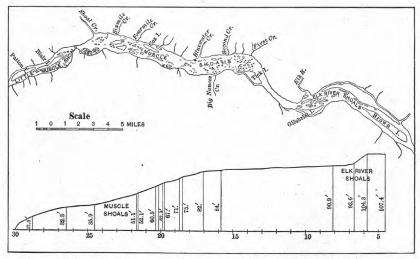


Fig. 96.-Map showing shoals in Tennessee River near Florence, Ala.

a fall of only 5 feet, leaving a fall of 155 feet in the 41 miles that cover the four shoals mentioned. The shoals are really more precipitous than the foregoing figures would indicate. For instance, 84.6 feet of the fall at Big Muscle Shoals is in a distance of 14 miles.

The bed rock of Elk River Shoals is Carboniferous limestone; that of Muscle Shoals is a hard siliceous rock of dark color and flinty structure.

The following is a statement of the minimum discharge of Tennessee River at Chattanooga:

	Secft.
From 1890 to 1895, inclusive	16,360
From 1896 to 1900, inclusive	6,600
From January 1 to November 16, 1901, inclusive	12,930

From this it is estimated that 6,600 second-feet is the minimum discharge for driest years and that 12,930 second-feet is the minimum for average years. Assuming that tributaries entering the river below Chattanooga will safely supply all of the water needed for lockage, we can use these discharges in estimating the water power of these shoals, which are about 200 miles below Chattanooga, by river, and drain an area more than 7,000 square miles greater than the watershed above Chattanooga.

Estimated minimum net horsepower of Tennessee River in Alabama on turbines realizing 80 per cent of the theoretical power.

	Locality.		Fall.	Minimum net power in driest years.	Minimum net power in average years.
			Feet.	Horsepower.	Horsepower.
Elk River Shoals			26	15,600	30,550
Big Muscle Shoals			85	51,000	99, 875
Little Muscle Shoals			23	13,800	27, 025
Colbert Shoals			21	12,600	24, 675
Total			155	93,000	182, 125
		CONTRACTOR OF THE PARTY OF THE		1	The state of the s

The foregoing table assumes that the total fall can in each case be utilized. While this assumption is not correct, it stands as an offset to the assumption that the water supply available will be as low as the minimum discharge at Chattanooga, 200 miles above. The drainage area above Chattanooga is 21,418 square miles, while the drainage area above the shoals under consideration is about 29,000 square miles. It may therefore safely be assumed that the actual power available for development at the shoals is greater than that shown by the table.

The foregoing statements of fall and distance are from a report by Mr. William B. Gaw, chief assistant engineer, United States Army, 1868, and the map and profile are from drawings prepared under the direction of Lieut. Col. J. W. Barlow, United States Engineers, 1890.

WATER SUPPLY FOR THE PROPOSED NATIONAL HOME FOR DISABLED VOLUNTEER SOLDIERS TO BE LOCATED NEAR JOHNSON CITY, TENN.

At the request of the board of managers of the National Home for Disabled Volunteer Soldiers, in April, 1901, an investigation was made of the water supply for the proposed Soldiers' Home to be located near Johnson City, Tenn. The following are extracts from the report of Mr. Cyrus C. Babb, who conducted the investigation:

CITY SUPPLY.

Johnson City receives its water supply from a number of springs at the foot of the Buffalo Mountains, 5 miles south of the town. About a dozen springs discharge into a reservoir, from which the water is piped to the town. The upper portion of the pipe line has a diameter of 20 inches, which is gradually reduced until at the outer limits of the town a 14-inch pipe is used. This conduit is ample for a much larger supply than at present runs through it. The main pipe that leads through the town to the Carnegie Iron Works is 12 inches in diameter.

The reservoir referred to was visited April 11, 1901, and an estimate was made of the volume of the springs discharging into it. Their flow is approximately 1,000,000 gallons per 24 hours. Sinking Creek formerly discharged directly into the reservoir, but a few years ago its course was changed, and it now passes completely around it.

On April 13 a visit was made to a number of springs a short distance above the reservoir, which are controlled by the City Water Company, and measurements of their discharge were made with a current meter. At present these springs discharge into Sinking Creek, but whenever they are needed to supplement the city supply they can easily be diverted into the reservoir, which it is the intention of the water company to do should the occasion arise. There are two series of these springs, known, respectively, as the W. S. Harvey Springs and the Price Springs. The Harvey Springs are about a half mile above the upper end of the reservoir, and consist of two springs rising within 50 feet of each other and discharging into Sinking Creek, about 40 feet distant. Their combined flow, as determined by current-meter measurements on April 13, 1901, is 140,700 gallons per 24 hours. Price Springs are about halfway between the upper end of the reservoir and the Harvey Springs. Their total discharge, which is the output of five springs, on April 13, 1901, was 1,218,340 gallons per 24 This was, however, probably somewhat above the normal flow, there having been heavy rains during the month preceding the measurements. The normal flow can safely be placed at about 850,000 gallons per 24 hours. Two of the springs at the head, however, with an estimated discharge of 300,000 gallons per 24 hours, do not belong to the water company. This leaves the average net discharge of the Price Springs controlled by the City Water Company 550,000 gallons per 24 hours. The total normal discharge of the Harvey and Price springs is 990,700 gallons per 24 hours; the combined flow controlled by the water company is 690,700 gallons per 24 hours.

SPRINGS AVAILABLE FOR SUPPLYING THE PROPOSED SOLDIERS' HOME.

Tom Story Spring.—This spring is about a half mile above the W. S. Harvey Springs, and, like them, discharges into Sinking Creek. Its flow on April 15 was estimated to be 180,000 gallons per day.

Howard Spring.—This spring is on the hillside, a short distance above the W. S. Harvey Springs, and discharges into Sinking Creek immediately above the latter springs. Its estimated discharge is 60,000 gallons per 24 hours.

Judge Smith Springs.—These springs, which are also known as the Ice-Plant Springs, water from them being pumped to supply an ice plant near by, are about 1 mile southeast of Johnson City. They are three in number. Two of them rise within 75 feet of each other, and the third is distant about 200 feet. Spring houses are erected at the first two, and a sheet-piling dam has been constructed across the outlet of the other one. The combined discharge of the former, as determined by a current-meter measurement on April 13, is 326,560 gallons per 24 hours; the discharge of the latter, immediately below the sheet-piling dam, is 663,360 gallons per 24 hours. This gives a combined flow of 989,920 gallons per 24 hours.

J. B. Cox Springs.—These springs are about a mile west of the town. The main spring has lately been cleaned out at the head and surrounded by a rough rock curbing. Its discharge, as determined by current-meter measurement on April 13, is 202,850 gallons per 24 hours, but its flow is materially increased in the course of a few rods by a number of small springs, the aggregate flow of which is considerable, so that at the point where the road crosses the stream issuing from the springs the discharge is considerably greater than that mentioned.

Williams Springs.—What are known as the Williams Springs are north of the Carnegie Land Company's tract. The largest of these springs, the one at which a spring house is located, was estimated on April 12 to be discharging 250,000 gallons in 24 hours. The main spring of the remaining supply, which might be called the Pitts Spring, a family of that name having formerly lived near it, is rather peculiar and interesting. It first appears in one of the sink holes which are common in this vicinity and which are said to denote underground water. These sink holes are inclosed basins having rather steep slopes and no surface outlet. After running a short distance, perhaps 100 feet, the Pitts Spring sinks into the ground. It appears again, perhaps 300 feet distant, passing under a ridge. The discharge of this spring, or, more correctly, these springs, was carefully estimated,

first immediately before the upper spring passes into the ground, and second, about 500 feet below where the spring again appears at the surface, or below the old limekilns. The discharge was about the same, and is placed at 400,000 gallons per 24 hours. A number of smaller springs, with an estimated flow of 250,000 gallons in 24 hours, contribute their supply to the Pitts Spring. The combined flow of the Williams Springs, including the Pitts Spring, is 900,000 gallons in 24 hours.

Joseph Lyle Spring.—This spring is 1 mile southwest of Johnson City, and discharges into Brush Creek, within a distance of a few hundred feet from its source. Its flow, as determined on April 13, is 332,840 gallons per day.

Upper Lyle Spring.—This spring is at the old Lyle farm, at present occupied by a family by the name of McNeal. It is $1\frac{1}{4}$ miles above the Joseph Lyle Spring and three-fourths of a mile below the Miller Springs. Its discharge, as determined on April 14, is 238,640 gallons per day.

Miller Springs.—These springs, three in number, are 3 miles southwest of Johnson City, in the basin of Brush Creek. In order to determine their discharge the flow of Brush Creek was measured immediately above the outlet of the upper spring and also immediately below the outlet of the lower or largest spring. The flow at the upper point was found to be, on April 14, 213,520 gallons, and below the outlet 571,480 gallons, a difference between the two points of 357,960 gallons per day, which represents the combined discharge of the Miller Springs. One of the springs is on the left side of the creek, and has a spring house erected over it; the other two springs are on the opposite side of the creek, and are not at present utilized.

Slagel Springs.—These springs are at the head of the South Fork of Brush Creek. At the time of the visit, April 15, they were discharging more than their normal volume, but an estimate was made of the flow of the two upper springs, which are said to vary little throughout the year and not to be affected materially by dry weather, and the discharge was placed at 263,760 gallons per 24 hours.

SUMMARY.

The volumes of the springs examined are as follows:

	Gallons in 24 hours.
Present city supply	1,000,000
Additional city supply:	
Harvey Springs	140,700
Price Springs—	
Measured volume	1, 218, 340
Estimated normal flow	850,000
Owned by water company, estimated	550,000
Tom Story Spring	180,000
Howard Spring.	

Judge Smith Springs:	Gallons in 24 hours.
Two springs at spring houses	
One spring at sheet-piling dam	
Total	989, 920
J. B. Cox Springs	202, 850
Williams Springs:	
Main Williams Spring	
Pitts Spring (from sink hole)	
Miscellaneous 250, 000	
Total	900,000
Joseph Lyle Spring.	332, 840
Upper Lyle, or McNeal, Spring	238, 640
Miller Springs.	357, 960
Slagel Springs	263, 760

ANALYSES OF WATER.

A number of samples of the water from two series of springs were collected and sent to the Department of Agriculture for chemical analyses. One of the samples was from the Joseph Lyle, or Lower Lyle, Spring, and three samples were from the Miller Springs, as follows: Miller No. 1, sample taken from the small spring on the left bank of Brush Creek, over which a spring house is constructed; Miller No. 2, sample taken from the smaller, or upper, spring on the right bank of Brush Creek; Miller No. 3, sample taken from the lower, or largest, of the three Miller Springs, which is on the right bank of Brush Creek. The analytical results obtained are given in the following table, expressed in parts per million:

Analyses of water from springs near Johnson City, Tenn.

Constituent.	Miller No. 1.	Miller No. 2.	Miller No. 3.	Lyle.
Solids.	204.000	188.000	169.000	204.000
Loss on ignition	18.000	19.000	21.000	23,000
Carbonate of lime	158.000	158.000	136.000	163.000
Nitrogen as free ammonia	0.010	0.005	0.029	0.005
Nitrogen as albuminoid ammonia	0.049	0.046	0.060	0.040
Nitrogen as nitrates	1.300	Trace.	Trace.	3.000
Nitrogen as nitrites	Trace.	Trace.	Trace.	Trace.
Chlorides	Trace.	Trace.	Trace.	Trace.

An inspection of the foregoing analyses shows that the principal part of the solid matter contained in the waters is carbonate of lime. The small quantity of nitrogenous substances present, as free and albuminoid ammonia and as nitrates and nitrites, shows that the waters are pure and free from any organic contamination. The amount of chlorides

is remarkably small, being only a trace in each sample. While the waters appear to be somewhat hard, the analyses show that they are good drinking waters.

BAROMETRIC ELEVATIONS.

Elevations of a number of points in the vicinity of Johnson City were taken on April 13 with an aneroid barometer, and the results are given in the following table:

Elevations near Johnson City, Tenn.

	Feet.
Railroad track at Johnson City	1,648
Upper Lyle Spring	1,694
Miller Springs	1,715
Small house, top of Lyle tract, highest point on proposed location	
of Soldiers' Home	1,738
John Lyle house	1,695
Top of ridge by Leonard farm	
Slagel Spring at head of South Brush Creek	1,822
Divide between Sinking Creek and South Brush Creek, near Bap-	
tist church	1,933
Old mill at Harvey Springs, on Sinking Creek	
Tom Story Spring, Sinking Creek.	1,960
Howard Spring, Sinking Creek	
Price's farm, 10 feet above spring	
City reservoir	

SCIOTO RIVER.

Stations have been maintained since 1898 on the Scioto and on its chief tributary, the Olentangy, at Columbus, Ohio, measurements being made in connection with the sanitary studies of the Ohio State board of health and with the cooperation of that board. The drainage of the State of Ohio is shown in fig. 97. In addition to the stations at Columbus, the Survey has maintained stations in that State on the Sandusky at Fremont and near Mexico, and on the Maumee near Waterville, the results of which for 1900 are given on pages 239 to 242.

Olentangy River, as shown in fig. 97, rises in the north-central part of Ohio and flows in a general southerly direction, entering the Scioto at Columbus. The watershed is in general flat and for the most part cultivated. Systematic measurements were begun in Columbus on November 22, 1898, when the station on the Fifth Avenue bridge was established by H. A. Pressey, C. N. Brown, Professor of Civil Engineering of the State University of Ohio, and B. H. Flynn, engineer of the Ohio State Board of Health. Measurements of discharge are made on the upstream side of the bridge, the field work

being done by students of the University under the direction of Professor Brown. At the same time a study has been made of the rainfall and run-off, in order to afford material for original investigations by the students, and to add to the general knowledge of the river, needed by the State Board of Health and by individuals.

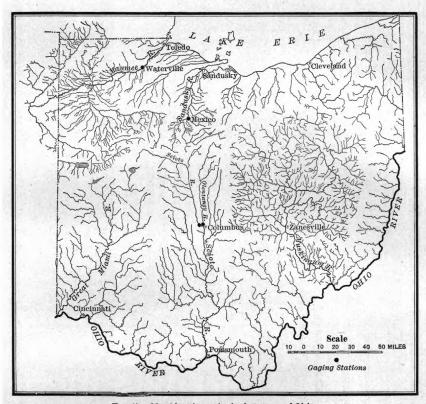


Fig. 97.—Map showing principal streams of Ohio.

The main branch, or Scioto River, rises immediately west of the headwaters of the Olentangy River, the drainage basin being similar to that of the Olentangy. The lands are highly cultivated above Columbus, while further south the country is hilly and less widely farmed. The point of measurement is at Grand View Avenue bridge in Columbus, work being carried on here largely by Professor Brown and his students.

 ${\it Estimated monthly \ discharge \ of \ Scioto \ River \ at \ Columbus, \ Ohio.}$

[Drainage area, 1,047 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1900.							
January	4,945	75	1,034	63, 574	0.990	1.141	2.57
February	3, 300	407	1, 455	80, 799	1.390	1.450	3. 62
March	9, 165	556	2, 131	131, 012	2.030	2.351	2.04
April	2, 150	430	$\cdot 1,042$	62,011	1.000	1.113	2. 22
May	362	92	182	11, 173	0.170	0. 201	1.54
June	479	11	149	8,842	0.142	0.159	3. 77
July	455	11	54	3, 342	0.052	0.060	3.43
August	407	5	104	6, 401	0.100	0.115	3.89
September	75	1	14	813	0.013	0.015	1.62
October	143	9	25	1,555	0.024	0.028	2. 32
November	1, 209	11	225	13, 374	0.215	0.240	3. 81
December	556	35	139	8, 527	0. 132	0. 153	1.13
The year	9, 165	1	541	391, 423	0.516	7. 026	31.96

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 220, discharge measurements, page 219; rating table in Paper No. 52, page 515.

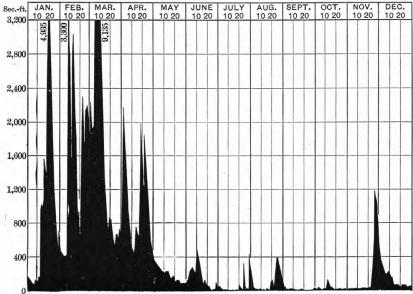


Fig. 98.—Discharge of Scioto River at Columbus, Ohio, 1900.

Estimated monthly discharge of Olentangy River at Columbus, Ohio.

[Drainage area, 514 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.	
Month.	Maxi- mum,	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1900.							
January	2,580	366	691	42, 504	1.345	1.551	2.52
February	2, 450	305	763	42, 385	1.485	1.546	3. 52
March	7, 492	347	1,090	67, 029	2. 121	2.445	2.46
April	2, 150	95	560	33, 310	1,089	1. 215	2.96
May	142	55	77	4,731	0.150	0.173	1.76
June	427	25	121	7, 220	0. 235	0.263	3.86
July	427	8	74	4, 546	0.144	0.166	3.44
August	1,630	8	240	14, 747	0.467	0.538	4.81
September	247	8	34	1,997	0.066	0.073	2.10
October	25	8	10	536	0.017	0.020	1.77
November	1,030	8	124	7, 404	0. 241	0.270	3.66
December	305	55	111	6,428	0. 216	0. 250	1. 28
The year	7, 492	8	322	232, 837	0. 627	8. 510	34. 14

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, pages 218 and 219; rating table in Paper No. 52, page 515.

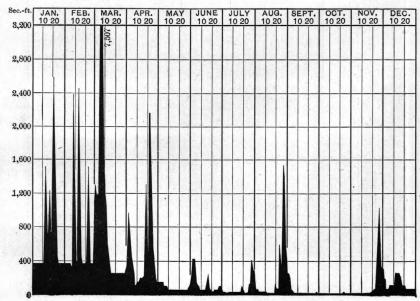


Fig. 99.—Discharge of Olentangy River at Columbus, Ohio, 1900.

GREAT LAKES DRAINAGE.

Of the streams in Ohio which contribute to the Great Lakes drainage, Maumee River has been measured near Waterville, Ohio, and Sandusky River near Mexico, Ohio, and at Fremont, Ohio, with the results given in the following tables. In New York several stations have been maintained, as follows: Seneca River at Baldwinsville, Chittenango Creek at Bridgeport, Oneida Creek at Kenwood, West Branch of Fish Creek at McConnellsville, Oswego River at high dam near Oswego, and Black River at Huntingtonville dam. Other data in regard to the stations in New York will be found in a table on pages 12 and 13, giving the location of the gaging stations in that State. During the last year gaging stations have been established by Robert E. Horton on several streams in Michigan which contribute to the Lakes drainage, as described more in detail on pages 254 to 268, and as shown on the maps on pages 254, 255, 257, 259, 261, 263, and 266.

The measurement of the smaller streams flowing into the Great Lakes have a peculiar interest in connection with the general study of the fluctuations of the lakes and the quantity of water discharged. Measurements of the outflow of the Great Lakes have been made from time to time at various points, particularly at Sault Ste. Marie, Saint Clair and Detroit rivers, Niagara River, and Saint Lawrence River, the results of which are given in the annual reports of the Chief of Engineers, United States Army, particularly that for 1900, on pages 5317 to 5401. As a result of this work it has been found that the discharge of Niagara River varies from 155,000 second-feet to 240,000 second-feet; and the discharge of Saint Clair River at Fort Huron ranges from 179,000 second-feet to 211,500 second-feet. This work has been under the direct supervision of Mr. E. E. Haskell, assisted by Mr. F. C. Shenehon on the Niagara River and Mr. L. C. Sabin on Saint Clair River. In addition to these, measurements have been made on Saint Marys River by Mr. Thomas Russell.

Estimated monthly discharge of Maumee River near Waterville, Ohio.

[Drainage area, 6,111 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1898.							
December	32, 120	680	8, 203	504, 407	1.325	1. 525	2. 41
1899.	40						
January	33, 250	780	10, 979	675, 072	1.796	2.070	2.60
February	26, 765	1,310	6, 301	349, 950	1.080	1.070	2.14
March	32, 100	8,700	19, 431	1, 194, 790	3. 180	3.660	4. 39
April	12,960	1,800	6,028	358, 661	0.986	1.095	1.11
May	2,750	1, 200	1,990	352, 360	0.325	0.375	3.66
June	2, 450	150	1,057	62, 814	0.173	0.203	1.88
July	1,200	. 3	285	17,536	0.046	0.046	4. 36
August	4,940	70	1, 362	43, 758	0. 223	0.253	2.09
September	990	20	259	15, 411	0.042	0.042	2.40
October	150	5	48	2,955	0.007	0.007	2.51
November	1,310	40	521	31,001	0.085	0.085	2. 12
December	9,950	10	2, 323	142, 847	0.380	0.450	3.08
The year	33, 250	3	5, 212	3, 017, 155	0. 689	9. 356	32. 34
1900.							
January	10, 200	1, 200	5, 054	310, 752	0.827	0.947	1. 25
February	18, 985	2, 450	7,944	441, 180	1.300	1.342	4. 50
March	42, 750	2,600	15, 610	959, 803	2.554	2.942	2. 13
April	13, 965	2,600	8, 149	484, 904	1.330	1.480	2.40
May	3,050	200	938	57, 657	1.530	1.760	2.65
June	6, 320	680	3, 444	204, 907	0.563	0.623	4. 30
July	5, 120	300	2,094	128, 724.	0.342	0.392	4.89
August	1,930	5	563	34, 598	0.092	0.104	3.56
September	250	5	27	1,596	0.004	0.004	1.48
October	250	5	41	2, 499	0.006	0.006	2.80
November	9, 700	10	2,619	155, 840	0.428	0.478	3.89
December	6, 320	70	1,509	92, 766	0. 246	0. 286	0.83
The year	42, 750	5	4,666	2, 275, 226	7. 635	10. 364	34. 65

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 220.

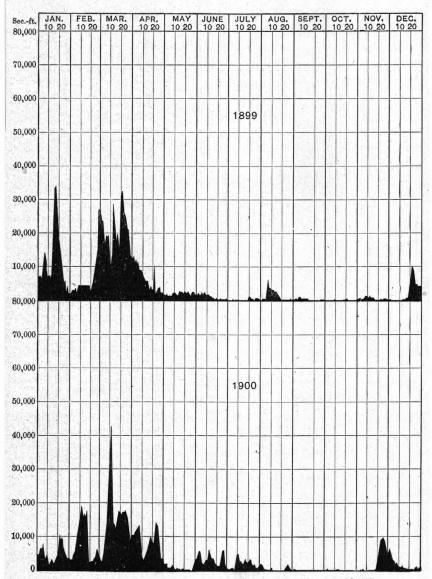


Fig. 100.—Discharge of Maumee River near Waterville, Ohio, 1899 and 1900.

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Estimated monthly discharge of Sandusky River near Mexico, Ohio.

[Drainage area, 776 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	ı-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1898.							
December	4, 035	100	727	44, 726	0.95	1.09	2, 65
1899.							
January	5, 410	240	1,516	93, 222	1.953	2. 253	3. 29
February	2, 725	100	636	35, 344	0.820	0.854	2. 21
March	3,580	795	1,871	115, 049	2.424	3.714	4.84
April	1,730	100	600	35, 714	0.773	0.856	1.44
May	1, 145	45	627	13, 933	0, 292	0.334	4.55
June	935	6	208	12, 347	0. 267	0. 297	2.95
July	100	4	32	1,949	0.040	0.040	4.82
August	375	3	44	2,699	0.056	0.066	1.86
September	6	2	3	173	0.003	0.003	2.34
October	30	2	9	547	0.011	0.011	2, 22
November	45	12	24	1,422	0.030	0.030	2. 28
December	655	30	171	10, 502	0. 220	0. 230	3. 20
The year	5, 410	2	497	322, 901	0.640	8, 688	36, 00
1900.					5 168 A.		
January	2, 245	8	656	40, 581	0.844	0.974	2. 22
February	2,380	125	889	49, 367	1, 145	1.192	4. 18
March	4,870	270	1,407	86, 513	1.813	2.093	2.64
April	1,355	180	686	40, 832	0.884	0.984	2.84
May	180	20	88	5, 436	0.114	0.134	2.57
June	445	80	162	9,610	0.208	0.228	3.94
July	410	6	79	4, 839	0.101	0.121	4.72
August	1,560	4	243	14, 917	0.312	0.362	4.76
September	125	4	38	2, 279	0.049	0.058	2.04
October	270	8	70	4, 310	0.090	0.100	2, 53

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 221.

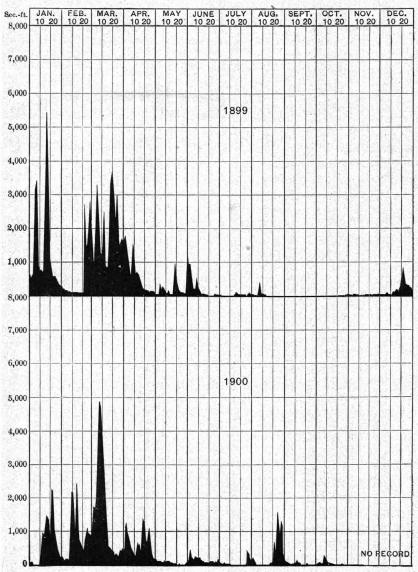


Fig. 101 - Discharge of Sandusky River near Mexico, Ohio, 1899 and 1900.

Estimated monthly discharge of Chittenango Creek at Bridgeport, N. Y. [Drainage area, 307 square miles.]

	Discha	rge in secor	nd-feet.		Rur	n-off.
) Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
September 16 to 30			129	3, 838	0.42	0. 23
October	972	130	344	, 21, 152	1.12	1. 29
November	1,571	331	612	36, 416	1.99	2. 22
December	1,401	261	597	36, 708	1.94	2. 24
1899.						
January	1,310	311	662	40, 705	2.16	2. 49
February	1, 314	342	551	30, 601	1.79	1.86
March	1,475	385	893	54, 908	2.91	3. 36
April	1,737	165	921	54, 803	3.00	3. 35
May	447	95	245	15,064	0.80	0.92
June	426	70	161	9,580	0.52	0.58
July	271	45	123	7, 563	0.40	0.46
August	169	15	.96	5,903	0.31	0.36
September	133	15	76	4,522	0.25	0. 28
October	141	15	64	3, 935	0.21	0. 24
November	228	25	95	5, 653	0.31	0. 35
December	706	113	281	17, 278	0.92	1.06
The year	1,737	15	347	250, 515	1.13	15. 31
1900.						
January	1,540	161	561	34,495	1.83	2. 11
February	1,700	187	725	40, 264	2, 36	2.46
March	1, 351	355	697	42, 857	2. 27	2.61
April	1,703	268	911	54, 208	2. 97	3. 31
May	295	40	207	12, 728	0.67	0.77
June	134	43	93	5, 534	0.30	0.38
July	252	33	110	6, 764	0.36	0.42
August	124	37	73	4, 489	0. 24	0. 28
September	117	15	68	4,046	0. 22	0. 25
October	136	33	81	4, 980	0. 26	0.30
November	1, 953	34	327	19, 458	1.07	1.19
December	1, 330	275	562	34, 556	1.83	2. 11
The year	1,703	15	368	264, 379	1.20	16. 14

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 49, pages 224 and 225. For hydrograph see page 245.

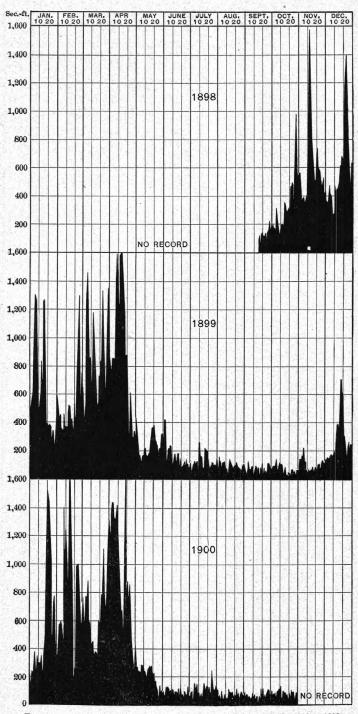


Fig. 102.—Discharge of Chittenango Creek at Bridgeport, N. Y., 1898 to 1900.

Estimated monthly discharge of Oneida Creek at Kenwood, N. Y. [Drainage area, 59 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month,	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
October 5 to 31	180	23	83	5, 103	1.41	1.63
November	274	51	105	6, 248	1.78	1.99
December	240	40	90	5, 534	1.53	1.76
1899.						
January	300	42	117	7, 194	1.98	2. 28
February	365	35	93	5, 165	1.58	1.64
March	254	22	157	9,654	2.66	3.07
April	496	86	183	10,889	3. 10	3.46
May	108	43	62	3, 812	1.05	1. 21
June	51	21	30	1, 785	0.51	0.57
July	51	18	25	1,537	0.42	0.48
October	31	15	23	1, 414	0.39	0.45
November	144	22	33	1,964	0.56	0.62
December	97	23	60	3, 689	1.02	1.18
1900.					7.2	
January	364	26	92	5, 657	1.56	1.80
March	394	48	148	9, 100	2, 51	2.89
April	382	61	198	11, 782	3.36	3.75
June	52	14	21	1, 250	0.36	0.40
July	80	22	38	2, 337	0.64	0.74
August	32	13	19	1, 168	0.32	0.37
September	19	13	16	952	0. 27	0.30
October	35	13	19	1,168	0.32	0.37
November	632	16	91	5,415	1.54	1.72
December	237	55	127	7,809	2.15	2.48

Note.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 49, pages 226 and 227.

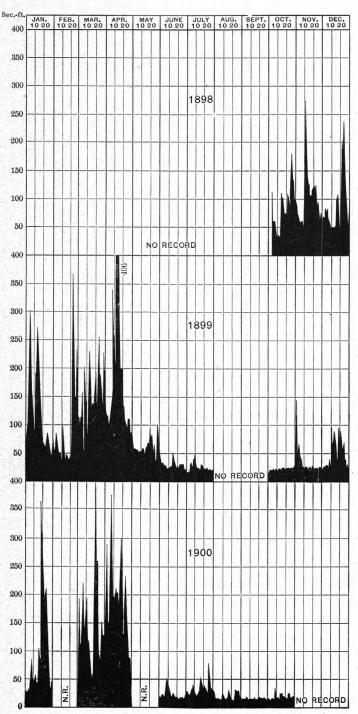


Fig. 103.—Discharge of Oneida Creek at Kenwood, N. Y., 1898 to 1900.

Estimated monthly discharge of West Branch of Fish Creek at McConnellsville, N. Y. [Drainage area, 186.7 square miles.]

	Dischar	ge in secon	id-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1898.						
September 13 to 30	360	47	134	7,974	0.72	0.80
October	1,097	50	333	20, 475	1.78	2.05
November	1,562	120	385	22, 909	2.06	2.30
December	468	120	211	12, 974	1. 13	1.30
1899.			Pany Park			
January	873	120	435	26, 747	2. 33	2.68
February	438	80	206	11, 441	1.10	1. 14
March	1,178	360	648	39, 844	3. 47	4.00
April	3,040	220	1, 206	71, 762	6.46	7. 20
May	700	50	239	14, 695	1.28	1.48
June	307	10	101	6,010	0.54	0.60
July	125	10	57	3, 505	0. 31	0.36
1900.						
May	278	38	143	8, 793	0.77	0.89
June	96	28	68	4,046	0.36	0.40
July	96	10	60	3, 689	0.32	0.37
August	168	10	57	3,505	0.31	0.36
September	239	10	65	3, 868	0.35	0.39
October	218	34	88	5, 411	0.47	0.54
November	355	78	168	9, 997	0.90	1.00
December	257	31	99	6, 087	0.53	0, 61

NOTE.—Daily discharge for 1898, 1899, and 1900 is given in Water-Supply Paper No. 49, pages 228 and 229.

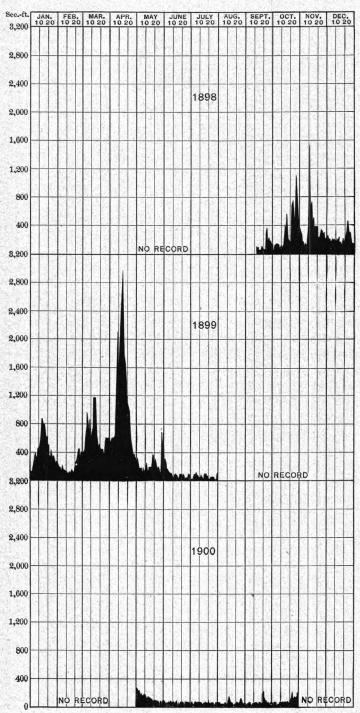


Fig. 104.—Discharge of West Branch of Fish Creek at McConnellsville, N. Y., 1898 to 1900.

 $Estimated\ monthly\ discharge\ of\ Oswego\ River\ at\ high\ dam\ near\ Oswego,\ N.\ Y.$ [Drainage area, 5,000 square miles.]

	Discha	rge in seco	nd-feet.		Rut	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1897. April	12, 150	7, 500	10,048	597, 891	2. 01	2. 24
	7, 750	5, 150	6, 166		1. 23	1. 42
May	4, 620	2,550	3, 801	379, 133 226, 175	0.76	0.85
July	3,500	1,470	2, 174	133, 674	0. 43	0. 49
August	3,300	1,760	2, 370	145, 726	0.43	0. 48
	1,840	720	1, 244	74, 023	0. 47	0. 28
September	1500 1 1 1 1 1 1 1		State of the state of			
October	1,300	750	1,076	66, 161	0. 22	0. 25
November	+3,650	1,020	1,821	108, 357	0.36	0.40
December	5,500	2,900	4, 168	256, 280	0.83	0.96
1898. January	7, 880	2,600	4, 896	301, 073	0.98	1. 18
February	8, 150	4,600	6, 238	346, 441	1. 25	1.30
March	10,550	8,820	9,898	608, 604	1.98	2. 28
April	9,400	5,900	7,578	450, 922	1.52	1.70
May	9, 120	6,550	8, 161	501,800	1.63	1.88
June	6,540	2,780	8, 331	495, 729	1.67	1.86
July, 14 days			1,834	50, 927	0.37	0. 19
August	1,480	630	925	56,876	0.18	0. 21
September	1,770	930	1, 377	81, 937	0.28	0. 31
October	3, 360	860	2,018	124, 082	0.40	0.46
November	5, 800	3,050	4, 452	264, 912	0.89	0.99
December	5, 800	2, 100	3, 899	239, 740	0.78	0.90
1899.				72 (C. 15)		
January	5,650	2, 300	4, 252	261, 445	0.85	0.98
February	3, 910	530	2, 475	137, 454	0.49	0. 51
March	6,830	850	4,874	299, 691	0.97	1, 12
April	9,900	6,300	7,684	457, 230	1.54	1.72
May	9,600	5, 400	6, 754	415, 287	1.35	1.56
June	5, 370	720	2,002	119, 127	0.40	0.45
July	1,000	580	748	45, 993	0.15	0.17
August	990	450	612	37, 630	0.12	0.14
September	2,670	450	615	36, 595	0.12	0.18
October	900	460	585	35, 970	0, 12	0.14
November	1,500	780	1,095	65, 157	0. 22	0. 25
December	2,700	650	1,612	99, 118	0.32	0.37
The year	9,900	450	2,776	2, 010, 697	0, 55	7. 54

Estimated monthly discharge of Oswego River at high dam near Oswego, N. Y.-Cont'd.

	Discha	rge in seco	nd-feet.	10114	Rui	n-off.
Month.	Maxi- mum.	Mini- mum-	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6,600	1,360	3,077	189, 199	0.62	0.71
February	7,960	1,360	4,653	258, 414	0.93	0.97
March	8,820	1,970	4, 991	306, 885	1.00	1. 15
April	17,550	11,600	14, 025	834, 546	2.81	3, 13
May	11, 480	4,800	7,645	470, 073	1.53	1.76
June	4,880	1,840	3, 132	186, 367	0.63	0.70
July	3,500	460	966	59, 397	0.19	0. 22
August	980	550	669	41, 135	0.13	0.15
September	780	550	670	39, 868	0.13	0.15
October	980	720	853	52, 449	0.17	0. 20
November	6,850	980	2, 418	143, 881	0.48	0.54
December	9, 130	4, 850	6, 990	429, 798	1.40	1.61
The year	17, 550	460	4, 174	3, 012, 012	0.84	11, 29

Note.—Daily discharge for 1897, 1898, 1899, and 1900 is given in Water-Supply Paper No. 49, pages 232 and 233.

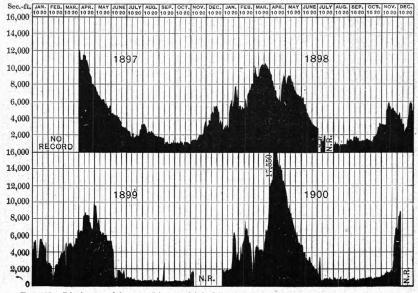


Fig. 105.—Discharge of Oswege River at high dam 2 miles above Oswego, N. Y., 1897 to 1900.

Estimated monthly discharge of Black River at Huntingtonville dam, New York.

[Drainage area, 1,889 square miles.]

Month,	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1897. February 22 to 26			2, 160			
March	16, 500	1,220	6, 317	388, 417	3. 34	3. 85
			Proposed States and States	564, 337	5. 02	5. 60
April	14, 142 8, 550	5,050	9,484 4,267	262, 368	2. 26	2. 60
May		Contract of	The state of the s		1.44	Company of the last of the las
June	6, 428	934	2, 713 879	161, 435	0.47	1.61
July	2,000	480		54, 048		0.54
August	7, 252	322	2, 280	140, 192	1. 21	1.39
October 14 to 31	0.000		954	34,060	0.51	0.34
November	9,890	598	4, 155	247, 240	2. 20	2. 45
December	8,500	1,804	4, 725	290, 529	2.50	2. 88
1898.				Secretary 1	THE S	
January	6, 176	1,580	3, 402	209, 181	1.80	2. 08
February	8, 164	2,300	3, 806	211, 374	2. 01	2.09
March	27, 900	2, 150	9,609	590, 834	5.09	5. 87
April	10, 140	2, 240	4,654	276, 932	2.46	2.74
May	4,776	1,940	3, 174	195, 162	1.68	1.94
June	2,770	1,066	1,639	97, 527	0.87	0.97
July	2,000	728	1,128	69, 358	0.60	0.69
August	3, 130	630	1,495	91, 924	0.79	0.91
September	2,865	330	1,483	88, 245	0.78	0.87
October	6,680	1,022	3, 138	192, 948	1.66	1.91
November	9, 240	1,658	3, 932	233, 970	2.08	2. 32
December	5,610	1,532	2,720	167, 246	1.44	1.66
The year	27, 900	330	3, 348	2, 424, 701	1.77	24. 05
1899.	10.000	0.000	4 710	900 500	0.40	0.05
January	10, 396	2,000	4,712	289, 730	2.49	2.87
February	3,530	1,850	2, 326	129, 179	1. 23	1. 28
March	8, 164	3, 230	5, 051	310, 574	2.67	3. 08
April	25,000	3, 565	13, 894	826, 751	7.35	8. 20
May	18,000	2, 362	5, 609	344, 884	2.97	3, 42
June	3, 095	1, 132	1,528	90, 922	0.81	0.90
July	2, 150	458	1, 205	74, 093	0.64	0.74
August	1,606	522	897	55, 154	0.47	0.54
September	1,532	480	990	58, 909	0.52	0.58
October	1,940	522	1,018	62, 594	0.54	0.62
November	4,055	782	1,652	98, 301	0.87	0.97
December	8, 404	1, 110	3, 501	215, 268	1.85	2.13
The year	25,000	458	3, 532	(2, 556, 359	1.87	25, 33

Estimated monthly discharge of Black River at Huntingtonville dam, New York-Cont'd.

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6, 260	1,580	2,834	174, 256	1.50	1.73
February	14, 030	2,060	5, 734	318, 450	3.04	3. 16
March	4,020	2,579	2,970	182, 618	1.57	1.81
April	30,000	3,800	13, 926	828, 655	7. 37	8. 22
May	11, 280	1,904	5, 711	351, 156	3.02	3.48
June	2,610	764	1,630	96, 992	0.86	0.96
July	2, 150	764	1, 321	81, 225	0.70	0.81
August	2, 120	480	1, 134	69, 727	0.60	0.69
September, 23 days	1,780	390	1,020	60, 694	0.54	0.60
October	2, 340	580	1, 218	74, 892	0.64	0.74
November, 27 days	13,900	1, 120	5, 014	298, 413	2.65	2.96
December	9, 900	2, 200	4, 230	260, 093	2. 24	2.59
The year	30,000	390	3, 895	2, 797, 171	2.06	27. 75

Note.—Daily discharge for 1897, 1898, 1899, and 1900 is given in Water-Supply Paper No. 49, pages 237, 238, and 239.

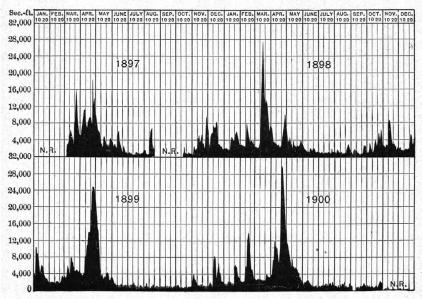


Fig. 106.—Discharge of Black River at Huntingtonville dam, near Watertown, N. Y., 1897 to 1900.

GRAND RIVER. a

This is the largest stream in Michigan, as may be seen by the map forming fig. 107, showing the principal streams and drainage basins of that State and the location of the gaging stations. Its drainage

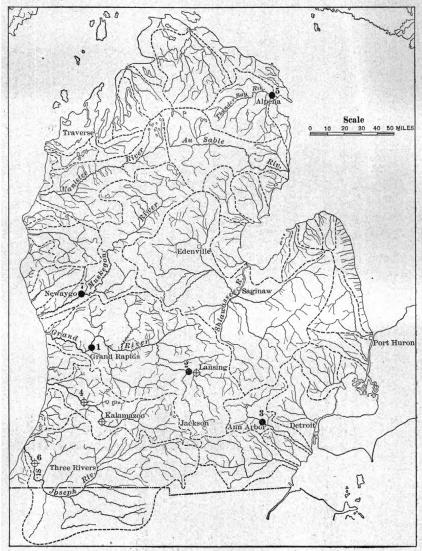
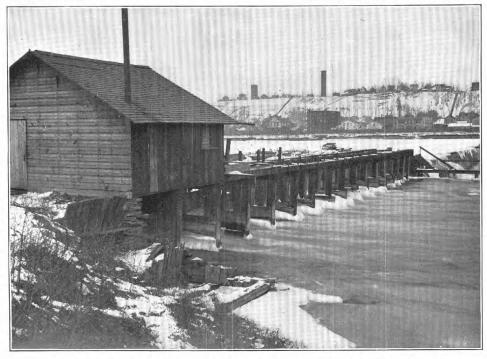


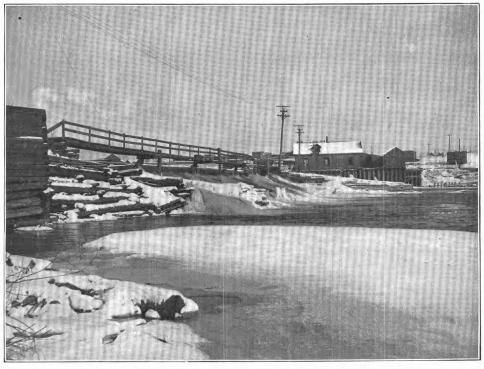
Fig. 107.—Map showing principal streams and drainage basins of the lower peninsula of Michigan and location of gaging stations.

- 1. Grand Rapids station on Grand River.
- 2. North Lansing station on Grand River.
- 3. Ann Arbor station on Huron River.
- 4. Allegan station on Kalamazoo River.
- 5. Alpena station on Thunder Bay River.
- 6. Buchanan station on St. Joseph River.
- 7. Newaygo station on Muskegon River.

^aThe data regarding Michigan streams are taken from a report by Robert E. Horton.



A. HEAD GATES OF WEST SIDE CANAL, GRAND RIVER, AT GRAND RAPIDS, MICH.



B. LOWER DAM ON MUSKEGON RIVER AT BIG RAPIDS, MICH.

basin, which includes a total area of 5,572 square miles, is in the central portion of the lower peninsula, and drains into Lake Michigan. It lies in the southern border of the pine belt, and is for the most part cleared. It is comparatively flat, and is overlain with glacial drift deposits, including sand, clay, overwash, gravel, and till, with outcroppings of rock at rare intervals. A stratum of limestone, said to be 52 feet thick, appears in the east side of the bed of the river at Grand Rapids, 100 feet above the Pearl street bridge. It dips in a northeasterly direction, at a slope of 50 feet to the mile, and does not appear in the West Side canal. A view of the head gates of this canal is shown in Pl. XVII, A. The watershed receives an annual rainfall varying from 25 inches in the region of the headwaters to 30 or 35

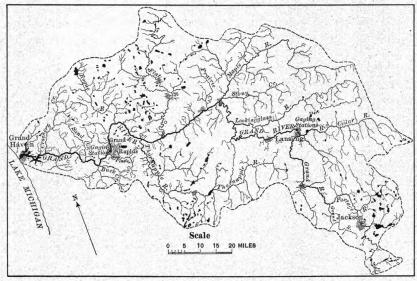


Fig. 108.—Drainage basin of Grand River, Mich., showing location of gaging stations.

inches near the mouth of the river. From the foot of the rapids formed by the limestone ledge at Grand Rapids to the mouth of the river at Lake Michigan the flow is very sluggish. In the upper half of that stretch of the river the immediate banks of the stream are high, sometimes forming natural levees at elevations greater than that of the adjacent flood plain. Below Lamont bayous and low swamps are common between the river banks and the foothills bordering the valley. The valley as a whole is narrow; gravel bluffs from 50 to 60 feet high occasionally stand close to the stream. The river below Grand Rapids is considered navigable, and a project has been formed for its canalization, the plan being for a waterway, with a navigable depth of 10 feet, connecting the city of Grand Rapids with Lake Michigan.

A map of the drainage basin is shown in fig. 108.

The total fall of the river from the extreme headwaters to the mouth, a distance of more than 200 miles, is about 350 feet. The northwestern and southeastern portions of the basin are thickly interspersed with small lakes. A considerable number of these have no surface outlets, and their drainage basins do not contribute to the run-off of the river except through ground water. The river water is hard, as shown by samples collected and analyzed in 1899.

In connection with proposed improvements for navigation, gaging stations have been established, one near Grand Rapids and two near Lansing. All gages are set with their zeros at the Lake Michigan datum, 581.28 feet above mean tide of the New York Harbor deepsea levels. Since 1890 observations have been taken at different stages of the stream, notably during high water, with a view to determining its slope. Cross sections have also been made, and these data will, when completed, form a basis for computing the flow of the river by means of Kutter's formula.

A nearly continuous record of the stage of the river at the Chicago and West Michigan Railroad bridge 1 mile below the dam in Grand Rapids has been kept since May 26, 1897, and is published in Water-Supply Paper No. 49 (pages 243 and 244), where will also be found discharge measurements and other data regarding the stream and its tributaries, their water powers, drainage areas, etc.

MUSKEGON RIVER.

The drainage basin of this stream lies immediately north of that of Grand River. Originally it was covered with pine timber, but now it is almost entirely cleared. Much of the soil is sand and gravel, unfit for profitable cultivation. Large stump-covered areas form a conspicuous feature of the topography. A map of the drainage basin is shown in fig. 109.

In March, 1901, a gaging station was established at the dam of the Newaygo Portland Cement Company. This dam crosses the river in a deep valley above the village of Newaygo. It is of timber, having framed cribs filled with stone. Its height is 21 feet. It rests on a hardpan foundation and is considered to be practically water-tight. It is provided with a main spillway, with logways, and with four floodways. The floodways are provided with Taintor segmental flood gates, which are operated by a traveling crab. A record is kept of the time and amount of opening of the flood gates and logways, as well as of the depth of water on the crests of the spillways. Ordinarily the flood gates and logways are closed, and the entire flow passes over the main spillway or through the turbines. Water is carried from the pond to the power house by a short headrace separated from the stream channel by a crib breakwater. The power house contains two pairs of 35-inch Leffel standard turbines on horizontal shafts. The

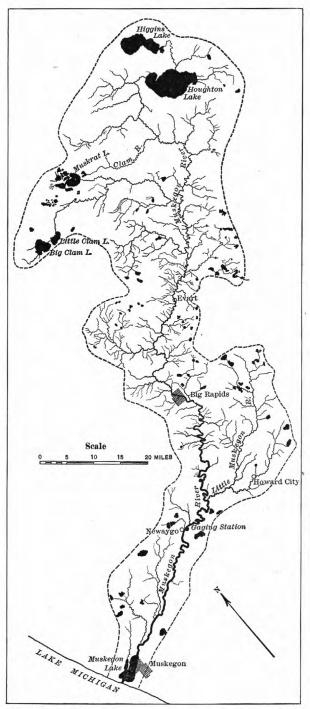


Fig. 109.—Drainage basin of Muskegon River, Michigan, showing location of gaging station. 22 GEOL, PT IV—01——17

water wheels are connected to electrical generators by endless rope drives. The power will be used for driving machinery in the adjoining cement mills, and the load and discharge of the turbines will be fairly constant. The record kept for the water wheels includes working head, hours run per day, and average width of gate opening for each pair of wheels, as indicated by the Lombard governors.

The Newaygo dam is the first one above the mouth of the stream. An effective head of 14 feet is obtained there. Power is also developed at Big Rapids, where there are two dams. The lower dam (see Pl. XVII, B) is a rough timber structure built with a view to use in log driving. One hundred and seventy-two horsepower is now in use for the generation of electricity, the head obtained being 8 feet. At the upper dam in Big Rapids power is distributed through two lateral hydraulic canals. The total flow is estimated as equivalent to the discharge through an orifice of 6,758 square inches area under a head of 8 feet with a coefficient of contraction of 0.7. Each user is entitled to install wheels having a certain number of square inches vent. The head varies from 6½ to 11 feet, the average or ordinary head being 8 or 9 feet. The rated power of the turbines installed is 668 horsepower. It is stated that but 350 horsepower is actually in The power utilized at Newaygo and Big Rapids aggregates 1,000 horsepower. Aside from the foregoing there is no power developed within the drainage basin, except in a small way on certain tributaries.

From the vicinity of Evart to Newaygo the river flows between high banks and has a rapid fall. Levels which have been run for the purpose show that within a distance of 10 miles—5 miles each way from Big Rapids—there is a total fall of 104 feet. Of this 16 feet is now utilized, leaving an available fall of 88 feet. There are favorable sites for the location of dams, so that practically the entire fall could be economically developed. At Rogers's bridge, 6 miles below Big Rapids, surveys have been made for the erection of a dam to give a head of 35 feet.

In connection with power development good opportunities exist for the conservation of flow by artificial storage. In the upper portion of the watershed there is a total lake area of about 110 square miles. Formerly a lumbermen's dam was maintained for the purpose of flooding logs between Houghton and Higgins lakes, but this has been washed out. A dam properly constructed at this site would flood an area of 15 square miles and would yield a storage of 400,000,000 cubic feet per foot of depth. A lumbermen's dam, built of logs and earth, which still remains about a mile below the foot of Houghton Lake, raises the water level in that lake 4 feet, providing a storage of, in round numbers, 3,350,000,000 cubic feet. A dam could be constructed at this site which would admit of a total storage 8 feet in depth, which would greatly increase the flooded area over that of the present lake.

HURON RIVER.

This river receives drainage from a broad, flat basin, interspersed with lakes, in southeastern Michigan. The inland basin is connected with Lake Erie by a long, narrow valley, in which occurs a large portion of the fall and available power of the stream. A map of the basin is shown in fig. 110. A gaging station has been established at Ann Arbor, under the immediate charge of Prof. J. B. Davis, of the Uni-

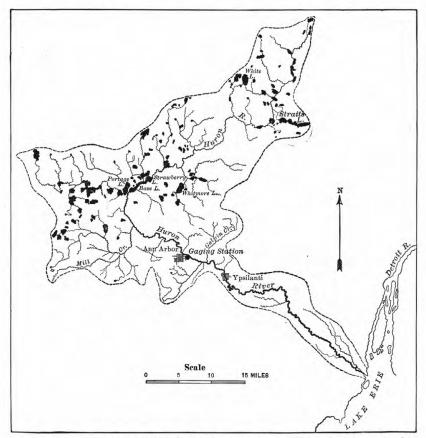


Fig. 110.—Drainage basin of Huron River, Michigan, showing location of gaging station.

versity of Michigan. Current-meter measurements are made from a temporary bridge, or by fording. The stream at this point winds. It flows in a shallow channel, and ordinarily does not overflow its banks. The bed is generally of gravel. The river usually freezes over during the winter, except immediately below the dams. Natural storage in the numerous lakes and marshes regulates the flow to some extent. The character of the watershed has changed somewhat during recent years. Areas of tamarack swamp lands, which were formerly only

quaking bogs, have been cleared and drained and are now under cultivation. The drainage area above the mouth of the river is 1,043 square miles; above Ann Arbor it is 841 square miles. A gaging of the bankfull flow of the stream at the Geddes dam, 3 miles below Ann Arbor, was made by Professor Davis, and the estimated discharge was 1,200 second-feet. The Geddes dam has a flat crest and is practically water-tight. The length of the crest is 200 feet, and the depth of water on the crest at the time the measurement was made was 1.7 feet.

THUNDER BAY RIVER.

Thunder Bay River is joined by two larger branches 8 and 10 miles, respectively, above its mouth. These branches, as well as the main stream, are further subdivided at short distances upstream, so that the river is of relatively small size, except for a few miles near its mouth, where occurs an outcrop of Traverse and St. Clair shales. It is in passing over this rock ledge that the most rapid fall of the stream The drainage area was formerly heavily timbered with Michigan pine. Most of the pine has, however, been cut, but a large amount of small conifers, hard woods, white birch, and cedar remains, so that the watershed may be considered as representing a forested rather than a cleared area. A record of precipitation is kept at Alpena, near the mouth of the stream. The outcrop of the Traverse and St. Clair shales crosses the watershed in a northeast-southwest direction, crossing the river channel a few miles west of Alpena. The surface above the line of this outcrop is almost continuous limestone, composed of calcium carbonate of 96 to 98 per cent purity, small areas being covered with sand or with thin drift deposits.

No water powers of importance have been developed on either of the branches. On the main stream there are two power dams. The lower one, which is at Alpena, was constructed in 1862. It is 1 mile from the head of Thunder Bay, an arm of Lake Huron. The river is navigable to the dam, forming a harbor. The dam and privileges of the river are owned jointly by the Alpena Water Works Company and the Alpena Booming Company. The water wheels installed have a rated capacity of 864 horsepower under a head of 9 feet. The power is used for pumping the municipal water supply and for the generation of electricity. The second dam is at the mill of the Fletcher Paper Company, 4 miles above Alpena, and 2,000 horsepower is developed from a fall of 17 feet. The only dams above the Fletcher mills are those used for floating logs. Spruce dam, at Long Rapids, gives a head of 7 or 8 feet. At Lower Rapids a head of 20 feet could be obtained by the construction of a dam.

The drainage basin, a map of which is shown in fig. 111, contains 30 lakes, with an average area of about 1 square mile. In addition to these is Hubbard Lake, which has a water surface of 134 square



A. SUNKEN LAKE AND DIVERTING DAM ON THUNDER BAY RIVER, MICHIGAN.



 ${\it B.}$ GAGING STATION ON THUNDER BAY RIVER AT MILLS OF FLETCHER PAPER COMPANY NEAR ALPENA, MICH.

miles. A timber dam at the foot of the latter lake produces a storage depth of 5 feet, with an aggregate storage capacity of 1,867,500,000 cubic feet, equivalent to a flow of 68 second-feet for thirty days. A similar dam at the foot of Beaver Lake gives a storage depth of 6 feet. The water from Beaver Lake is used chiefly for driving logs.

The limestone area contains numerous sink holes, often deep and precipitous. Surface water entering these pits disappears with greater or less rapidity by finding outlets to a lower level through limestone fissures. Such a pocket, known as Sunken Lake (see Pl. XVIII, A), is near the North Branch of Thunder Bay River, and it absorbed the

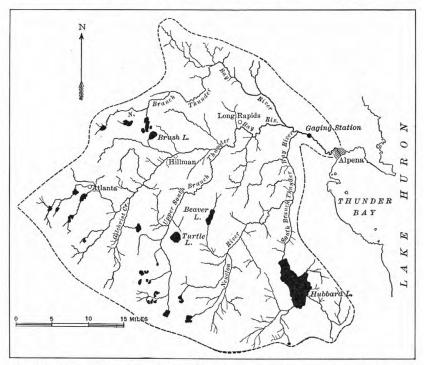


Fig. 111.—Drainage basin of Thunder Bay River, Michigan, showing location of gaging station.

entire flow of that tributary, involving a considerable loss to power users, until in 1900 a clay puddle dam (shown in Pl. XVIII, A) was constructed across the channel leading from the stream to the sink hole in such a manner as to turn the water down its original channel. Owing to the pervious nature of the rock strata the effective and apparent boundaries of the watershed may differ materially.

A gaging station (see Pl. XVIII, B) has been established in connection with the dam and mill of the Fletcher Paper Company. The record kept includes the depth flowing over the main dam and logway and the discharge through the turbines. There are four pairs of Trump "Model" wheels set on horizontal shafts. The water wheels are not run otherwise than at full gate. The dam, which is of timber

crib work filled with stone, is on a limestone rock foundation, and is 20 feet high and 454 feet long between abutments. A log slide divides the spillway into two sections. The slide has a channel 6 feet in width and is closed by plank flashboards to an elevation of 1 foot above the crest line. The spillway has a vertical face and a crest 4 feet in width, sloping upstream, with a batter of 1 vertical to 5 horizontal. The upstream face of the dam has a batter of about 3 horizontal to 1 vertical. The left section of the spillway is $255\frac{1}{4}$ feet long. The flat crest is covered with sheet iron, slightly rounded at the lip. The right spillway section is 181.7 feet in length, and the crest is faced with planking.

ST. JOSEPH RIVER.

St. Joseph River rises at Bunday Hills, in northern Hillsdale County, Mich., flows southwesterly into Indiana, turns northward at South Bend, recrosses the State line near Bertrand, and debouches into Lake Michigan at St. Joseph. The total area drained is approximately 4,586 square miles, of which 2,916 square miles are in Michigan and 1,670 square miles in Indiana. The drainage basin, a map of which is shown in fig. 112, contains more than 400 small lakes, varying in surface area from an eighth of a square mile to 6 square miles. Of these approximately 100 are in Indiana and 300 in Michigan. No storage is developed on the stream. The drainage areas of the river and its more important tributaries are given in the following table:

Drainage areas of St. Joseph River and its tributaries.

Stream.	Location.			
	No. 10 to 10	Sq. miles.		
St. Joseph River	Above Three Rivers	868		
Prairie River	Above mouth	164		
Portage River	do	178		
Rack River	do	213		
St. Joseph River	Below Three Rivers	1, 417		
Do	Above Niles	3,616		
Dowagiac River	Above mouth	281		
St. Joseph River	Below mouth of Dowagiac River	3,898		
Do	Above mouth of Pawpaw River	4, 157		
Pawpaw River	Above mouth	429		
St. Joseph River	Below mouth of Pawpaw River	4,586		

The drainage basin lies in a completely glaciated region, and is covered with diversified drift deposits. The current of the river from South Bend to its mouth was formerly reversed, and this valley formed an outlet for the waters of Lake Michigan, which turned to the southwest, through Kankakee River, at South Bend, and thus reached the Mississippi through Illinois River. Leverett states a that

^{*}Water resources of Indiana and Ohio, by Frank Leverett: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, p. 439.

there is still a well-defined river channel connecting St. Joseph River with the Kankakee, the surface of which, where it leaves the St. Joseph, is but 45 or 50 feet above the present low-water surface of that stream. The watershed of St. Joseph River in Michigan contains relatively little marsh land not artificially drained and relatively little uncleared land. About a third of the lakes are, however, without outlets. The proportion of undrained lakes in Indiana is smaller, and the swamp lands are much more extensive.

Elkhart River, one of the principal Indiana tributaries of the St. Joseph, drains an area of about 500 square miles, which contains large lakes and extended swamp areas, the principal fall occurring in the passage of the stream from marsh to marsh.

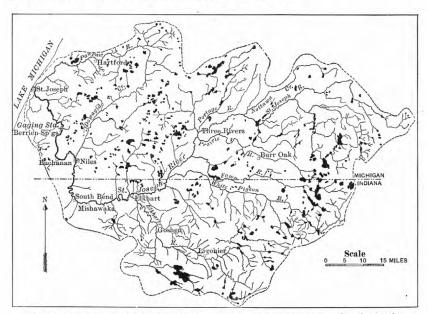


Fig. 112.—Drainage basin of St. Joseph River, Michigan, showing location of gaging station.

St. Joseph River was formerly navigable for boats as far as Elkhart, or perhaps farther, and the older dams were provided with locks, long ago abandoned and closed. Prof. James Du Shane is of the opinion that at the present time the low-water depth of the river over the rapids is from 1½ to 2 feet. A rise of 5 feet represents ordinary high water, and a rise of 8 feet represents extreme high water. Within the last twenty-two years two freshets have occurred which raised the water in some portions of the river higher than here given. The average width from bank to bank is 400 feet, and the average slope from Elkhart to Berrien Springs is 2.1 feet to the mile.

The first water-power mill in southwestern Michigan was constructed by Eli Ford, in 1827, on Dowagiac Creek, near its confluence with St. Joseph River, at Niles. This mill, known as the Volante mill, has been in operation since 1828. Power development on St. Joseph River began at a somewhat later date. The dam at Niles was built about 1856. At South Bend the power was developed by the South Bend Manufacturing Company, and was sold in the form of rights to the flow through wheels of a certain number of square inches vent under the available head. The dam is 10 feet high, with lateral power canals on each side. Under an order of the court the water is to be maintained at a stage not lower than 6 inches below the crest of the dam. Nineteen privileges have been granted, calling for a flow of 3,195.5 cubic feet per second under a head of 9.5 feet. Fourteen of these privileges are now in use. The minimum flow of the stream is usually considered to be 1,000 second-feet, but it is stated to have fallen considerably lower during the months of July and August, 1895. Elkhart there is a similar power development, the flow of the stream being divided among eleven mills. The power at Elkhart was originally divided by priority, the amount being specified as so many runs of stone, or "sufficient for the purpose of the mill."

The following table gives the principal facts regarding water powers: in the St. Joseph River Basin, so far as reported:

Developed water powers in St. Joseph River Basin.

			Number	Effective head or fall.			Rated power of
Stream.	Location.	Number of dam.	of mills at dam.	Greatest.	Least.	Average.	water wheels reported.
				Feet.	Feet.	Feet.	Horse- power.
St. Joseph River	Buchanan	1				11.0	
Do	Niles	2	2			12.0	4,018
Do	South Bend	3	14	12.0	4.0	9.5	2,588
Do	Mishawaka	4	3	11.0	7.0	10.0	1,760
Do	Elkhart	5	3	13.0	6.0	10.0	1,920
Do	Constantine	6					
Do	Three Rivers	. 7	3	10.0	6.0	8.5	600
Do	Below Mendon	8					
Do	Burlington	9					
Do	Tekonsha	10	1	8.0	6.0	7.0	- 89
Pawpaw River	Watervliet	1	1	14.0	6.0	10.0	600
Do	Hartford	2					
Do	Lawrence	3					
South Branch of Pawpaw River.	Pawpaw	1	1	14.0	12.5	13.5	132
Do	do	2	1	17.0		17.0	108
Spring Brook	Almena	1					
Dowagiac Creek	Niles	1	2			12.0	356
Do	Above Niles	2	1			14.5	715
Pokagon Creek	Sumnerville	1					
South Branch of Dowagiac Creek.	Dowagiac	1	1	10.0	8,0	9,0	98
Do	Lagrange	2					
Christiana Creek	Elkhart	1					

Developed water powers in St. Joseph River Basin-Continued.

			Number	Effect	Rated power of		
Stream.	Location.	Number of dam.	of mills at dam.	Greatest.	Least.	Feet. 7.0 14.5 9.5	water wheels reported.
				Feet.	Feet.	Feet.	Horse- power.
Elkhart River	Elkhart	1		8.5	4.0	7.0	60
Do	Goshen	2	2	17.0	10.0	14.5	700
Do	Benton	3					
Portage River	Three Rivers	1	1	10.5	8.5	9.5	297
Rocky River	do	1	1	15.0	11.0	14.0	459
Swan Creek	Colon	1	1	10.0	5.0	8.0	107
Coldwater River	Union City	1	1	9.0		9.0	52
Do	Above Union City.	2	1				
Do	Hodunk	3	1				
Nottawa Creek	Athens	3	1	9.0	6.5	8.0	35

There are a number of undeveloped powers between the present dams, and projects are now formed to utilize them. The power is to be used largely for the generation of electricity for transmission to neighboring towns. A part of it will supplement the power at existing dams. At Berrien Springs, Mich., a concrete dam 30 feet in height is proposed. This will make available a fall of 20 feet. Eighteen water wheels of a rated capacity of 7,500 horsepower are to be installed. This power is in sec. 18, T. 17 W., R. 6 S., Michigan meridian. At Bertrand, Mich., a fall of 12 feet could be obtained by the construction of a suitable dam.

Two available sites for dams exist between Mishawaka and Elkhart, Ind. The former is in sec. 11, T. 38 N., R. 2 E., second principal meridian, where a 12-foot fall is available. The width of the river is about 350 feet. The latter site, called the Twin Branch site, is in sec. 12, T. 37 N., R. 3 E., second principal meridian. A dam 422 feet long is proposed at this point, which would make available a fall of 21 feet.

At Bristol, Ind., a dam formerly existed, but it was washed out. A site exists in sec. 31, T. 38 N., R. 5 E., second principal meridian, where a fall of 16 feet could be obtained by the construction of a dam 600 feet in length.

At Mottville, Mich., in sec. 6, T. 8 S., R. 5 W., Michigan meridian, a fall of 9½ feet could be obtained by the construction of a dam 540 feet in length.

An undeveloped water power also exists near Three Rivers, Mich., in sec. 1, T. 6 S., R. 11 W., where about 9 feet fall could be obtained.

The available power of tributaries of St. Joseph River is of little value, as is indicated by the existence of numerous abandoned sites where dams have been carried away by freshets. At Ligonier, Ind., a dam formerly existed on Elkhart River, but it was washed out.

There are three undeveloped powers on Pawpaw River, in Antwerp Township, Van Buren County, Mich., with falls of 9 feet, 14 feet, and 9 feet, respectively.

Arrangements have been made with the Berrien Springs Power Company for the maintenance of a record of flow of St. Joseph River at their plant, when completed. The record will include discharge over the 500-foot concrete dam, and the run of water wheels, which will be eighteen in number, arranged in sets of three pairs each. In the meantime a temporary gaging station has been established at the dam of the Berrien Springs Power Company at Buchanan, Mich., 10 miles above Berrien Springs. The dam is of timber, of the Beardsley gravity type, with a straight crest approximately 400 feet long. It is 9.83 feet high, and is built on an earth foundation.

The stated depth of extreme high water on the crest of the Niles dam is 5 feet, indicating a freshet discharge of about 15,000 second-feet, or 4.5 second-feet per square mile. The extreme high-water flow over the Dowagiac River dam at Niles is stated to be 2 feet depth on the crest of the 120-foot spillway, corresponding to a flow of about 1,200 second-feet, or 4.3 second-feet per square mile, from a drainage area of 281 square miles.

KALAMAZOO RIVER.

The details of the hydrography of this stream have been given in an earlier report.^a A map of the drainage basin is published herewith, fig. 113.

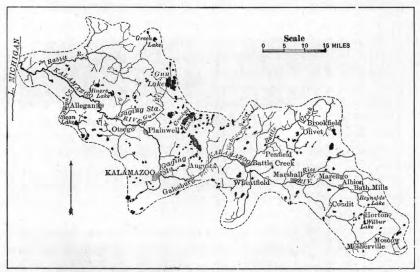


Fig. 113.—Drainage basin of Kalamazoo River, Mich., showing location of gaging stations.

[•] Report on the run-off and water power of Kalamazoo River, by Robert E. Horton: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 30, pp. 22-38.

The drainage areas of the river and its tributaries are as follows:

Drainage areas of Kalamazoo River and its tributaries.

Stream.	Location.	Area.
		Sq. miles.
North Branch of Kalamazoo River	Albion	138
South Branch of Kalamazoo River	do	136
Kalamazoo River	Below junction of North and South branches	274
Do	Marshall	448
Do	Above Battle Creek	608
Battle Creek	At mouth	244
Kalamazoo River	Below Battle Creek	847
Do	At Plainwell	1,307
Do	At Allegan	1,108
Do	At mouth	2,064

The accompanying table gives a summary of the developed water powers of the drainage basin. Most of the powers on the main stream are utilized. In 1898–99 a dam giving 23 feet head was built between Allegan and Otsego, to develop 2,000 horsepower for electrical transmission. This plant has the merit of being the first large long-distance transmission plant in the State. A portion of the fall between this dam and Allegan is still undeveloped, and it is claimed that a head of 20 feet could be obtained by the construction of a dam 2 miles above that city. Above Otsego, on the main river, there are one or two rapids having falls of several feet which are not yet developed.

Developed water powers in Kalamazoo River Basin.

	*	37	Number	Effect	Rated		
Stream.	Location.	Number of dam.	of mills at dam.	Greatest.	Least.	Feet. 23.0 12.0 9.0 12.0 6.0 13.0	of water wheels reported.
				Feet.	Feet.	Feet.	Horse- power.
Kalamazoo River .	Allegan	1	12				1,150
Do	Above Allegan	2	1			23.0	2,000
Do	Otsego	3	5			12.0	1,725
Do	Plainwell	4	5			9.0	786
Do	Battle Creek	5	7	12	10	12.0	469
Do	do	6	1				
Do	Ceresco	7	1			8.0	289
Do	Marshall	8	1			6.0	(b)
Do	do	9	1	14	12	13.0	200
Do	Marengo	10	1				118
North Branch	Albion	11	1				
Do	Newburg Mills	12	1				
Do	Bath Mills	13	1				33
Do	Concord	14	1			9.0	118
Do	Horton	15	1			10.0	55

^a Proc. Mich. Eng. Soc. 1900, pp. 84-91; also Engineering Record, Jan. 13, 1900.

^b Undershot water wheel.

Developed water powers in Kalamazoo River Basin-Continued.

*			Number	Effect	Rated		
Stream.	Location.	Number of dam.	of mills at dam.	Greatest.	Least.	Average.	of water wheels reported.
				Feet.	Feet.	Feet.	Horse- power.
South Branch	Albion	1	2				
Do	North Homer		1				69
Do	Homer	3	1				214
Do	Mosherville	4	1				80
Rice Creek	Marshall	. 1	1			12.0	136
Battle Creek	Battle Creek	1	1			6.0	86
Do	Bellevue	2	1				
Do	Olivet	3	1				
Augusta Creek	Augusta	1	1	18	17	18.0	260
Gull Lake outlet	Galesburg	1	1	13	12	13.0	81
Do	Howlandsburg	2	1	12	10	11.0	70
Do	Yorkville	3	1			20.0	80
Comstock Creek	Comstock	1	1	12		11.5	22
Portage Creek	Kalamazoo						
Wilder Creek	Eckford						
Wabasacon Creek	Bedford						
Comstock Creek	/	2				23.0	38

It is stated that a dam could be built 1 mill above the mouth of Swan Creek, which enters Kalamazoo River 8 miles below Allegan, and a head of 40 feet be obtained.

During a portion of 1900 a daily record of the river stage was kept at Kalamazoo, the results of which are given in Water-Supply Paper No. 49, page 259. Earlier records will be found in Water-Supply Paper No. 30, page 36. Arrangements have been made for the maintenance of a gaging record at the electric-power dam at Trowbridge, 6 miles above Allegan. The plant includes four pairs of 45-inch Leffel-Sampson turbines on horizontal shafts. The gate opening and discharge of two pairs are controlled by Lombard governors. The excess of flow not taken by the turbines is discharged over a spillway having three Taintor flood gates, each 20 feet long. The spillways have flat crests 20 feet in width, with slopes of 1 to 1 on the upstream and downstream faces. The discharge on the downstream side is received on a floating apron 20 feet in width, which is anchored to the flood-gate cribs by chains.

PROPOSED DIVERSION OF ST. MARY RIVER, MONTANA.

Most of the rivers receiving the drainage from the eastern side of the Rocky Mountains continue across the plains, carrying their waters into the Missouri or other great tributaries of the Mississippi. At the extreme northern end of this range in the United States, however, the drainage which starts on its eastern course meets a barrier of glacial débris brought from the north by the ice sheet which invaded this country in comparatively recent geologic times. These waters, prevented from flowing down the slope of the plains to the east, are turned north by the barrier of bowlders and gravel, and flow into Canada as a stream known as St. Mary River, a tributary of Belly River, its waters finally entering Hudson Bay through the Saskatchewan.

St. Mary River appears to flow directly across what might be termed the natural course of the drainage. It skirts along the foothills, separating them from the low, undulating country whose irregular outlines are characteristic of land formerly buried under moving ice. The water falling upon this land is held partly in lakes, or, escaping, meanders for some distance in streams with apparently aimless course, finally working its way easterly, most of it entering Milk River, a

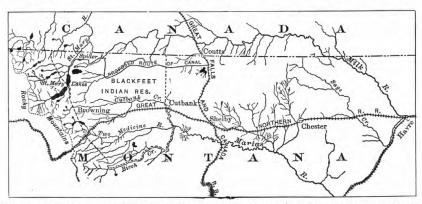


Fig. 114.—Map showing proposed canal line from St. Mary River to the head of Milk River and eastward; also the drainage basin of the latter stream.

tributary of the Missouri. Milk River, not receiving any water from the mountains, is extremely erratic in its behavior, floods following local rains and the channel becoming nearly dry during the summer. In its long, easterly course through the plains it passes land of great value in agriculture, but the ordinary supply of water is not sufficient for the irrigation of more than a small fraction of the fertile but drought-stricken region.

In studying a map of northern Montana one is at once impressed with the thought that St. Mary River has robbed Milk River of its headwaters in the mountains, and the question arises whether the eastward-flowing mountain streams which now drain into St. Mary River can not be restored to Milk River by an artificial cut on the east bank of the St. Mary, allowing the streams to continue their eastward course and finally discharge their waters into Milk River, thus restoring to that stream the drainage which in earlier geologic times undoubtedly flowed eastward toward the low country.

An examination of the region at the head of Milk River and along the side of St. Mary River was made during the summer of 1900, and it was found that it is feasible to divert water across the low divide and into the North Fork of Milk River. The Canadian boundary, however, has been so drawn as to include a considerable portion of the upper course of Milk River, and it was feared that if the waters of St. Mary River should be diverted into the North Fork of Milk River they would be taken out upon lands in Canada and not be permitted to continue easterly back into the United States. It was necessary, therefore, to determine whether some plan could not be devised to keep these waters upon the soil of Montana, and a further reconnaissance was made, the results of which demonstrate that it is feasible to retain the greater portion of the waters falling upon this part of the Rocky Mountains within the United States by constructing a canal which will conduct it easterly to the agricultural lands along or near Milk River in Montana. The canal line proposed is shown on the accompanying map, fig. 114, which also shows the drainage basin of Milk River and its course through Canada and into the United States. The details of the examination made by Charles H. Fitch and Gerard H. Matthes are given in the following report.

ST. MARY RIVER.

St. Mary River heads in northern Montana, near the Canadian boundary line, on the eastern slope of the main range of the Rocky Mountains, in a region of perpetual snow and in the midst of numerous glaciers. It starts from the great Blackfoot Glacier (probably the largest in the Rocky Mountains within the United States), and receives affluents from at least a dozen lesser ones. These small streams unite within a short distance from their sources and flow into a lake hemmed in by high mountains, known as Upper St. Mary Lake. Below this, separated by a narrow strip of land, is Lower St. Mary Lake. The aggregate length of these two lakes is about 22 miles. The river flows out of the lower lake, the elevation of which is 4,460 feet above sea level, and within 2 miles is joined by a stream nearly if not quite as large as itself, known as Swift Current Creek, which receives the water of the Grinnell Glacier and four lesser ones. From the confluence of these streams to the boundary of the British possessions, a distance of 12 miles, the river flows in a northerly direction. Entering Alberta, it empties into Belly River, its waters at length finding their way through Saskatchewan River into Hudson Bay. A canal has recently been constructed in Canada, by the Canadian Northwest Irrigation Company, which diverts water from the right bank of St. Mary River about 5 miles below the international boundary line. This canal is claimed to have a capacity of 400 cubic feet per second, and a length, including the several laterals, of approximately 200 miles.

Without a good map of the catchment basin of the river in the United States it is difficult to measure its drainage area, but it will approximate 450 square miles at the international boundary.^a

Discharge measurements of St. Mary River were made as follows: June 16, 1900, a gaging just below the outlet of Lower St. Mary Lake indicated a flow of 750 second-feet; two days later the discharge at Main, Mont., was found to be 2,294 second-feet. Between these points of measurement the river receives Swift Current Creek, and the gagings seem to indicate that its flow at the time was considerably in excess of the flow of St. Mary River where it leaves the lake. Later in the summer, however, this proportion was not found to exist, and the discharge of the creek appears as a rule to be less than that of the main river. Subsequent measurements of the river were made at Main, on August 6 and October 14, when the flow was found to be 750 and 552 second-feet, respectively, the latter representing the very low stage which the river usually reaches during the fall of the year.

MILK RIVER.

The great ridge which separates the St. Mary drainage from the Milk River system is much lower in altitude than the main range. It is generally dry, and the streams flowing east from it are small, running through prairies from almost the start. None of them are snow fed, and most of them start from the springs at the foot of the The main branch of Milk River is the South Fork. also flow the Middle Fork, Livermore Creek, and numerous smaller streams; but not until it has run a considerable distance into Canada is it joined by the North Fork. After a detour of 100 miles or more in that country it reenters the United States, entirely changed in character, however. From a clear, narrow brook, flowing through small meadows which require no irrigation to be productive, it has become a wide, shallow stream (see Pl. XIX), milky in color and often dry in midsummer, when water is most needed for the irrigation of its semiarid valley. It finally reaches the Missouri not far from the Great Northern Railroad, near the town of Glasgow, in the northeastern part of Montana. (See also page 287.)

The North Fork of Milk River from its headwaters to its confluence with the South Fork flows in a canyon the sides of which are steep and do not permit the ready diversion of water by means of ditches. Moreover, the character of the land adjoining the river is so irregular as to be unfit for irrigation. Two possibilities, however, present themselves along this portion of the North Fork for the diversion of water into the St. Mary River drainage.

The first site is at a low gap in the divide west of the North Fork,

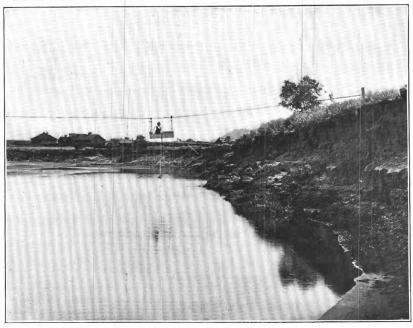
^a From recent (1901) topographic maps of the region drained by the river its catchment area in Montana has been found to be 452 square miles at the international boundary.

known as Whisky Gap, at one time a famous trail for smuggling between the United States and Canada. This gap, which is on Canadian soil, about 10 miles below Hall Gap, measures about 4 miles across the divide, and its highest elevation, as determined by vertical angulation, is 4,221 feet above sea level. It was also ascertained that this point was at approximately the same elevation as the high benches skirting the river valley, or, in other words, about 200 feet above the level of the river opposite the gap. Assuming the fall of the river to be 30 feet per mile, a ditch 7 miles long would be required to divert water through Whisky Gap. The physical possibilities which a diversion of this nature offers are, however, rendered valueless because of the geographic location of Whisky Gap, it being but $1\frac{1}{2}$ miles north of the international boundary, or 2 miles following the course of the river, thus rendering the enterprise impracticable.

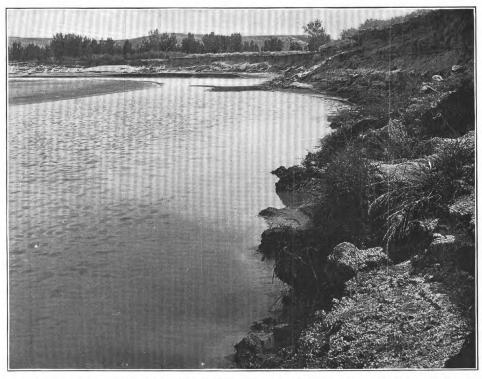
The only tributary of any importance that enters the North Fork from the west is the drainage from Lonely Valley, which empties into the river a few miles above the confluence of the North and South forks. The creek heads in the divide between the watersheds of St. Mary River and Milk River, and at first glance this appears to be a canal route forming a connecting link between the two basins, were it not for the comparatively high elevation of the divide, which would render a diversion at that point a difficult undertaking and one the cost of which would be prohibitory.

On August 15, 1900, the confluence of the North and South forks was visited. The amount of water in the streams appeared to be about the same—estimated at 20 second-feet and giving a discharge in Milk River proper below the confluence of 40 second-feet. The river bed at the latter place is gravelly and the water clear, in marked contrast with the peculiar white turbidity of the stream farther down its course, from which it has earned the name Milk River. The white sediments carried in suspension, often mistaken for alkali, are mainly composed of an impalpably fine, white clay, the amount of alkali in solution being in fact small. It was observed that the discharge of the river varies materially along different parts of its course, with a tendency to gradually diminish in quantity. Evidently seepage is an important factor affecting the flow.

The valley of Milk River in Canada varies in width from a half mile to a mile, and is incased between high benches averaging from 100 to 300 feet in height, the slopes being in most places steep or abrupt. On both sides of the river extend rolling and uneven prairie lands, producing crops of grass inferior to that produced at the headwaters. The bottom lands are settled at intervals by ranchers, but nowhere has irrigation on them been attempted, notwithstanding that ditches could be taken out at little expense and that there is a fair supply of water in the river during the irrigation season. Several miles above, where



A. MILK RIVER GAGING STATION AT HAVRE, MONT., LOOKING DOWNSTREAM.



B. MILK RIVER AT HAVRE, MONT., JUST ABOVE GAGING STATION, LOOKING UPSTREAM, SHOWING CHARACTER OF BANKS.

the Alberta Railway and Coal Company's narrow-gage railroad crosses the river, the valley widens and the benches slope off more gradually, which characteristic is retained to about a mile below the railroad bridge, where the valley again narrows and is inclosed between precipitous banks. The country traversed by the river from about 10 miles above the bridge referred to down to where it recrosses into the United States is level prairie land, interrupted by but few coulées, and would be well adapted for irrigation if water could be brought to it.

The reconnaissance of Milk River proper as it flows through Canada brings to light the fact that irrigation of adjacent lands is not feasible, except at considerable expense, due in the first place to the high and steep banks to be overcome and in the second place to the very slight fall of the river. Actual measurements made by Mr. J. T. Berthelote, of Goldbutte, Mont., establish the fall of the river at 30 inches per mile. In general it may safely be stated that, excepting that portion of the valley in the vicinity of the narrow-gage railroad bridge alluded to, diversion of water from Milk River for irrigating purposes would be attended with serious obstacles of a physical nature which would make the cost of the works prohibitive. Along the entire course of the river through the Dominion of Canada no irrigation is practiced, in spite of the fact that ranches along the stream are numerous and that during the irrigation season the river furnishes a supply that might be applied to good advantage.

The following discharge measurements were made of the forks of the river:

Date.	Stream,	Point of measurement.	Dis- charge.
1900.			Secft.
June 14	South Fork	Near Paul's ranch, 12 miles above junction with Middle Fork.	31
June 21	Middle Fork	Nine miles above junction with South Fork	7
June 19	North Fork	Near Hall's ranch.	12

Discharge measurements of forks of Milk River.

INTAKE OF CANAL.

The site selected for the intake of the canal is along the east bank of St. Mary River, about three-fourths of a mile below where the river emerges from Lower St. Mary Lake. The east bank there is about 30 feet high. The selection was made principally on account of the quality of the rock encountered, the outcrops exhibiting a variety of close-grained, homogeneous sandstone entirely lacking the loose shaly texture characteristic of the sandstone occurring throughout the region, and insuring substantial masonry abutments and wing walls for the head gates, the solid rock being used where practicable—a construction which will prove of great advantage, particularly as regards the cost

of maintenance in a climate where the winters are long and the action of frost is unusually severe on works of this class. The site also possesses other advantages. A dam can be constructed at this point to raise the level of Lower St. Mary Lake and at the same time serve to divert water into the head of the proposed canal. The river at the site selected for the dam is narrow, and the dam along its highest portion would be only 200 feet long, the remainder of its length extending across the valley, the level of which rises rapidly toward the west.

The two St. Mary lakes cover an area of approximately 10 square miles, their respective levels differing by only about 10 feet. By the construction of a dam about 40 feet high an immense amount of water could be stored in them and be made available for use during the lowwater season.

DIVERSION OF SWIFT CURRENT CREEK.

The elevation of this creek where it emerges into the valley is about 60 feet higher than the level of the lake. The flow can therefore readily be diverted into St. Mary Lake or into St. Mary River at any point between the proposed dam site and the lake, the work of construction required in either case being merely that of building a levee to guide its turbulent waters into one of the many abandoned channels of its delta formation. A diversion of this kind possesses the inestimable advantage of increasing the available water supply for the canal from 30 to 100 per cent at a comparatively low cost. No surveys for a diversion of this nature have, however, been made.

ROUTE OF CANAL.

The topography of the canal route is varied. A short distance below the intake steep hillsides are encountered, which although interrupted at intervals and crossed by numerous coulées continue for 5 miles down the river. It is probable that this part of the line will present some of the most difficult features that will be met in the construction of the canal, the natural slopes being steep, in places precipitous, while the material consists of a tough, clayey soil containing more or less loose rock, and part of the excavation will be in the solid rock. Both as regards first cost and maintenance this section will be of an expensive character.

About 6½ miles below the intake the canal would pass through a gap in the ridge, the elevation of which is 4,471 feet, and thence into the narrow valley of Willow Creek, in the highest part of which is situated Spider Lake, the level of which is 4,430 feet. This lake drains into St. Mary River through a low gap just north of the gap through which the canal would pass. Immediately northeast of the lake are the headwaters of Willow Creek, which drain in a northeasterly direction,

ultimately discharging into St. Mary River. A low natural dike at the north end of Spider Lake prevents the latter from draining into Willow Creek.

It being impossible, without building long dams at both ends of the lake, to raise the level of Spider Lake to the level of the canal along this section, it will be necessary to continue the canal around the east side of the lake. The hillside work along this section, however, presents none of the difficult features encountered along that part of the route just described. The canal would follow the east side of the valley of Willow Creek for 4 miles, when it would swing into an easterly direction and cross gently undulating country for a distance of 3 miles, would then follow the south side of the narrow valley leading to Hall Gap for a distance of $1\frac{1}{2}$ miles, and after crossing the gap would enter the valley of the North Fork of Milk River.

COST OF CONSTRUCTION.

As designed the cross section of the canal along the route described will be 50 feet wide on top, 30 feet wide on the bottom, and 10 feet deep, giving a capacity, on a grade of 0.02 per cent, of about 1,100 cubic feet per second, the mean velocity being less than 3 feet per second. In order to obtain a preliminary estimate of cost, a first location and cross-sectioning of 9 miles of the canal line were accomplished during the season of 1900. The canal paralleling the river for a considerable distance at two places will require heavy cutting in order to safeguard against seepage and the sliding of the banks. Riprap will be used along the river where necessary to protect the canal embank-A number of small creeks and springs will be crossed by the In order to provide a safe overflow for their discharge, spillways will be constructed at suitable places to relieve the canal of surplus water from that source and also such as may result from heavy rainfalls. The watersheds of these creeks being very limited, freshets need not be feared.

In the following table, giving estimates of cost for the first 9 miles, or to Spider Lake, excavation is classified as earth and solid rock, earth being all material that can be moved without blasting, at an estimated cost of 12 cents per cubic yard. The rock is a soft sandstone, easily worked at an estimated cost of 80 cents per cubic yard. The cost of riprap is placed at \$3 per cubic yard, and the clearing and grubbing of timber and brush at \$30 per acre.

Estimated cost of first 9 miles of	t. Mary	Canal, or fr	rom the intake to	Spider Lake.
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	Excav	ration.			Cost.
Section.	Earth.	Solid rock.	Riprap.	Clearing.	
	Cu. yds.	Cu. yds.	Cu. yds.	Acres.	
First mile	185, 010. 5	63, 035. 4	880	9	\$75, 539. 58
Second mile	132, 244. 3	6, 900. 0	400	3	22, 679. 32
Third mile	211, 968. 0	15, 500.0	650	10	40, 086. 16
Fourth mile	138, 137. 4			8	16, 816. 49
Fifth mile	219, 851.4	6, 400.0		9	31, 772.17
Sixth mile	101, 995. 0			5	12, 389. 40
Seventh mile	102, 800. 9			9	12,606.13
Eighth mile	108, 945. 2			5	13, 223. 45
Ninth mile	132, 791. 9	1,000.00		12	17, 095. 08
Last 400 feet	20,060.2	600.00			2, 887. 22
Total for 9.07 miles	1, 353, 804. 8	93, 435, 4	1,930	70	245, 094. 90
Dam and head gates					44,000.00
Engineering and contingencies					43, 405. 10
Total					332, 500. 00

CROSSING THE DIVIDE.

Hall Gap is a deep natural depression in the divide separating the drainage basins of St. Mary River and Milk River. The highest place in the gap has an elevation of 4,541 feet. Assuming the canal level at that point to be 4,442 feet, there is a difference in elevation of 99 feet to be overcome either by means of a cut or a tunnel. Subsequent surveys will determine whether the route through the gap is the most practicable way of reaching the North Fork of Milk River. It may be found less costly to continue the canal along the north side of the ridge separating the St. Mary River drainage from that of Milk River, and finally pass it through Emigrant Gap, a depression in the ridge about 5 miles northeast of Hall Gap, thus reaching the North Fork of Milk River without making the enormous and costly cut at Hall Gap. Should it be decided to continue the canal east of the North Fork, an inverted siphon will be required to carry the water from Emigrant Gap across the valley of the North Fork.

DIVERSION FROM THE NORTH FORK INTO THE SOUTH FORK OF MILK RIVER.

In order to determine the approximate elevations of the gaps in the divide between the North and South forks of Milk River, the triangulation which served as a basis for the topographic mapping of the upper section of the canal route was extended to include the divide mentioned, and the elevations of several points on this divide were determined by vertical angles. Plane-table traverses were then run from these points through the principal gaps, three in number, and

their elevations found to be 4,723, 4,757, and 4,560 feet, respectively, in order from south to north. A complete reconnaissance was made of the divide as far north as the international boundary, and a planetable traverse was run from the gaps along the divide to within 2 miles of the boundary. No additional gaps were encountered connecting the watersheds of the two rivers, and the northernmost of the three gaps referred to, known as McLeod Trail Gap, was therefore found to be the lowest available route for a possible diversion of water from the North Fork into the South Fork.

It is estimated that by extending the canal from where it emerges from Hall Gap to McLeod Trail Gap the cut required at the latter point will be 150 feet in the deepest place. The gap is 5½ miles due south of the international boundary, or 6 miles measuring along the divide. The latter is a narrow ridge, interrupted at this point for a distance exceeding 1 mile. Through the gap passes the muchtraveled emigrant route known as the McLeod Trail, which, after fording the North Fork, crosses the divide west of the river through Emigrant Gap.

Although the difference in elevation between the canal level and the lowest point in the gap is considerable, the latter could be penetrated without serious difficulty, the gap being a short one and the watersheds sloping off rapidly on either side. The length of the canal from Hall Gap to McLeod Trail Gap is estimated at 12 miles. Of this 6 miles would be in difficult sidehill work, after which the canal would for 6 miles be in the flat bench lands between the river canvon and the divide. Four miles below Hall Gap the canal would cross the mouth of the Dry Fork, a small tributary entering the North Fork from the right. The canyon of this creek is about a quarter of a mile wide, with steep sides. A flume would be required at this point, the height above the bed of the Dry Fork being about 100 feet. This would be the only flume of importance between the two gaps. The canal would cross the several gulches which drain the flat bench lands, but they are of minor significance, and many of them can no doubt be overcome without fluming.

RECONNAISSANCE EAST OF MILK RIVER.

On September 21, 1900, a reconnaissance was commenced with a view to determining a route for the canal east of the South Fork of Milk River. After passing through the McLeod Trail Gap the water would find its way into the South Fork through natural drainage channels. About 5 miles below where it would discharge into the river a wide, low valley was discovered entering the valley of the South Fork from the east. In following up this valley, about 2 miles from the river a low divide was reached, the crest of which, by hand level, proved to be approximately 80 feet above the level of the river. Assuming the

fall of the South Fork to be 20 feet per mile, a very conservative estimate, a canal 4 miles long would pass over this divide without any cutting, the route lying for the greater part along easy hillslopes, interrupted at few intervals only by steep banks. On the other side of the divide a wide, shallow basin containing two alkali sinks was encountered. At its southern end this basin drains through a narrow cut, in an easterly direction, into the headwaters of Rocky Coulée, a tributary of Cutbank Creek.

Thence the reconnaissance was pursued along the headwaters of the latter creek, through a country of even and gentle slopes, in which canal construction could be carried on at moderate cost. The entire country sloping off toward the southeast, the question of eventually determining the proper grade for a canal to run in an easterly direction becomes a relatively simple problem, much latitude in the selection of the route being afforded. The country lying east of the South Fork of Milk River is eminently well adapted for irrigation. It is devoid of springs and perennial streams and produces a scanty growth of grass fit for sheep grazing only, while its topography is such that every foot of it could be put under ditch.

In pushing the reconnaissance farther east the divide was reached separating the headwaters of Red River, a tributary of Milk River, from the headwaters of Rocky Coulée. The latter gulch was reconnoitered for several miles and found to be a tortuous canyon cut into a soft, shaly sandstone. At the time of the visit, September 26 and 27, no flow was perceptible, the channel being a mere succession of stagnant pools of alkaline water containing a large percentage of alum.

A different country was found in the vicinity of the Great Falls and Canada Railway, west of which the topography is irregular and in places broken, finally ending in an abrupt escarpment several hundred feet high, at the foot of which extends a vast alkali flat, running in a north-south direction, in which the tracks of the railway are located. This flat varies in width from 2 to 6 miles, and is bounded on the east by a low ridge projecting from the base of the Sweetgrass Hills and extending in a southerly direction.

From the reconnaissance it appears that there are no obstacles of an unsurmountable nature to be overcome in carrying the water across the irregular topography of the area just described, but it is impossible without extensive leveling operations to make even the merest guess as to the proper route. It is probable that the only method of crossing the alkali flats will be by means of an inverted siphon, for it is certain that taking the water across the flats in a graded canal will carry it too far south in bringing it around the low ridge to the east. By means of an inverted siphon it will be possible to carry the water across this ridge at such a point as may be found most desirable with reference to the best location of the canal east of the ridge. The latter

portion of the route lies at the foot of the Sweetgrass Hills, an imposing series of buttes extending for 40 miles south of the Canadian line. The country south of these hills is characterized by an exceedingly level topography, devoid of deep coulées or other salient features, and this topography was found to continue eastward to Sage Creek, a tributary of Milk River, which discharges into the latter just above Havre, Mont.

Although the reconnaissance along this part of the canal route was of the most hasty character, it may safely be stated that canal construction throughout this region would be comparatively easy and inexpensive, while on the other hand a vast area of arable land would be controlled by the location of the canal immediately south of the Sweetgrass Hills.

A continuance of the survey another season will conclusively determine doubtful points and properly locate the canal throughout its entire length on United States soil.

SUMMARY.

The results of the reconnaissance may briefly be summarized as follows:

(1) After leaving Lower St. Mary Lake, St. Mary River has a flow during the irrigation season of about 1,000 second-feet. This can be greatly increased by storage.

(2) The flow of Swift Current Creek can at little expense be turned into St. Mary Lake, thus increasing the available water supply.

- (3) By diverting the river three-fourths of a mile below the lake a canal can be constructed, on a grade of 0.02 per cent, to carry 1,000 second-feet over the ridge east of St. Mary River to Hall Gap and into the headwaters of the North Fork of Milk River, a total distance of 16 miles. The cost of constructing the first 9 miles, inclusive of dam and head gates, would be \$332,500.
- (4) The canal can be continued from Hall Gap on the same grade, and be made to pass over the divide between the North and South forks of Milk River, a distance of 12 miles, after which natural channels can be taken advantage of down to the South Fork.
- (5) Reconnaissance shows it to be possible to again divert the water from the South Fork of Milk River over the divide east of the latter, and eventually construct a canal entirely within the United States, emptying into Sage Creek, a tributary of Milk River.
- (6) Vast areas of irrigable lands can be controlled by a canal between the South Fork of Milk River and Sage Creek.

UPPER MISSOURI RIVER DRAINAGE.

Nearly half of the arid region drains into the Gulf of Mexico, mainly through the Mississippi and Rio Grande. By far the most important tributary to the former is the Missouri, which drains, in whole or in part, the States of Kansas, Nebraska, the Dakotas, Wyoming, Colorado, and Montana, comprising in its basin nearly one-third of the entire arid region. The Missouri is formed by the junction, in southeastern Montana, at Threeforks, of Jefferson, Madison, and Gallatin rivers. Its principal tributaries are the Milk and Yellowstone, which, for convenience, are considered separately. Discharge measurements are in progress in the basins of all of these streams, as well as on Middle Creek, a tributary of East Gallatin River, the results of which for the year 1900 are given on the following pages. The results for previous years have been given in former reports. The Upper Missouri proper is measured at Townsend, Mont., where the Missouri River Commission maintains a gage.

Estimated monthly discharge of West Gallatin River near Salesville, Mont.

[Drainage area, 860 square miles.]

	Dischar	rge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.			- 1			
January a			600	36, 893	0.70	0.81
February a			500	27, 769	0.58	0.60
March a			500	30, 744	0.58	0. 67
April	1,573	630	960	57, 124	1.12	1. 25
May	5, 410	1,200	3,044	187, 168	3.54	4.09
June	5, 410	1,300	3,259	193, 924	3.79	4. 23
July	1,300	560	795	48, 883	0.92	1.06
August	595	400	517	31, 789	0.60	0. 69
September	560	385	472	28, 086	0.55	0.61
October	560	385	488	30,006	0.57	0.66
November	500	280	401	23, 861	0.47	0. 52
December	400	330	358	22, 013	0.42	0.48
The year			991	718, 260	1. 15	15. 67

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 261; rating table in Paper No. 52, page 516. For hydrograph see page 281.

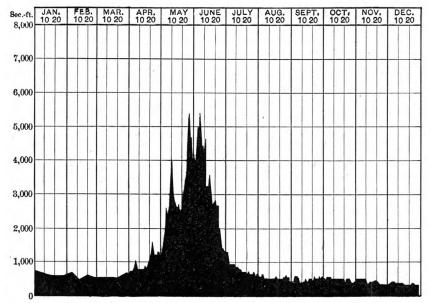


Fig. 115.—Discharge of West Gallatin River near Salesville, Mont., 1900.

Estimated monthly discharge of Middle Creek near Bozeman, Mont.

[Drainage area, 55 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
June 18 to 30			222	5, 724	4.04	1.95
July	118	66	89	5, 472	1.62	1.87
August	88	48	55	3, 382	1.00	1.15
September	48	48	48	2,856	0.87	0. 97
October 1 to 13			48	1, 238	0.87	0.42

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 262: discharge measurements, page 261; rating table in Paper No. 52, page 516.

Estimated monthly discharge of Gallatin River at Logan, Mont.

[Drainage area, 1,620 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	160					
January a			900	55 339	0.56	0.65
February a			1,000	55, 537	0.62	0.64
March a			1,000	61,488	0.62	0.71
April	1,638	940	1, 141	67, 894	0.70	0.78
May	4, 805	1,575	3, 123	192, 026	1.93	2. 23
June	4,615	605	2, 255	134, 182	1.39	1.55
July	605	240	328	20, 168	0. 20	0. 23
August	400	290	341	20, 967	0. 21	0. 24
September	530	400	484	28, 800	0.30	0.33
October	680	530	606	37, 261	0.37	0.43
November	1,080	605	700	41,653	0.43	0.48
December	680	605	633	38, 922	0.39	0.45
The year			1,043	754, 237	0.64	8. 72

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 263; discharge measurements, page 262; rating table in Paper No. 52, page 516.

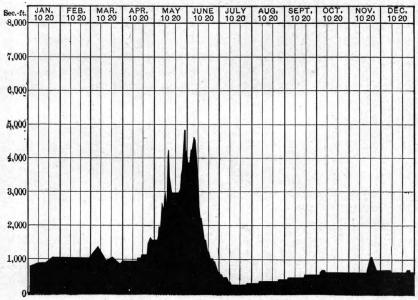


Fig. 116.—Discharge of Gallatin River at Logan, Mont., 1900.

MADISON RIVER.

A proposed diversion of Madison River, designed to increase the supply of the city of Helena, Mont., and to furnish water for irrigation, power, and mining along the route of the canal to be constructed, has been a subject of much interest to and has frequently been discussed by the press and citizens of Helena. In order to determine the feasibility of such a canal and the possibility of conveying water across the intervening divides, during the field season of 1900 preliminary lines of spirit levels were run, four routes being surveyed by S. H. Martin. Three of them, however, are considered impracticable, not only because of the length of line required, the high elevations to be surmounted, and the difficulties of construction, but because of the prior appropriation, by an electric company, of the water of the river at the head of Madison The fourth route contemplates diverting the water near the mouth of Cottonwood Gulch, after it has been returned to the river by the power company. From there the canal would continue along the banks of the river, with ordinary hillside cuts to the wagon bridge crossing the stream, where would be encountered almost perpendicular rock walls for a distance of a half mile. It would then pass through a gravelly country containing large bowlders, occasionally through a clay flat, and through some hillside sections with slopes of 20 degrees from the horizontal, until it reaches the top of the plateau on the west bank of Madison River, about 3 miles south of Hyde post-office. Thence it would continue westerly across the plateau to where the latter begins to slope toward Jefferson River, when a southerly course would be followed to where the canal would cross the latter stream. To make this crossing would necessitate the construction of a flume about 6 miles long, with a siphon pipe under the railroad. elevation at Sappington is 4.187 feet above sea level, and at Whitehill, near where the canal would cross the river, it is 4,345 feet. course along the west and north banks of the Jefferson would be through a gravelly clay containing occasional large bowlders. Near Threeforks the canal would pass west of the mountain ridge which borders Missouri River, to a point opposite Toston. The earth along this valley is gravelly clay, with short rock reefs. The course is thence along the foothills west of the Missouri to Townsend, and from there to Winston, where an old placer ditch would be encountered, which the canal would follow until crossing a divide near the latter place. From Winston to Helena the cost of construction would be moderate, on account of the considerable fall in the ditch, whereby rock bluffs could easily be avoided.

The canal as designed would be more than 100 miles in length. Although no estimate has been made, more complete surveys being necessary for that purpose, it can safely be said that the cost of the

canal, excepting a short stretch at its head and another stretch after the Jefferson has been crossed, would be comparatively small for construction in a mountainous country.

Estimated monthly discharge of Madison River near Redbluff, Mont.

[Drainage area, 2,085 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	100					
March a			860	52, 879	0.41	0.47
April	2,530	860	1,764	104, 965	0.85	0.95
May	5, 655	3,005	4, 259	261, 876	2.04	2.36
June	5, 380	2,075	3,602	214, 334	1.73	1.93
July	2,075	1,640	1,855	114,060	0.89	1.03
August	1,850	1,640	1,667	102, 500	0.80	0. 92
September	1,850	1,640	1,689	100, 502	0.81	0.90
October	1,850	1,850	1,850	113, 752	0.89	1.03
November	1,850	1,640	1,661	98, 836	0.80	0.89
December	1,640	1,640	1,640	100, 840	0.79	0. 91

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 264; discharge measurements, page 263; rating table in Paper No. 52, page 516.

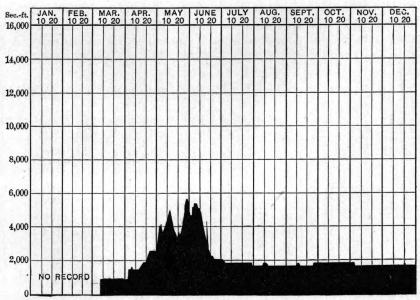


Fig. 117.—Discharge of Madison River near Redbluff, Mont., 1900.

Estimated monthly discharge of Jefferson River at Sappington, Mont.

[Drainage area, 8,984 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean,	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
April	2,645	1,870	1,992	118, 532	0.22	0. 25
May	7,645	2,020	4, 915	302, 212	0.55	0.63
June	15, 470	7, 445	10, 933	650, 558	1. 22	1.36
July	11, 165	2, 485	6, 159	378, 702	0.69	0.80
August	2,485	1,455	2,003	123, 160	0. 22	0. 25
September	1,325	- 1,090	1, 297	77, 177	0.14	0.16
October	2, 170	1,090	1,614	99, 241	0.18	0. 21
November	2,170	1,725	1,936	115,200	0. 22	0. 25
December 1 to 14			1,925	53, 455	0. 21	0. 11
1900.						
March 10 to 31	2,485	1,725	2,098	129,001	0. 23	0. 27
April	3,870	2,020	3,067	182, 499	0.34	0.38
May	9,075	3,870	6, 511	400, 346	0.72	0.83
June	5,890	2,020	4,070	242, 182	0.45	0.50
July	1,870	600	1,024	62, 963	0.11	0.13
August	600	475	519	31,912	0.06	0.07
September	980	515	743	44,212	0.08	0.09
October	1,590	1,090	1,363	83, 808	0.15	0.17
November	1,590	1, 455	1,486	88, 423	0.17	0.19
December	1,725	1, 325	1,541	94, 752	0.17	0.20

Note.—Gage heights for 1900 are given in Water Supply Paper No. 49, page 265: discharge measurements, page 264; rating table in Paper No. 52, page 516. For hydrograph see pages 286 and 287

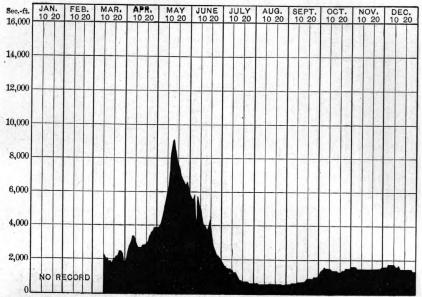


Fig. 118.—Discharge of Jefferson River at Sappington, Mont., 1900 (discharge for 1899 is shown in fig. 119).

Estimated monthly discharge of Missouri River at Townsend, Mont.

[Drainage area, 14,500 square miles.]

Month.	Dischar	ge in seco	nd-feet.		Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	20, 150	2,810	6, 810	418, 733	0.47	0.54
February	16,880	2,810	10, 156	564, 035	0.70	0.73
March	23, 400	3, 825	8,645	531, 564	0.60	0.69
April	7, 875	3,825	5, 973	355, 418	0.41	0.46
May	17, 340	8, 265	13,776	847, 058	0.95	1.09
June	14,600	4, 130	9,610	571, 834	0.66	0.73
July	3, 825	1,950	2, 309	141, 975	0.15	0.17
August	1,950	1,825	1,836	112, 892	0.12	0.14
September	2, 415	1,825	2, 169	129, 064	0.14	0.16
October	3,025	2,600	2, 897	178, 129	0.19	0. 22
November	9, 585	3,025	3, 794	225, 758	0. 26	0. 29
December	9, 585	1,825	3, 697	227, 320	0. 25	0. 29
The year	23, 400	1,825	5, 973	4, 303, 780	0.41	5. 51

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, pages 265 and 266; rating table in Paper No. 52, page 516.

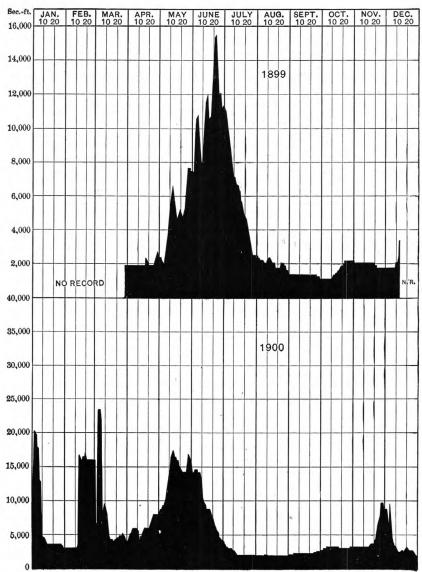


Fig. 119.—Discharge of Jefferson River at Sappington, Mont., 1899, and of Missouri River at Townsend, Mont., 1900.

MILK RIVER.

This river rises in northern Montana, and after flowing in a northeasterly direction about 30 miles it crosses into Canadian territory, reentering Montana farther to the east, and eventually discharging its waters into the Missouri. The gaging station is at Havre, Mont. (See Pl. XIX, A.) It was established in 1898. During the summer and fall of 1900 an examination of the drainage basin was made in connection with the proposed diversion of St. Mary River, which is discussed on pages 268 to 279, where will be found additional interesting facts regarding the stream.

Estimated monthly discharge of Milk River at Havre, Mont.

[Drainage area, 7,300 square miles.]

Month.	Dischar	ge in secon	nd-feet.	1		Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.	- 91						
April 10 to 30	640	280	394	23, 445	0.05	0.04	
May	1,575	129	435	26, 747	0.06	0.07	
June	355	.76	154	9, 164	0.02	0.02	
July	. 91	21	43	2,644	0.01	0.01	
August	232	8	40	2,460	0.01	0.01	
September	169	21	76	4,522	0.01	0.01	
October	355	76	186	11, 437	0.03	0.03	
November 1 to 15	169	63	114	6, 783	0.02	0.02	
December 17 to 22			15				

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 267; rating table in Paper No. 52, page 516.

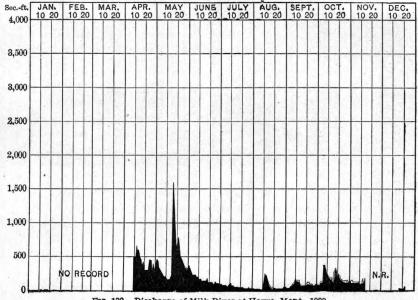


Fig. 120.-Discharge of Milk River at Havre, Mont., 1900.

YELLOWSTONE RIVER.

This river is the outlet of Yellowstone Lake, Wyoming, which acts as a regulator of its flow, so that its fluctuations are moderate for a stream in that region. For a long distance it flows in a profound canyon, at the lower end of which the gaging station is located, near Livingston, Mont. Two other gaging stations are maintained in its basin, one on Bighorn River near Thermopolis, Wyo., and the other on Clear Creek near Buffalo, Wyo.

Estimated monthly discharge of Yellowstone River near Livingston, Mont.

[Drainage area, 3,580 square miles.]

	Dischar	rge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899. January ^a			3,096	190, 366	0. 86	0, 99
February a	A		3, 107	172, 554	0.87	0.91
March		3, 130	3, 302	203, 032	0. 92	1.06
April	5, 275	3, 270	4, 016	238, 969	1. 12	1. 25
May	F. 1.			472, 717	2. 15	2. 48
	13, 225	4, 075	7,688		10.00	
June, 7 days			14, 174	196, 796	3. 96	1.03
July 23 to 31	100 m 100 m 100 m		13, 856	247, 347	3. 87	1. 29
August	12,005	4,730	7, 904	485, 998	2. 21	2.55
September	4,630	2,855	3, 621	215, 464	1.01	1.13
	2,790	2, 260	2,541	156, 240	0.71	0, 82
November ^a			2, 083	123, 947	0.58	0.65
December ^a			1,590	97, 765	0.44	0.51
1900.			1000	•		
January a			1,400	86, 083	0.39	0.45
February ^a			1,400	77,752	0.39	0.41
March a			1,300	79, 934	0.36	0.42
April	2,922	1,340	1,894	112, 701	0.53	0.59
May	14, 805	2,490	7, 530	463, 002	2.10	2. 43
June	15, 362	7, 995	11, 415	679, 239	3. 19	3.56
July	7, 270	3, 420	4,811	295, 817	1.34	1.54
August	3, 345	2, 150	2,666	163, 926	0.74	0.85
September	2, 100	1,715	1,878	111,749	0.52	0.58
October	1,760	1,500	1,607	98, 811	0.45	0. 52
November	1,500	1, 190	1,391	82,770	0.39	0.44
December	2,050	1,030	1, 513	93, 031	0.42	0.48
The year			3, 241	2, 349, 694	0.90	12. 29

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 268; rating table in Paper No. 52, page 516. For hydrograph see page 290.

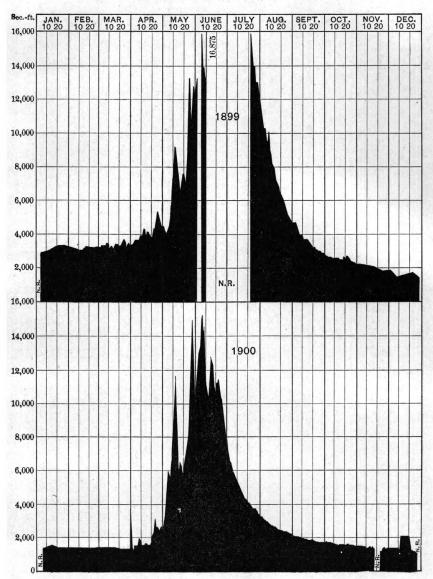


Fig. 121.—Discharge of Yellowstone River near Livingston, Mont., 1899 and 1900.

Estimated monthly discharge of Bighorn River near Thermopolis, Wyo.

[Drainage area, 8,184 square miles.]

Month.	Dischar	harge in second-feet.			Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
June	14,090	7, 270	9,617	572, 251	1.18	1.32
July	7,050	2,870	4,697	288, 807	0.57	0.66
August	3,530	2, 210	2,732	167, 984	0.33	0.38
September 1 to 15	2, 210	760	1,502	89, 375	0.18	0. 20

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 269; rating table in Paper No. 52, page 516.

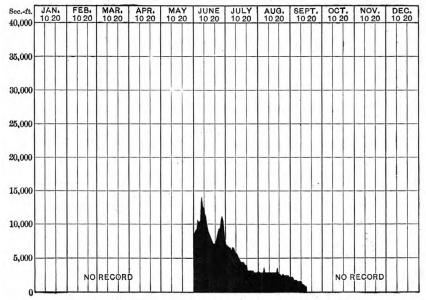


Fig. 122.—Discharge of Bighorn River near Thermopolis, Wyo., 1900.

OWL CREEK.ª

A low range of hills extending from the Washakie Needles, a prominent landmark at the intersection of the Owl Creek and Shoshone mountain ranges, to a point on Bighorn River between Basin and Alamo, Wyo., form a divide or watershed diverting the drainage on the south and east in a southeasterly direction to Bighorn River. Dry Cottonwood, Gooseberry, Meeyero, and Owl creeks, with their numerous tributaries, are important streams during the early months of

the year, but supply little or no water for other than stock or domestic purposes after July 15. All of these creeks flow through valleys that would add largely to the agricultural area of the State could the flood waters of the spring months be conserved for use when most needed, and all, with the possible exception of Owl Creek, seem to possess natural storage basins, where water sufficient for irrigating large tracts could be stored at reasonable cost.

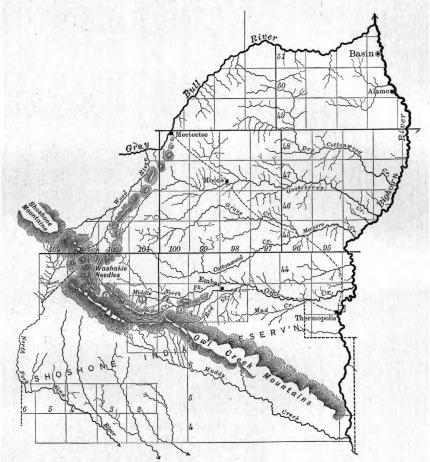


Fig. 123.—Drainage basin of Owl Creek, Wyoming.

Owl Creek, which marks the northern boundary line of the Shoshone Indian Reservation, is the largest and most important of the streams mentioned, having its source in the canyons and ravines about the Washakie Needles, and running in an easterly direction, passing through the canyons of the Owl Creek Mountains, then through a valley from 1 to 5 and in some places 10 miles in width, for a distance of nearly 30 miles, until it empties into Bighorn River. A map of the drainage basin is shown in fig. 123. The principal tributaries of

the creek are, on the north, the North Fork, a considerable stream, discharging from 1,000 to 2,000 second-feet during the flood season, the quantity gradually diminishing, however, until after July 1, when there is little or no moving water, and the Middle Fork, a flood-water stream carrying no running water after the spring freshets, except the run-off from storms, but furnishing a large number of springs which serve as watering places for stock the year round. On the south Red Creek and Mud Creek are perpetual streams, both draining the northern slope of the Owl Creek Mountains, neither carrying large volumes of water during the spring months, but both furnishing a supply of spring water during the driest seasons.

Owl Creek was perhaps the first stream in the Bighorn Basin upon which permanent settlement was made, the Embar Cattle Company more than twenty years ago establishing their home ranch at what is now the town of Embar. The soil of the bottom lands is deep and productive, the climate mild, and the elevation from 4,500 to 7,000 feet above sea level. Varieties of vegetables and fruits are grown successfully which are not produced elsewhere in the State outside of the Bighorn Basin. A number of well-cultivated ranches are to be seen, producing largely hav and grain, stock raising being the chief industry. Alfalfa thrives. At the Basin ranch of the Embar company is a field containing nearly 500 acres, from which two crops of alfalfa are harvested each year, while at several other ranches fields of 100 acres and more are cultivated. The water supply of the creek is almost entirely employed in irrigating cultivated lands, it being of too great value to be used on native grasses.

In 1899 the irrigating canals from Owl Creek and its tributaries were surveyed, showing that there had been constructed 55 miles of ditches and that 4,600 acres of land had been reclaimed and converted into farms. Preparations were also being made to reclaim as many more acres, flood-water permits for the same having been issued, which will enable settlers to use water until about July 1, or until after

their first crop of hav has been secured.

The natural productiveness of the soil and the facts that the water supply is now practically exhausted and that there still remains from 20,000 to 30,000 acres of unoccupied lands which could be irrigated at little cost if water could be had, have led to preliminary steps toward an investigation of the water resources of the region. In August, 1899, and again in October, 1900, trips up Owl Creek and the Middle Fork were made for the purpose of ascertaining whether it would be possible to impound the flood waters of those creeks to advantage and at a reasonable outlay. The reconnaissance extended from Embar, above which place the valleys are narrow, to near the head of the streams, where the mountains break into foothills. It was ascertained that in T. 43 N.,

R. 101 W., the Middle Fork passes through a narrow gorge between two ranges of hills, where a survey might prove the feasibility of constructing a reservoir at moderate cost. In T. 43 N., R. 102 W., where Owl Creek leaves the mountains in the foothills, there is a natural basin several square miles in extent, through which the creek runs and where it is reenforced by the waters of several smaller streams draining the springs of the surrounding mountains; and while but little water, perhaps 4 or 5 second-feet, was found in the channel 20 miles below, here the discharge was between 30 and 40 second-feet. In leaving the basin the creek enters a canyon, at the mouth of which it is from 150 to 200 feet wide, the walls of solid rock rising perpendicularly 60 feet, where there is a small platform. From this platform the rocky sides of the hills rise at an angle of about 30 degrees. At the mouth of the canyon the basin widens out in circular form, and a level taken indicated that a dam 60 feet high would back water a half mile, and that by raising the dam a proportionately greater surface would be covered. The cost of the dam can be determined only after a careful survey. Rock work would not be expensive, the material being at hand.

From this point to that where the creek again enters the valley the distance through the canyon is, in a direct line, 12 or 13 miles, but much greater if the channel be followed. The walls are precipitous. in many places almost perpendicular, rising to a height of from 1,500 to 2,000 feet, and, except at intervals, where the sides are cut by ravines and gulches, the bed of the stream can be reached only by most dangerous climbing. In October, 1900, an attempt was made to pass through the canyon. The bed of the creek was gained by descending a dry gulch about 2 miles below the upper basin. The slope of this gulch is probably 1,500 feet in less than a mile. The estimated discharge of the stream was 30 second-feet. It flows over a bed moderately free from bowlders, which has been worn through an almost solid sandstone formation. Now and then there are rapids and falls where the water drops 5, 10, and even 20 feet, and occasionally the stream is blocked by enormous masses of fallen rock. It was found impossible to proceed farther than 2 or 3 miles along the channel. After a difficult climb the top of the walls was reached and was followed to a few miles above the mouth of the Middle Fork, but no opening or basin suitable for a reservoir was discovered. About 2 miles below the mouth of the Middle Fork, Owl Creek again enters a gorge between two rocky points of a mountain spur, which seems a practicable site for a reservoir if it were found after a survey that the expense would be moderate.

There are two other methods of obtaining a water supply. First, that of carrying water by ditch from the creek to some large natural

basin, which seems feasible to one in passing through the country; and second, the turning of the North Fork of Wind River into Owl Creek. Whether either of these projects is feasible can only be determined after detailed surveys.

GREY BULL RIVER.^a

The Grey Bull, next to Shoshone River, is the largest tributary of the Bighorn. It has its source near the summit of the main range of the Rocky Mountains, within a few miles of the headwaters of Yellowstone, Snake, and Wind rivers. With its numerous tributaries, of which Wood River is the most important, it drains an area of more than 1,600 square miles, including a region containing the highest mountain ranges within the State of Wyoming, upon whose summits and heavily timbered slopes the snow never entirely disappears, but furnishes a perpetual supply of running water of considerable volume. The fall of the river through the mountains is considerable, in many places exceeding 100 feet to the mile, until near its junction with Piney Creek, where it leaves the canyons. From that point its descent for the next 50 miles averages about 50 feet to the mile.

At the mouth of Piney Creek is the first settlement on the river. The valley there is perhaps a half mile wide, broadening out gradually until Fenton is passed, where the water is carried in irrigation ditches on either side over a valley 20 miles in width. On no large stream in Wyoming have the waters been so thoroughly utilized or the irrigated area so largely cultivated as here. The banks of the river are not high, and its rapid fall has enabled the irrigators to turn water upon the land at little cost. A recent survey by the State engineer's office shows 360 miles of ditches and canals constructed and in use—with many more in the course of construction—furnishing water for about 35,000 acres of land, the greater part of which is cultivated. The water supply of the ordinary season is fully appropriated, and the problem is no longer to find settlers for vacant irrigable lands, but to provide water for those who have settled upon lands without an adequate supply, as well as to irrigate as much as possible of the many thousand acres contiguous—the best land in the State—for which there is no supply.

During the spring and early summer months the river discharges a great volume of surplus water, and it is believed that a careful survey will demonstrate that several feasible reservoir sites of considerable capacity exist at its headwaters, also on Wood River and on Rawhide and Meeteetse creeks.

In November, 1899, through the courtesy of Col. W. D. Pickett and Mr. Nathan Rush, who have for many years been residents on the Upper Grey Bull and have become thoroughly acquainted with all that mountainous country east of the Yellowstone National Park in which the river and its many tributaries have their source, it was possible to make a hurried trip through the lower canyons to a basin which was reported to possess many natural advantages for impounding water at moderate cost. The lateness of the season precluded a survey at that time, but a few observations with a level showed that the stream had less fall than at any point below for more than 50 miles. The width

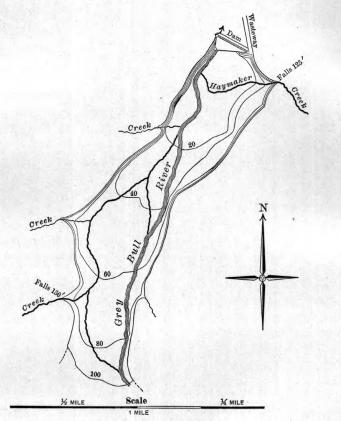


Fig. 124.—Map of reservoir site on Grey Bull River.

of the valley was estimated to be from a quarter to a half mile, the greater part of it smooth and level, as was proved by the fact that the river had no well-defined channel, but changed its bed from year to vear, plowing its way from one side of the valley to the other during high water. The lower end of the basin was moderately narrow and the quantity and quality of material required in the construction of a dam were abundant and near at hand.

This hasty reconnaissance showed that the expense of a survey was warranted, and in the latter part of September, 1900, a party was out-

fitted at Fourbear to make a detailed survey of the site. A fall of about 12 inches of snow during the night before the start was made prevented the trail through the canyon being taken, by which route the distance to the dam site is only about 15 miles. The course taken was in a southwesterly then northwesterly direction, over two mountain ranges, a circuitous journey of 25 miles to the basin, which is on the strip of unsurveyed land between the thirteenth guide meridian and the east line of the timber land reserve, Yellowstone Park. The distance from Fourbear, in a direct line a little south of west, is 10 miles. Owing to the depth of the snow on the higher points and to the great distance of any known Government corner, no attempt was made to ascertain the exact geographic location.

At the lower extremity of the basin, where it narrows down to the canyon, there is an immense deposit, perhaps 40 acres in extent, of

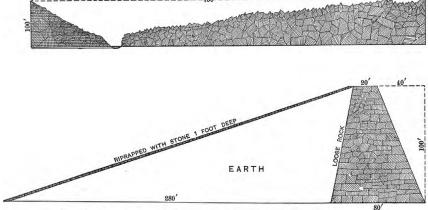


Fig. 125.—Cross sections of dam site and dam proposed on Grey Bull River.

broken, ragged porphyritic rocks, varying in size from pieces weighing a few pounds to blocks of a hundred tons or more, extending from the river channel, where they are piled up from 30 to 50 feet high, back to the cliffs on the east, where their height is not less than 200 The southern line is a veritable stone wall, very steep in places, and forming an angle of about 80 degrees with the stream and the western walls. Along the southern line of this moraine is the site chosen for the dam. A natural wasteway (see fig. 124), which only requires the removal of a limited amount of rock to give it capacity to carry off surplus flood waters, at an elevation of 98 feet above the present water line, determined the height to which the dam could most economically be built. And with that height as an initial point and high-water line the survey was made. A map of the reserv ir site is shown in fig. 124, and sections of the dam site and the dam proposed in fig. 125.

The presence of vast quantities of rock suitable for the purpose, and the ease with which it could be handled by means of a derrick or by a chute from the greater heights, makes a rock-fill dam the most desirable. Earth for reenforcing and adding to the stability of the structure is not wanting, for the tract of land north of Haymaker Creek (see map, fig. 124) and between it and the moraine is comparatively free from bowlders and could be handled to advantage at very low cost. The material which will have to be brought in from the outside is cement for use in the masonry work of the sluiceway and the iron sluice gates and tower, the total cost of which, however, need not exceed \$1,000.

The superficial area of the reservoir would be 256 acres, the capacity 14,024 acre-feet. Following is the estimate of cost:

Estimate of cost of Grey Bull reservoir.

146,040 cubic yards of earth at \$0.15	\$21,906
52,536 cubic yards of rock at \$0.40	21, 014
715 cubic yards of masonry at \$7	
4,149 square yards of riprapping at \$0.25	1,037
Two 3-foot sluice gates	
Iron for tower	500
Total	49, 962

BIG SIOUX RIVER.

In the systematic determination of the water supply of the United States and the measurement of the principal rivers many questions arise regarding the influence of lakes upon the behavior of streams, and whether the industrial value of the latter can not be greatly improved by regulating the outlets of lakes situated near their headwaters. One of the projects most strenuously urged by the people of eastern South Dakota is the possible improvement of Big Sioux River as a source of water power by storing the flood waters in the broad, shallow lakes along its course. In that part of the country fuel is expensive, and every available source of power for manufacturing, transportation, and municipal and domestic lighting is eagerly sought and considered in its effect upon local development.

In response to requests for definite information concerning Big Sioux River a reconnaissance of the stream was made in 1900, and systematic measurements were begun by Prof. O. V. P. Stout, resident hydrographer, Lincoln, Nebr., of the flow of water at various important points. A survey of two of the more important lakes in the basin was made by Gerard H. Matthes in order to obtain data regarding the feasibility of storing flood waters in them. The results of the reconnaissance and the survey are given in the following report of Mr. Matthes.



 $\it A.\,$ QUEEN BEE MILL AND FALLS OF BIG SIOUX RIVER AT SIOUX FALLS, S. DAK.



B. NEAR VIEW OF FALLS OF BIG SIOUX RIVER AT SIOUX FALLS, S. DAK.

WATER STORAGE IN BASIN.

The headwaters of Big Sioux River are in the gently undulating plains of eastern South Dakota, rising about 30 miles north of Water-For the first 70 miles the river assumes the nature of a shallow, sluggish stream, winding its way through meadow lands and old glacial moraines, with a fall of only 5 feet to the mile. The country traversed is a region of lakes, a number of which are connected with the river by means of channels. The direction of flow in the channels is in many instances variable and depends upon the relative elevations of the water level in the lake and river. In the lower part of its course the river flows between steep banks, and its bed is rocky and accentuated by riffles and falls. The stream is subject to freshets, which have been the cause of much damage by the flooding of adjacent farm lands and other property. While along its apper course the flooding is largely due to the slight fall of the river, the shallow character of its bed, and the obstructions caused by excessive plant growth, all of which factors tend to retard flow and render the stream incapable of discharging large volumes of water within the limits of its banks, ice gorges are mainly responsible for congestions of the channel farther downstream, where the conditions otherwise are favorable for the rapid passage of storm or snow waters.

The water powers of the river have been extensively developed, in fact more than its regimen would seem to warrant. The majority of the plants are in South Dakota, among them the Queen Bee Milling Company, of Sioux Falls, which probably owns the greatest power on the stream. It has been pointed out repeatedly that improvements in the flow of the river, principally in the direction of storing flood waters for subsequent use in eking out the low-water flow, would not only be of benefit in preventing the periodic devastation of lands and destruction of property by floods, but incidentally would benefit the users of water powers by furnishing them more power during the summer and fall months. Besides, the river being a tributary of the Missouri, the interception and storage of its flood flows would be directly in line with the policy of constructing storage reservoirs on the headwaters of the Mississippi River system.

The following list of users of water powers on Big Sioux River was furnished by Mr. George E. Wheeler, of the Cascade Milling Company, at Sioux Falls, S. Dak.: Akron Milling Company, Akron, Iowa; A. G. Ensign, Calliope, Iowa; A. Spencer, Fairview, S. Dak.; Henderson & Guinter, Beloit, Iowa; L. N. Crill & Company, Richland, S. Dak.; Bannings Mill (unused), near Sioux Falls, S. Dak.; Drake Polishing Works, Sioux Falls, S. Dak.; Queen Bee Milling Company, Sioux Falls, S. Dak.; St. Olaf Mills, Baltic, S. Dak.; Wm. Van Eps, Dell Rapids, S. Dak.;

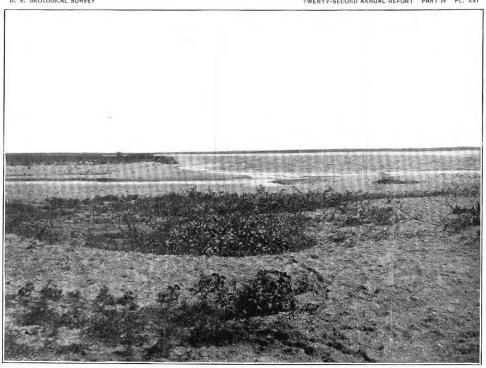
and S. E. Twitchell & Co., Flandreau, S. Dak. A significant fact is the general complaint of a lack of power during the low-water season. In the case of the Queen Bee Milling Company's mill (see Pl. XX), which was built to utilize a 56-foot fall with a 36-inch turbine, disappointment in regard to the amount of water available has been the reason that this magnificent mill, constructed nearly twenty years ago, has never been operated. During the field season of 1900 the United States Geological Survey established gaging stations at Sioux Falls and near Watertown, with a view to determining the variations in the discharge of the river and its minimum low-water flow. A measurement made at the Watertown station in July, 1900, by Professor Stout, gave a discharge of 5.2 second-feet. When measured at the same place on November 12 the discharge was 7.1 second-feet. A view of the river at Watertown is shown in Pl. XXI, B.

Of the lakes communicating with the river, already alluded to, the following have been found to be advantageous reservoir sites: Lakes Pelican and Kampeska, situated near Watertown, in Codington County, and Lake Poinsett, situated in Hamlin and Brookings counties.

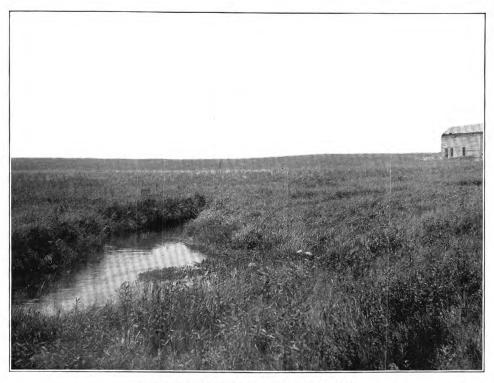
LAKES KAMPESKA AND PELICAN.

These lakes are within 2 miles of each other, in the vicinity of Watertown, Lake Kampeska, the northernmost, lying 3 miles northwest of the town. From the accompanying map, fig. 126, it will be seen that Lake Kampeska connects with the river by means of a channel 1 mile long, about 5 miles above the town. The flow in this connecting channel is in either direction, according to the relative stages of river and lake, and is at times uncertain. Thus, when visited by Professor Stout in July, 1900, the current was from the river into the lake, the channel where it enters the lake being about 15 feet wide and 1 foot deep. A stiff breeze evidently was in part responsible for this, for a few days later, when the wind was blowing in the reverse direction, the flow was intermittently from the lake into the river. Again, when visited in November it was found that although the lake was at nearly the same level as in June a sand bar had formed across the lake end of the inlet-outlet channel, effectually closing it to all outward appearances. There was, however, little doubt that there was at the time a flow of water either into or out of the lake through the porous gravel of the bar. A view of the outlet of the lake is shown in Pl. XXI. The bottom of the lake and its beaches is gravel underlain by strata of clay. Consequently the waters of the lake are clear and wholesome, and from them is drawn the water supply of Watertown, the pump house being located on the border of the lake.

The area of Lake Kampeska is given on the county map published by E. Frank Peterson as 5,000 acres. A record of the fluctuations of



 $\it A$. OUTLET OF LAKE KAMPESKA, SOUTH DAKOTA.



B. BIG SIOUX RIVER AT WATERTOWN, S. DAK.

the lake level has been kept since January 1, 1889, by the Watertown Water, Light and Power Company, the level of the pump-house floor being used as a datum (elevation, 1,746.5 feet). The variation of the lake level has not been very pronounced. High-water mark was reached April 2, 1897, the level of the lake on that date being 1,741.75 feet above sea level, while the extreme low water of December 1, 1891, indicated an elevation of 1,732.6 feet. An average of the records establishes the normal elevation of the lake at 1,736 feet. The lake is surrounded by steep banks and high lands, except at the east end,

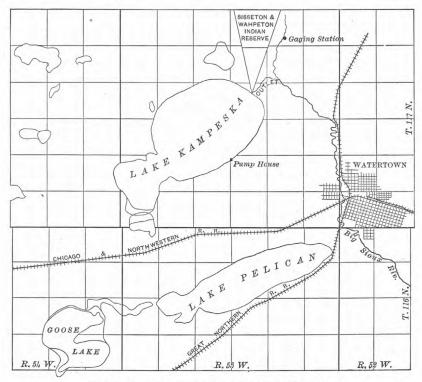


Fig. 126.—Map of lakes Kampeska and Pelican, South Dakota.

where the banks are not more than 4 or 5 feet high and the land consists of low meadows extending east to Big Sioux River. In considering the storage possibilities it should therefore be borne in mind that raising the level of the lake more than 4 feet will involve the flooding of considerable areas, probably exceeding 700 acres, of first-class hay lands valued at from \$20 to \$30 an acre. Construction of levees on the border of the lake for the protection of these lands can not be attempted owing to the porosity of the gravel bed, which, as experience elsewhere in this neighborhood has taught, will transmit large

amounts of water by percolation. From an interview with the manager of the Watertown Water, Light and Power Company, Mr. L. D. Lyon, it appears that although the company would favor any project calculated to raise the level of the lake, they would be opposed to raising the level more than 5 feet, owing to the danger, during stormy weather, of injury to the floor and machinery of the pump house, wave and ice action on the lake being very severe at such times.

The level of Lake Pelican is lower than that of Lake Kampeska and is subject to much fluctuation. Within the limits of its meandering lines it covers an area of 2,878 acres. It lacks the gravelly bottom characteristic of Lake Kampeska, which is one of the charms of that lake as a summer resort, but has instead a dense aquatic vegetation, and during the hot summer months has frequently been known to dry up. An outlet channel connects it with Big Sioux River about three-fourths of a mile below Watertown. The lands surrounding the lake are worth little as hay producers, the soil being hummocky and marshy, the vegetation consisting largely of species of swamp grass. The flooding of these lands that would result from a conversion of the lake into a storage reservoir would not, therefore, constitute a serious item of expense.

From November 11 to November 15, 1900, an investigation was made and sufficient leveling was done to ascertain the feasibility of controlling storage waters in lakes Kampeska and Pelican by constructing only one dam across Big Sioux River near Watertown. On the date of the survey, November 14, the elevation of Lake Pelican was 1.726 feet above sea level, the lake at the time being at a very low stage and completely frozen. The level of Lake Kampeska on November 15 was 1,736 feet, or 1 foot above its normal level. The elevation of the river at the Great Northern Railway bridge was 1,728 From the levels run it appears that by constructing a dam 11 feet high across the river just above this bridge, the level of the river would be raised, backing water into Lake Kampeska for a distance of 6 miles and raising the level of that lake 3 feet above the normal, while at the same time water could be made to flow into Lake Pelican, raising the level of that lake 13 feet. The storage capacity thus obtained would be 15,000 acre-feet in Lake Kampeska and 40,000 acre-feet in Lake Pelican, nearly all of which, deducting losses by evaporation, could be utilized during the summer season to swell the discharge of Big Sioux River.

For the proper control of this storage the following construction works would be required: (1) A dam 500 feet long on Big Sioux River, with ample spillway provisions and the necessary gates; (2) a dam and gates across the outlet of Lake Pelican, this dam to form part of a levee that would have to be built parallel with the Great Northern

tracks for a distance of 2 miles, the average height of the levee to be 7 feet; and (3) in order to divert water from the dam site into Lake Pelican a channel would have to be excavated for a distance of 600 feet, to a depth of 10 feet, which would permit water to drain immediately into the low basin in which the lake is situated, the connecting channel to be furnished with a set of gates. By these means the storage of water in either lake could be controlled at will, rendering it possible to fill one lake at a time, and, similarly, to draw upon the storage of one lake to any desired extent independently of the storage in the The dam proposed on the river would cause the flooding of a long strip of land on its right bank opposite the town, and would render necessary the rebuilding of two small wooden highway bridges and the raising of the Kemp avenue iron highway bridge, including the raising of the embankments which now serve as approaches to these bridges. A wooden highway bridge would also be required over the excavated channel referred to. The best place for such a structure is at the head gates of the channel. The land that would be flooded is worth little, and it is estimated that the cost of damages would be less than the cost of building levees for the protection of the land.

The cost of this storage project has been estimated as follows:

Estimate of cost of storing water in lakes Kampeska and Pelican.

Earthwork in dams and levees, 105,000 cubic yards at \$0.10	\$10,500
Excavation of channel, 8,000 cubic yards at \$0.10	800
Three sets of wooden gates and one spillway	
Raising Kemp avenue bridge	
Building three wooden highway bridges	
Land damages, approximately 600 acres at \$10	6,000
Raising approaches to bridges, 10,000 cubic yards at \$0.10	
Surveys	2,000
Engineering and contingencies	2, 500
Total .	26,000

LAKE POINSETT.

Lake Poinsett is in Hamlin and Brookings counties, S. Dak. A channel 4 miles long connects it with Big Sioux River opposite the town of Dempster. The country in which the lake is situated is one of glacial moraines, the lake being surrounded by low hills, except on the southeast side. A reconnaissance made November 21, 1900, showed that its level could be raised at least 10 feet without danger of flooding lands immediately surrounding the lake, there being ample evidence, in the nature of old shore lines, to indicate that the level of the lake has been at that elevation at some previous epoch. On the north it connects with a dry lake and on the west it receives the drainage from Albert, John, Mary, and other lakes. In addition, it is fed by

Big Sioux River, its level, as a rule, being lower than that of the river at the mouth of the connecting channel. The amount of water flowing into Lake Poinsett from these sources is small, and in spite of the fact that there is no flow out of the lake the evaporation from its surface, which covers, according to E. Frank Peterson's map, an area of 8,205 acres, is so great that the general tendency of the lake has been to gradually dry up. Time was when its waters got so low that millions of fish died, giving rise to very unpleasant odors. It is stated by citizens of Estelline, S. Dak., that in 1881, when after the rapid melting of a heavy snowfall the lake was unusually high, flow was observed to take place from Lake Poinsett into Big Sioux River, thus reversing the usual condition. Afterwards citizens of Estelline constructed a loose rock dam on the river just below the outlet of the lake for the purpose of maintaining the level of the water in the lake. This dam, by reason of causing the flooding of farm lands along Big Sioux River, occasioned much animosity between the farmers affected and the citizens of Estelline responsible for the construction of the dam. culminating in its partial destruction by the farmers. In spite of this the dam has proved of great benefit in raising the level of the lake, which at the time of the reconnaissance was stated to be about the same as that of the river a short distance below the dam. A gaging of the connecting channel made by Professor Stout in 1900 indicated a flow of 16.5 second-feet from the river into the lake.

The following elevations, taken from a report by Professor Stout, were furnished by Gen. George W. Carpenter, county surveyor of Codington County, from surveys made by him at the time of the construction of the dam:

Elevations of and along Lake Poinsett, S. Dak.	
	Feet.
Elevation of river bed at dam (assumed)	1,710.00
Elevation of center of outlet channel 1,200 feet from dam	1,710.40
Elevation of center of outlet channel 4,000 feet from dam	1,714.45
Elevation of center of outlet channel 7,800 feet from dam	1,715.75
Elevation of center of outlet channel 10,000 feet from dam	1,713.40
Elevation of center of outlet channel 17,000 feet from dam	1,705.14
Surface of water in lake 21,000 feet from dam	1,702.24

At the time of the reconnaissance, November 21, the latter elevation was probably 1,709 feet. In the present condition of the dam the lake is not of value as a storage reservoir. The flow being from the river into the lake, during floods the latter acts as a safety valve to the river, relieving it of a portion of its flood flow; but little or none of the water stored is available for subsequent use, for the lake level can not be maintained with the present defective dam. It has been proposed to remedy the situation by-building a substantial dam about 10 feet high and about 100 feet long, provided with head gates and ample

spillways, a short distance below the present structure; and the inletoutlet channel should be straightened, dredged, and graded. A dam of this height would raise the lake surface 10 feet, representing a storage capacity of 82,050 acre-feet, all of which, less the losses due to evaporation, could be drawn from the lake during the low-water season. A narrow strip of land on both sides of the connecting channel and a certain amount above the dam would be flooded when the reservoir is full. The approximate cost of the project is as follows:

Estimate of cost of storing water in Lake Poinsett.

Cost of rock-fill dam with masonry core wall and gates	\$2,000
Land damages, 200 acres at \$10	2,000
Improvement of channel, dredging, etc	
Surveying	
Engineering and contingencies	
Total	9 000

A map of the lake and surrounding country is shown in fig. 127.

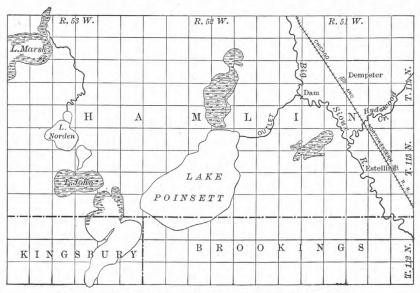


Fig. 127.—Map of Lake Poinsett, S. Dak., and surrounding country.

SUMMARY.

- (1) Big Sioux River is subject to flood discharges which in the past have caused considerable damage to property.
- (2) It is desirable to store the flood waters, not only to prevent further damage, but to utilize them during the low-water months to supplement the flow of the river.
 - (3) Lakes Pelican and Kampeska are natural reservoir sites com-22 geol, pt iv-01-20

municating with Big Sioux River. Their capacity can be increased and their storage controlled at will by building a dam across the river near Watertown and constructing such levees and other works as may be found necessary, as outlined in this report. The total expense of construction, including land damages and cost of surveys, will be about \$26,000.

- (4) The total storage capacity of the two reservoirs will exceed 56,000 acre-feet, and the cost per acre-foot will therefore be very low, viz, 46 cents.
- (5) Lake Poinsett can be similarly utilized, yielding a storage capacity of 82,050 acre-feet, by building a dam on Big Sioux River and improving the connecting channel, at a cost of \$9,000, or 11 cents per acre-foot.
- (6) The benefits to be derived from the project may be enumerated as follows: (a) The prevention of devastation by floods; (b) increased flow during low-water season, which will be of special importance to all milling interests on the river; and (c) improvement of the Watertown water supply.

PLATTE RIVER DRAINAGE.

Platte River rises on the eastern slope of the Rocky Mountains and drains an important part of the arid region, including portions of Wyoming, Colorado, and Nebraska. Its headwaters are extensively utilized for irrigation, and data regarding the quantity of water flowing in the main stream as well as its various tributaries are therefore very important. Accordingly no less than twenty stations are maintained in its basin, including one on Laramie River, at Woods, near the southern boundary of Wyoming, one on Grand Encampment Creek, a minor tributary near the head of the Platte, four on the North Platte, four on the South Platte, one each on Bear, Clear, South Boulder, Boulder, St. Vrain, and Big Thompson creeks and Cache la Poudre and Loup rivers, one on the main stream near Columbus, Nebr., and two on Elkhorn River. The results of measurements at these stations for the year 1900 are given in the following tables, pages 307 to 331.

Estimated monthly discharge of Laramie River at Woods, Wyo.

[Drainage area, 435 square miles.]

Month.	Dischar	ge in secon	d-feet.		n-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January a			178	10, 945	0.41	0.47
February a			211	11,718	0.49	0.50
March a			174	10,699	0.40	0.46
April	380	50	125	7, 438	0.29	0. 32
May	3, 995	290	1,940	119, 286	4.46	5. 14
June	3, 777	290	1,776	105, 679	4.08	4. 55
July	290	60	111	7,010	0.26	0.30
August	70	40	50	3,074	0.11	0.13
September	55	40	44	2,618	0.10	0.11

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 274; discharge measurement page 273; rating table in Paper No. 52, page 516.

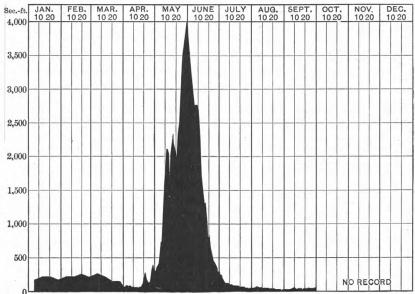
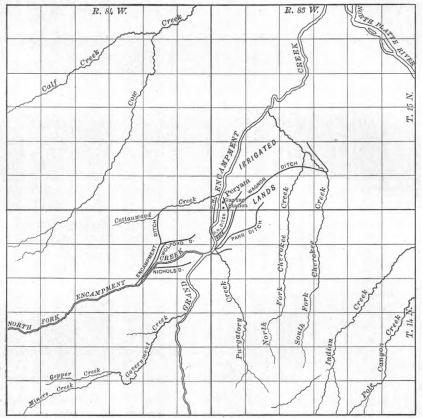


Fig. 128.—Discharge of Laramie River at Woods, Wyo., 1900.

GRAND ENCAMPMENT CREEK.

This creek is one of the largest tributaries of the North Platte. It has its source in the Sierra Madre, south of the boundary line between Wyoming and Colorado. It is, however, practically a Wyoming stream, accumulating its waters largely from small creeks and springs on the Wyoming slope of its watershed, an area now being brought into public notice by the discovery and development of many large deposits of copper ore. After leaving the foothills near the mouth of



Frg. 129.—Map of Grand Encampment Creek, showing irrigated lands and location of ditches and gaging station.

the North Fork the creek flows through a fertile valley about 2 miles in width, around and across which numerous large ditches have been constructed, irrigating nearly 8,000 acres of land, a portion of which is now under cultivation; but the greater part is being irrigated for native grasses, which grow luxuriantly, although at an elevation of more than 7,000 feet.

The many applications for permits to use water for mining, power, town-site, and irrigation purposes made it important that a more thor-

ough knowledge of the discharge of the creek be obtained. With that end in view, in May, 1900, a gaging station was established near Peryam's ranch, the gage rod being attached to the east pier of Mr. Peryam's bridge. After that date daily observations, morning and evening, were taken until October 1. Five discharge measurements were also made at different stages of its flow, and a table was prepared showing the daily gage heights and the total discharge for that period, which was published in Water-Supply Paper No. 49. The monthly discharge, run-off, etc., are given in the accompanying table, page 310. The maximum discharge was on May 29, when the flow was 4,685 second-feet; the minimum discharge occurred on September 2 and 3, when the discharge was 10 second-feet. The minimum discharge at the station does not, however, represent the total amount carried at low water. A view of the creek at low water is shown in Pl. XXII, B.

On July 19, 1900, measurements were made of the water flowing in the main channel of the creek above points of diversion, in the North Fork (which discharges into the main channel above the gaging station), and in several ditches which take their supply from these streams above the gaging station, with the following results:

Discharge measurements of Grand Encampment Creek, North Fork, and diversion ditches.

Secon	d-feet.
North Fork, above diversion	24.3
Nichols ditch, near head gate 4.9	
Wolford ditch, near head gate 5.2	
Town-site ditch, near head gate 2.4	
	12.5
Discharge into Grand Encampment Creek	11.8
Grand Encampment Creek above diversions	
Whambaker ditch, near head gate	
Parr ditch, near head gate 5.1	
Wagoner ditch, near head gate 49.0	
Mill race, near head gate	
Peryam-Nichols ditch, near head gate 2.1	
Grand Encampment Creek at gaging station 38.8	
Not accounted for 1.7	
Total	129.1

Notwithstanding that the season was one of unusually small precipitation, the supply is shown to be sufficient for present requirements.

Estimated monthly discharge of Grand Encampment Creek at Peryam's ranch, Wyoming.

[Drainage area, 252 square miles.]

\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	Dischar	ge in secon	nd-feet.	1		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
May 16 to 31	4,685	1,640	2,929	180, 097	11.62	13. 39	
June	3, 635	630	1,758	104, 608	6.98	7.78	
July	570	40	153	9, 408	0.61	0.70	
August	130	25	84	5, 165	0.33	0.38	
September	195	10	63	3,749	0.25	0. 28	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 273; rating table in Paper No. 52, page 516.

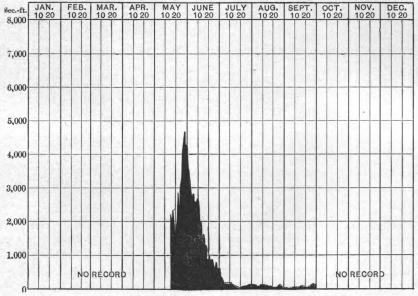
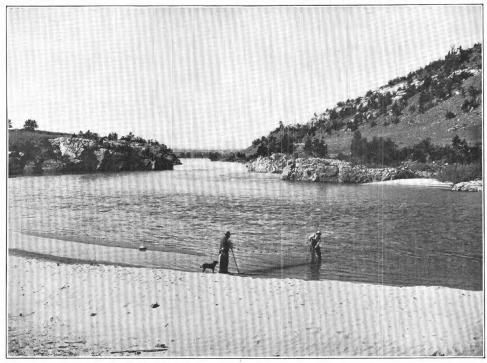


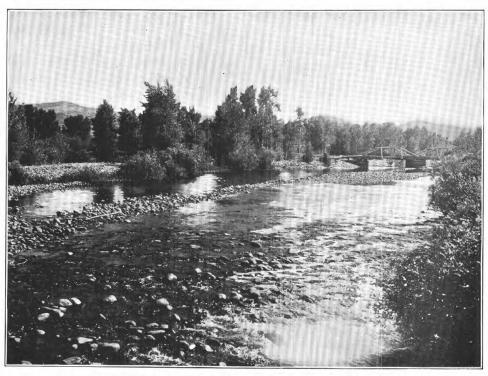
Fig. 130.—Discharge of Grand Encampment Creek at Peryam's ranch, Wyoming, 1900.

NORTH PLATTE RIVER.

The North Platte has its source in the mountains of North Park, in northern Colorado. The general elevation of the park is 8,000 feet. It is surrounded by mountains which attain elevations of 12,000 feet. There is considerable irrigation from small ditches which are used almost entirely, however, to flood native grass lands for forage purposes. On entering Wyoming the river passes through a short, narrow canyon and then flows northerly through the upper Platte Valley,



 $oldsymbol{A}$. GUERNSEY DAM SITE, NORTH PLATTE RIVER, WYOMING, LOOKING DOWNSTREAM.



B. GRAND ENCAMPMENT CREEK, WYOMING, DURING LOW WATER.

which extends from the State line down to Fort Steele. After passing the latter place it continues in a northerly direction, receiving a number of important tributaries, notably Sweetwater River, in the basin of which considerable irrigation is practiced. After passing into

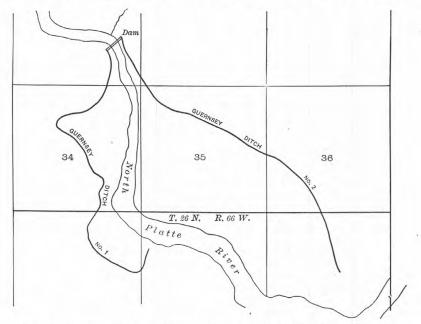


Fig. 131.—Map showing location of Guernsey dam site on North Platte River, Wyoming.

Nebraska the river does not receive any tributaries of importance. A number of canals divert water between the State line and North Platte. The tables on pages 312 and 313 give the results obtained at the gaging stations during the year 1900.

In 1900 a survey of what is known as the Guernsey reservoir site was made by private parties, the results of which were filed in the

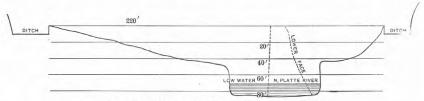


Fig. 132.—Sectional elevation of Guernsey dam site.

State engineer's office at Cheyenne, Wyo. The height of the proposed dam is 85 feet, and the estimated cost of construction \$150,000. The principal object is the development of electric power for use in the mining district in the vicinity of Hartville and Sunrise, Wyo. The reservoir would irrigate about 1,500 acres of land in the vicinity of

Guernsey. Pl. XXII, A, is a view of the dam site looking downstream, fig. 131 a map showing the location of the dam site, and fig. 132 a sectional elevation of the dam site.

Estimated monthly discharge of North Platte River near Guernsey, Wyo.

[Drainage area, 16,243 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
June 14 to 30	9, 790	3,950	6, 355	378, 149	0.39	0.44
July	3, 270	1,060	1,772	108, 956	0.11	0.18
August	780	310	483	29, 698	0.03	0.08
September 1 to 13			289	7, 452	0.02	0.01

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 275; rating table in Paper No. 52, page 516.

Estimated monthly discharge of North Platte River at Gering, Nebr.

[Drainage area, 24,340 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per quare mile.	Depth in inches.
1900.						
April 18 to 30			6, 582	169, 718	0. 27	0.13
May	14,800	9, 480	11,672	717, 684	0.48	0.55
June	15, 800	5, 400	10, 737	638, 896	0.44	0.49
July	5, 320	1, 200	2,689	. 165, 340	0.11	0.13
August	1, 157	395	713	43, 841	0.03	0.03
September	400	356	378	22, 493	0.02	0.02
October	522	399	431	26, 501	0.02	0.02

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 4ξ , page 276. For hydrograph see page 313.

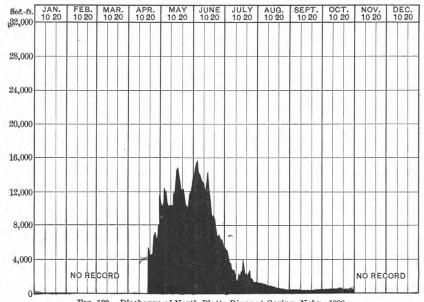


Fig. 133.—Discharge of North Platte River at Gering, Nebr., 1900.

Estimated monthly discharge of North Platte River at Camp Clarke, Nebr.

[Drainage area, 24,830 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum,	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
April 8 to 30	8,400	2,910	5, 328	317, 038	0.21	0. 23
May	14,000	8, 195	10, 379	638, 180	0.42	0.48
June	14, 275	3,960	9, 771	581, 415	0.39	0.44
July	4,000	770	2, 227	136, 933	0.09	0.10
August	900	230	471	28, 961	0.02	0. 02
September	425	180	289	17, 197	0.01	0.01
October	600	200	369	22, 689	0.01	0.01

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 277. For hydrograph see page 314.

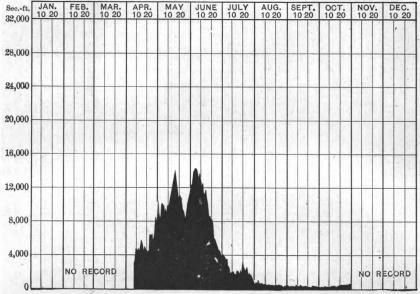


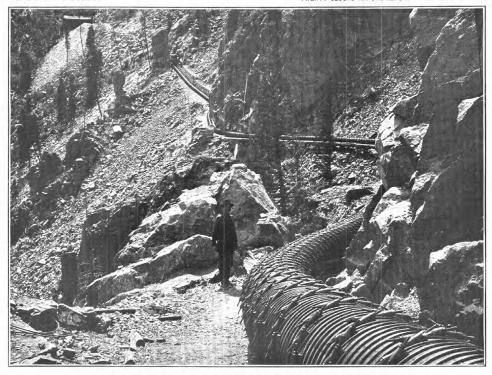
Fig. 134.—Discharge of North Platte River at Camp Clarke, Nebr., 1900.

SOUTH PLATTE RIVER.

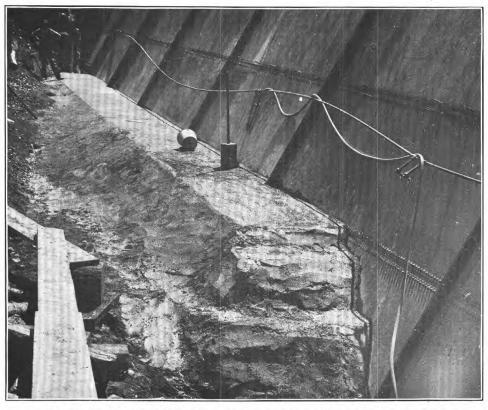
WATER STORAGE IN BASIN. a

On the headwaters of South Platte River and adjacent streams a number of large works have been and are being constructed for water storage. Among the most notable of these is Lake Cheesman, formed by the construction of a large masonry dam on South Platte River immediately below the mouth of Goose Creek, or Lost Park Creek, shown on the Platte Canyon topographic atlas sheet of the Geological Survey. The drainage area at this point is 1,677 square miles. Two views of this reservoir site are shown in the Twenty-first Annual Report, Part IV, Pl. XII, and an estimate of the monthly discharge of the river at that point is given on page 210 of the same volume. Southerly from this, in the vicinity of Victor, Colo., is a small reservoir constructed by the Pikes Peak Power Company. This plant is notable chiefly for the use of steel plates in the construction of the dam, which is illustrated in Pls. XXIII, B, and XXIV. The power developed is used at the mines in the neighborhood of Cripple Creek. The source of supply is Beaver Canyon, and the storage capacity of the reservoir is estimated at 3,443 acre-feet. A portion of the pipe line leading from the reservoir is shown in Pl. XXIII, A. This pipe line consists of wooden-stave pipe held in place by rods.

For about five years the Division of Hydrography of the United States Geological Survey has been making investigation of the flow of



A. PIPE LINE OF PIKES PEAK POWER COMPANY NEAR VICTOR, COLO.



B. PORTION OF STEEL-FACED DAM OF PIKES PEAK POWER COMPANY NEAR VICTOR, COLO,

water in South Platte River. The measurements have shown that very large volumes of water go to waste, both in the winter season and at flood stages. This fact having been demonstrated, in December, 1900, a series of investigations was inaugurated to determine the feasibility of storing water in reservoirs by means of canals from the river. The following facts are taken from the report of Mr. A. L. Fellows, who made the reconnaissance of the basin.

The plan here outlined, which has been adopted after a careful study of the situation, contemplates taking a canal out of the river below the mouth of the Cache la Poudre, which is the lowest tributary of the South Platte having a mountainous drainage. The adoption of this plan was influenced by the fact that if water were stored at points as high above the mouth as possible there would eventually be a very large return to the river from seepage and waste water, and thus a perennial flow could be relied upon lower down the main stream, which supply might in turn be taken out for the purpose of irrigating other tracts of land in the vicinity of Julesburg.

Certain reservoir sites known to exist in the region north of Orchard, Colo., which is in the territory under consideration, had previously been visited, and two were found to be excellent for storage purposes, viz, Jackson Lake reservoir site, with a capacity of 67,790 acre-feet, and Sanborn Draw reservoir site, with a capacity of 70,260 acre-feet, both of which had previously been surveyed and filed upon by private parties. Persons familiar with the country stated that there were a number of other sites that would hold from 23,000 to 230,000 acre-feet of water.

On December 14, 1900, a gaging station was established at Kersey, on South Platte River, immediately below the mouth of the Cache la Poudre, this being regarded the most suitable locality for river measurements and records. A reconnaissance tends to show that there would be no difficulty in carrying a canal of suitable size across the country north of the river. The opportunities for head gates are good, and the soil is of excellent quality for a canal; indeed, it is thought that no matter how long the canal might be it would not strike rock anywhere, except possibly in the vicinity of Pawnee Buttes, and even if rock were encountered the position of the ledges is such that construction would not be difficult.

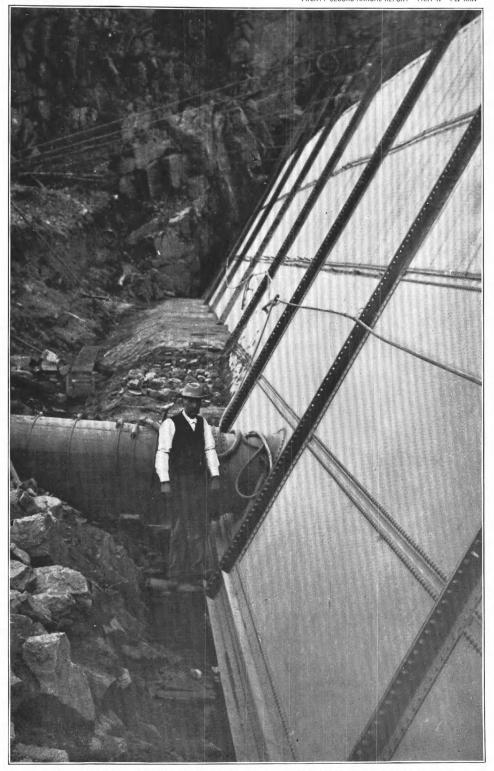
At the time of the visit to Kersey about 600 second-feet were going to waste, an amount considerably less than the normal winter flow, as the last season was an extremely dry one, and on that account the seepage and return waters had fallen off considerably. Records of previous years show that during the summer months there are times when as many as 2,000 or 3,000 cubic feet per second are available, and it is recommended that the project embrace the conveyance of at least 2,000 second-feet to the reservoirs under consideration.

A week later a visit was made to the Pawnee Pass reservoir site, which is about 15 miles northwest of Sterling, Colo., and among the reservoir sites that could be reached by means of such a canal as that projected. This site has been surveyed by private parties, namely, Messrs. D. A. Camfield and George H. West. The results of their survey, which it seems was carefully and thoroughly made, gave a capacity of 285,696 acre-feet. It would take a canal about 80 miles long to reach this site. There would, however, be no great difficulties in the way of construction, as has been stated before, and it is quite probable that even before this was reached a careful topographic survey would reveal enough reservoir sites to take the entire capacity of the proposed canal. The Pawnee Pass site is at the junction of three branches of Pawnee Creek. The country is rolling and of the prairie type. In order to create a reservoir a dam would have to be built between two buttes approximately a mile apart, although sloping to the center, so that the deepest places would be at the watercourse itself, which is usually dry, although at times carrying large volumes from rains and melting snows. The buttes, known as Pawnee Buttes, are capped by sandstone strata, great fragments of which are broken off and lie scattered over the ground. If the dam should be built it would probably be of earth backed by rock. The expense would necessarily be great, but only a detailed survey can determine whether it would be too great to pay for the advantages accruing. The amount of land that could be irrigated if water could be stored satisfactorily is very great, there being hundreds of thousands of acres of prairie land of the finest quality susceptible of a high state of cultivation.

The following data have been compiled concerning some of the reservoir sites that are known to exist under the proposed system. The figures are taken from records of surveys filed in the State engineer's office at Denver, and from examination of the sites it is believed they are practically correct.

Area and capacity of reservoir sites in northeastern Colorado.

Reservoir site.	Contour.	Area.	Storage capacity.
	Feet.	Acres.	Acre-feet.
Sanborn Draw	45	3,811	70, 260
Orchard		463	5,700
Jackson Lake	45	2,987	67, 790
Wild Cat No. 1		270	2,000
Wild Cat No. 2.		670	9,000
Wild Cat No. 3		650	7,900
Pawnee Pass	100	6,896	285, 696



PORTION OF STEEL-FACED DAM OF PIKES PEAK POWER COMPANY NEAR VICTOR, COLO.

The locations of the reservoir sites and the proposed canal line are shown in fig. 135. In all of these sites it may be said that the depth is to a certain extent arbitrary. The Pawnee Pass, for example, might be made 100 feet deep at the lowest place, or possibly as much as 200 feet, if desired, it being simply a question of the height of the dam to be constructed. Nearly all of the reservoir sites of this region are natural basins that can be filled with water to be drawn off by means of canals. The Pawnee Pass site would, however, require a dam from the bottom. Borings made at that site indicate that all the way across the valley hardpan would be reached within a few feet of the surface.

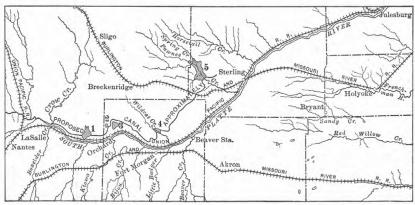


Fig. 135.—Map of northeastern Colorado showing location of reservoir sites and proposed canal line.

1. Sanborn Draw.
2. Orchard.
4. Wild Cat.
5. Pawnee Pass.

Jackson Lake.

In general the material for this dam as well as for others would have to be earth, which is of fairly good quality at each site; but it is possible that it might be deemed best to make the Pawnee dam a rock-fill faced with earth, the rock in that vicinity being a massive sandstone that will hold and last well.

The reconnaissance was of a hurried nature, but the following facts were brought out: (1) That there is an abundant supply of water; (2) that there are a number of reservoir sites; (3) that there are no material difficulties in the way of canal construction; (4) that there is a large amount of most desirable land in need of irrigation.

Estimated monthly discharge of South Platte River near Platte Canyon, Colo.

[Drainage area, 2,620 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	175	68	103	6, 333	0.04	0.05
February	68	41	55	3,054	0.02	0.02
March	225	77	157	9,654	0.06	0.07
April	2,445	160	826	49, 150	0.32	0.36
May, 19 days	2,685	2,085	2, 376	146, 095	0.91	1.05

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 281; discharge measurements, page 280; rating table in Paper No. 52, page 517.

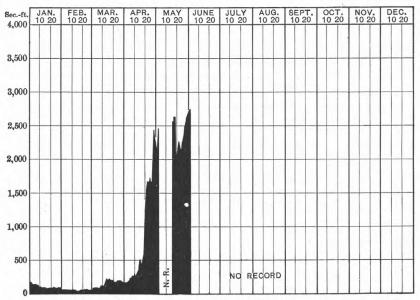


Fig. 136.—Discharge of South Platte River near Platte Canyon, Colo., 1900.

Estimated monthly discharge of South Platte River at Denver, Colo.

[Drainage area, 3,840 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean,	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	273	173	204	12, 543	0.05	0.06
February	242	160	193	10, 719	0.05	0.05
March	227	136	184	11, 314	0.05	0.06
April	5, 570	113	1,635	97 289	0.43	0.48
May	5, 163	3, 209	4, 188	257, 510	1.09	1. 26
June	4, 348	991	2,817	167, 623	0.73	0.81
July	947	113	379	23, 304	0.10	0.12
August	257	51	148	9, 100	0.04	0.05
September	273	51	123	7, 319	0.03	0.03
October	160	51	104	6, 395	0.03	0.03
November	242	113	186	11, 068	0.05	0.06
December	227	113	177	10, 883	0.05	0.06
The year	5, 570	51	861	625, 067	0. 22	3. 07

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 282; discharge measurements, page 281; rating table in Paper No. 52, page 517.

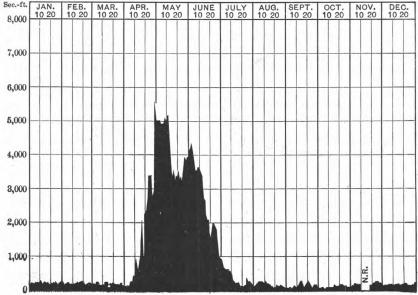


Fig. 137.—Discharge of South Platte River at Denver, Colo., 1900.

Estimated monthly discharge of South Platte River at Orchard, Colo.

[Drainage area,	12,260 squa	re miles.]
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	Dischar	rge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	2,834	614	1,634	100, 471	0.13	0.15
February	1,909	799	1, 268	70, 421	0.10	0.10
March	1,539	452	683	41,996	0.06	0.07
April	8, 939	452.	4, 180	248, 727	0.34	0.38
May	11, 159	6, 164	8,617	529, 839	0.70	0.81
June	7, 459	614	4,638	275, 980	0.38	0.42
July	452	130	171	10, 514	0.01	0.01
August	121	113	114	7,009	0.01	0.01
September	241	113	142	8, 450	0.01	0.01
October	452	260	431	26, 501	0.04	0.05
November	799	452	611	36, 357	0.05	0.06
December	614	614	614	37, 753	0.05	0.06
The year	11, 159	. 113	1, 925	1, 394, 018	0.16	2. 13

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49 page 283; rating table in Paper No. 52, page 517.

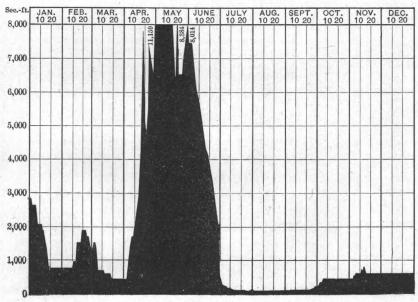


Fig. 138.—Discharge of South Platte River at Orchard, Colo., 1900.

NEWELL.]

Estimated monthly discharge of Bear Creek near Morrison, Colo. [Drainage area, 170 square miles.]

		Dischar	ge in secon	id-feet.		Run	Run-cff.	
	Month,	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
-	1900.	1						
April	l 15 to 30			321				
May		664	394	487	29, 944	2.86	3. 30	
June		583	189	379	22, 552	2. 23	2.49	
July		163	88	115	7,071	0.68	0.78	
Augu	ıst	103	27	50	3,074	0. 29	0.33	
Octo	ber	42	21	. 29	1,783	0.17	0.20	
Nove	ember	25	10	17	1,012	0.10	0.11	
Dece	mber 1 to 4			15				

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 285; discharge measurements, page 284; rating table in Paper No. 52, page 517.

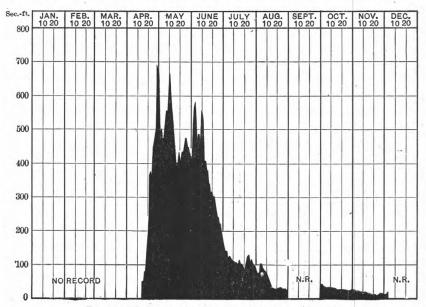


Fig. 139.—Discharge of Bear Creek near Morrison, Colo., 1900.

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Estimated monthly discharge of Clear Creek at Forkscreek, Colo.

[Drainage area, 345 square miles.]

	Dischar	ge in secon	id-feet.		Rui	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
March 10 to 31	75	44	60	3, 689	0.17	0. 20	
April	403	58	178	10, 592	0.52	0.58	
May	1,259	367	821	50, 481	2.38	2.75	
June	1, 259	719	968	57, 600	2.81	3. 13	
July	719	235	378	23, 242	1.10	1. 27	
August	235	84	137	8, 424	0.40	0.46	
September	75	44	58	3, 451	0.17	0.19	
October	75	51	58	3,566	0.17	0. 20	
November	58	51	51	3, 035	0.15	0.17	
December 1 to 4			51				

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 286; rating table in Paper No. 52, page 517.

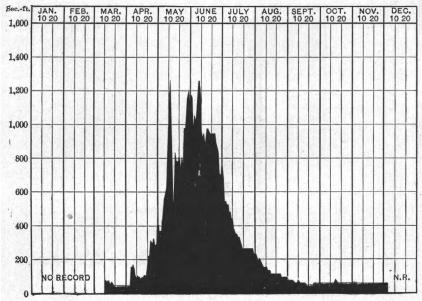


Fig. 140.—Discharge of Clear Creek at Forkscreek, Colo., 1900.

Estimated monthly discharge of South Boulder Creek near Marshall, Colo. [Drainage area, 125 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
May 6 to 12			850			
June	582	207	356	21, 183	2.85	3. 18
July	207	34	92	5, 657	0.74	0.85
August	55	5	29	1, 783	0.23	0. 27
September	17	5	9.	536	0.07	0.08

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 287.

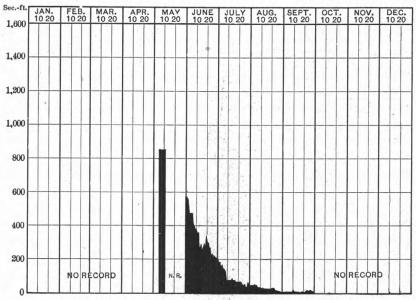


Fig. 141.—Discharge of South Boulder Creek near Marshall, Colo., 1900.

Estimated monthly discharge of Boulder Creek near Boulder, Colo.
[Drainage area, 102 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
May	778	502	624	38, 368	6. 12	7.06
June	801	483	640	38, 083	6. 27	6.99
July	444	161	254	15, 618	2.49	2.87
August	161	47	94	5,780	0.92	1.06
September	149	28	55	3, 273	0.54	0.60
October	69	6	33	2,029	0.32	0.37

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 288; rating table in Paper No. 52, page 517.

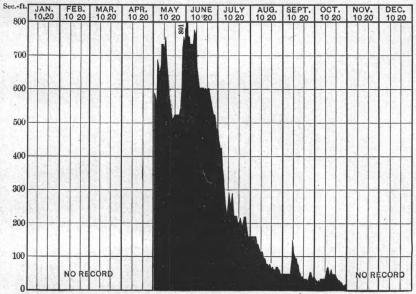


Fig. 142.—Discharge of Boulder Creek near Boulder, Colo., 1900.

Estimated monthly discharge of St. Vrain Creek near Lyons, 'Colo.

[Drainage area, 209 square miles.]

	Dischar	ge in secon	d-feet.		Rui	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.		1		1			
March ^a			17	1,045	0.08	0.09	
April, 17 days	918	10	360	21,421	1.72	1.92	
May	882	447	634	38, 983	3.03	3.50	
June	810	429	623	37,071	2.98	3. 32	
July	447	179	270	16, 602	1.29	1.49	
August	152	52	98	6,026	0.47	0.54	
September	207	40	67	3, 987	0.32	0.36	
October	88	31	47	2,890	0. 22	0. 25	
November 1 to 12			29	690	0.14	0.06	

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 49, page 289; rating table in Paper No. 52. page 517

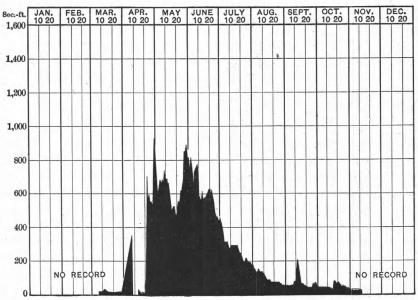


Fig. 143.—Discharge of St. Vrain Creek near Lyons, Colo., 1900.

Estimated monthly discharge of Big Thompson Creek near Arkins, Colo.

[Drainage area, 305 square miles.]

	Dischar	ge in secon	id-feet.		Rui	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
April	1,990	4	412	24, 516	1.35	1.51	
May	2,090	895	1,382	84, 976	4.53	5. 22	
June	1,990	737	1,352	80, 450	4.43	4.94	
July	556	208	349	21, 459	1.14	1.31	
August	208	88	137	8, 424	0.45	0.52	
September	88	60	77	4, 582	0. 25	0.28	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 49, page 291; discharge measurements, page 290; rating table in Paper No. 52, page 517.

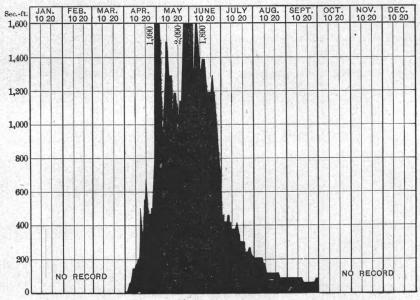


Fig. 144.—Discharge of Big Thompson Creek near Arkins, Colo., 1900.

Estimated monthly discharge of South Platte River below Lake Cheesman, Colo.

[Drainage area, 1,645 square miles.]

	Dischar	ge in seco	nd-feet.		Ru	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.					8	
January	27	23	26	1,599	0.016	0.018
February	27	27	27	1,500	0.016	0.017
March	103	27	80	4, 919	0.05	0.06
April	547	92	254	15, 114	0.15	0.17
May	1,540	562	1,038	63, 824	0.63	0.73
June	1,945	550	1, 204	71, 643	0.73	0.81
July	522	40	208	12, 789	0.13	0.15
August	126	58	88	5, 411	0.05	0.06
September	103	63	.79	4, 701	0.05	0.06
October	155	39	84	5, 165	0.05	0.06
November	90	37	69	4, 106	0.04	0.04
December	67	18	33	2, 029	0.02	0.02
The year	1,945	18	266	192, 800	0.16	2.13

Estimated monthly discharge of Cache la Poudre River near Fort Collins, Colo.

[Drainage area, 1,060 square miles.]

9	Dischar	ge in secon	nd-feet.	Total in acrefect.	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.			-			
April 18 to 30			1,376	35, 480	1.30	0.63
May	4, 560	2,049	2,808	172, 657	2.65	3.06
June	4, 376	1, 325	2,942	175, 061	2.78	3. 10
July	1,360	460	721	44, 332	0.68	0.78
August	460	195	265	16, 294	0.25	0. 29
September	260	113	149	8,866	0.14	0.16
October 1 to 16	141	122	132	8, 116	0.12	0.14

Note.—Daily discharge for 1900 is given in Water-Supply Paper No. 49, page 292.

Estimated monthly discharge of Loup River near Columbus, Nebr.

[Drainage area, 13,542 square miles.]

Month.	Dischar	ge in secon	nd-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.			1			
April	4,744	2,380	3, 352	199, 458	0. 25	0. 28
May	10,550	2,382	3,717	228, 549	0. 27	0.31
June	14, 300	2,085	3, 493	207, 848	0.26	0. 29
July	5, 380	1,980	3,265	200, 757	0. 24	0. 28
August	7,475	1,610	3, 462	212, 870	0. 26	0.30
September	7,550	2, 375	3, 363	200, 112	0. 25	0. 28
October	3, 700	2,900	3,222	198, 113	0.24	0. 28
November 1 to 17	3, 150	2,300	2,679	159, 412	0.20	0, 22

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 307.

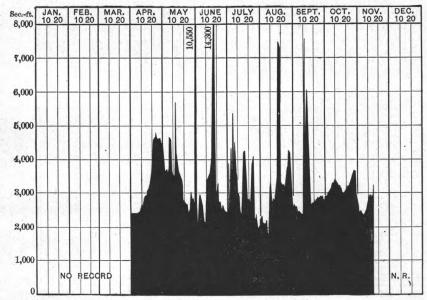


Fig. 145.—Discharge of Loup River near Columbus, Nebr., 1900.

Estimated monthly discharge of Platte River near Columbus, Nebr.

[Drainage area, 56,867 square miles.]

	Discha	rge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.				All Miles	The state of the s	- 15"
April 8 to 30	14,530	1,594	5, 584	332, 271	0.10	0.11
May	35, 400	7, 300	19,039	1, 170, 662	0. 33	0.38
June	25, 770	6, 700	14, 696	874, 473	0. 26	0. 29
July	10,500	200	2,883	177, 269	0.05	0.06
August 25 and 26 a			149			
September 11 to 17 ^a			1,588			
October 24 to 31 a			806			
November 1 to 9b			472			

a Remainder of month water too low to obtain gage readings.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 308.

Estimated monthly discharge of Elkhorn River near Norfolk, Nebr.

[Drainage area, 2,474 square miles.]

	Dischar	ge in secon	id-feet.	Total in acrefeet.	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean,		Second- feet per square mile.	Depth in inches.
1900.		1				
April	1,570	318	586	34, 869	0. 24	0. 27
May	2,400	360	721	44,332	0. 29	0.33
June	513	220	316	18, 803	0.13	0.15
July	304	145	223	13, 712	0.09	0.10
August	400	110	203	12, 482	0.08	0.09
September	290	180	220	13, 091	0.09	0.10
October	425	195	265	16, 294	0.11	0.13
November 1 to 17	380	337	357	21, 243	0.14	0.16

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 309; discharge measurements, page 308. For hydrograph see page 330.

b River frozen during remainder of month.

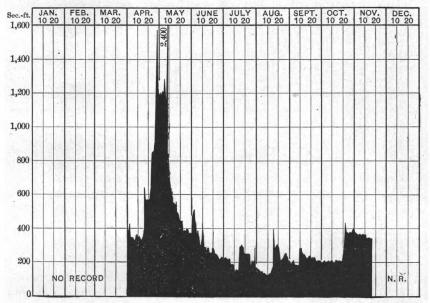


Fig. 146.—Discharge of Elkhorn River near Norfolk, Nebr., 1900.

Estimated monthly discharge of Elkhorn River near Arlington, Nebr.

[Drainage area, 5,980 square miles.]

	Dischar	ge in secon	nd-feet.	Total in acrefeet.	Run-off.	
Month,	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
April	1,811	484	742	44, 152	0.12	0.13
May	2, 283	654	1, 166	71, 695	0.19	0. 22
June	927	390	610	36, 298	0, 10	0.11
July	1, 293	325	562	34, 556	0.09	0.10
August	1, 250	322	627	38, 553	0.10	0.12
September	4, 160	426	1, 331	79, 200	0. 22	0. 25
October	3,656	470	824	50, 666	0.14	0.16
November 1 to 24	1,880	590	1,034	61, 527	0.17	0.19

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 310; discharge measure, ments, page 309. For hydrograph see page 331.

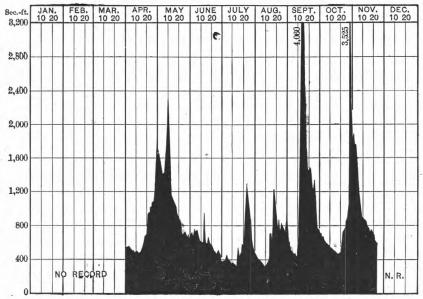


Fig. 147.—Discharge of Elkhorn River near Arlington, Nebr., 1900.

KANSAS RIVER DRAINAGE.

Kansas River is the largest river which has its source in the region of the Great Plains. Rising in low, arid country, its headwaters are all insignificant in size for a considerable distance from their source. The main stream is formed by the junction of Republican and Smoky Hill rivers at Junction, Kans. The former river is by far the longest tributary. Upon it systematic measurements are made at two points, viz, near Superior, Nebr., and at Junction, Kans., the latter place being near the mouth of the river. Smoky Hill River is measured at Ellsworth, Kans., and its principal tributary, Saline River, near Salina, Kans. Solomon River, another large tributary, is measured near Niles, Kans., and Blue River, which joins the Kansas at Manhattan, is measured near the latter place. The gaging station on Kansas River proper is now located at Lecompton, Kans.; formerly the river was gaged at Lawrence, Kans.

Estimated monthly discharge of Republican River near Superior, Nebr.

[Drainage area, 22,347 square miles.]

Month.	Dischar	ge in secon	nd-feet.		Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.				V	•	
April	1,671	565	909	54, 089	0.04	0.04
May	2,945	320	735	45, 193	0.03	0.03
June	674	250	392	23, 326	0.02	0.02
July	349	67	159	9,777	0.006	0.007
August	1,278	24	149	9, 162	0.006	0.007
September	2,010	8	156	9, 283	0.006	0.007
October	148	26	69	4, 943	0.003	0.003
November 1 to 24	162	36	87	5, 177	0.004	0.004

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, pages 312 and 313.

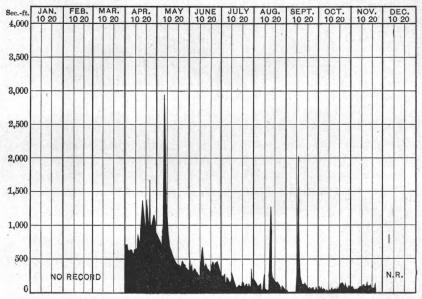


Fig. 148.—Discharge of Republican River near Superior, Nebr., 1900.

Estimated monthly discharge of Republican River at Junction, Kans. [Drainage area, 25,837 square miles.]

	Dischar	ge in secon	id-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.
1900.						
January	670	400	559	34, 372	0.02	0.02
February	890	550	716	39, 765	0.03	0.03
March	4,875	610	1, 327	81, 594	0.05	0.06
April	3, 450	500	1,465	87, 173	0.06	0.07
May	3, 260	735	1, 362	83, 746	0.05	0.06
June	975	450	554	32,965	0.02	0.02
July	735	225	373	22,935	0.01	0.01
August	450	150	275	16, 909	0.01	0.01
September	3,090	198	771	45, 878	0.03	0.03
October	345	150	258	15, 864	0.01	0.01
November	225	130	162	9,640	0.01	0.01
December	500	173	257	15,802	0.01	0.01
The year	4, 875	130	673	486, 643	0.03	0. 34

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 314; discharge measurements, page 313; rating table in Paper No. 52, page 517.

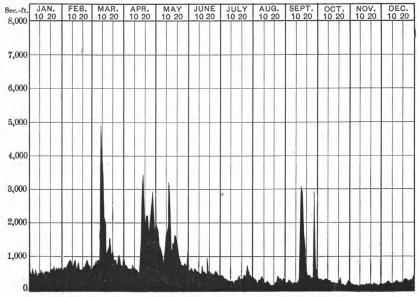


Fig. 149.—Discharge of Republican River at Junction, Kans., 1900.

Estimated monthly discharge of Solomon River near Niles, Kans.

[Drainage area, 6,815 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	128	58	90-	5, 534	0.01	0.01
February	159	74	103	5, 720	0.02	0.02
March	1,870	80	246	15, 126	0.04	0.05
April	4,627	74	760	45, 223	0.11	0.12
May	1, 156	211	532	32, 711	0.08	0.09
June	860	80	230	13, 686	0.03	0.03
July	630	54	135	8, 301	0.02	0.02
August	860	66	242	14, 880	0.04	0.05
September	2,020	54	294	17, 494	0.04	0.04
October	755	66	116	7, 133	0.02	0.02
November	100	54	71	4, 225	0.01	0.01
December	100	58	75	4, 612	0.01	0.01
The year	4, 627	54	241	174, 645	0.04	0.47

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 315; discharge measurements, page 314; rating table in Paper No. 52, page 517.

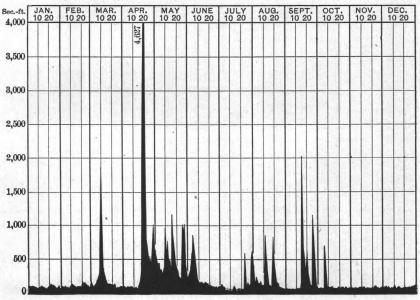


Fig. 150.—Discharge of Solomon River near Niles, Kans., 1900.

Estimated monthly discharge of Saline River near Salina, Kans.

[Drainage area, 3,311 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	55	42	49	3, 013	0.01	0.01
February	55	42	47	2,610	0.01	0.01
March	700	44	114	7,010	0.03	0.03
April	2,930	50	471	28, 026	0.14	0.16
May	1, 100	166	347	21, 336	0.10	0. 12
June	1,427	70	245	14, 578	0.07	0.08
July	3,370	46	382	23, 488	0.12	0.14
August	370	36	76	4, 673	0.02	0.02
September	1, 160	40	120	7, 141	0.04	0.04
October	133	40	56	3, 443	0.02	0.02
November	76	46	51	3,035	0.02	0. 02
December	60	46	53	3, 259	0.02	0, 02
The year	3, 370	36	168	121, 612	0.05	0. 67

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 316; discharge measurements, page 315; rating table in Paper No. 52, page 517.

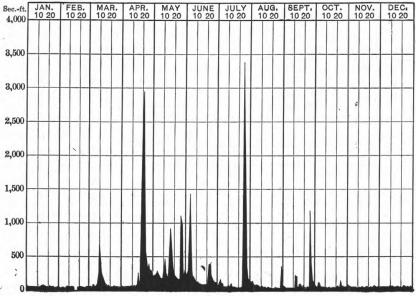


Fig. 151.—Discharge of Saline River near Salina, Kans., 1900.

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans
[Drainage area, 7,980 square miles.]

	Dischar	ge in secon	d-feet.	Total in acrefeet.	Run-off,	
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
January 5 to 28	97	40	49	3, 013	0.006	0.007
February a			60	3, 332	0.008	0.008
March 4 to 31	183	40	66	4,058	0.008	0.009
April	594	35	156	9, 283	0.02	0.02
May	660	77	147	9,039	-0.02	0.02
June	616	87	241	14, 340	0.03	0.03
July	705	35	117	7, 194	0.01	0.01
August	97	18	47	2,890	0.006	0.007
September	616	18	140	8, 331	0.02	0.02
October	144	40	78	4,796	0.01	0.01
November	40	22	28	1,666	0.004	0.004
December	26	18	21	1, 291	0.003	0.003

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 317; discharge measurements, page 316; rating table in Paper No. 52, page 517.

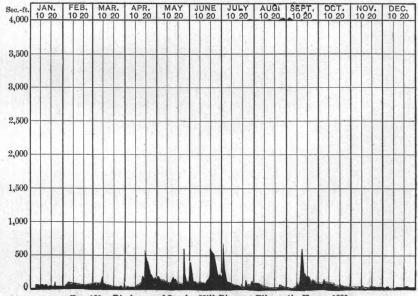


Fig. 152.—Discharge of Smoky Hill River at Ellsworth, Kans., 1900.

 ${\it Estimated monthly discharge of Blue \ River \ near \ Manhattan, \ Kans.}$

[Drainage area, 9,490 square miles.]

	Discha	rge in secon	nd-feet.		Rur	ı-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	960	270	619	38,061	0.07	0.08
February	815	460	585	32, 489	0.06	0.06
March	5, 705	657	1,388	85, 345	0.15	0.17
April	4, 457	522	1,392	82, 830	0.15	0.17
May	8, 240	1, 160	2,736	168, 230	0.29	0. 33
June	1,690	590	967	57, 540	0.10	0. 11
July	23,280	400	2,580	. 158, 638	0.27	0.31
August	2,927	500	973	. 59, 827	0.10	0. 12
September	4,410	522	1,812	107, 821	0.19	0. 21
October	1,110	545	731	44, 947	0.08	0.09
November	1,500	590	727	43, 259	0.08	0.09
December	635	460	589	36, 216	0.06	0.07
The year	23, 280	270	1, 258	915, 203	0.13	1.81

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 318; discharge measurements, page 317; rating table in Paper No. 52, page 518.

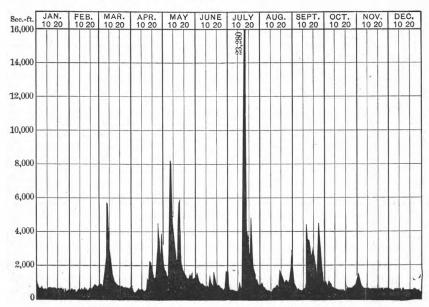


Fig. 153.—Discharge of Blue River near Manhattan, Kans., 1900.

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Estimated monthly discharge of Kansas River at Lecompton, Kans.

[Drainage area, 58,550 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month,	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	3, 481	2,960	3, 421	210, 349	0.06	0.07
February	3, 613	2,830	3, 234	179, 607	0.06	0.06
March	24, 898	3, 220	7,807	480, 034	0.13	0.15
April	9,520	4, 150	5, 896	350, 836	0.10	0.11
May	12, 220	6,045	7, 965	489, 749	0.14	0.16
June	9, 200	3,880	6, 303	375, 055	0.11	0.12
July	18, 722	3, 613	7, 340	451, 319	0.13	0.15
August	5, 095	3, 481	4, 455	273, 927	0.08	0.09
September	15, 635	3,880	6, 947	413, 375	0.12	0.13
October	7,810	3,746	4,913	302, 089	0.08	0.09
November	8, 110	3, 613	4,622	275, 028	0.08	0.09
December	3, 613	3, 350	3, 418	210, 165	0.06	0.07
The year	24, 898	2,830	5, 527	4, 011, 533	0.10	1. 29

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 319; discharge measurements, page 318; rating table in Paper No. 52, page 518.

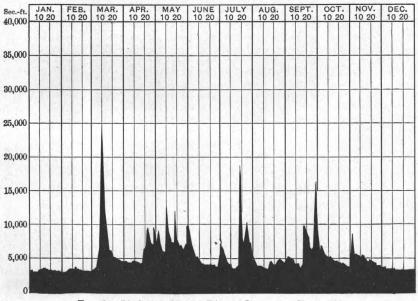


Fig. 154.—Discharge of Kansas River at Lecompton, Kans., 1900.

ARKANSAS RIVER DRAINAGE.

Arkansas River rises near the summit of the Rockies, its basin adjoining that of the Platte. Throughout the mountainous area the volume of the river increases, but as the stream emerges onto the Great Plains the water is gradually diverted by lines of canals, so that at the Kansas line the river is usually dry during the summer. In its mountainous course it makes a descent from 10,000 feet at Leadville to 5,300 feet at Canyon, a distance of 120 miles. Gaging stations on tributaries of the river are maintained on Lake Creek at Twin Lakes, Colo., on Verdigris River near Liberty, Kans., and on Neosho River near Iola, Kans. Arkansas River proper is measured at the following places, in order downstream: At Salida, near Canyon, at Pueblo, near Nepesta, near Rockyford, at Prowers, at the head gates of the Amity canal, and near Granada, all in Colorado; also at Hutchinson, Kans.

Estimated monthly discharge of Lake Creek at Interlaken station, Twin Lakes, Colo.

[Drainage area, 104 square miles.]

Month.	Dischar	ge in secon	d-feet.		Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900. July 22 to 31			87	1,725	0.84	0. 31
August	59	36	43	2, 644	0.41	0.47
September 1 to 8			36	571	0.35	0.10

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 322; discharge measurements, page 321; rating table in Paper No. 52, page 518.

Estimated monthly discharge of Lake Creek below Twin Lakes, Colo.

[Drainage area, 109 square miles.]

	Dischar	rge in secon	d-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
July 22 to 31			149	2, 955	1.37	0.51
August	187	40	119	7, 317	1.09	1. 26
September 1 to 8			35	555	0.32	0.10

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 322; discharge measurements, page 321; rating table in Paper No. 52, page 518.

Estimated monthly discharge of Arkansas River at Salida, Colo.

[Drainage area, 1,160 square miles.]

	Dischar	ge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.					160	Tall a
April	452	65	155	9, 223	0.13	0.15
May	3, 633	364	1, 791	110, 124	1.54	1.78
June	3, 633	992	2,083	123, 947	1.80	2.01
July	1, 106	392	635	39, 045	0.55	0.63
August	452	236	319	19, 614	0.28	0. 32
September	392	236	291	17, 316	0. 25	0. 28
October	284	106	192	11, 805	0.17	0.20

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 323; rating table in Paper No. 52, page 518.

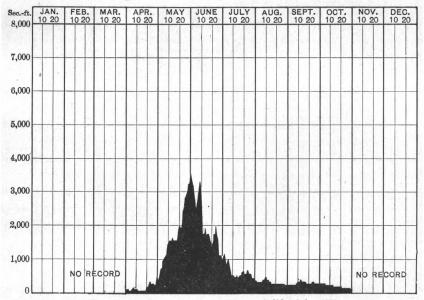


Fig. 155.—Discharge of Arkansas River at Salida, Colo., 1900.

 $\label{lem:extracted} \textit{Estimated monthly discharge of Arkansas River near Canyon, Colo.}$

[Drainage area,	3.060	square	miles.]
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	Discha	rge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January a			345	21, 213	0.11	0.13
February a			353	19,605	0.12	0.12
March a			439	26, 993	0.14	0.16
April	1,190	485	736	43, 795	0. 24	0.27
May	4,520	812	2,251	138, 409	0.74	0.85
June	4,520	2, 189	3, 492	207, 788	1.14	1.27
July	2,078.	283	891	54, 785	0. 29	0.33
August	362	217	273	16, 786	0.09	0.10
September	229	194	211	12, 555	0.07	0.08
October	297	217	241	14, 818	0.08	0.09
November	328	217	266	15, 828	0.09	0.10
December	328	268	298	18, 323	0.10	0. 12
The year			816	590, 898	0. 27	3. 62

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 324; rating table in Paper No. 52, page 518.

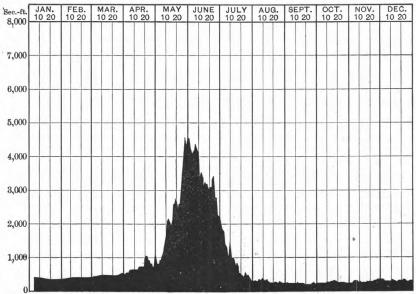


Fig. 156.—Discharge of Arkansas River near Canyon, Colo., 1900.

Estimated monthly discharge of Arkansas River at Pueblo, Colo.

[Drainage area, 4,500 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches,
1900.						
January	566	334	411	25, 271	0.09	0.10
February	566	218	418	23, 214	0.09	0.09
March	538	263	391	24, 042	0.08	0.09
April	2,910	218	821	48, 853	0.18	0. 20
May	6, 703	1,357	2,995	184, 155	0.65	0.75
June	6, 980	1,788	4,007	238, 433	0.87	0.97
July	1,676	334	878	53, 986	0.19	0. 22
August	511	174	314	19, 307	0.07	0.08
September	458	134	233	13, 864	0.05	0.06
October	407	218	320	19,676	0.07	0.08
November	511	382	435	25, 884	0.09	0.10
December	407	310	393	24, 165	0.09	0.10
The year	6, 980	134	968	700, 850	0. 21	2, 84

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 326; discharge measurements, page 325; rating table in Paper No. 52, page 518.

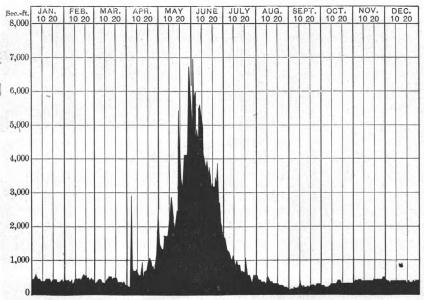


Fig. 157.—Discharge of Arkansas River at Pueblo, Colo., 1900.

${\it Estimated monthly discharge of Arkansas \ River near \ Nepesta, \ Colo.}$

[Drainage area, 9,130 square miles.]

	Dischar	ge in secon	id-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
May	9,600	4, 246	5, 875	361, 240	0.64	0.74
June	7,782	4,064	5, 497	327, 094	0.60	0.67
July	3, 700	427	1,699	104, 467	0.19	0. 22
August	1,519	172	422	25, 948	0.05	0.06
September	427	172	262	15, 590	0.03	0.03
October	610	314	435	26, 747	0.05	0.06
November	792	259	514	30, 585	0.06	0.07

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 327; discharge measurements, page 326; rating table in Paper No. 52, page 518.

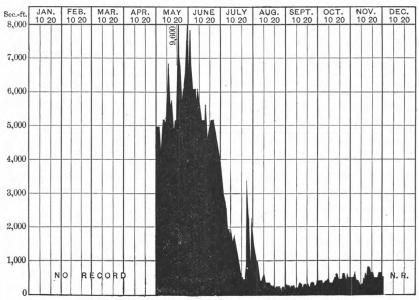


Fig. 158.—Discharge of Arkansas River near Nepesta, Colo., 1900.

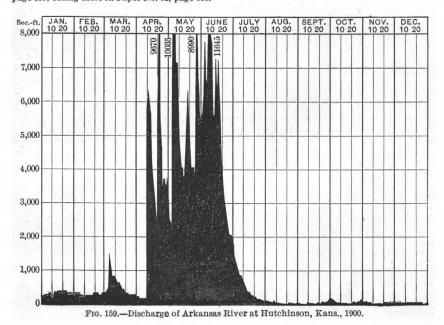
344 PROGRESS OF STREAM MEASUREMENTS FOR 1900.

Estimated monthly discharge of Arkansas River at Hutchinson, Kans.

[Drainage area, 34,000 square miles.]

1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	Dischar	ge in secor	id-feet.		Ru	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean. Total in acrefeet.		Second- feet per square mile.	Depth in inches.
1900.			1			
January	369	210	309	19,000	0.009	0.01
February	315	262	285	15, 828	0.008	0.008
March	1,512	262	515	31,666	0.02	0.02
April	9,670	168	3, 139	186, 783	0.09	0.10
May	10,035	2, 280	5, 394	331, 664	0.16	0.18
June	11,645	1,855	5, 397	321, 143	0.16	0.18
July	1,512	107	488	30,006	0.01	0.01
August	107	35	63	3,874	0.002	0.002
September	168	28	55	3, 273	0.002	0.002
October	168	44	78	4,796	0.002	0,002
November	96	49	66	3, 927	0.002	0.002
December	69	55	63	3,874	0.002	0.002
The year	11,645	28	1, 321	955, 834	0.04	0.52

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 330; rating table in Paper No. 52, page 518.



Estimated monthly discharge of Verdigris River near Liberty, Kans.

[Drainage area, 3,067 square miles.]

	Dischar	ge in secor	d-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.
1900.						
January	90	55	65	3, 997	0.02	0.02
February	240	40	82	4, 554	0.03	0.03
March	10, 200	170	1,323	81, 348	0.43	0.50
April	10, 750	140	1, 236	73, 547	0.40	0.45
May	16,500	280	2, 455	150, 952	0.80	0.92
June	5, 400	110	593	35, 286	0.19	0.21
July	23, 610	222	1,824	112, 153	0.59	0.68
August	155	7	53	3, 259	0.02	0.02
September	36, 950	10	3,714	220, 998	1.21	1, 35
October	35, 075	280	3, 236	198, 974	1.06	1. 22
November	25, 430	860	3, 766	224, 093	1.23	1.37
December	860	368	531	32, 650	0. 17	0. 20
The year	36, 950	7	1,573	1, 141, 811	0. 51	6. 97

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 331; rating table in Paper N \sim 52, page 518.

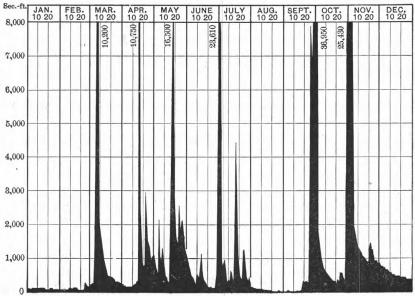


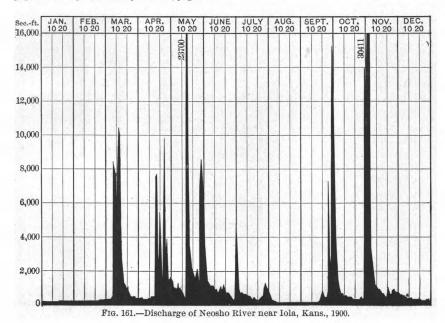
Fig. 160.—Discharge of Verdigris River near Liberty, Kans., 1900.

Estimated monthly discharge of Neosho River near Iola, Kans.

[Drainage area, 3,670 square miles.]

	Dischar	ge in secon	nd-feet.		Run	-off.
Month.	Maxi- mum.	Mini- mum. Mean. Total in acre- feet.	Second- feet per square mile.	Depth in inches.		
1900.						
January	192	145	, 179	11,006	0.05	0.06
February	292	192	200	11, 107	0.05	0.05
March	10, 412	292	2,604	160, 114	0.71	0.82
April	9,800	338	2, 229	132, 635	0.61	0.68
May	23, 700	385	4,098	251, 976	1.12	1. 29
June	4,725	256	1,061	63, 134	0.29	0.32
July	4,025	292	766	47, 099	0. 21	0. 24
August	650	145	201	12, 359	0.05	0.06
September	15, 350	145	2,025	120, 496	0.55	0.61
October	13, 950	338	2,019	124, 143	0.55	0.63
November	30, 411	510	3, 418	203, 385	0.93	1.04
December	650	292	382	23, 488	0.10	0.12
The year	30, 411	145	1,598	1, 160, 942	0.43	5. 92

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 332; rating table in Paper No. 52, page 518.



WESTERN GULF DRAINAGE.

RIO GRANDE AND TRIBUTARIES.

Rio Grande is one of the important irrigation rivers of the West. Its source is in the Rocky Mountains of Colorado, and its general course is southward. The drainage basin has been described in the Twelfth Annual Report, pages 240 to 282. The first point of measurement is near Del Norte, Colo., at the head of the San Luis Valley, above irrigation diversion. The river is also measured at Cenicero, Colo., at Embudo, N. Mex. (above Espanola Valley), at Rio Grande, N. Mex. (below the latter valley), and near San Marcial, N. Mex. In Texas measurements of the river are made at the following places, in order downstream: Near El Paso, near Fort Hancock, about 7 miles above and about 6 miles below Presidio, near Langtry, near Devilsriver, and near Eagle Pass. Conejos River, a tributary of Rio Grande in Colorado, was measured during March, 1900, near Los Mogotes, Colo. Rio Pecos, an important tributary in Texas, is measured near Pecos and near Moorhead. Devils River, another Texas tributary, is gaged near Devilsriver. The records for the Del Norte, Embudo, and El Paso stations extend back several years; the other stations are comparatively new.

Estimated monthly discharge of Rio Grande near Del Norte, Colo.

[Drainage area, 1,400 square miles.]

	Dischar	ge in secon	id-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						T T
January a			868	53, 371	0.62	0.71
February a			1,011	56, 148	0.72	0.75
March a			399	24, 533	0.28	0.32
April b	518	320	418	24, 873	0.30	0.33
May	5, 454	553	2,850	175, 240	2.04	2.36
June	5, 379	1,020	2,688	159, 947	1.92	2.14
July	978	289	546	33, 572	0.39	0.45
August	320	169	228	14, 019	0.16	0.18
September	384	198	255	15, 174	0.18	0.20
October	384	320	342	21,029	0.24	0. 28
November	320	198	251	14, 936	0.18	0, 20
December ^a			761	46, 792	0.54	0.62
The year			885	639, 634	0.63	8. 54

Approximate.

^bFrom April to November gage readings made every second day.

NOTE.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 347; rating 'able in Paper No. 52, page 519. For hydrograph see page 348.

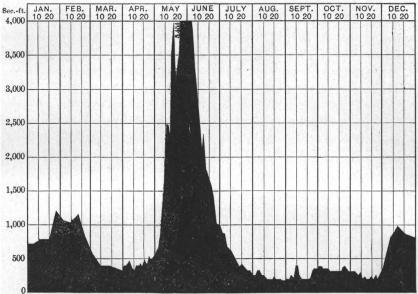


Fig. 162.—Discharge of Rio Grande near Del Norte, Colo., 1900.

Estimated monthly discharge of Conejos River near Los Mogotes, Colo.

[Drainage area, 282 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
March	671	214	372	22, 873	1.32	1.52

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 348; rating table in Paper No. 52, page 519.

Estimated monthly discharge of Rio Grande at Cenicero, Colo.

[Drainage area, 7,695 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	1, 134	594	638	39, 229	0.08	0.09
February	1, 134	22	759	42, 153	0.10	0.10
March	1, 134	236	583	35, 847	0.08	0.09
April	504	183	350	20, 826	0.05	0.06
May	3, 294	414	1,430	87, 927	0.19	0.22
June	3, 294	79	1,424	84, 734	0.19	0.21
July	58	22	- 29	1,783	0.004	0.005
August	22	16	22.	1, 353	0.003	0.003
September	43	16	31	1,845	0.004	0.004
October	58	31	37	2, 275	0.005	0.006
November	504	58	155	9,223	0.002	0.002
December	594	414	571	35, 109	0.07	0.08
The year	3, 294	16	502	362, 304	0.06	0.87

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 349; rating table in Paper No. 52, page 519.

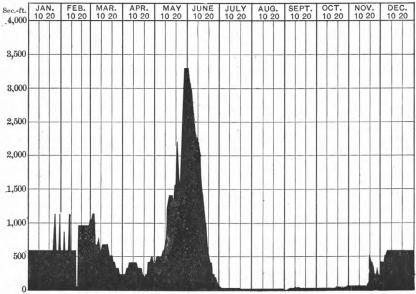


Fig. 163.—Discharge of Rio Grande at Cenicero, Colo., 1900.

Estimated monthly discharge of Rio Grande at Embudo, N. Mex.

[Drainage area, 10,090 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	530	465	508	31, 236	0.05	0.06
February	530	520	521	28, 935	0.05	0.05
March	640	520	581	35, 724	0.06	0.07
April	530	480	513	30, 526	0.05	0.06
May	6,950	520	2, 323	142, 836	0.23	0. 27
June	6,700	500	2,814	167, 445	0.28	0.31
July	475	180	289	17,770	0.03	0.03
August	210	170	179	11,006	0.02	0.02
September	500	170	250	14, 876	0.02	0.02
October	280	240	248	15, 249	0.02	0.02
November	475	240	327	19, 458	0.03	0.03
December	420	280	363	22, 320	0.04	0.05
The year	6, 950	170	743	537, 381	0.07	0.99

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 350.

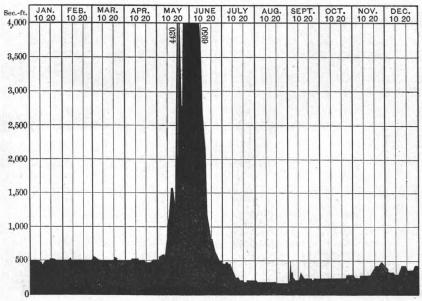


Fig. 164.—Discharge of Rio Grande at Embudo, N. Mex., 1900.

Estimated monthly discharge of Rio Grande at Rio Grande, N. Mex.

[Drainage area, 14,050 square miles.]

	Dischar	ge in secor	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	670	520	598	36, 770	0.04	0.05	
February	670	420	582	32,322	0.04	0.04	
March	1,430	600	859	52, 818	0.06	0.07	
April	1,350	670	866	51,531	0.06	0.07	
May	7,500	1,070	3, 440	211, 517	0. 24	0. 28	
June	7,500	510	2,914	173, 395	0. 21	0. 23	
July	650	160	297	18,262	0.02	0.02	
August	370	110	165	10, 145	0.01	0.01	
September	6,030	130	716	42,605	0.05	0.06	
October	460	320	387	23, 796	0.03	0.03	
November	570	360	425	25, 289	0.03	0.03	
December	570	360	472	29, 022	0.03	0.03	
The year	7,500	110	977	707, 472	0.07	0. 92	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 351.

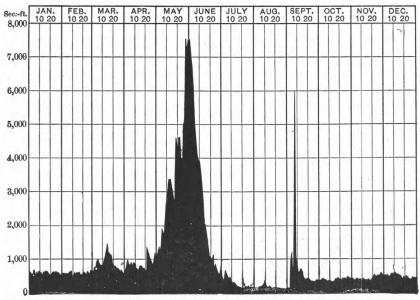


Fig. 165.—Discharge of Rio Grande at Rio Grande, N. Mex., 1900.

Estimated monthly discharge of Rio Grande near San Marcial, N. Mex.

[Drainage area, 28,067 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	980	370	660	40, 582	0.02	0.02	
February	980	420	632	35, 099	0.02	0.02	
March	1,300	140	540	33, 203	0.02	0.02	
April	170	20	105	6, 248	0.004	0.004	
May	6, 250	90	2,010	123, 590	0.07	0.08	
June	7,460	65	2,687	159, 888	0.10	0.11	
July	0	0	0	0	0	0	
August	0	0	0	0	0	0	
September 8 to 30	8,500	15	1, 230	73, 190	0.04	0.04	
October	0	0	0	0	0	0	
November	80	10	41	2,440	0.001	0.001	
December	280	30	164	10, 084	0.006	0.007	

Note.—There was no discharge during the months of July, August, and October. Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 353.

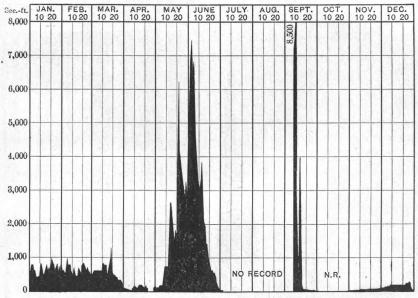


Fig. 166,-Discharge of Rio Grande near San Marcial, N. Mex., 1900.

Estimated monthly discharge of Rio Grande near El Paso, Tex.

[Drainage area, 30,000 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	330	90	132	8, 110	0.004	0.005
February	150	75	102	5,680	0.003	0.003
March	65	0	8	460	0.0002	0.0002
April	5	5	5	300	0,0002	0.0002
May	2,500	0	729	44, 810	0.02	0.02
June	3,550	10	1,565	93, 100	0.05	0.06
July	5	0	1	70	0	0
August	0	0	0	0	0	0
September	1,690	0	277	16, 483	0.01	0.01
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	45	0	12	738	0.0004	0.0005
The year	3, 550	0	236	169, 751	0.007	0.01

Note.—There was no flow during the months of August, October, and November. Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 353.

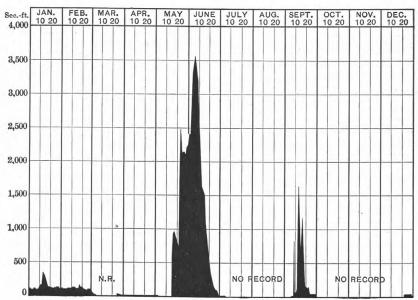


Fig. 167.—Discharge of Rio Grande near El Paso, Tex., 1900.

Estimated monthly discharge of Rio Grande near Fort Hancock, Tex.

Month.	Dischar			
	Maxi- mum.	Mini- mum,	Mean.	Total in acre-feet.
1900.				
May	2,000	0	293	18,050
June	2, 370	0	964	57, 350
July	0	0	0	0
August	0	0	0	0
September	230	0	65	3, 869
October ^a	740	0	43	2, 644

a River dry except from 15th to 18th.

Note.—There was no flow during the months of July, August, November, and December. Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 354.

Estimated monthly discharge of Rio Grande 7 miles above Presidio, Tex.

Month.	Dischar			
	Maxi- mum-	Mini- mum,	Mean.	Total in acre-feet.
1900.				
May	660	0	64	3, 930
June	2, 120	105	787	46, 810
July	1,500	0	160	9,830
August	320	0	41	2, 521
September	820	0	204	12, 139
October	1,500	0	181	11, 129
November	0	0	0	0
December	0	0	0	0

Note.—There was no flow during the months of November and December. Gage heights and discharge measurements are given in Water-Supply Paper No. 50, page 355.

$Estimated\ monthly\ discharge\ of\ Rio\ Grande\ 6\ miles\ below\ Presidio,\ Tex.$

Month.	Dischar			
	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.
1900.				
May	3, 100	15	274	16, 850
June	3,060	110	1,057	62,900
July	12,000	300	4,576	281,330
August	14, 920	1,830	6, 201	381, 285
September	12, 510	1,100	2,916	173, 514
October	4,700	510	1,720	105, 760
November	560	320	410	24, 397
December	320	210	237	14, 573

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 356.

Estimated monthly discharge of Rio Grande near Langtry, Tex.

Month.	Dischar			
	Maxi- mum,	Mini- mum,	Mean.	Total in acre-feet.
1900.				
May	4, 100	320	1,008	61, 970
June	4, 160	800	1,994	118, 640
July	13, 300	1,200	5,033	309, 390
August	21,680	2,860	7,976	490, 425
September	13, 200	2,070	3, 867	230, 102
October	7, 780	1, 190	2,915	179, 236
November	1, 290	770	903	53, 732
December	770	620	678	41, 690

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 358, discharge measurements page 357.

Estimated monthly discharge of Rio Pecos near Moorhead, Tex.

Month.	Dischar			
	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.
1900.		1		
May	3, 300	370	816	50, 140
June	1,600	470	843	50, 130
July	4,600	300	555	34, 120
August	840	340	497	30, 559
September	2, 200	260	972	57, 840
October	2, 430	990	1,511	92, 908
November	1,540	530	829	49, 329
December	530	450	489	30, 067
	7			

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 263.

Estimated monthly discharge of Devils River at Devilsriver, Tex.

Month.	Dischar	Discharge in second-feet.			
	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	
1900.					
May	3,800	980	1, 321	81, 180	
June		960	1,516	90, 210	
July	1, 380	840	970	59, 610	
August	3,030	860	1, 133	69, 665	
September	52, 420	760	4,634	275, 740	
October	2, 110	1,04C	1, 216	74, 769	
November	2, 410	900	1,075	63, 967	
December	900	850	879	54, 050	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 364.

Estimated monthly discharge of Rio Grande near Devilsriver, Tex.

Month.	Dischar			
	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.
1900.			,	
May	9,800	1,550	3, 553	218, 430
June	17,500	1,850	4, 451	264, 770
July	12,600	2,770	6, 506	399, 930
August	26, 750	4,710	10, 545	648, 420
September	(a)	3,800		
October	7,300	3,610	5, 217	320, 781
November	4,880	2,560	3, 171	188, 688
December	2,560	2,350	2,472	151, 990

^a From 22d to 24th gage readings so high that even approximate discharges could not be given. Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 365.

Estimated monthly discharge of Rio Grande near Eagle Pass, Tex.

Month.	Dischar	200.230		
	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.
1900.				
May	45,000	3, 750	8,820	542, 200
June	18,500	3,500	5, 952	354, 060
July	17,000	3, 430	8, 247	506, 990
August	32,560	6, 370	12, 597	774, 555
September	50,090	4,830	13, 882	826, 020
October	15, 940	6, 440	9, 190	565, 071
November	7,080	4,800	5, 509	327, 808
December	4,860	3,420	4, 121	253, 390

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 366.

COLORADO RIVER DRAINAGE.

The Colorado drains nearly a fourth of the arid region, its basin extending from the Wind River Mountains in Wyoming to the Gulf of California, below the Mexican boundary. It is formed by the junction, in Utah, of Grand and Green rivers. No gaging station is now maintained on Green River proper, but Black Fork of Green River is measured near Granger, Wyo., and gaging stations are maintained on Uinta, Whiterocks, and Duchesne rivers and Ashley Creek, tributaries in Utah, as follows: On Ashley Creek near Vernal; on Uinta River

near Whiterocks, at Fort Duchesne, and at the Ouray School; on Whiterocks River near Whiterocks; on Lake Creek near its mouth; and on Duchesne River at Price road bridge. Grand River is measured at Glenwood Springs and at Grand Junction, Colo., on the western slope of the Rockies, and receives its principal tributary, the Gunnison, at the latter place. Gunnison River is measured at Iola, Colo., and its principal tributary, the Uncompangre, is measured at Montrose, Colo. Dolores River, a tributary of the Grand, is measured at Dolores, Colo. The next important tributary of the Colorado below the entrance of the Grand is the Rio San Juan, in the basin of which the following streams are measured: Los Pinos River at Ignacio, Animas River at Durango, and Mancos River at Mancos. Gila River joins the Colorado at Yuma, Ariz. Only one station was maintained in the Gila basin during 1900, viz, at San Carlos, where a storage reservoir is contemplated.

During the year 1900 a number of reconnaissances and reservoir surveys were made in the basins of these streams, as described on the following pages.

Utilization of the streams of Utah for power purposes nas proceeded rapidly within the last year or two. Pl. XXV, A, is a view of the power station in American Fork Canyon, Utah. In the foreground is shown the weir which divides the water into three parts. Pl. XXV, B, shows the pipe line of the power plant leading along the steep walls of the canyon.

GREEN RIVER IN WYOMING.

The drainage oasin of Green River occupies nearly all of the southwest quarter of Wyoming, its headwaters rising in the high, snow-covered mountains known as the Gros Ventre and Wind River ranges, about the middle latitude of the State, and flowing southwardly into Colorado. Numerous small streams enter at intervals, principally on the western side, few flowing in from the east, although one of its eastern tributaries (New Fork) is nearly if not quite equal in volume to the main stream. About 60 miles below this junction Big Sandy Creek enters from the east, and although it has a comparatively large catchment area the stream is a small one.

The valley of Green River is narrow, and is generally confined between high bluffs. Here and there, particularly where the side streams enter, and therefore more abundantly on the west side, are valleys of rich bottom lands from 1 to 2 miles in width, but not of very great length, being terminated at intervals by the near approach of the bluffs to the river. Some of these bottom lands are cultivated, being irrigated from the small streams, instead of from the river, on account of the greater facility, and consequently the reduced expense, with which the water can be placed upon the land. Large canals for



A. THREE-DIVISION WEIR IN AMERICAN FORK CANYON, UTAH.



B. PIPE LINE OF POWER PLANT IN AMERICAN FORK CANYON, UTAH.

irrigating the bottom lands along the river are not needed, on account of the limited amount of such lands and the difficulty and expense of construction along the steep bluffs.

The farms which are cultivated grow oats, wheat, hav, and alfalfa, and the surrounding country is devoted to the grazing of large flocks of sheep and herds of cattle, the former occupying the southern portion of the basin and the latter the northern portion. Winter feeding of the stock in this country has not been practiced to any great extent, but from present appearances the cultivation of forage for use in the winter months must soon become a necessity, owing to the scarcity of grass, the lack of which is doubtless due to the continued overstocking of the range. The altitude is too high (more than 6,000 feet) for a diversity of crops, but with the use of water the plateau land, of which there is a large amount favorably situated for irrigation, will doubtless produce abundant forage crops and certain cereals. In order to determine the feasibility of diverting water to the plateau between Green River and Big Sandy Creek, during the season of 1900 a number of preliminary lines of levels were run below the junction of New Fork and East Fork. First starting about 2 miles below the junction, where was found a suitable place for diverting the water, the line followed near the river down to where it was expected that a sufficient elevation would be attained to pass around the west end of the divide which extends across the plateau from east to west. This, however, was found not to be feasible. Nor was it possible, after continuing levels down Green River to a point nearly opposite the mouth of Labarge Creek, to gain sufficient elevation to surmount the river bluffs, which rise from 200 to 300 feet above the stream, as the average fall of the river was only about 6 or 7 feet to the mile.

From the investigations made it appears to be impracticable to divert water below the junction of New Fork and East Fork in order to carry it to the area mentioned, although a continuation of the investigation might have shown the possibility of conveying water to a portion of the land at the southern extremity, and thence to land south of Big Sandy Creek. In view, however, of the cost of such a canal, which would of necessity follow many miles along extremely steep and broken river bluffs, it would seem to be necessary to look farther upstream for a point of diversion. A reconnaissance of the headwaters of Green River, East Fork, and New Fork, including such lines of levels as might be necessary to determine the practicability of diverting one or more of these streams to the plateau land mentioned, could probably be made at slight cost. If found feasible, a complete and careful survey should be made for a canal route and of such reservoir sites as might be determined desirable adjuncts to the project.

BLACK FORK OF GREEN RIVER.

The Black Fork, with its numerous tributaries, drains the extreme southwestern portion of Wyoming. Hams Fork and Little Muddy and Muddy creeks on the north rise in the Sublette Range and the Bear River divide, respectively, while the Black Fork proper and Smiths Fork, its only important tributary from the south, have their

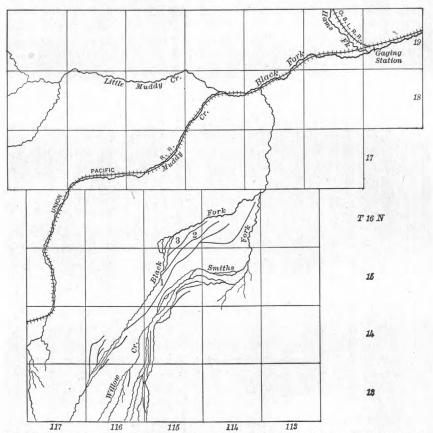


Fig. 168.—Drainage basin of Black Fork of Green River, showing irrigation canals and location of gaging station. 1, Black Fork canal; 2, Fort Bridger canal; 3, Jackson ditch.

sources in the Uinta Mountains, in Utah. Below the point where Hams Fork joins the Black Fork little has been done in the way of irrigation. This is also true of the Black Fork as far up as its junction with Smiths Fork, so that in adjudicating the waters of these streams in the State engineer's office the latter (Black and Smiths forks) are considered a system separate from the others.

In this valley are found the oldest ditches in the State of Wyoming. Some of them are still in use, though nearly ruined by the thick growth of willows which have overspread their banks and the land adjoining. In 1854 the Mormon Church established a supply station several miles above Fort Bridger, where a flour mill was erected and where farming evidently was carried on on a small scale. Several hundred families have settled in the valleys, and ditches have been taken out of all of the streams, on both sides and far up into the foothills, irrigating numerous small tracts, covering in all about 15,000 acres. Farther down several large canals carry water upon the higher lands, the largest of them being the Black Fork canal, which has a capacity of nearly 100 second-feet and carries water upon the low plateau between Black and Smiths forks, in Ts. 15 and 16 N., Rs. 114 and 115 W. (See fig. 168.)

For a number of years complaints have been frequent of the excessive appropriation of the water supply, notwithstanding that only flood-water permits have been granted by the State engineer for new appropriations. It being important to ascertain the conditions as they really exist, on July 26, 1900, a visit was made and measurements were taken near the headwaters of the Black Fork, above the point where ditches were in use. It was found that the stream was running in three distinct channels, discharging, respectively, 62.8, 1.3, and 7 cubic feet per second, or 71.1 second-feet in all. On the next day Smiths Fork was measured above the diversions, and five distinct channels were found, carrying 0.41, 9.14, 1.5, 2.93, and 5.4 second-feet, respectively, or a total of 19.38 second-feet. The same day 3 second-feet were found in the channel of Smiths Fork at Mountain View, while a few miles below all water had been taken from the stream by small ditches. The Black Fork at old Fort Bridger was also dry. A measurement was made of the volume running in the Black Fork canal south of Fort Bridger, and the discharge was found to be 41.9 second-feet. Other ditches carrying considerable water were passed, but were not measured. It was believed, however, that no great amount was lost by percolation, and it was evident that only a very small fraction of the water diverted from the streams found its way back into the original channel above Fort Bridger. On the next day, July 28, the discharge of Hams Fork at Granger was 20.66 second-feet; all other tributaries were dry. A few hours later the Black Fork below Granger measured 26.8 second-feet, showing that at points below Fort Bridger 6.2 second-feet had been taken up in some manner.

Estimated monthly discharge of Black Fork of Green River near Granger, Wyo.

[Drainage area, 2,400 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
January a			740	45, 501	0.31	0, 36
February a			935	51, 927	0.39	0.41
March a			763	46, 915	0.32	0.37
April	970	340	608	36, 178	0.25	0.28
May	2,410	850	1,677	103, 115	0.70	0.81
June	2,050	120	895	53, 256	0.37	0.41
July	100	15	45	2,767	0.02	0.02
August	27	27	27	1,660	0.01	0.01

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 367.

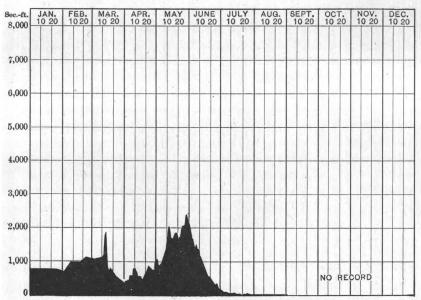


Fig. 169.—Discharge of Black Fork of Green River near Granger, Wyo., 1900

ASHLEY CREEK.

This stream drains an area in northeastern Utah directly east of the Uinta River drainage. It flows southeasterly, entering Green River about 25 miles below the place where the latter stream crosses the State line between Colorado and Utah. About 7½ miles above the town of Vernal the creek leaves its mountainous area and enters what

is known as Vernal Valley. This valley is approximately 20 miles long and 3 miles wide, its boundaries being sharply defined by the foothills. A large portion of the valley has been taken up by white settlers, and a considerable acreage is now under cultivation, through irrigation. There are three principal canals in use, as follows: Rock Point canal, which diverts water on the east side of the creek and covers about 10,000 acres; Upper Ashley canal, on the west side, built in 1880 and covering about 20,000 acres; and Central Ashley canal, built in 1878 and covering approximately 10,000 acres. There are also a number of smaller canals lower down, the principal one being known as Island ditch. This ditch irrigates land between the two main forks. Ashley Creek is similar to Uinta River in that as soon as it leaves its canyon it divides into a number of branches. A more detailed description of the valley will be found in the Twenty-first Annual Report, Part IV, pages 311 and 312.

By a decree of the district court dated November 17, 1897, the waters of Ashley Creek are divided as follows: Upper Irrigation Canal Company (Upper Ashley canal), $\frac{8.0}{8.1}$ of one-third of discharge; Ashley Central Irrigation Canal Company, $\frac{8.6}{8.7}$ of one-third of discharge; Rock Point and other canals (Union, Turner & Dodds, Island, Steinaker, and Colton), $\frac{7.7}{1.7}$ of one-third of discharge; and Green River interveners, the remainder. In accordance with this bill, the water commissioner ordered all canal companies to install weirs so constructed as to bring the water to a quiet state 60 feet above the weirs. A weir 30 feet wide was placed in the river above the head of all canals, and weirs of the following dimensions were ordered placed in the canals, the sum of the widths of the weirs being approximately the width of the river weir:

Weirs on Ashley Creek canals.		
· Constitution Con	Ft.	In.
Upper Ashley canal	9	10.4
Central Ashley canal, including Green River interveners (5.75		
inches) and deducting Colton canal (3.70 inches)	10	0.47
Union canal		7.11
Turner & Dodds ditch		11.52
Island ditch		17.41
Steinaker ditch		3, 52
Rock Point canal	5	8.79
Colton ditch (decree of court $\frac{164}{2,252}$, deed from Central Ashley		
$\operatorname{canal}\left(\frac{3}{7}\right)$		12.21

The two Ashley canals and the Rock Point canal are the only ones maintaining weirs. They are of the rectangular type, so constructed that each has two end contractions. No attempt is made to measure the quantity of water. When the creek is at its lowest stages and it becomes necessary to divide the water among the canals, the flow into them is so regulated that exactly the same height of water

is allowed to pass over each weir, the regulation stake, which is level with the crest of the weir, being placed a short distance above. As the lengths of the weirs correspond with the court decrees, the amount of water is supposed to be in the required proportion. On account of the end contractions of the weirs of the two Ashley canals and the Rock Point canal, those ditches do not receive the same proportion of water for varying heights, as the reduction of length for end contractions is a function of the height of the water.

During the flood stages of the creek more water passes down than the canals can carry, and therefore no attempt is then made to divide the water. It is only when the lower stages of the creek are reached that the water is divided. No head gates are maintained in the canals, the flow being regulated by placing or removing rocks in the rough dam—an unsatisfactory method, of course.

Pl. XXVI, A, shows the drop in the Central Ashley canal near Vernal, Utah.

The principal canals of the valley were measured twice during 1900, once in May, when the creek was in flood and a considerable amount of water was passing all canals and wasting into the stream below. The measurements therefore show approximately the maximum capacity of the various ditches. A second series of measurements was made in August, when the creek was at a low stage and after the water had been divided. The following table contains the results of the measurements made:

Discharge measurements in Vernal Valley, Utah.

Date.	Stream.	Locality.	Discharge.
1900.			Second-feet.
May 28	Ashley Creek	Gaging station	776.0
May 29	Upper Ashley canal	Measuring weir	181.0
Do	Central Ashley canal	do	138.0
Do	Rock Point canal	Near head	25.0
Do	Steinaker canal	do	1.5
August 21	Ashley Creek	Gaging station	40.0
Do	Upper Ashley canal	Measuring weir	12.0
Do	Central Ashley canal	do	10.0
Do	Rock Point canal	Near measuring weir	6.8

On March 15, 1900, a gaging station was established in the canyon of Ashley Creek, a short distance above the head of the upper canal. Results of measurements during the year are given in the following table:



 $A.\,\,\,$ DROP IN CENTRAL ASHLEY CANAL NEAR VERNAL, UTAH.



B. WEIR IN CENTRAL ASHLEY CANAL NEAR VERNAL, UTAH.

Estimated monthly discharge of Ashley Creek near Vernal, Utah.

[Drainage area, 250 square miles.]

	Discharge in second-feet.		Rui	un-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.			1.5			
March 15 to 31	37	37	37	2, 275	0.15	0.17
April	49	37	40	2,380	0.16	0.18
May	859	43	478	29, 391	1.91	2. 20
June	534	112	245	14, 578	0.98	1.09
July	102	55	74	4,550	0.30	0.35
August	49	40	45	2,767	0.18	0. 21
September	64	37	43	2, 559	0.17	0.19
October	55	43	44	2,705	0.18	0. 21
November	49	40	42	2, 499	0.17	0.19
December	40	37	38	2, 337	0. 15	0.17

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 369; discharge measurements, page 368; rating table in Paper No. 52, page 519.

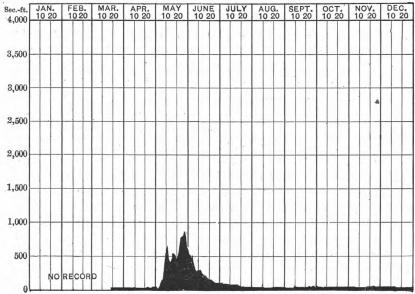


Fig. 170.—Discharge of Ashley Creek near Vernal, Utah, 1900.

DUCHESNE RIVER AND TRIBUTARIES.

Duchesne River has its source in the high peaks of the Uinta and Wasatch mountains, and flows in a general easterly direction, emptying into Green River 3 miles above the mouth of White River. Practically the entire drainage basin is included within the Uinta Indian Reservation, Utah, and a thorough examination of it was made during the years 1899 and 1900, in connection with an investigation of the water supply of that reservation. The results of the work done during the latter year are contained on the following pages; those for the former year were published in the Twenty-first Annual Report, Part IV. Gaging stations have been maintained on Uinta River near Whiterocks, at Fort Duchesne, and at the Ouray School; on Whiterocks River near Whiterocks, on Lake Creek near its mouth, and on Duchesne River at Price road bridge.

INVESTIGATION OF THE WATER SUPPLY OF THE UINTA INDIAN RESERVATION, UTAH. a

In northeastern Utah, within the Uinta Indian Reservation, are a number of streams that carry a considerable amount of water throughout the year. At present only a small portion of this water is utilized, the most of it running to waste. Within recent years efforts have been made by various persons and corporations to obtain permission to divert this surplus water from the reservation to adjacent arid lands. From time to time reports have been received at the office of the Secretary of the Interior in regard to the water resources of the reservation. Some of these reports state that the supply is more than sufficient for the future needs of the Indians; others are to the effect that if the attempt were made to bring all of the arable lands on the reservation under cultivation there would be a shortage of water for irrigation purposes. In view of these conflicting reports the Secretary of the Interior, under date of June 14, 1899, requested the Director of the United States Geological Survey to detail a sufficient number of topographers and engineers to ascertain the facts in the case, making the investigation of sufficient scope to cover the points noted in the Congressional act cited in the following letter:

Washington, June 14, 1899.

Sir: The following provision was made by the Indian appropriation act for the fiscal year ending June 30, 1900, approved March 1, 1899 (Public No. 104, p. 19):

That the Secretary of the Interior be, and he is hereby, authorized in his discretion to grant rights of way for the construction and maintenance of dams, ditches, and canals on or through the Uintah Indian Reservation in Utah for the purpose of diverting and appropriating the waters of the streams in said reservation for useful purposes: Provided, That all such grants shall be subject at all times to the paramount rights of the Indians on said reservation to so much of said waters as may have been appropriated, or may hereafter be appropriated or needed by them for agricultural and domestic purposes; and it shall be the duty of the Secretary of the Interior to prescribe such rules and regulations as he may deem necessary to secure to the Indians the quantity of water needed for their present and prospective wants, and to otherwise protect the rights and interests of the Indians and the Indian Service.

The Department is in receipt of a letter from Hon. J. L. Rawlins calling attention to the act referred to, in which he states that there is "a vast surplus of water rising in that reservation running to waste which may and ought to be utilized for the reclamation of adjoining lands capable of affording homes to many people without any detriment to the Indians."

The Department is also advised that the Indians will need all the waters flowing

on or through the reservation.

In view of the apparently conflicting opinion, I desire that the necessary number of competent topographers and engineers from your office be detailed to proceed to the Uinta Reservation, there to make an investigation and to ascertain the amount of available water upon the reservation for a permanent supply, and the number of acres of irrigable land thereon.

It is desired that the quantity of water from each of the several streams, the names of which should be given, shall be shown separately, and also in the same manner the number of acres of contiguous land that can be irrigated by the water from each of the streams, and whether the waters thereof are sufficient or more than sufficient, or deficient, to supply irrigation for the quantity of land contiguous thereto; also, what surplus of water, if any, there will be from each of the streams.

It is further desired that this investigation and the report thereof shall be made with the express view of placing at the disposal of the Department such information as will enable it to intelligently carry out the intent of the act cited with respect to the rights of the Indians, and also with respect to the rights of others than the Indian occupants of the reservation.

Very respectfully,

THOS. RYAN, Acting Secretary.

The DIRECTOR OF THE GEOLOGICAL SURVEY.

Mr. Cyrus C. Babb, hydrographer, was detailed to make the investigation required, and in September, 1899, an allotment of \$2,000 was obtained from the Indian Office for the purpose of defraying the expenses of the survey, the allotment being available until June 30, 1900, when another allotment of \$5,000 was made by the Indian Office for the continuation of the work during the next fiscal year. A progress report of the investigation was published in the Twenty-first Annual Report of the United States Geological Survey, Part IV, pages 305 to 330, and the following pages contain Mr. Babb's supplemental report, covering the results for the field season of 1900.

PHYSICAL FEATURES OF THE RESERVATION.

The Uinta Indian Reservation is in the northeastern corner of Utah. At the time it was set aside it was the intention to have it include the drainage basin of Duchesne River and its main tributary, Uinta River. The surveys that were made of the boundary, however, excluded certain portions of these basins, and hence the area of the reservation does not wholly correspond to the area drained. The reservation comprises 2,039,040 acres, or 3,186 square miles, an area half as large as that of the State of Connecticut. The main stream is Duchesne River, which flows in an easterly direction, entering Green River just above the mouth of White River. Its main upper tributary is Strawberry Creek, which drains an area of 1,166 square miles. This creek passes through what is known as Strawberry Valley, a fine tract of land with

an average elevation of 7,500 feet. The country is rather high for general agricultural purposes, but is splendidly adapted to grazing. It is well grassed and has an abundant water supply. Lake Creek is an important tributary of Duchesne River, draining a region in the central portion of the reservation. The source of the stream is on the southern slope of the high Uinta Mountains, and it flows in a southerly direction, entering Duchesne River about 3 miles above the Price road bridge. The total area drained by it is 475 square miles.

Uinta River and its principal tributary, Whiterocks River, drain the eastern portion of the reservation and adjacent areas beyond the reservation limits. These streams rise in the extreme northern end of the reservation, on the southern slopes of the Uinta Mountains. They flow in a general southeasterly direction, the various channels uniting between the Indian agency at Whiterocks and the military post at Fort Duchesne. From that point they flow in one channel, joining the main Duchesne River 6 miles below, near the Ouray School. Both rivers (Whiterocks and Uinta) emerge from their canyons about 10 miles above the Indian agency at Whiterocks. North of that point the country is distinctly mountainous and difficult of access. South of the canyons it is flat for a considerable distance west of the river, and has a distinct southern slope of about 40 feet to the mile. Uinta River and various washes cut this country with a still greater slope (about 70 feet to the mile), and in the first 5 or 7 miles below the mountainous area they have dissected the plateau into a number of mesas of varying width. As a result of the differences in the slope of the mesas and of the washes, cliffs from 150 to 200 feet in height are formed bordering Duchesne River on the north side. Immediately south of the latter stream the bottom land is bordered by a cliff from 200 to 300 feet high, with a series of mesas extending southward for a number of miles.

FIELD WORK.

When the investigation was inaugurated in 1899, in order to ascertain the amount of water in the rivers the following gaging stations were established, as described in Water-Supply Paper No. 37, pages 288 to 292: On Whiterocks River, 10 miles above the Indian agency; in the canyon of Uinta River, 10 miles above the agency; on Uinta River at Fort Duchesne; on Uinta River at the Ouray School; on Duchesne River at the bridge on the Price road; and on Lake Creek 1 mile above its mouth. A plane-table survey of the agricultural lands of the reservation was also commenced, on a scale of 1 mile to 2 inches, with a contour interval of 20 feet. Owing to the shortness of the season in 1899, only a small portion of the area could be mapped, and attention was therefore confined to the arable land

east of Uinta River, both on and off the reservation, and to the area immediately to the west of that river between Whiterocks and Fort Duchesne. The latter is the principal section at present cultivated by the Indians.

At the close of the field season in 1899 176 square miles had been mapped and measurements at various gaging stations had been systematically made. From the results thus obtained, as stated in the first report, a the conclusion was reached that there was not sufficient water for the future needs of the Indians. The measurements upon which this conclusion was based, however, were made in the fall, during the lowest stages of the rivers, and it was thought that measurements made the next spring, during the flood stages—when water is most needed for irrigation-might show a surplus that could be diverted and used off of the reservation. Accordingly measurements at the various gaging stations were continued throughout the winter and spring, until active field work was resumed in May, 1900, when a party was organized and surveys were continued on the same plan as during the preceding fall, measurements at the gaging stations being also systematically carried on. The survey of the agricultural area tributary to Uinta River was completed early in July, 1900.

In the first report^b it was stated that possibly a portion of the water of Lake Creek could be diverted and used on some of the lands adjacent to Uinta River, in order to release a portion of the water of the latter stream, so that permission could be given for its use off the reservation. A reconnaissance in June, 1900, showed a large area of arable land to the east of Lake Creek, within the lower portion of Dry Gulch Basin. In order to ascertain the possibilities of using the Lake Creek water, this area was next mapped, on the scale of 1 mile to 2 inches, with a 20-foot contour. The area comprises a strip of bench land bordering the east side of Lake Creek, and extending from the junction of the two forks of that stream southeastward for about 14 miles, where it broadens out to a strip draining into Dry Gulch Creek. On the completion of the map of this section attention was turned to the Duchesne River area.

Immediately south of Duchesne River is a series of benches admirably adapted to irrigation purposes. Topographic work was continued in this section through August, being extended from the Duchesne bridge westward to about the mouth of Antelope Creek, an area of 35 square miles being thus mapped. Early in September Mr. Babb was obliged to leave the work, and Mr. A. L. Fellows, resident hydrographer, Denver, Colo., was placed in charge. The work of the previous month had shown conclusively that there was a large area of irrigable land in this vicinity, and the next step was to ascertain the feasibility of a

a Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 305-330.

b Op. cit.

canal from Duchesne River to carry water to it. This was the project to which Mr. Fellows turned his attention. Upon the disbandment of the party in October, Mr. C. T. Prall was, as during the previous season, left in charge of stream gagings during the winter, in order that continuous measurements might be obtained during the low stages.

The total area surveyed at the close of the field season in 1900 was 404 square miles, divided as follows: Surveyed in 1899, 176 square miles; surveyed in 1900, area tributary to Uinta River and Lake Creek, 193 square miles, and area south of Duchesne River, 35 square miles.

AGRICULTURAL LANDS AND WATER SUPPLY.

UINTA RIVER.

The land that can easily be irrigated from Uinta River, both on and off the reservation, lies on both sides of the river. Within the area a large proportion of the Indians of the reservation are settled, and there also is the greatest area of cultivated land, lying principally in two tracts, namely, the bench land between Fort Duchesne and the Indian agency at Whiterocks and the area east of the Ouray School. A more detailed description of these lands will be found in the first progress report. a The principal canals of the reservation are also in this section, including Canal No. 1, which heads on the right bank of Uinta River about three-fourths of a mile southwest of the Indian agency, extends in a southwesterly direction across the mesa for 5 miles, and then is turned into the head of a gulch, from which it is taken out at the eighth milepost. In this distance of 3 miles there is a descent of 480 feet. Up to the present time the little water drawn from this canal has been used for small areas on the mesa and for the Government farm, which at present is conducted by an employee of the Indian Service. The object of this farm is to have it operated by an experienced farmer, in order that the Indians can be instructed in the best methods of agriculture.

The second principal ditch is known as the Bench ditch. It heads about 5 miles south of the Indian agency, and serves land to the west of Uinta River, principally on what is known as The Bench, where are prosperous-looking ranches of alfalfa and a number of the cereals, which show what the Indians can do if they are inclined and have the proper facilities. The estimated area under cultivation in the bench country is 1,000 acres, but 5,000 acres are available for irrigation.

The third section under cultivation is a small area west of the Indian agency, settled principally by the White River Indians, the land being served by a number of small ditches from Whiterocks River.

The fourth section of irrigable land is that west of the Ouray School. It receives most of its water supply from the ditch heading from

Duchesne River about 8 miles above the school. An attempt was made to supply a portion of this area from the ditch heading immediately below the bridge over Dry Gulch Creek, utilizing also the waste waters from Canal No. 1 and the Bench ditch. Owing, however, to the water being heavily charged with sediment, the latter canal has been almost completely filled with sand and is of little use at present.

Elsewhere in this report (p. 386) there is an estimate which shows that 55,200 acres will be required by the Indians of this reservation when they are allotted lands in severalty.

This acreage could be obtained in the Uinta area, but a large percentage of the land is of inferior quality and not nearly so suitable for cultivation as that in other sections of the reservation. This is especially true of that portion of T. 1 N., R. 1 W. which lies west of Uinta River. It is a fairly flat country, and from a casual inspection would seem to be adapted to cultivation. It is, however, of a very rocky nature, and is largely covered with a growth of cedar common to rocky so?!. The bottom lands of Uinta River are of a similar rocky nature and little adapted to irrigation. They appeal, however, to the Indians as desirable lands for settlement, being crossed in various directions by different branches of Uinta River, the banks of which are lined with a dense growth of brush and cottonwood, forming an excellent wind guard for the detached open areas. Nearly the entire area of T. 2 S., R. 1 W., is also of an inferior quality of soil, being of an alkali nature and easily eroded by running streams, so that even small irrigation ditches do not stand for any length of time.

The best land for irrigation is the northeast half of T. 1 S., R. 1 W., and the bench country west of Uinta River. Good land is also to be found east of the streams, in what is known as the Deep Creek country. In the latter section there is a total irrigable area of 16,300 acres, but of the better land there are only 7,000 acres. The fourth section, as before mentioned, is west of the Ouray School, between Uinta and Duchesne rivers.

In the first progress report of this investigation a there is given a rather detailed description of the irrigable lands off the reservation and of the best method of carrying water to them. These lands are in two principal areas, one of 6,600 acres, in what is known as The Strip, and the other of 21,200 acres, in the so-called Green River triangle. The latter area is east of the Ouray School, and is bounded on the west by the reservation boundary line and on the east by Green River, forming an approximate triangle.

The following table gives the amount of arable land that can be supplied with water from Uinta and Whiterocks rivers:

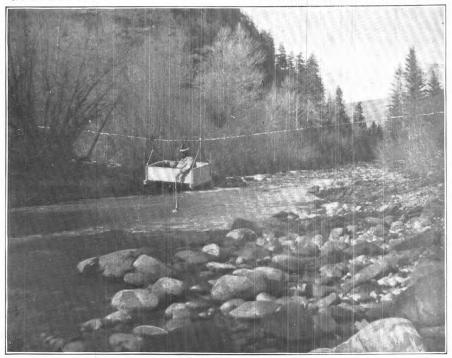
Irrigable lands along Uinta and Whiterocks rivers.

On reservation:	Acres.
River bottom	8,900
Mesa west of Uinta River, northeast half of T. 1 S., R. 1 W	21,400
Bench country	7, 100
Miscellaneous areas north of Fort Duchesne	
Deep Creek country	16,300
Miscellaneous in lower Uinta Basin	5, 200
Total	68, 500
Off reservation:	
The Strip.	6,600
Green River area	
Total	27, 800

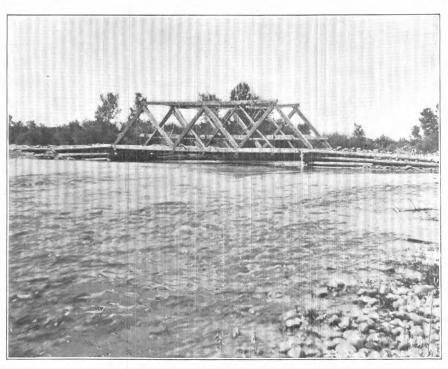
The best method for the irrigation of these lands is by the enlargement of the present canal system. The carrying capacity of Canal No. 1 could be increased so as to supply sufficient water to the mesa west of Uinta River. It should also be extended from about the fourth milepost westward around the head of the gulch down which it is now turned. This extension would supply water for the entire mesa extending southward immediately west of the Government farm valley. Bench ditch could also be enlarged; and the Deep Creek country, if water from Whiterocks River is allowed to be diverted from the reservation, could be supplied from Uinta River.

The main features of a canal to carry water off the reservation are as follows: It should head in Uinta River at such an elevation as to cross the little divide in sec. 35, T. 1 S., R. 1 W., at, say, the 5,180-foot contour. About 1½ miles from its head it would cross Deep Creek, continuing eastward for a short distance and then southward. It would control most of The Strip country, and would cross the Vernal road divide at the 5,100-foot contour, about 11 miles from its head. The fall would be greater in the next 3-mile course down the dry wash. The water could then be diverted at the 4,900-foot contour, after which the general direction would be southeasterly for 8 miles, then practically due south, in which direction it would continue until Green River and the lower end of the triangular tract of land were reached. The following are the approximate distances along the canal from its head:

	Miles.
Deep Creek	
Reservation line	4.0
Vernal road divide	11.0
4,900-foot contour	14.5
Bend to the south	22.0
End of canal	29.0



A. GAGING STATION ON WHITEROCKS RIVER, UINTA INDIAN RESERVATION, UTAH.



B. GAGING STATION ON UINTA RIVER AT FORT DUCHESNE, UTAH.

No difficult engineering features would be encountered along the route. The excavations for the greater portion of the way would be through the cemented gravel common to the country. This formation is difficult, and hence expensive, to work, and the cost would be near that of rock-cutting, or about \$1 per cubic yard.

Water supply.—As already stated, a number of gaging stations were located within the Uinta River area, so that an estimate of the available water supply could be made. These gaging stations are described in Water-Supply Paper No. 37. The first one is in the canyon of Uinta River, about 10 miles above the Indian agency at Whiterocks, and the gagings show the amount of water that the river will furnish for the irrigation of the region below. The second station is in the canyon of Whiterocks River, about 10 miles north of the Indian agency (see Pl. XXVII, A). The third station is on Uinta River at Fort Duchesne (see Pl. XXVII, B). A comparison of the flow at this point with the combined discharge of Uinta and Whiterocks rivers in their canyons shows considerable loss between the points—greater than the amount diverted by the ditches. This is undoubtedly due to percolation and evaporation from the many channels which form a network through the river bottom. The fourth gaging station is on Uinta River, at the bridge crossing to the Ouray Indian school, about a mile above the mouth of the stream. The increase in flow between this station and Fort Duchesne is from the waste waters of Canal No. 1 and the Bench ditch, which enter through Dry Gulch Creek. The Bench ditch was measured twice during the season, near its head, the first measurement being on June 9, when, at a gage height of 1.1 feet, the discharge was 39 second-feet, and the second measurement on October 10, when, at a gage height of 0.7 foot, the discharge was 22 second-feet. Canal No. 1 was measured on June 9, when the gage height was 1.1 feet and the discharge 31 second-feet, and on October 10, when the gage height was 0.8 foot and the discharge 9 second-feet.

On July 26, 1900, a series of discharge measurements was made on Canal No. 1, in order to ascertain the loss by evaporation and percolation. In the first 5 miles of its course the canal passes through a very rocky soil, partially cemented, and measurements along this section would show approximately the conditions that would exist in other parts of the reservation if similar canals were built. The measurements show a slight gain between the head of the canal (shown in Pl. XXVIII, A) and the first milepost, but considering the limit of error it is thought that in this section there is neither gain nor loss. Between the first and second mileposts the loss is 2.3 second-feet; between the second and third mileposts the loss is 0.7 second-foot; between the third milepost and the head of the main lateral (about $4\frac{\pi}{4}$ miles from the head gate), down which all of the water in the canal was flowing, two small ditches diverted 2.7 second-feet. This would show a slight gain (0.8)

second-foot), which is considered doubtful, however, and probably is due to lack of refinement in the measurements. The next measurement was on the main lateral, about $1\frac{3}{4}$ miles from its head, and the loss was 1.7 second-feet, or practically 1 second-foot to the mile. The fall of the lateral in this distance is 180 feet. Between this point, or where the farm road crosses the lateral, and the ninth milepost (see Pl. XXVIII, B), or after it has made its descent over the bluff, there is neither gain nor loss. It is believed that in canals having considerable fall the average loss over rocky bench lands is about 1 second-foot per mile. The following is a summary of the measurements made in Canal No. 1 and the ditches diverting water from it:

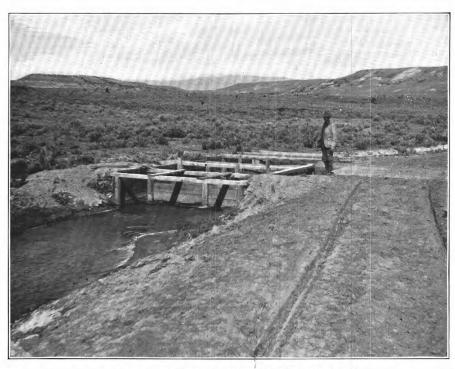
Discharge measurements of Canal No. 1 and diversion ditches.

		Discharge.		
Canal.	Locality.	In canal.	In diver-	
		Secfeet.	Secfeet.	
Canal No. 1	Near head gate	16.3		
Ditch 25 feet below gaging station on			0.7	
Canal No. 1.				
Canal No. 1	First milepost	15.7		
Do	Second milepost	13.4		
Do	Third milepost	12.7		
Two small ditches near Indian farm	Head gates		2.7	
Main lateral	½ mile below head	10.8		
Do	At bridge on Government farm road, 12 miles from head gate.	9.1		
Two small ditches below bridge	Head gates		2.5	
Canal No. 1.	Ninth milepost	6,6		
Total			5.9	

Daily gage readings at the heads of Whiterocks and Uinta rivers could not be made during the season, but a large number of discharge measurements were made, from which the average monthly flow at the two stations was computed, as shown in the following tables. Daily gage readings were kept at the Fort Duchesne station, however, and after a comparison of the results obtained there with those obtained at the two canyon stations, the data for the latter two points were verified, and it is considered that the figures given represent a fair approximation of the average flow.



A. HEAD GATE OF CANAL NO. 1, UINTA INDIAN RESERVATION, UTAH.



B. CHECK GATE OF CANAL NO. 1 AT NINTH MILEPOST.

Estimated monthly discharge of Uinta River near Whiterocks, Utah.

[Drainage area, 218 square miles.]

	Mean dis- charge in second-feet.	Total in acrefeet.	Run-off.		
Month.			Second-feet per square mile.	Depth in inches.	
1900.					
January	112	6, 887	0.51	0.59	
February	112	6, 220	0.51	0.53	
March	125	7,686	0.57	0.66	
April	138	8, 212	0.63	0.70	
May	650	39, 967	2.98	3.44	
June	597	35, 524	2.74	3.06	
July	223	13, 712	1.02	1.18	
August	184	11, 314	0.84	0.97	
September	157	9, 342	0.72	0.80	
October	154	9, 469	0.71	0.82	
November	138	8, 212	0.63	0.70	
December	145	8, 916	0.67	0.77	
The year	228	165, 461	1.04	14. 22	

Note.—All figures are approximate, daily gage heights not being kept during 1900. Discharge measurements for the year are given in Water-Supply Paper No. 50, page 369; rating table in Paper No. 52, page 519.

Estimated monthly discharge of Whiterocks River near Whiterocks, Utah.

[Drainage area, 114 square miles.]

			Run-off.		
Month.	Mean dis- charge in second-feet.	Total in acrefeet.	Second-feet per square mile.	Depth in inches.	
1900.		0.000	0.41	0.45	
January		2,890	0.41	0. 47	
February		2, 666	0.42	0.44	
March	50	3,074	0, 44	0.51	
April	44	2,618	0.39	0.44	
May	400	24, 595	3.51	4.05	
June	253	15, 055	2. 22	2.48	
July	82	5,042	0.72	0.83	
August	62	3, 812	0,54	0.62	
September	55	3, 273	0.48	0.54	
October	44	2,705	0.39	0.45	
November	59	3, 511	0.52	0.58	
December	55	3, 382	0.48	0, 55	
The year	100	72, 623	0.88	11. 96	

Note.—All figures are approximate, daily gage heights not being kept during 1900. Discharge measurements for the year are given in Water-Supply Paper No. 50, page 370; rating table in Paper No. 52, page 519.

Estimated monthly discharge of Uinta River at Fort Duchesne, Utah.

[Drainage area, 672 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	L					
January a			125	7, 686	0.19	0.22
February a			125	6, 942	0.19	0. 20
March	193	85	123	7, 563	0.18	0.21
April	128	85	99	5, 891	0.15	0.17
May	2, 343	95	924	56, 814	1.38	1.59
June	1, 270	140	431	25, 646	0.64	0.71
July, 17 days	140	25	67	4, 120	0.10	0.12
August	62	20	36	2, 214	0.05	0.06
September	125	25	62	3, 689	0.09	0.10
October	110	70	98	6,026	0.15	0.17
November	140	90	105	6, 248	0.16	0.18
December	140	55	90	5, 534	0.13	0.15
The year			190	138, 373	0.28	2.88

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 371; discharge measurements, page 370; rating table in Paper No. 52, page 519.

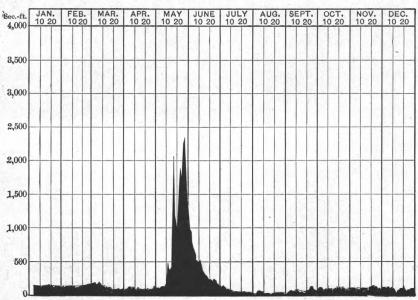


Fig. 171.—Discharge of Uinta River at Fort Duchesne, Utah, 1900.

Estimated monthly discharge of Uinta River at the Ouray School, Utah.

[Drainage area, 967 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	0.					
January a			100	6, 148	0.10	0.12
February a			100	5, 554	0.10	0.10
March 9 to 31	179	56	97	5, 964	0.10	0.12
April	232	64	88	5, 236	0.09	0.10
May	1,497	92	689	42,365	0.71	0.82
June	1, 123	179	451	26, 836	0.47	0.52
July	156	28	65	3, 997	0.07	0.08
August	40	19	32	1,968	0.03	0.03
September	242	37	89	5, 296	0.09	0.10
October	156	113	122	7,501	0.13	0.15
November	200	64	128	7,617	0.13	0.15
December, 6 days			91			

a Approximate.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 372; rating table in Paper No. 52, page 519.

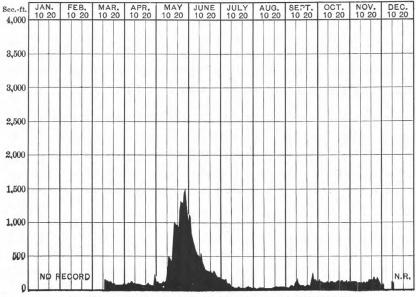


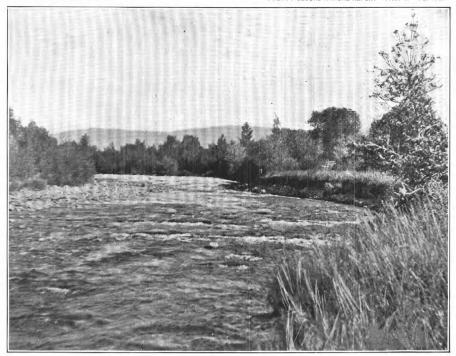
Fig. 172-Discharge of Uinta River at the Ouray School, Utah, 1900.

LAKE CREEK.

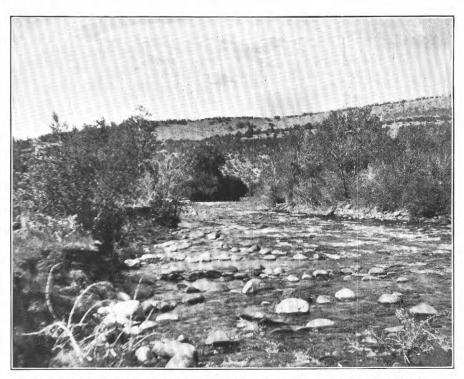
This creek is an important tributary of Duchesne River, draining a section of country immediately adjoining the Uinta Basin on the west, and discharging into the river about 3 miles above the bridge on the stage road to Price. There has been more or less discussion regarding the feasibility of diverting the waters of the creek to irrigate lands adjoining Uinta River, especially those under Canal No. 1, and it was thought desirable to investigate the possibilities of the project.

A strip of land suitable for agriculture was found along the eastern side of the stream, and this was mapped, in 20-foot contours. The creek flows in a gorge about 200 feet deep. The most feasible point for its diversion is about a half mile below the junction of the North and South forks (see Pl. XXIX), where the cliffs on the east side are in a succession of terraces, and a canal taken out there would in a distance of about $2\frac{1}{2}$ miles bring water to the top of the mesa. A map was made, on a scale of 200 feet to the inch, with 5-foot contours, covering $2\frac{1}{2}$ miles of the country downstream from the junction of the two forks, or to the top of the highest terrace. The construction of this map will show the proper location for a canal line, and it is on a scale large enough to permit a computation of the amount of excavation required, from which a fair estimate of the cost of that portion of the canal can be made.

The Lake Creek agricultural area as mapped can be naturally divided into three portions. The first comprises a strip of 18,000 acres of bench land extending from the junction of the two forks southward for about 14 miles, when it broadens out into the second division the strip draining into Dry Gulch Creek—consisting of about 12,600 The third area is the mesa between the latter division and Duchesne River, containing 5,300 acres. The upper section referred to has a very steep slope, but the subsoil is of the same formation as that along which Canal No. 1 flows - a partially cemented gravel. It is believed that a canal can be built directly down the mesa, and that the amount of erosion will be very small. After the canal, heading below the forks of the creek, has attained the top of the mesa, it could be divided, one branch extending southward, to serve the lands of the upper section, and the other branch continuing in a general easterly direction for about 4 miles, when it could be turned into the gulch in sec. 6, T. 1 S., R. 3 W. This wash has its outlet in sec. 21, T. 2 S., R. 3 W., and the water could be diverted there and used to irrigate the second division, known as the Dry Gulch country. The mesa referred to—the third section of the agricultural area—comprises, as already stated, an area of 5,300 acres, to which water could be taken by constructing a lateral from the mouth of the gulch mentioned, extending it southeasterly across the flat country for about 4 miles, when a side hill would be encountered, along which the canal would run for a distance of about 3 miles before the top of the mesa could be reached.



 $m{arDelta}.$ Lake creek, utah, a half mile below north and south forks, at proposed diversion works, looking upstream.



 B_{\cdot} LAKE CREEK, UTAH, A HALF MILE BELOW NORTH AND SOUTH FORKS, LOOKING DOWNSTREAM.

The following are the areas of the three sections:

$Agricultural\ lands\ along\ Lake\ Creek.$	
	Acres.
North section	
Dry Gulch country	12,600
Mesa north of Duchesne River	5, 300
Total	35, 900

There is another area of agricultural land tributary to Lake Creek that could be irrigated from it. It comprises about 16,100 acres and is on the west side of the creek, north of Duchesne River, in T. 3 S., R. 3 W. Owing to lack of time this section was not surveyed during 1900, but it should be considered in connection with the possibilities of irrigation from the creek. There is thus a total of 52,000 acres tributary to the creek that can be irrigated from it.

In regard to the feasibility of using the waters of Lake Creek for the irrigation of lands in the Uinta area, if a canal were diverted from about the forks of the creek and carried westward to the Uinta region, it would pass through some very rough country, besides crossing two deep gulches, including that of Dry Gulch Creek, and the cost would be excessive. On this account, as well as because of the large extent of agricultural land immediately tributary to the creek, it is recommended that no attempt be made to carry water from this stream to the Uinta area.

Water supply.—On August 6 the East Fork of Lake Creek was measured immediately above its mouth, and at a gage height of 2.1 feet on a temporary rod a discharge of 112 second-feet was found. On August 14 the same stream, at a gage height of 1.94 feet, was carrying 87 second-feet.

On August 6 the West Fork of Lake Creek was measured immediately above its mouth, and at a gage height of 1.4 feet on a temporary rod the discharge was 93 second-feet. On August 14 the same stream, at a gage height of 1.22 feet, was discharging 69 second-feet.

On August 6 Lake Creek was measured a half mile below the junction of the two forks at the location suggested for the canal, and the height on a temporary rod was 2.67 feet and the discharge 290 second-feet. On August 14 it was measured at the same place, and the gage height was 2.49 feet and the discharge 192 second-feet.

The areas drained by these streams are as follows: East Fork, 147 square miles; West Fork, 160 square miles; Lake Creek, a half mile below the junction of the two forks, 308 square miles.

The gaging station on Lake Creek was established July 3, 1900, on the wagon bridge near its mouth. It is described in Water-Supply Paper No. 50, pages 372 and 373. Daily readings were not maintained, but a large number of discharge measurements were made, so that it has been possible to estimate the flow of the stream at that point. It is given in the accompanying table (p. 380).

Estimated monthly discharge of Lake Creek, Utah, near mouth.

[Drainage area, 475 square miles.]

			Run-off.		
Month.	Mean dis- charge in second-feet.	Total in acrefeet.	Second-feet per square mile.	Depth in inches.	
1900.				-	
July	195	11,990	0.41	0.47	
August	97	5, 964	0.20	0. 23	
September	112	6, 664	0.24	0. 27	
October	117	7, 194	0.25	0. 29	
November	115	6, 843	0. 24	0. 27	
December	124	7,624	0.26	0.30	

Note.—All figures are approximate, daily gage heights not being kept during 1900. Discharge measurements for the year are given in Water-Supply Paper No. 50, page 373.

From the foregoing table it will be seen that the discharge of Lake Creek in July (the critical period for irrigation) was 195 second-feet. With a duty of water of 1 second-foot to 100 acres the creek would serve 19,500 acres.

DUCHESNE RIVER.

The course of Duchesne River after its junction with Strawberry Creek is in a general easterly direction, flowing through a bottom land averaging 2 miles in width. Immediately south of this strip occurs a line of bluffs of about 300 feet elevation, from the top of which a series of mesas extend southward. This higher land west of Antelope Canyon is greatly dissected by side canyons draining toward Duchesne River, and is not suitable for agricultural purposes. East of Antelope Canyon, however, the mesas are little cut up, and as a result there is a large tract of land well suited for cultivation, if water could be brought to it. Considerable topographic work was executed in this area during 1900, and a number of lines for canal locations were run. The topographic work showed that an elevation of 5,600 feet should be attained on the mesa in order to reclaim the greater portion of it. An elevation on Duchesne River somewhat greater than this is about 6 miles above the mouth of Strawberry Creek, from which a line for a canal was started, with the idea of taking water from the right bank of the river. The line was run a distance of 20 miles, when it crossed Strawberry Creek to the south side, and then was continued eastward another 20 miles before the agricultural area was reached. On account of its length, and also because of the excessive cost of construction, the line was considered impracticable and was abandoned. Another line was then started, the initial point being on the right bank of Duchesne River a short distance below the mouth of Strawberry Creek. This line follows the river closely for a distance of 8 miles, or to about 3

miles west of the Indian village near the mouth of Antelope Canyon. About opposite this settlement the line recedes to perhaps $1\frac{1}{2}$ miles from the river. It shortly reaches Antelope Canyon, up which it continues for a distance of about 2 miles, then crosses the canyon, turns down again, and continues in front of the hills, with the exception of a few cut-offs, until the top of the mesa is reached, at an elevation of 5,340 feet, about 6 miles southeast from the Duchesne bridge and 4 or 5 miles east of Antelope Canyon. The following description of these canal lines is from Mr. Fellows's report:

Duchesne canal lines.—The location of the initial point of the survey for the first canal line was on the right bank of Duchesne River, about 6 miles above the mouth of Strawberry Creek. From station 0 to station 49, a distance of nearly 1 mile, practically no difficulty was met, except that one flume, about 400 feet in length, across a deep wash would be necessary. At station 50 the line strikes a steep sidehill, with a slope of about 1 to 3, which is overlain with gravel and bowlders; but a line is practicable, although rather expensive, along this entire hillside, which continues to station 195, a distance of nearly 3 miles. From the top of the bench at station 195 to station 225, about three-fifths of a mile, the line is across a level country and could be made perfectly straight. From that point (station 225), by crossing a ridge with a maximum cut of 17 feet at station 238, the cut ending at station 240, about three-fourths of a mile might be saved, besides some very expensive sidehill work. Both lines were surveyed, but the one including the cut would be much the better. From station 240 the line runs along a very steep sidehill—the slope in places being as high as 40 degrees from the horizontal—where deep cuts, sidehill flumes, and even tunnels would be necessary, with practically no easy work until station 390 is reached. At that point two courses are open to cross a deep wash sloping toward Strawberry Creek: First, to continue around the wash, along the sidehill slope—which is of about the same nature as that previously traversed for a mile or more—or to flume for about 1,000 feet, to the opposite side. As between 3 and 4 miles of canal would be necessary if the circuit were made to a point opposite station 390, and only 1,000 feet from it, it is clear that the best plan would be to cross the creek by means of a flume, although this flume would probably be not less than 80 feet in height at the bottom of the draw. Another course, however, seemed possible. The line to this point (station 390) is extremely crooked. From here, however, it runs almost directly toward station 0, and a reconnaissance indicated that probably a tunnel from the starting point to the head of the ravine to be crossed at this place would not be more than three-fourths of a mile in length, and perhaps considerably less, saving approximately 8 miles of bad canal work and 20 feet in grade. For reasons given later, however, this line was not surveyed. Crossing this wash, therefore, at station 390, and striking grade again at about station 400,

the line proceeds by a fairly easy route to station 425, a distance of about a half mile, with no serious difficulties, but still by no means an ideal line. At station 425 the sandstone bluffs along the north side of Strawberry Creek are reached, the first one being about 50 feet in height, along the face of which the line would run to station 460, approximately another three-fourths of a mile of very bad sidehill work, much of which would have to be fluming. From station 460 to station 481 the line traverses a country in which it would be fairly easy to construct a canal, but at station 481 the main bluffs along the north side of Strawberry Creek are reached, and from that point the line for the next 10 or 12 miles, excepting only about a half mile, would run along sandstone bluffs, which would have to be flumed before Strawberry Creek could be crossed.

At station 805, however, it was decided that the line was absolutely impracticable, as the expense would be too great to justify any construction at that elevation. It was evident, moreover, that while it would require approximately 20 miles of canal, running through an extremely rugged country, to reach Strawberry Creek, it would require as long a line, over equally impracticable and perhaps even worse ground than that traversed in the first 20 miles, to reach anything like an open country. The cost of these 40 miles would be probably not less than \$10,000 a mile, and there are not more than 1,000 acres of irrigable land lying below the canal, excepting such as can be watered by small ditches taken directly from Duchesne River and Strawberry Creek. The fall due to the grade would, moreover, lower the line to such an extent that it would be impossible to reach as high an elevation upon the mesa lands below as desired. A number of careful reconnaissance trips demonstrated beyond question that it was impracticable for a canal to be taken out at a higher elevation than that attempted, as the bluffs along Duchesne River and Strawberry Creek become steeper and more rocky the higher upstream one goes.

It being evident that a canal run at so high an elevation as at first seemed desirable was impracticable, from the nature of the country, it was decided to investigate the feasibility of taking out a canal below the mouth of Strawberry Creek and carrying it to the mesa below. Accordingly a trial line was run several miles along the bluffs on the south side of Duchesne River, to determine the practicability of the upper part of the proposed canal, which should avoid the bluffs near the mouth of Indian Canyon, which unites with Strawberry Creek just above its junction with Duchesne River. As it appeared that this line presented desirable features—it would cover a considerable portion of the nearly level country south of Duchesne River—and nothing absolutely impracticable being seen, the survey of the grade line was commenced, the same fall being used as in the first survey, viz, 2.56 feet to the mile. The 0 point of this survey was at an elevation of 5,434.81 feet, referring to the datum of the topographic survey.

The grade assumed was 2.56 feet to the mile. From station 0 to station 35, about three-fourths of a mile, the country is favorable for a perfect line, but at the latter point a sidehill is reached, which although not impracticable for a canal route still presents material difficulties of construction. The line runs along this sidehill from station 35 to station 103, and there is more or less sidehill work of the same character until station 175 is reached, after which no difficulties, excepting short flumes, are encountered for about 2 miles. Then, however, the line again strikes a deep hillside, in which there is but little if any rock, and runs along nothing but sidehill lands and through cuts, with an occasional short stretch of level country, for about 30 miles, when the top of the mesa is finally reached, at station 1855. This line was continued to station 1895, where the elevation is about 5,340 feet. The survey was little more than a trial line. It could be very much improved by starting about 20 feet higher on Duchesne River, crossing Strawberry Creek on grade, and running with a fall not to exceed 2 feet to the mile (a little less would be better), shortening the distance as much as possible by constructing flumes, wherever practicable, across the ravines encountered, even flumes 100 feet high and from 1,000 to 1,500 feet long. By keeping the grade as high as possible a cut could be made through three ridges and a saving of probably 10 miles be effected. By these means it is believed that an elevation of approximately 5,380 feet could be reached. Although the higher canal line would require more expensive construction near the head, the difference would be more than compensated by the advantages gained farther down.

Just below the mouth of Strawberry Creek there is a very narrow neck of land between two bends in the river. In case the canal should head below the creek there would be danger of the river cutting across this neck, making an extension of the canal necessary to at least the mouth of Strawberry Creek. In case the canal were constructed 20 feet higher up, as suggested, during the greater portion of the year the water would be taken directly from Strawberry Creek and only a small canal from Duchesne River would be needed for use during low water. This canal would cost in the neighborhood of \$300,000, and 21,800 acres could be irrigated from it, although the land covered is not of the best quality, being well down toward points of the mesa, and lying to a great extent in the sandy draw through which runs the road between Price and Fort Duchesne.

A third preliminary survey for a canal was made in October. The head of this canal would be on the left bank of the river, a short distance below the mouth of Strawberry Creek and about a half mile below the head of Canal No. 2, just described. It could be made to irrigate about 2,000 acres of land on the north side of Duchesne River.

A reconnaissance was also made by Mr. Fellows from Duchesne River above the mouth of Strawberry Creek to a point some distance above the mouth of Rock Creek, with a view to ascertaining whether or not it would be possible to cover a large tract of land lying upon the mesa north of the river. After a careful examination, however, the conclusion reached was that such a line was not feasible, as about 10 miles of the canal would have to be constructed along a very rocky hillside, and it would reach the level of the mesa at so low an elevation as to permit little irrigation. It was suggested that this high land might possibly be covered by means of a ditch taken out of Rock Creek, an important tributary of Duchesne River carrying a considerable volume of water at even low stages, but there was not sufficient time for an investigation of this route. From the information obtainable, however, it is thought that the project is not feasible, as the country is more rocky and broken the higher up it is explored.

The bottom land along Duchesne River from Lake Creek down the stream (6,800 acres) has practically all been allotted to the Uncompangre Indians, who are to pay the Uintas for it, and the territory is, therefore, not available for future allotment to the latter tribe, but water will have to be furnished to it to supply the Uncompagres. The bottom land from the mouth of Lake Creek up to Antelope Canyon, comprising an area of 7,500 acres, is, however, available for settlement. This land is now covered by a canal heading about 1½ miles above Antelope Canyon. It is 15 feet wide, and can be made to furnish a good supply of water for this section. The benches south of the river and above the bottom land have an area of 21,800 acres of good land, to which, as the investigation shows, a canal can be constructed. Below there is another section of bench country, comprising 21,900 acres, which might be irrigated by a canal heading on the right bank of Duchesne River about 1 mile above the Price bridge. There is, therefore, an irrigable area of 58,000 acres tributary to Duchesne River.

Water supply.—On September 15, 1900, Duchesne River was measured a quarter of a mile above Strawberry Creek, and at a gage height of 2.10 feet on a temporary rod a discharge of 216 second-feet was found. On the same date Strawberry Creek just above its mouth and below Indian Creek was carrying 84 second-feet. On October 5 both streams were again measured at the same points, and Duchesne River, with a gage height of 2.14 feet, was discharging 232 second-feet, while Strawberry Creek with a gage height of 1.20 feet. was discharging 92 second-feet.

The regular gaging station on Duchesne River (described in Water-Supply Paper No. 37, page 291) is at the Price road bridge, which is below the mouth of Lake Creek. The discharge of the latter stream should be deducted from the discharge of the river, as the flow of the creek will be applied to the area tributary to it. The July flow of Duchesne River was 377 second-feet. Deducting the July flow of Lake Creek (195 second-feet), would leave a balance of 182 second-feet available for the Duchesne lands. With a duty of water of 1 second-foot to 100 acres this flow would serve 19,500 acres.

The monthly discharge at the gaging station during 1900 is given in the following table:

Estimated monthly discharge of Duchesne River at Price road bridge, Utah.

[Drainage area, 2,746 square miles.]

	Dischar	ge in secon	d-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January			370	22, 750	0.13	0.15	
February			370	20, 549	0.13	0.14	
March	700	315	394	24, 226	0.14	0.16	
April	860	350	467	27, 788	0.17	0.19	
May	5, 880	630	2, 327	143, 082	0.85	0.98	
June	4, 440	600	1,702	101, 276	0.62	0.69	
July	570	275	377	23, 181	0.14	0.16	
August	350	235	271	16, 663	0.10	0.12	
September	450	245	296	17, 613	0.11	0.12	
October	330	300	313	19, 246	0.11	0.13	
November	330	288	305	18, 149	0.11	0. 12	
December 1 to 15	395	300	342	21, 029	0.12	0.14	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 374; rating table in Paper No. 52, page 519.

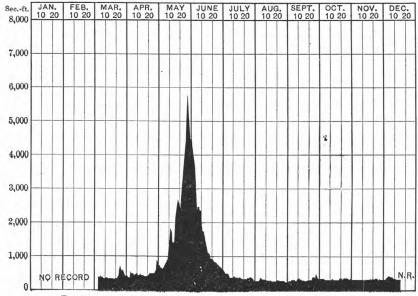


Fig. 173.—Discharge of Duchesne River at Price road bridge, Utah, 1900.

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FUTURE NEEDS OF THE INDIANS AND WATER AVAILABLE.

In the first progress report an estimate was made of the acreage that the Uinta and White River Indians would require if in the future lands should be allotted to them in severalty and the remainder of the reservation be thrown open to settlement. The estimate could not be made direct, however, as allotments are always to heads of families and to other persons over eighteen years of age, while the census simply gives the total number of men, women, and children on the reserva-The estimate was therefore based upon the Uncompangre allotments when that reservation was thrown open to settlement, which showed that 80 acres of land were given to each man, woman, and child, 40 acres being irrigated land and 40 acres grazing land. The Indian Office census of 1899 gave a total population of 830 Uinta and White River Indians, and therefore, on the basis of 40 acres to each person, an area of 33,200 acres will ultimately be required for The 550 Uncompangre Indians that have already been allotted lands on the reservation require 22,000 acres, making a total of 55,200 acres for which water must be supplied.

The Eleventh Census, however, gives 27 acres as the average size of the irrigated farms in Utah, and this is about what one man can handle to advantage. On that basis the 1,380 Indians on the Uinta Reservation, including men, women, and children, would require 37,260 acres. It will thus be seen that the estimate of 55,200 acres which is used in this report is a liberal one.

The following table gives the amount of arable land on and off the reservation which should naturally be irrigated from the various streams:

Arable lands tributary to Uinta, Whiterocks, and Duchesne rivers and Lake Creek.

LANDS ON UINTA INDIAN RESERVATION,	
Uinta River area: Acres.	
River bottom 8,900)
Mesa west of Uinta River)
Bench country)
North of military post)
Deep Creek Basin)
Lower Uinta Basin)
Lake Creek area:	- 68, 500
North section	
Dry Gulch Basin)
Mesa north of Duchesne River 5, 30)
Area west of Lake Creek, estimated	
Duchesne River area:	- 52,000
Mesa)
Bottom land)
LANDS OFF UINTA INDIAN RESERVATION.	- 58,000
The Strip)
Green River area. 21, 20	
21, 20	- 27,800
Total arable lands tributary to the three rivers	206, 300

^a Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 305-330.

The critical period for irrigation is in July, when the rivers are low and when as much water is required as at any other time. The discharge of the streams for that month will therefore be considered the controlling figure in estimating the amount of land that can be irrigated in the different basins.

The duty of water is here assumed to be 1 second-foot to 100 acres. In July, 1900, the flow of Uinta River in its canyon was 223 secondfeet, which with the foregoing duty of vater would serve 22,300 acres. During the same month Whiterocks River was carrying 82 second-feet, which would irrigate 8,200 acres; Lake Creek was carrying 195 secondfeet, which would serve 19,500 acres; and the flow of Duchesne River, after deducting the flow of Lake Creek, was 182 second-feet, sufficient to irrigate 18,200 acres. The total discharge of the four streams during that month was 682 second-feet (sufficient to irrigate 68,200 acres). It was found that the Indians would require water for 55,200 acres, or a flow of 552 second-feet, which would leave a surplus of 130 secondfeet (sufficient to irrigate 13,000 acres). According to reports, the flow of all streams was unusually low in 1900, and during most years it will seldom drop to the figures given here. If the area which could be served from Whiterocks River (8,200 acres) be deducted from the 68,200 acres, there will still remain 60,000 acres, a surplus of 4,800 acres over the lands of the Indians.

Several ways are open for the future settlement of these Indians on irrigable lands. The results of the investigations show that there is more agricultural land with a sufficient water supply than the future needs of the Indians require. The disposal of the lands, and consequently of the question whether the Indians shall be settled on large tracts or on detached areas, the whites being allowed to take up intermediate sections and thus the Indians and whites be intermingled, rests with the Department of the Interior. In the discussion of the Indian question both policies have been advocated, but it seems to the writer that the former method—having the Indians occupy large tracts of land by themselves—is preferable.

If the Department should decide that water shall only be used on lands tributary to the rivers, it would follow that the irrigable areas off the reservation would, on account of their location, receive some of the Uinta or Whiterocks water, as they are naturally tributary to it, and this area off the reservation is much better for agricultural purposes than some of the Uinta area within the reservation.

The Department has under consideration the advisability of allowing certain amounts of water to be diverted from Whiterocks or Uinta rivers to irrigate lands outside of the reservation. If the water is allowed to be diverted, or if the surplus agricultural lands beyond the needs of the Indians are placed upon the market, the rights of the Indians should be protected as fully as possible.

In the first progress report it was recommended that if a ditch were allowed to take water from Uinta River off the reservation, it should be located fairly well downstream; and it was also recommended that no diversion be allowed north of secs. 26 and 27, T. 1 S., R. 1 E. A canal taken out within these limitations could control all of the arable area off the reservation. Further consideration of this matter, however, inclines to the belief that even if the canals of the Indians should head above other diversions, complications might still arise, and it is believed that if the flow of some stream could be entirely disposed of-that is, sold outright for the benefit of the Indians-it would be much better for them than to have a joint control with the white settlers. Whiterocks River is a stream that could be disposed of in this way, and we have already seen that exclusive of its discharge there will, during even years of minimum flow, still be sufficient water to irrigate 60,000 acres on the reservation, or water for 4,800 acres more than the Indians will eventually require. There is only a small area (Deep Creek Basin, 16,000 acres) on the reservation that is naturally tributary to Whiterocks River, and even that could be served from Uinta River. If the Department decides that the Indians are entitled to only the amount of water they can economically use, the water of Whiterocks River could, if desired, be given away. If, on the other hand, it is decided that the Indians own all of the water on the reservation, a value could be placed upon it and it could be offered for sale, the proceeds being devoted to the Indians.

The question then arises: What is the value of an irrigation stream? A fair estimate of the value of agricultural lands with water is \$25 an acre. With a duty of water of 1 second-foot to 100 acres the value of each second-foot would be \$2,500. The value of a stream depends upon its low-water discharge. In the case of Whiterocks River the records show that the minimum July discharge is 82 second-feet, which at the rate of \$2,500 per second-foot is worth \$205,000. From this there should be deducted the cost of the canal system required to bring the water to the land.

GRAND RIVER AND TRIBUTARIES.

Grand River has its source in north-central Colorado, on the western slope of the Continental Divide, near the headwaters of North Platte, South Platte, and Arkansas rivers. It flows in a general south-westerly direction, passing out of the State of Utah into Wyoming. Sixty miles below the crossing of the Rio Grande Western Railway, in Utah, the river joins Green River to form the Colorado. Its principal tributaries are Gunnison and Dolores rivers. The gaging station on the former stream is at Iola, Colo., and that on the latter river at Dolores, Colo. Uncompander River, a tributary of the Gunnison, is measured at Montrose, Colo. Two gaging stations are maintained on Grand River—one at Glenwood Springs and the other at Grand Junction.

Estimated monthly discharge of Grand River at Glenwood Springs, Colo.

[Drainage area, 5,838 square miles.]

- 111	Dischar	ge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						
May 12 to 31	13, 765	5,910	10,453	642, 730	1.79	2.06
June	25, 445	7, 100	16, 258	967, 418	2.78	3. 10
July	9,620	1,515	4, 320	265,626	0.74	0.85
August	1,460	1,005	1, 173	72, 125	0.20	0.23
1900.						
January	970	810	890	54, 724	0.15	0.17
February	935	810	882	48, 984	0.15	0.16
March	1,460	902	1, 187	72, 986	0.20	0. 23
April	3, 490	1, 120	1,815	108,000	0.31	0.35
May	22, 895	3,245	11,963	735, 577	2.05	2. 37
June	22, 390	7,622	14, 817	881, 673	2.54	2.83
July	7, 272	1,515	3, 121	191, 903	0.53	0.61
August	1,460	935	1, 134	69, 727	0.19	0. 22
September	870	755	800	47,603	0.14	0.16
October	755	755	755	46, 423	0.13	0.15
November	935	727	. 807	48, 020	0.14	0.16
December	840	580	682	41, 934	0.12	0.14
The year	22, 895	580	3, 238	2, 347, 554	0.55	7. 55

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 376; rating table in Paper No. 52, page 520.

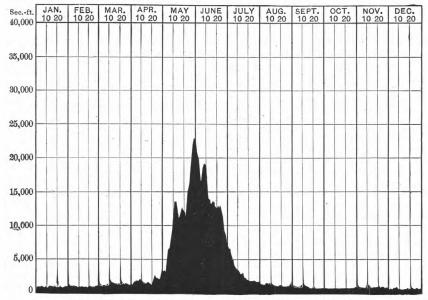


Fig. 174.—Discharge of Grand River at Glenwood Springs, Colo., 1900.

Estimated monthly discharge of Gunnison River at Iola, Colo. [Drainage area, 2,298 square miles.]

	Dischar	ge in secon	d-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
April	1, 258	551	783	46, 592	0.34	0.38	
May	4, 388	1, 157	2,875	176, 777	1. 25	1.44	
June	4, 265	1,460	2,726	162, 208	1.19	1.33	
July	1,359	350	727	44, 701	0.32	0.37	
August	450	350	360	22, 136	0.16	0.18	
September	350	250	260	15, 471	0.11	0. 12	
October	250	250	250	15, 372	0.11	0.18	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 379; discharge measurements, page 378; rating table in Paper No. 52, page 520.

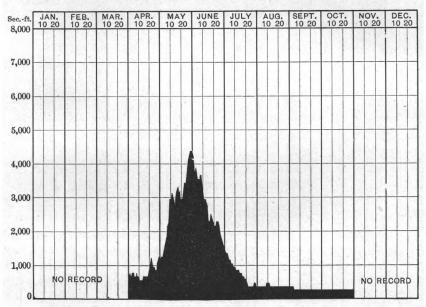


Fig. 175.—Discharge of Gunnison River at Iola, Colo., 1900.

Estimated monthly discharge of Dolores River at Dolores, Colo. [Drainage area, 524 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum,	Mini- mum.	Mean.	Total in acre-	Second- feet per square mile.	Depth in inches.	
1900.							
January	220	164	200	12, 298	0.38	0.44	
February	164	82	107	5, 942	0.20	0. 21	
March	192	37	101	6, 210	0.19	0. 22	
April	555	100	284	16, 899	0.54	0.60	
May	1,736	483	1, 319	81, 102	2. 52	2. 91	
June	1,596	280	808	48, 079	1.54	1.72	
July	220	37	84	5, 165	0.16	0.18	
August	37	20	29	1,783	0.06	0.07	
September	250	23	89	5, 296	0.17	0.19	
October	118	56	83	5, 103	0.16	0.18	
November	220	37	88	5, 236	0.17	0.19	
December	412	100	216	13, 281	0.41	0.47	
The year	1,736	20	284	206, 394	0.54	7.38	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 381; discharge measurements page 380; rating table in Paper No. 52, page 520.

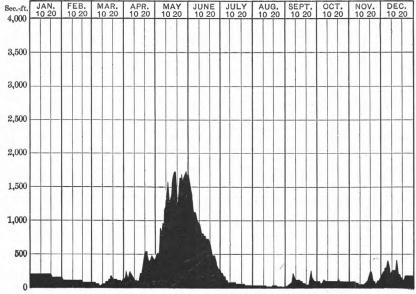


Fig. 176.—Discharge of Dolores River at Dolores, Colo., 1900.

Estimated monthly	discharge of	Uncompangre	River	at	Montrose,	Colo.	
	[Drainage at	rea. 565 square m	iles.1				

	Dischar	ge in secon	d-feet.	Total in acrefeet.	Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.	
1900.							
April 8 to 30	73	20	51	3, 035	0.09	0.10	
May	369	51	177	10, 883	0.31	0.36	
June	369	122	259	15, 412	0.46	0.51	
July 1 to 7			127	1,763	0. 22	0.06	

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 380; rating table in Paper No. 52, page 520.

SAN JUAN RIVER AND TRIBUTARIES.

San Juan River rises in the San Juan Mountains, the small streams at the head flowing westerly, the opposite of the direction taken by the branches of the Conejos. The country is generally mountainous and rough, and but little irrigation is practiced along the river, except in the bottom lands adjacent to the channel. The stream flows a short distance through Colorado and then enters New Mexico, through which Territory it flows for about 100 miles, then crosses the southwestern corner of Colorado, and flows through Utah to its junction with the Colorado at the Henry Mountains. The principal tributaries flowing from Colorado into this river are the Piedra, Los Pinos, Florida, Animas, La Plata, and Mancos rivers, all of which flow through comparatively natural valleys, crossing the line into New Mexico before they unite with the San Juan. A large portion of this country remained a part of the Southern Ute Indian Reservation until 1899, when the western half of that reservation was thrown open to settlement, and since then a number of tracts have been taken. A very considerable portion of the most desirable lands, however, was taken by the Indians in severalty. There are a number of excellent mesas of good farming land which will without doubt eventually be irrigated; a number of surveys have already been made of canal lines to cover these tracts, which will be pushed to a speedy conclusion.

The only stations maintained in this basin in 1900 were at Ignacio, on Los Pinos River; at Durango, on Animas River; and at Mancos, on Mancos River. The stations at Arboles, on the San Juan and the Rio Grande, and at Durango, on Florida River, were abandoned, their objects having been accomplished. Owing to the impossibility of obtaining a sufficient number of measurements at the Mancos station it was impossible to make a rating table, and the results for 1900 have

therefore not been worked up. The gage heights for the year and the measurements which were made will be found in Water-Supply Paper No. 50, pages 384 and 385. The results for the stations on Los Pinos and Animas rivers are given in the following tables:

Estimated monthly discharge of Los Pinos River at Ignacio, Colo.

[Drainage area, 450 square miles.]

	Dischar	ge in secon	nd-feet.	Total in acrefeet.	Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.	
1900.						т	
January	101	61	82	5,042	0.18	0. 21	
February	61	61	61	3, 388	0.14	0.15	
March	141	61	94	5, 780	0. 21	0. 24	
April 1 to 7			166				
May 9 to 26	1,326	785	998	61, 365	2. 22	2. 56	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 383; discharge measurements page 382; rating table in Paper No. 52, page 520.

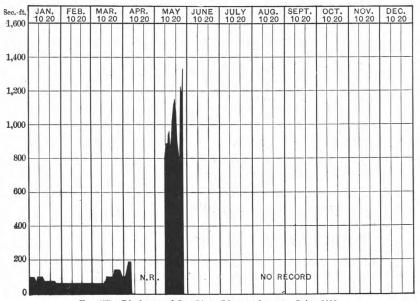


Fig. 177.—Discharge of Los Pinos River at Ignacio, Colo., 1900.

Estimated monthly discharge of Animas River at Durango, Colo.

[Drainage	area,	812	square	miles.]	
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	Dischar	rge in secon	d-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January a			178	10, 945	0. 22	0. 25
February a			132	7, 331	0.16	0.17
March	272	122	224	13, 773	0.28	0. 32
April	490	236	334	19,874	0.41	0.46
May	3,830	490	2, 183	134, 227	2.69	3. 11
June	3, 466	811	1,990	118, 413	2.45	2.73
July	811	236	409	25, 148	0.50	0.58
August	236	143	179	11,006	0. 22	0. 25
September	394	143	_ 231	13, 745	0.28	0.31
October ^a			252	15, 495	0.31	0.36
November ^a			205	12, 198	0. 25	0. 28
December ^a			214	13, 158	0. 26	0.30
The year		No.	544	395, 313	0.67	9. 12

a Approximate.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 50, page 384; discharge measurements page 388; rating table in Paper No. 52, page 520.

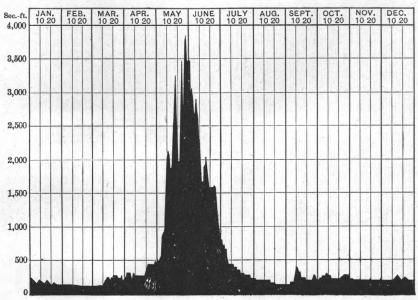


Fig. 178.—Discharge of Animas River at Durango, Colo., 1900.

LOW-WATER MEASUREMENTS IN NORTHWESTERN COLORADO.3

A trip for the purpose of making low-water measurements in north-western Colorado was made in the fall of 1900, the start being made on October 3, from Vernal, Utah. Two years before, measurements were made upon some of the streams of that region, but it was deemed important that new measurements should be made at the same places, to supplement those previously taken, and that gagings should also be made at other localities.

The road from Vernal to Green River traverses the lower part of the Ashley Valley, irrigated to some extent by Ashley Creek, although there is considerable unimproved land, owing to the limited supply of water in that stream. Ashley Creek was measured in October a short distance above its junction with Green River, and a discharge of only 11 cubic feet per second was found. Green River was crossed by means of a ferry, but was not measured, owing to lack of facilities for gaging so large a stream. The land along the borders of the river is well settled, and some of it is irrigated. The amount cultivated may perhaps be largely increased at an early date by the construction of a canal starting at the canyon of Split Mountain and running along the bluffs east of the river, a project that seems entirely feasible.

It is about 25 miles from Green River to a ranch known as K ranch, just across the Colorado line, Blue Mountain being passed en route. The country traversed is dry and desolate, and there is little possibility of any great amount of it ever being cultivated. During the next drive, about 45 miles, to Elk Springs, Skull Creek and Boxelder Creek were crossed, in each of which there was flowing about 1 cubic foot per second, which is used for stock purposes, many cattle feeding over that portion of the country. No cultivation is possible, owing to the scarcity of water. On account of the unusually dry season, no water was found at Elk Springs, and a dry camp was made there.

On November 1 the drive to Yampa River at Lily Park was made. Here, at the junction of Yampa and Snake rivers, there is a fine tract of land of a few thousand acres. Nearly all of the tillable land in the park is cultivated, and hay is raised for stock. Snake and Yampa rivers were measured at this point, and a discharge of 65 second-feet was found in the former and 371 second-feet in the latter. Both of these streams were at that time somewhat higher—perhaps 10 per cent—than they had been a little earlier in the season.

After finishing the measurements in Lily Park a drive of about 20 miles was made, the road following up Yampa River for a considerable distance, to the mouth of the canyon formed by that river breaking through Cross Mountain, and then turning around the southern end of

the mountain and returning to the river near its entrance into the same canyon. Templeton's ranch is about 6 miles above the latter point. Up to the present time the lands in this vicinity have been cultivated very little, as the fall of the river is so slight that it has been found difficult to get the water out upon the adjacent tillable area. Canals are now being constructed, however, diverting water about 20 miles above, which will cover all the best lands along the river, reclaiming perhaps 20,000 acres in all.

On November 2 the drive to the ranch of Albert Gent, on Spring Creek, was made, Yampa River being gaged at Thornburg bridge on the way, a discharge of 322 second-feet being found. In the next drive, to Craig, the Sand Hills were crossed—great tracts of land that might be cultivated to advantage if irrigation were possible, but there seems to be no practicable method of getting water upon these uplands.

On November 5 Yampa River was measured opposite Craig and a discharge of 278 second-feet was found. The road from Craig to Hamilton, on Williams Fork of Bear River, passed over an upland country usually covered with sagebrush, but broken at times by canyons and ravines. The next day—November 6—Williams Fork was measured at Hamilton and was found to be carrying 35 second-feet, and Axial Creek, on the way to Meeker, was discharging 5 second-feet. There is a considerable area of arable land in the basin of Axial Creek, but little of it is cultivated, the supply of water being inadequate for the demands. It is reported that an available reservoir site exists on Morapos Creek. This also was mentioned in the report made two years ago, but lack of time prevented a visit to it.

White River, on the banks of which the town of Meeker is located, flows through a comparatively narrow valley of bottom lands. A few of the low-lying benches are irrigated, but no large ditches have been constructed to take water from the stream, owing to the height of the bluffs along its borders. On November 7, 1900, the river showed a discharge of 394 second-feet at Meeker. On the same day Piciance Creek was discharging 13 second-feet near its mouth, a short distance below the city of Whiteriver. It appears to be feasible to construct a canal in this vicinity, diverting water from White River to irrigate perhaps 4,000 or 5,000 acres along the north side of the river.

On November 8 the drive to Rangely was made. Here there is a considerable area of cultivated land, but a still larger tract might be irrigated by the construction of an expensive canal, taking water out about 8 or 10 miles above the post-office. On the same day (November 8) the river was measured at the bridge below Rangely and a discharge of 413 second-feet was found.

The road from Rangely, on White River, to Fruita, on Grand

River, is across the Book Cliff divide, which reaches an altitude of a little more than 9,000 feet. The country in general is desolate and dry, although many head of stock range over it.

GILA RIVER.

This river rises in southwestern New Mexico and flows in a general southwesterly direction until it crosses the Territorial line into Arizona at about 32° 40′ north latitude. Its principal sources of supply are from the Black Range on the east and from a number of ranges on the west, including Little Range, Mogollon Range, and Diablo Range. The average elevation of these mountain peaks is from 9,000 to 10,000 feet. The general character of the country is a high and rolling plateau, the river flowing through it in a deep canyon, and there are practically no agricultural lands within its area. The river emerges from its upper canyon about 10 miles before it reaches the Arizona line, and then flows through a valley of considerable width, known as Duncan Valley, until just before it receives the waters of San Francisco River. Gila River is a tributary of Colorado River, which it joins at Yuma, Ariz.

During 1900 only one station was maintained in the basin, viz, at San Carlos, where a storage reservoir is contemplated. The results of the observations are given in the following table:

Estimated monthly discharge of Gila River at San Carlos, Ariz.

[Drainage area, 13,455 square miles.]

	Dischar	ge in secor	id-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.
1900.						
April 4 to 30	11	6	9	536		
May	7	4	5	307		
June 1 to 16	4	0	2	119		
July	0	0	0	0		
August 17 to 31	3,400	0	414	25, 456	0.03	0.03
September, 28 days	6,630	30	846	50, 340	0.06	0.07
October	77	22	42	2,582	0.003	0.003
November	3, 240	6	177	10,532	0.01	0.01
December	111	60	93	5, 718	0.007	0.008

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 50, page 386; rating table in Paper No. 52, page 520. For hydrograph see page 398.

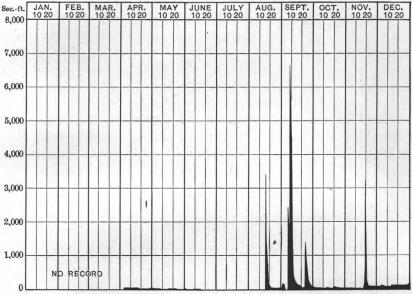


Fig. 179.—Discharge of Gila River at San Carlos, Ariz., 1900.

INTERIOR BASIN DRAINAGE.

This basin has no outlet to the sea, the rivers all discharging their water into sinks or lakes, from which it is evaporated, the climate being very arid. It includes nearly the whole of Nevada, the northern and western parts of Utah, and small portions of California and Idaho. The largest of the lakes is Great Salt Lake, which receives the waters of that portion of the basin lying in northern Utah and Idaho. Southwestern Utah drains into Sevier Lake. Other important lakes are Humboldt, Pyramid, Winnemucca, Carson, and Walker, all in western Nevada. These lakes receive the basin drainage from Nevada and California.

The longest river of Nevada is the Humboldt, which flows into Humboldt Sink. It is measured at four places, viz, near Elko, near Golconda, and near Oreana, on the main stream, and at Mason's ranch, on the South Fork.

Truckee River rises in the sierras in California and flows into Pyramid Lake, in Nevada. It has in its basin several beautiful lakes, affording economical storage reservoirs for all of its surplus waters. The largest of these is Lake Tahoe, in which Truckee River has its source. A gaging station is maintained at the outlet of that lake. Truckee River is also measured at the State line, near the proposed point of diversion, and at Vista, Nev. Steamboat Creek, a tributary of the Truckee, is gaged at Steamboat Springs, Nev. The results at

these stations for 1900 are given in the following tables; in two or three instances the results for 1899 are given also:

Estimated monthly discharge of Humboldt River near Elko, Nev.

[Drainage area, 2,840 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	266	70	141	8,670	0.05	0.06
February	240	95	158	8,775	0.06	0.06
March	253	144	198	12, 175	0.07	0.08
April	416	144	231	13, 745	0.08	0.09
May	762	319	521	32, 035	0.18	0.21
June	945	416	723	43, 021	0. 25	0. 28
July	388	22	95	5, 841	0.03	0.03
August	18	0	2	123	0.001	0.001
September	14	7	8	476	0.003	0.003
October	18	10	14	861	0.005	0.006
November	56	14	39	2, 321	0.01	0.01
December	70	56	62	3, 812	0.02	0.02
The year	945	0	183	131, 855	0.063	0.85

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 396; discharge measurements, page 395; rating table in Paper No. 52, page 520.

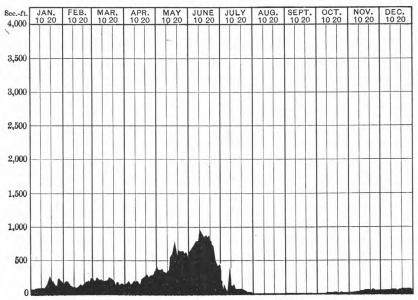


Fig. 180.—Discharge of Humboldt River near Elko, Nev., 1900.

Estimated monthly discharge of South Fork of Humboldt River at Mason's ranch, Nev. [Drainage area, 1,150 square miles.]

	Dischar	rge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	122	35	69	4, 243	0.06	0.07
February	89	35	64	3, 554	0.06	0.06
March	131	89	109	6,702	0.09	0.10
April	182	131	157	9, 342	0.14	0.16
May	710	182	449	27, 608	0.39	0.45
June	740	251	521	31,002	0.45	0.50
July	239	24	92	5, 657	0.08	0.09
August	19	0.5	4	246	0.003	0.008
September	7	0.5	3	179	0.003	0.008
October	41	.7	24	1,476	0.02	0.02
November	67	41	50	2,975	0.04	0.04
December	67	24	44	2, 705	0.04	0.05
The year	740	0.5	132	95, 689	0.11	1.54

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 397; discharge measurements, page 396; rating table in Paper No. 52, page 520.

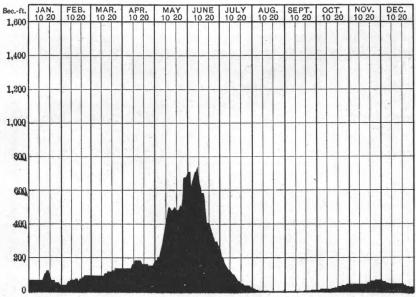


Fig. 181.—Discharge of South Fork of Humboldt River at Mason's ranch, Nev., 1900.

Estimated monthly discharge of Humboldt River near Golconda, Nev.

[Drainage area, 10,780 square miles.	[Drainage	area,	10,780	square	miles.	1
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	Dischar	ge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.					(
January	213	139	179	11,006	0.02	0.02
February	282	220	247	13, 717	0.02	0.02
March	290	193	247	15, 187	0.02	0.02
April	186	82	102	6,069	0.01	0.01
May	385	70	192	11,806	0.02	0.02
June	464	220	352	20, 945	0.03	0.03
July	220	10	72	4, 427	0.007	0.008
August	10	3	5	307	0.0005	0.0006
September	3	3	3	179	0.0003	0.0003
October	3	3	3	184	0.0003	0.0003
November	3	2	3	179	0.0003	0.0003
December	35	2	17	1,045	0.002	0.002
The year	464	2	118	85, 051	0.01	0.13

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 398; discharge measurements, page 397; rating table in Paper No. 52, page 520.

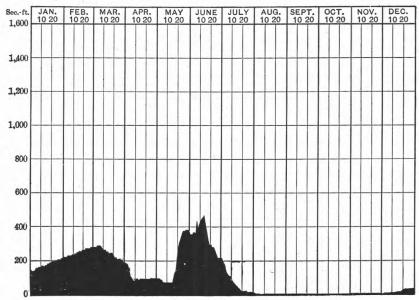


Fig. 182.—Discharge of Humboldt River near Golconda, Nev., 1900.

Estimated monthly discharge of Humboldt River near Oreana, Nev.

[Drainage area, 13,800 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	430	182	308	18, 938	0.02	0.02
February	284	204	252	13,995	0.02	0.02
March	316	128	255	15, 679	0.02	0.02
April	182	37	89	5, 296	0.006	0.007
May	44	26	32	1,968	0.002	0.002
June	284	26	118	7,021	0.01	0.01
July	351	69	190	11,683	0.01	0.01
August	-78	26	. 45	2, 767	0.003	0.003
September	52	22	28	1,666	0.002	0.002
October	44	26	34	2,091	0.002	0.002
November	52	31	41	2, 440	0.003	0.003
December	144	31	50	3,074	0.004	0.005
The year	430	22	120	86, 618	0.009	0.104

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 399; discharge measurements; page 398; rating table in Paper No. 52, page 520.

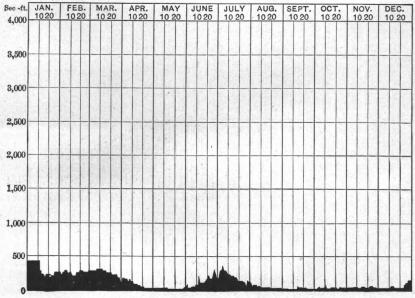


Fig. 183.—Discharge of Humboldt River near Oreana, Nev., 1900.

Estimated monthly discharge of Truckee River at Tahoe, Cal.

[Drainage area, 502 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.		1				
June 17 to 30			112	3, 110	0. 22	0.12
July	260	a 0	214	13, 158	0.43	0.50
August	260	212	235	14, 450	0.47	0.54
September	224	177	196	11,663	0.39	0.44
October	177	155	159	9,776	0.32	0.37
November	200	a 0	135	8,033	0. 27	0.30
December	99	a 0	81	4, 980	0.16	0.18

a Gates closed.

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 403; discharge measurements, page 402; rating table — Paper No. 52, page 520.

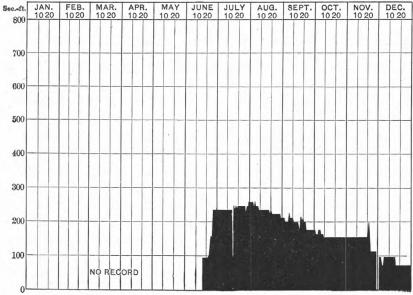


Fig. 184.—Discharge of Truckee River at Tahoe, Cal., 1900

Estimated monthly discharge of Truckee River at Nevada-California State line.

[Drainage area, 955 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	ı-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.						5.4
September 7 to 30	363	295	303	18,030	0.32	0.36
October	632	295	354	21,767	0.37	0, 43
November	1,566	295	581	34, 572	0.61	0.68
December	328	264	295	18, 139	0.31	0.36
1900.						
January	897	295	392	24, 103	0.41	0.47
February	363	264	318	17,661	0.33	0.34
March	1, 131	295	797	49,006	0.83	0.96
April	1,409	735	902	53, 673	0.94	1.05
May	1,885	1, 196	1,528	93, 953	1.60	1.84
June	1,409	328	950	56, 529	0.99	1.10
July	533	401	459	28, 223	0.48	0.55
August	486	328	396	24, 349	0.41	0.47
September	486	205	367	21, 838	0.38	0.42
October	897	234	481	29, 575	0.50	0.58
November	897	328	480	28, 562	0.50	0.56
December	1, 131	205	407	25, 025	0.43	0.50
The year	1, 885	205	623	452, 497	0.65	8. 80

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 404; discharge measurements, page 403; rating table in Paper No. 52, page 521.

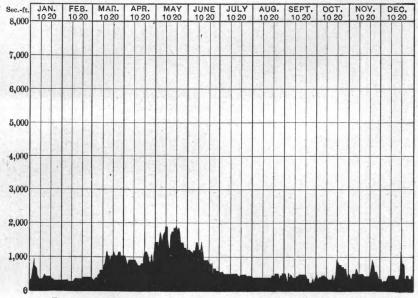


Fig. 185.—Discharge of Truckee River at Nevada-California State line, 1900.

Estimated monthly discharge of Truckee River at Vista, Nev.

[Drainage area, 1,435 square miles.]

	Dischar	rge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1899.			774	0.100	0.00	0.04
August 18 to 31	100		114	3, 166	0.08	0.04
September	188	74	123	7, 319	0.09	0.10
October	1,066	144	378	23, 242	0. 26	0.30
November	1, 123	356	530	31,537	0.37	0.41
December	709	331	456	28, 038	0.32	0.37
1900.						
January	1,210	380	547	33, 634	0.38	0.44
February	529	380	428	23, 770	0.30	0.31
March	1,094	454	857	52, 695	0.60	0.69
April	1,239	479	755	44, 926	0.53	0.59
May	1,477	. 843	1,257	77, 290	0.88	1.01
June	1, 239	259	709	42, 188	0.49	0.55
July	307	38	110	6, 764	0.08	0.09
August	283	48	122	7,501	0.09	0.10
September	283	105	192	11, 425	0.13	0.15
October	1, 123	166	429	26, 378	0.30	0.35
November	1,298	331	567	33, 739	0.40	0.45
December	1,268	429	561	34, 494	0.39	0.45
The year	1,477	38	544	394, 804	0.38	5. 18

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 405; discharge measurements, page 404; rating table in Paper No. 52, page 521.

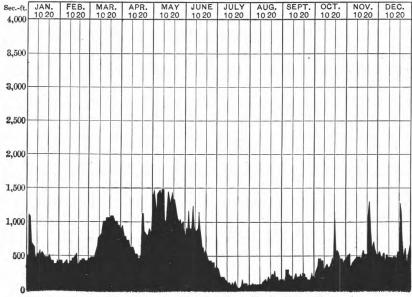


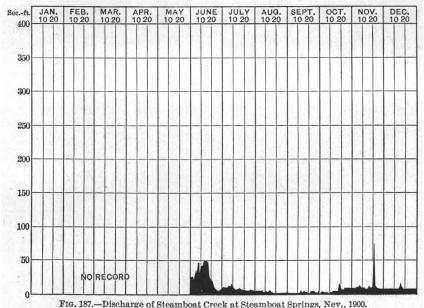
Fig. 186.—Discharge of Truckee River at Vista, Nev., 1906.

Estimated monthly discharge of Steamboat Creek at Steamboat Springs, Nev.

[Drainage area, 40 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
June	50	4	25	1,488	0.62	0, 69
July	14	5	7	430	0.17	0. 20
August	4	2	3	184	0.07	0.08
September	4	. 1	3	179	0.07	0.08
October	14	2	5	307	0.12	0.14
November	73	- 8	11	655	0.27	0.30
December	14	8	8	492	0.20	0.23

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 406; rating table in Paper No. 52, page 521.



BEAR RIVER AND TRIBUTARIES.

Bear River is tributary to Great Salt Lake. Five stations are maintained on streams in its basin: Two on Bear River proper (one at Battlecreek, Idaho, and one near Collinston, Utah); one on Cub River, at Franklin, Idaho; one on Logan River, near Logan, Utah; and one on Blacksmith Fork, at Hyrum, Utah. The results at these stations for the year 1900 are given in the following tables:

 $Estimated\ monthly\ discharge\ of\ Bear\ River\ at\ Battlecreek,\ Idaho.$

[Drainage area, 4,500 square miles.]

	Dischar	ge in secon	nd-feet.	**	Rui	n-off.
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	1,037	705	841	51, 711	.0.19	0. 22
February	1,212	455	729	40, 487	.0.16	0.17
March	2,432	737	1,484	91, 248	0.33	0.38
April	2,065	1,460	1,654	98, 420	0.37	0.41
May	2,537	2, 117	2,268	139, 454	0.50	0.58
June	2, 222	802	1,544	91, 874	0.34	0.38
July	802	522	660	40, 582	0.15	0.17
August	522	455	482	29, 637	0.11	0.13
September	580	455	486	28, 919	0.11	0.12
October	705	580	617	37, 938	0.14	0.16
November	770	672	692	41, 177	0.15	0.17
December	737	551	654	40, 213	0.15	0.17
The year	2, 537	455	1,009	731, 660	0.23	3.06

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 410; discharge measurements, page 409; rating table in Paper No. 52, page 521.

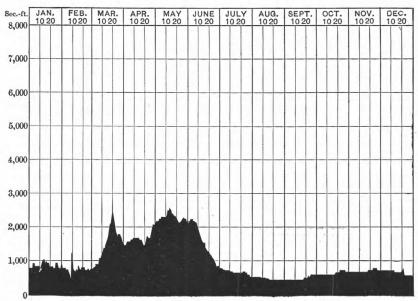


Fig. 188.—Discharge of Bear River at Battlecreek, Idaho, 1900.

Estimated monthly discharge of Cub River at Franklin, Idaho.

[Drainage area, 53 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
July 23 to 31			77	1,375	1.45	0.48
August	77	60	66	4,058	1.25	1.44
September	64	55	60	3,570	1.13	1.26
October	64	51	57	3, 505	. 1.08	1. 25
November	60	34	44	2,618	0.83	0.93

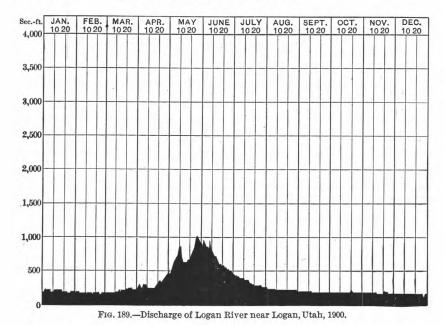
Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 411; discharge measurements, page 410; rating table in Paper No. 52, page 521.

Estimated monthly discharge of Logan River near Logan, Utah.

[Drainage	area,	218	square	miles.]

Month.	Dischar	ge in secon	id-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
January	205	170	193	11, 867	0.89	1.03
February	187	152	169	9, 386	0.78	0.81
March	245	170	191	11,744	0.88	1.01
April	456	245	300	17, 851	1.38	1.54
May	1,015	456	721	44, 332	3. 31	3. 81
June	935	456	691	41, 117	3.17	3.53
July	456	265	339	20, 844	1.56	1.80
August	265	205	230	14, 142	1.06	1. 22
September	205	187	194	11,544	0.89	0.99
October	205	187	188	11,560	0.86	0.99
November	205	170	180	10, 711	0.83	0.93
December	170	110	166	10, 207	0.76	0.88
The year	1,015	135	297	215, 305	1.36	18. 54

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 412; discharge measurements, page 411; rating table in Paper No. 52, page 521. For hydrograph see page 409.



 ${\it Estimated monthly discharge of Blacksmith Fork at Hyrum, Utah.}$

[Drainage area, 286 square miles.]

Month.	Dischar	ge in secon	d-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
July 19 to 31			147	3, 791	0.51	0.25
August	147	122	130	7, 993	0.45	0.52
September	275	. 122	139	8, 271	0.49	0.55
October	275	122	129	7,932	0.45	0.52
November	122	119	120	7, 141	0.42	0.47
December	119	112	117	7, 194	0.41	0.47

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 413; discharge measurements, page 412; rating table in Paper No. 52, page 521. For hydrograph see page 410.

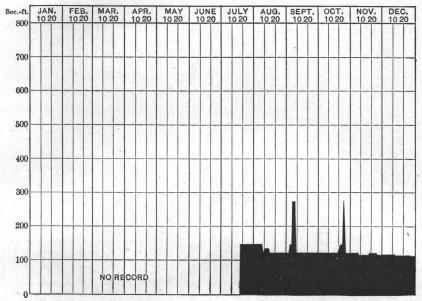


Fig. 190.—Discharge of Blacksmith Fork at Hyrum, Utah, 1900.

Estimated monthly discharge of Bear River near Collinston, Utah.

[Drainage area, 6,000 square miles.]

Month.	Dischar	ge in secon	id-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
January	2, 280	1, 360	1,735	106, 681	0.29	0.33
February	1,850	1, 275	1,549	86, 027	0.26	0. 27
March	3, 250	1,650	2,400	147, 570	0.40	0.46
April	3, 640	2, 165	2, 592	154, 235	0.43	0.48
May	4,650	3,510	3, 902	239, 925	0.65	0.75
June	3,640	1, 190	2, 298	136, 741	0.38	0.42
July	1, 105	415	677	41,627	0.11	0.13
August	750	525	621	38, 184	0.10	0.12
September	1,360	580	763	45, 402	0.13	0.15
October	1,405	950	1, 180	72, 555	0.20	0.23
November	2,055	1,317	1,432	85, 210	0. 24	0. 27
December	1, 450	915	1, 316	80, 918	0, 22	0. 25
The year	4,650	415	1,705	1, 235, 075	0. 28	3. 86

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 414; discharge measurements, page 413; rating table in Paper No. 52, page 521. For hydrograph, see page 411.

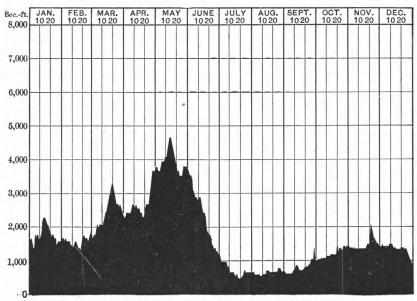


Fig. 191.—Discharge of Bear River near Collinston, Utah, 1900.

WEBER RIVER.

This river rises in the high country east of the Wasatch Mountains. Passing through that range, it appears in the plains region in the vicinity of Ogden, where, after receiving the waters of Ogden River, it discharges into Great Salt Lake. There are a number of good reservoir sites on its upper tributaries, some of which have been utilized within the last year. The gaging station, which was established in October, 1899, is near Uinta, Utah. The results for 1900 are given in the following table:

Estimated monthly discharge of Weber River near Uinta, Utah.
[Drainage area, 1,600 square miles.]

Month.	Dischar	ge in secon	id-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
July 16 to 31	255	75	99	6, 087	0.06	0.07
August	255	75	123	7, 563	0.08	0.09
September	195	75	142	8, 450	0.09	0.10
October	435	195	297	18, 262	0.19	0, 22
November	915	315	484	28, 800	0.30	0.33
December, 17 days	375	315	319	19, 614	0.20	0. 23

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 415; discharge measurements, page 414; rating table in Paper No. 52, page 521. For hydrograph see page 412.

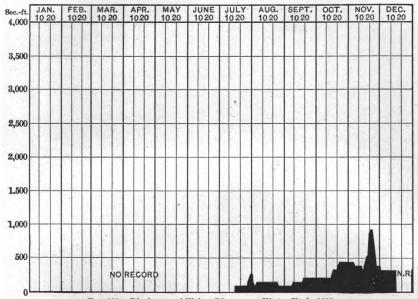


Fig. 192.—Discharge of Weber River near Uinta, Utah, 1900.

GREAT SALT LAKE, UTAH.

Various descriptions of the fluctuations of the level of Great Salt Lake have been published in the reports of the United States Geological Survey, notably in Monograph I, entitled Lake Bonneville, by G. K. Gilbert, and in the Thirteenth Annual Report, Part III, page 20. Records of the level of the lake have been kept since 1875, on various gages, which in 1899 were reduced to the Garfield Beach datum and the record published in Water-Supply Paper No. 38, pages 346 to 348. The lake is very shallow, averaging less than 20 feet, the greatest depth being only 60 feet. The western and eastern shores slope so gradually that a fall of a foot in the level exposes many square miles. It will thus be seen that the area of the lake varies considerably according to the stage of the water. Mr. Gilbert states a that the area of the water surface is 1,750 square miles, according to the Stansbury survey made in 1849 and 1850, when the lake was at an exceedingly low level. According to the King survey made in 1869, when the level was within a few inches of its highest recorded stage, the area of the water surface is 2,170 square miles, the increment being 24 per cent of the smaller area.

Two articles relative to the fluctuations of this lake have recently appeared, from which the following facts have been taken: On Decem-

a Mon. U. S. Geol. Survey, Vol. I, p. 244.

^b Relation of the water level of Great Salt Lake to the precipitation, by L. H. Murdoch, section director; and, The water level of Great Salt Lake, by G. K. Gilbert: Monthly Weather Review, Jan., 1901.

ber 31, 1900, the water level of the lake was 9 inches below the zero of the Garfield Beach gage. When this rod was established in 1875 its zero was placed at what was believed to be 1 foot below the lowest known stage of the lake. In 1848, according to report, there was a dry bar extending from the mainland to Antelope Island. In September, 1900, this bar was again exposed, and since then it has been possible to drive or walk to the island dry shod. There can be little doubt that the reading of -9 inches is the lowest water level reached since the settlement of the State. One cause which probably accounts in part for this fall of the level is the fact that every year more and more water has been diverted for irrigation purposes from the streams discharging into the lake.

With a view to ascertaining to what extent a shortage in precipitation is responsible for the decline in the lake level, all of the precipitation data collected in the Great Salt Lake Basin were tabulated and the averages calculated and compared, as shown in the following table:

Mean annual precipitation in Great Salt Lake Basin.

Year,	Rainfall.	Year.	Rainfall.
	Inches.		Inches.
1863	6.73	1882	11, 76
1864	12.33	1883	11.74
1865	16.92	1884	18.6
1866	22, 25	1885	19. 21
1867	28.00	1886	14.45
1868	17.06	1887	9.37
1869	22.27	1888	12.55
1870	20.24	1889	16.6
1871	15.32	1890	12.5
1872	10.85	1891	18.9
1878	15.71	1892	15.1
1874	13.96	1893	15. 3
1875	20.45	1894	12.8
1876	15, 25	1895	9.8
1877	11.90	1896	14.1
1878	14.57	1897	14.75
1879	10.99	1898	12.7
1880	9.73	1899	13.9
1881	13.47	1900	11.8

The three points at which rainfall observations have been taken are Salt Lake City, including Fort Douglas, the record dating back to 1863, and Ogden and Corinne, the records for which are complete back to and including 1871. While it is recognized that the heaviest precipitation occurs in the mountains at the headwaters of the streams which furnish the supply of water to the lake, at the same time it is considered that a study of the data at the lower points will give results from which certain deductions can be made. Fig. 193 is a diagram showing

the average annual precipitation at the three stations mentioned, and the fluctuations of the water level of the lake itself from 1863 to 1900. The upper line indicates the precipitation and the lower one the lake level; the dotted lines indicate the periods of no authentic observations or that the data have been approximated.

The following quotation is from Mr. Murdoch's article, already referred to:

The average annual precipitation for these three stations, Great Salt Lake, Ogden, and Corinne, from 1863 to 1900, inclusive, is 14.65 inches. The last decline in the water level of the lake began in 1887. The average precipitation from 1863 to 1885, inclusive, is 15.32 inches, while the average from 1886 to 1900, inclusive (fifteen years), is only 13.67 inches, which is 0.98 inch below the average for all years and 1.65 inches below the average for the preceding twenty-three years. The year 1886 has been included with those following because it was a decline in the precipitation that year which caused the lake to fall the following year. Of course the average for

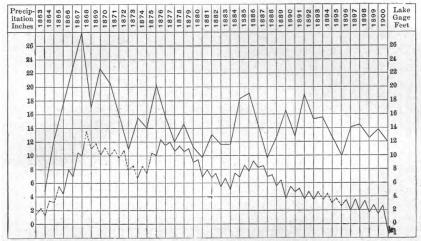


Fig. 193.—Diagram showing average annual precipitation in Great Salt Lake Basin and fluctuations of water level of Great Salt Lake from 1863 to 1900, inclusive.

the entire period gives the best normal, and as the comparison of the average for the last fifteen years with this normal shows an average shortage of 0.98 inch for each year, the total shortage for the fifteen years ending 1900 is 14.70 inches. With a shortage of 14.70 inches in rainfall a decided fall in the lake level would naturally be expected, and a fall of 9 feet and 11 inches occurred. The fall was from a maximum of about 9 feet 2 inches in 1886 to a minimum of minus 9 inches at the close of 1900.

The average precipitation for the fifteen years preceding 1886, or from 1871 to 1885, inclusive, was 14.24 inches, which is 0.57 inch greater than the average for the fifteen years ending 1900, but 0.41 inch below the normal. The average for the eight years from 1863 to 1870, inclusive, approximating the precipitation of 1866 at 22.25 inches, is 18.22, or 3.57 inches above the normal. The wettest fifteen consecutive years were those from 1864 to 1878, inclusive, with an average of 17.14 inches, and during this period the lake rose to a maximum height of about 13 feet 5 inches in 1868, fell to a minimum of about 6 feet in 1874, and reached a maximum height of about 12 feet 5 inches in 1876. The rise of 1868 was preceded by 28 inches of rainfall in 1867, and the rise of 1876 by 20.45 inches in 1875.

Mr. Gilbert, referring to the data compiled by Mr. Murdoch and published in the article cited, writes as follows, a carrying Mr. Murdoch's discussion still further:

He [Mr. Murdoch] has shown that the recent great fall of the lake surface corresponds to a period of defective precipitation, but he has not attempted to show whether the change in precipitation is fully adequate to account for the lowering of the lake. Making use of his tables, and neglecting, as before, the years for which the lake record is interpolated, I find that there were eight years in which the recorded precipitation exceeded the normal, the total excess amounting to 36.46 inches. In six of those eight years the lake rose 9.9 feet, and in the other two it fell 2.8 feet, leaving a net rise of 7.1 feet. In fifteen years the rainfall was less than the normal, giving a total defect of 32.99 inches. In thirteen of those years the lake fell 12.4 feet, and in the other two rose 1.5 feet, leaving a net fall for the period of 10.9 feet. Summing these data, without regard to signs, we have a total of deviations of precipitation from the normal amounting to 69.45 inches, corresponding to a total of accordant changes in the level of the lake amounting to 18.0 feet. This gives 0.26 foot, as the amount of lake change corresponding to one inch excess or defect of precipitation, and we may apply this factor to the period of defective rainfall mentioned by Mr. Murdoch. In the fifteen years from 1886 to 1900, inclusive, the total shortage of rainfall is 14.70 inches, and this, according to the scale just determined, will account for 3.82 feet of fall in the lake. The actual fall was considerably greater, being 9.9 feet.

While this discussion is not fully satisfactory, and is open to the objection that the lake change per unit of precipitation is derived in part from some of the observations to which it is afterwards applied, it may yet be accepted as indicating that shortage of rainfall does not suffice to account for the whole of the fall of the lake surface.

The problem is complex, and if a complete analysis were possible, it would probably serve to show that a number of factors have conspired to produce the observed shrinkage of the lake. I apprehend that a prominent place among these factors would be accorded to irrigation, or the diversion to cultivated fields of waters which would otherwise flow unimpeded to the lake. I understand that the area of irrigated land within the drainage district of the lake has been greatly enlarged during the last decade, and I do not see how this could fail to influence that balance between inflow and evaporation which determines the height of the lake. The water spread upon the farm lands is in part evaporated directly and in part transpired by plants, and both these parts are carried away by the air. A portion also finds its way into the ground, and eventually reaches the lake through springs. That which enters the air increases the local relative humidity, and doubtless increases precipitation on the great mountain range to the eastward, so that a portion of it is returned to the rivers, but as the period of principal evaporation and transpiration from the land does not correspond with the period of principal precipitation on the mountains, it is probable that the share of irrigation water thus prevented from escaping the drainage basin is not great. It certainly is not sufficient to prevent the work of irrigation from greatly diminishing the amount of water which the rivers discharge to the lake.

In the natural condition of the country, before the advent of the white man, the rise and fall of the lake was a climatic index responding to the conjoined influences of variations in temperature, precipitation, and wind. Had the gage record been then kept it would have constituted a valuable contribution to the history of climate. But the same immigration which instituted observations of lake changes also established various industries tending to modify the condition of the land and interfere with the reaction of natural agencies, and now that agriculture is striving to divert to its own

purposes as much as possible of the normal tribute of the lake, the gage has practically lost its value as a register of climate. Much interest, both economic and scientific, still attaches to its readings, and part of that interest is meteorologic, but it has become practically impossible to discriminate between the consequences of natural and human influences.

PROVO RIVER.

This river rises on the western slope of the Uinta Mountains and after receiving a number of tributaries enters what is known as Heber Valley, where considerable irrigation is practiced. After crossing this valley it passes through the Wasatch Mountains in a picturesque canyon, and finally enters Utah Valley, where its summer flow is completely diverted for irrigation purposes. Its flood waters discharge into Utah Lake. The gaging station, which was established July 27, 1889, is near Provo, Utah.

Estimated monthly discharge of Provo River near Provo, Utah.

[Drainage area, 640 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
May 21 to 31			1,240	27, 055	1.94	0.79
June	1,310	155	404	24, 040	0.63	0.70
July	200	175	181	11, 129	0.28	0. 32
August	175	155	170	10, 453	0.27	0.31
September	200	155	176	10, 473	0.28	0.31
October	255	200	218	13, 404	0.34	0.39
November	788	255	359	21, 362	0.56	0.62
December 1 to 8			316	5, 014	0.49	0.14

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 417; discharge measurements, page 416; rating table in Paper No. 52, page 521.

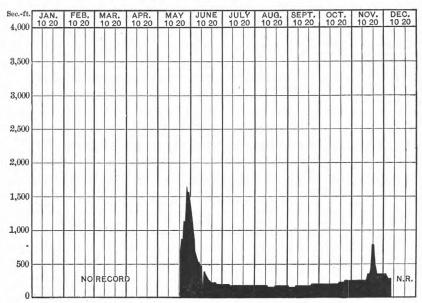


Fig. 194.—Discharge of Provo River near Provo, Utah, 1900.

SEVIER RIVER AND TRIBUTARIES.

Sevier River drains a large area in the southwestern part of Utah. It flows northerly until it enters Juab County, then makes a short bend and flows southwesterly until its waters are lost in the Sevier Sink. The gaging station, which was established June 29, 1900, is at the bridge which crosses the stream 4 miles west of the town of Gunnison. Tributaries of the river are gaged as follows: Salina Creek near Salina, Utah; Manti Creek near Manti, Utah; and San Pitch River near Gunnison, Utah.

Estimated monthly discharge of Salina Creek near Salina, Utah.

[Drainage area, 255 square miles,]

	Discha	rge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						2017
July	25	. 8	12	738	0.05	0.06
August 1 to 18	9	7	8	492	0.03	0.03
September 9 to 30	18	10	12	714	0.05	0.06
October	18	11	15	922	0.06	0.07
November	18	13	14	833	0.05	0.06
December	25	13	16	984	0.06	0.07

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 424; discharge measurements, page 423. For hydrograph see page 418.

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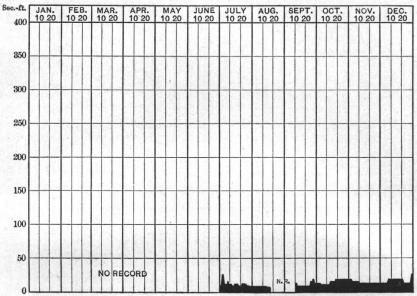


Fig. 195.—Discharge of Salina Creek near Salina, Utah, 1900.

Estimated monthly discharge of Manti Creek near Manti, Utah.

[Drainage area, 31 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
August 2 to 25	17	7	9	553	0.29	0.33
September	15	6	9	536	0, 29	0. 32

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 424.

Estimated monthly discharge of San Pitch River near Gunnison, Utah.

[Drainage area, 836 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
·1900.						
July	95	37	67	4, 120	0.08	0.09
August	27	13	17	1,045	0.02	0.02
September	32	13	18	1,071	0.02	0.02
October	30	14	18	1, 107	0.02	0.02
November, 23 days	23	17	20	1, 190	0.02	0.02
December	27	9	15	922	0.02	0.02

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 425; rating table in Paper No. 52, page 521.

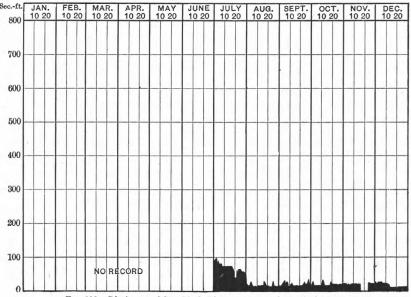


Fig. 196.—Discharge of San Pitch River near Gunnison, Utah, 1900.

Estimated monthly discharge of Sevier River near Gunnison, Utah.

[Drainage area, 3,986 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
July	59	10	26	1,599	0.007	0.008
August	19	17	18	1, 107	0.005	0.006
September	33	19	22	1,309	0.006	0.007
October	41	31	34	2,091	0.009	0.01
November	43	35	39	2, 321	0.01	0.01
December	64	35	47	2,890	0.01	0.01

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 426; discharge measurements page 425; rating table in Paper No. 52, page 521.

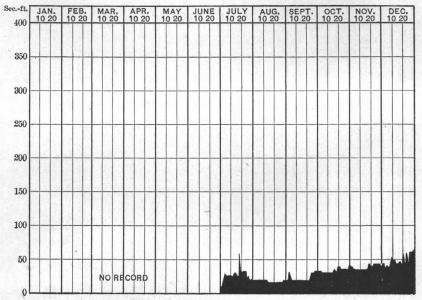


Fig. 197.—Discharge of Sevier River near Gunnison, Utah, 1900.

COLUMBIA RIVER DRAINAGE.

WATER RESOURCES OF A PORTION OF SOUTHEASTERN IDAHO.ª

SNAKE RIVER DESERT.

Extending from northeast to southwest across the greater portion of Fremont County is a plain from 50 to 60 miles wide, which owes its existence mainly to comparatively recent lava flows. This plain is an extension, toward the northeast, of Snake River Desert, as it is termed, on both the eastern and western sides of which are high mountains. The mountains on the east culminate in the great peaks of the Teton Range, some of which are more than 13,000 feet high. The mountains on the west are seemingly less rugged, but some of the peaks in the Lost River Mountains—Diamond Peak, for instance—are said to be 12,000 feet high, and this estimate can not be greatly in error, for the elevation of Snake River Desert to the west of Market Lake is about 5,000 feet, and the peaks on that side rise 5,000 or 6,000 feet above its surface.

The mountains separating Big Lost and Little Lost rivers, the rugged range between Little Lost River and Birch Creek, and the range between Birch Creek and Blue Creek, are of the general character of the basin ranges of Utah and Nevada, but trend in a southeast-northwest direction. These ranges are composed in part of stratified rocks, among which a compact blue limestone is an important member, and in part of usually light-colored igneous rocks, of which rhyolite is probably the most abundant. The northern slopes of the mountains above an elevation of about 7.000 feet are forest covered. The mountains to the southeast and northwest of Snake River Desert unite on the northeast, in the vicinity of the Yellowstone National Park, in such a manner that the numerous streams flowing from them converge toward the desert. The streams fail to unite, however, except at the extreme northeastern end of the desert, in the vicinity of Lake Henry. The numerous streams flowing westward from the Teton and associated ranges unite to form Snake River, which follows the southeastern border of the desert, while those flowing from the mountains on the west are more or less indefinite, some of them disappearing, through evaporation or percolation, while others during the winter and spring supply playas or temporary lakes on the desert, the water during the summer, however, being in most instances lost by evaporation.

Before irrigation was practiced Big Lost River formed a lake of at least 10 or 15 square miles area, Little Lost River spread out in an adjacent basin on the desert, scarcely less in area, and Birch Creek and Medicine Lodge Creek ended in a similar way. The largest of the playa lakes referred to is known as Mud Lake. It receives the waters of Camas Creek and presumably of Beaver Creek. It is said to have an area during some years of from 40 to 50 square miles, while during exceptionally arid years it evaporates to dryness. It was dry in 1891 and was lower during 1900 than at any time since. When dry, the lake beds are smooth plains of fine and exceedingly rich soil, which, when irrigated, produces magnificent crops.

The portion of Snake River Desert which was visited during the reconnaissance is a lava plain, but it is only at a few localities that the lava is now visible at the surface. Of the entire desert plain in Fremont and Bingham counties, it is safe to say that lava does not appear at the surface over more than half the area, and probably a more detailed examination would show that it forms the surface of less than a third of the entire extent. The deposits of the temporary lakes mentioned cover large areas. Borings in the sink of Big Lost River have shown that the fine, silt-like material deposited on the lava has a thickness of 40 feet. Similar deposits cover other extensive areas, which are not known to have been occupied by water since white men visited the region. It is probable that shallow lakes similar to Mud Lake and the others mentioned have existed from time to time over very large portions of the western half of the region. In addition to the deposits from lakes, the surface of the lava, more especially on the border of the desert, is concealed beneath vast alluvial fans deposited by the streams from the mountains. These are extensive, and for the most part consist of gravel, but on their outer borders grade into fine vellow silt.

Besides the deposits just mentioned, which rest on the lava and form the surface of the desert, there are extensive areas of blown sand and æolian dust, which, however, do not form conspicuous dunes, except about the base of a group of hills 20 or 25 miles northeast of Market Lake. In a few localities on the roads from Market Lake to Howe and Reno the sand has accumulated so as to make traveling difficult, and in two or three places the road has been changed in order to avoid these drifts. Possibly if the sagebrush and greasewood, the most conspicuous vegetation of the desert, could be removed for a distance of about 100 feet on each side of the road where the sand accumulates, the action of the wind would keep the surface of the silt and clay clear. With the exception of a few miles of drifting sand and a less extent of rough lava, the roads referred to traverse a practically level and nearly smooth plain of hard mud—hard during at least the dry season, but soft and in places impassable during wet weather.

The lava that comes to the surface on Snake River Desert is a black, scoriaceous rock, without soil, and, with the possible exception of the areas where sand and dust have accumulated in the hollows, unfit for agriculture. The lava surface is rough and in many places rises in

round-topped hillocks 10 or 15 feet high, which are usually traversed by open fissures. These hillocks are most frequently from 100 to 200 feet in length, with a shorter axis measuring perhaps half as much, and have the appearance of having been raised by lateral pressure. In the writer's judgment most of the hillocks seen were produced by the movement of liquid lava beneath a hardened crust. In certain cases, however, as on the desert 2 miles southeast of Reno, there are round-topped buttes a mile or 2 miles in length and possibly a mile in width, which have a height of 300 or 400 feet or more, are composed of scoriaceous lava, and are without a crater at the summit. These low buttes, of which there are several on the desert, are of a different nature from the hillocks mentioned, and indicate localities of local lava eruptions.

In addition to the hillocks and buttes the monotony of the desert is relieved by several mountain-like summits from 500 to 2,350 feet high. The most conspicuous of these isolated mountains are the Crater Buttes, or Market Lake Buttes, as they are also known, about 6 miles, in a direct line, northeast of the village of Market Lake, and East Butte, Middle Butte, and West Butte. They belong to two classes, namely, volcanic craters and old mountain peaks that have been surrounded by lava. The Market Lake Buttes, two in number, are examples of the former class, while the three other buttes are the summits of mountains which rise through the widely extended sheets of basalt forming the surface of the plain.

The Market Lake Buttes are true craters, composed mainly of dark basaltic lapilli, and rise between 500 and 600 feet above the surrounding lava plain. Each one is about 2,500 or 3,000 feet across at the The butte lying farther to the northwest has in its summit a well-defined crater, which is now deeply filled with material blown or washed from its walls, and is grass covered. Both the inner and outer slopes of the crater bear a scanty growth of juniper trees. lapilli on the outer slope dips away from the crater in all directions at an angle of about 20 degrees, and the bedding is well exposed, owing to the action of the wind, which has blown away considerable portions of the more loosely consolidated beds, leaving the edges of the harder or more compact layers in bold relief. The lapilli sheets on the inner slopes of the crater dip inward at angles of about 25 or 30 degrees. Mingled with the lapilli are many rounded pebbles of quartz and hard igneous rock, showing that beneath the lava there are one or more sheets of stream-deposited pebbles. This fact has a bearing on the question of obtaining artesian water in Snake River Desert, and it will be referred to further on. Embedded in the lapilli are also occasional blocks of scoriaceous basalt measuring a foot or 2 feet in diameter, but presumably no lava flowed from either of the Market Lake craters. A few feet below the surface the moderately compact lapilli is suffi-

ciently soft to be cut with an ax, but it hardens on exposure to the air, and on the bank of Snake River it has been quarried for building purposes. In Menan there are two or three houses built of this stone. The plain about the buttes is smooth for a distance of from 1,000 to 2,500 feet from their bases, the lapilli having been washed or blown from it. Beyond this belt, except to the southward, where the alluvial deposits of Snake River have modified the surface, there is a rough plain of basalt. The character of the material thrown out by these volcanoes, and so far as observed the absence of lava flows from them, suggest that they are of the nature of parasitic cones, due to the lava which forms the surrounding plain having encountered a body of water at the time it was extruded, producing violent steam explosions. These buttes are of interest if, as now seems probable, the lava of Snake River Desert is the eastern extension of the Columbia River lava, for the reason that no similar craters are known in the western portion of that great series of basaltic lava flows.

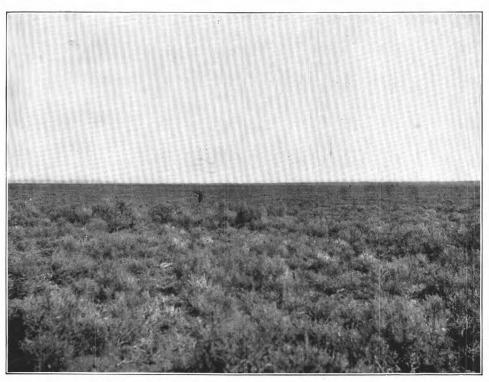
HYDROGRAPHY.

The most peculiar features in the drainage of the central portion of Fremont County-plainly shown on the maps of that region-are the many divisions or distributaries of the South Fork of Snake River in the lower 20 miles of its course and the indefinite endings of the streams entering Snake River Desert from the west. These find an explanation in the fact that in the central portion of the county a wide and deep depression surrounded by rugged mountains on all sides, except to the southwest, has been deeply filled with lava. This lava forms a plain which has not vet been dissected by erosion. Snake River has extended its canyon to Idaho Falls, about 15 miles south of Market Lake, but above that locality it is practically a surface stream. (See Pl. XXX, A.) Before the natural conditions were interfered with by the construction of canals and embankments, during spring freshets Snake River overflowed its banks at Market Lake so as to form a sheet of water from 10 to 20 miles broad. At Idaho Falls the river enters a narrow canyon about 25 or 30 feet deep and forms a rapid. Above that point the streams from the mountains, in carrying their débris to the master stream, are building alluvial cones on the lava plain. The best example of these is furnished by the South Fork of Snake River, which meets the lava plain about 15 or 20 miles east of Market Lake, where it has built a vast alluvial fan, on which the stream formerly divided into several more or less permanent distributaries. These conditions were highly favorable for irrigation, and many ditches have been dug and the waters of the South Fork have been extensively utilized. There is a very large surplus volume, however, which is not used.

Formerly, during high-water stages, when Snake River overflowed



A. SNAKE RIVER 5 MILES ABOVE MARKET LAKE, IDAHO, LOOKING EAST.



B. SNAKE RIVER LAVA PLAIN 10 MILES WEST OF MARKET LAKE, LOOKING SOUTH.

its banks the basin of Market Lake was flooded, but a dike several miles long has been built along the east side of the track of the Oregon Short Line, and the water is now held back. The dike, however, is only a low embankment, and it is not at all improbable that the basin, which has a system of ditches and is partly under cultivation, a few ranch houses being located in it, will be again inundated. The banks of Snake River in the vicinity of Market Lake are about 7 feet above the river during its low stages, and the waters are easily diverted into canals. One canal of large size leaves the river near the Market Lake Buttes and passes to the west of Market Lake. At the intake there is no deflecting dam, and at present there is no gate. The stream there is a veritable river, about 500 feet broad and 2 or 3 feet deep, with a coarse gravel bottom and a swift current, so that the conditions are unusually favorable for canalization.

The North Fork of Snake River and its several tributaries from the east are extensively utilized for irrigation; in fact so much water is taken out that the channel just above its junction with the South Fork is at times nearly dry.

In the region visited on the west side of Snake River Desert the streams from the mountains flow through wide alluvial-filled valleys and are building alluvial fans where they emerge onto the lava plain of the great central depression. These streams, however, have not yet upgraded their courses sufficiently to enable them to cross the lava plain and join Snake River. In fact they are weak streams, especially in summer, when owing to the aridity of the climate they disappear altogether. In spring they are greatly extended, and spread out so as to form shallow lakes, but during the summer their waters are entirely evaporated.

The following facts concerning the areas irrigated from the streams on the west side of Snake River Desert were obtained from Mr. F. A. Reno:

Irrigated lands on west side of Snake River Desert.

	Acres.
Big Lost River	5,000
Little Lost River	2,500
Birch Creek	700 to 800
Warm Creek (65 miners' inches)	95
Miser Creek (110 miners' inches)	100
Blue Creek	80
Deep Creek	
Medicine Lodge Creek (3,000 to 3,500 miners' inches)	2,500 to 3,000
Beaver Creek (water fails in late summer)	1,000
Camas Creek (7,000 to 8,000 miners' inches during high stages, but is not largely utilized).	

The waters of Beaver and Camas creeks supply Mud Lake. At the time of the reconnaissance (September, 1900) Camas Creek was dry for several miles above Mud Lake, and excavations 3 feet deep in its

bed failed to reach water. A half mile above the lake, however, a well about 100 feet from the bank of the river reached water at a depth of 20 feet.

All of the streams mentioned, excepting Camas Creek, concerning which few data were obtained, are utilized to their full capacity during the summer, but no attempts have been made to store the winter water.

Along Little Lost River, in the vicinity of Howe, the soil is an extremely fine, dust-like silt, which has been deposited by the stream and is highly productive. It is stated that the surface several miles above Howe is composed of gravel. The ranches are along the lower portion of the river, the last one being about $2\frac{1}{2}$ miles southeast of Howe.

Birch Creek is perhaps most nearly the typical stream of the region visited. It flows down a valley from 10 to 15 miles wide, bordered on each side by rugged mountains. The valley is deeply filled with alluvial material, and all about the bases of the mountains are great alluvial fans which extend into the valley a distance of 5 or 6 miles. Between these alluvial fans is the still vaster deposit laid down by Birch Creek itself. This central alluvial fan is composed of rather clean gravel, and on reaching the border of Snake River Desert it expands until it is fully 20 miles across. Where it merges with the lacustral deposits and blown sand of the desert the soil changes from gravel to fine silt and sand. On account of the manner in which the valley of Birch Creek has been deeply filled it has a peculiar cross profile, the central portion of the valley being markedly convex until the bordering alluvial fans are reached.

At one time or another Birch Creek has wandered over every portion of its alluvial fan. At present, throughout at least the lower portion of its course, it occupies a central position. Its waters are easily deflected, thus facilitating its use for irrigation. All of the summer water is utilized, but not in an economical way. All but one of the several ranches along the creek are located on the gravel of the central alluvial fan. The exception is a new ranch, taken up as a desert claim, about 6 miles northeast of Reno, on the fine silt lands of Snake The water is taken to this ranch by means of a ditch 8 River Desert. miles long. According to Mr. Reno, the gravel lands require 3 miners' inches of water per acre to produce a moderate yield of grain or lucern, while the silt lands require only 1 miners' inch per acre—and this during the first year-to produce more than twice as abundant crops as do the gravel lands. The limited supply of water would thus be at least six times as effective if it were used on the silt lands instead of on the gravel lands.

There are thousands of acres of nearly level silt land available about the outer border of the Birch Creek alluvial cone, to which the waters of the creek could easily be carried. If this were done it would result in the saving of water in another way, viz, by reducing evaporation and percolation. The creek is tortuous, with many pools, thus facilitating evaporation; and the loss by percolation is also said to be considerable. These losses could be greatly lessened if the water were conducted through a straight, narrow ditch. In view of these considerations the ranchers along Birch Creek should be allowed to abandon their present farms and locate on lands along the borders of Snake River Desert.

Birch Creek has its source in large springs about 25 miles northwest of Reno. A short distance below these springs there is a narrow gorge which seems favorable for the construction of a dam. This gorge should be examined with the view to ascertaining its fitness for a storage reservoir.

There is current a report concerning Birch Creek to the effect that in winter, while the springs are still flowing as usual, the water several miles downstream at times sinks, leaving the channel below dry. This appears to be the fact, and the only explanation seems to be that in winter, when the temperature at times falls to 30° or 40° below zero, the freezing of the bed of the creek breaks its lining of silt deposited with the gravel and allows the water to reach the uncemented gravel beneath.

IRRIGATION POSSIBILITIES.

The natural conditions in Fremont County are usually favorable for irrigation, but all of the available water is not at present utilized, and, as already stated, some of that diverted is not wisely used. The greatest amount of irrigated land lies to the east of Snake River, but even there the streams, especially the South Fork of Snake River, are by no means fully utilized. On Snake River Desert, more especially in its western portion, there are many hundreds of thousands of acres of excellent land still in a desert condition. At present these lands are used only for pasturage, principally for sheep, during the winter, when snow takes the place of water. The pasturage, however, is poor, even for a sagebrush desert.

To encourage and facilitate irrigation a survey of Fremont County should be made, all favorable reservoir sites being indicated. In this survey special attention should be given to Lake Henry, in the extreme northeastern portion of the county, as it seems possible that its waters might be conducted to Camas Creek and made available in the western portion of Snake River Desert. All of the streams from the mountains should be studied with reference to the possible presence of reservoir sites, although the vast amount of upgrading that has been done by them would seem to warrant little hope of finding suitable places for water storage. Careful surveys should also be made for the purpose

of determining to what extent the water of Snake River above the Market Lake Buttes can be carried westward. Regarding the South Fork of Snake River, it is an engineering possibility to carry the surplus waters of that stream directly westward—crossing Snake River in the vicinity of Market Lake—to the desert lands beyond. A view of the lava plain about 10 miles west of Market Lake is shown in Pl. XXX, B.

Increased irrigation in Fremont County must be looked for (1) in a more economical use of the water now diverted, (2) in the more complete utilization of the South Fork of Snake River, and (3) in the storage of winter water.

ARTESIAN WATER.

The examination of the region about Market Lake was too hasty to form from it a definite opinion concerning the possibilities of obtaining artesian water, but what was done, coupled with a knowledge of the conditions existing in the western portion of the vast Columbia River lava formation, prompts the following suggestions:

As already stated, the broad central basin in Fremont County is floored with lava sheets. The surface laver may have been formed by two or more separate flows, but it is essentially a continuous sheet of wide extent, occupying the central basin and extending 10 or 15 miles into the lateral valleys, such as those of Little Lost River and Birch Presumably there are other lava sheets beneath the one exposed, but owing to the fact that the material filling the valley has not been disturbed from its original horizontal position, and that it is not cut by streams, the number of sheets can be told only by a study of Snake River Canyon below Idaho Falls, or by drilling. The most plausible hypothesis is that the basin was partially filled with alluvium, and that several lava flows occurred so as to form successive sheets. Between the outflows of lava—judging from what is known of the Columbia River lava in western Idaho and Washington—there probably are sheets of alluvium, lacustral deposits, and volcanic dust and lapilli. If this be so, there is certainly a possibility that water under pressure exists in the porous layers.

Although the rocks referred to have not been deformed so as to acquire a basin shape, the manner in which they were laid down would produce conditions favorable to obtaining flowing water by drilling. To illustrate: The central basin and its numerous branches were probably filled to a considerable depth with alluvium before the first lava flow, provided the climatic conditions were then approximately what they are now. This filling would be thickest in the lateral valleys and thinnest toward the center of the main basin. A lava inundation in the main valley would extend up the lateral valleys until it was checked by the alluvial fans. Under these conditions the porous portions of

the alluvium would be water charged, and a well drilled through the lava and into the beds beneath should find water under pressure. After the first lava flow more alluvium would be carried down the lateral valleys and deposited on the lava flooring the central basin, in the same manner that the basin is now being slowly filled. In fact, it is possible that between each two layers of lava there is a sheet of alluvium, lacustral deposits, or volcanic dust and lapilli. These beds between the lava sheets should be thickest in the portions adjacent to the bordering mountains and in the lateral valleys and should thin out and become finer in texture toward the middle of the central basin. The sedimentary beds between the lava sheets should extend up the lateral valleys beyond the border of the lava, and there be exposed so as to readily become water charged.

The conditions here suggested are practically the same as those existing in the vast alluvial fans and lacustral deposits in the vicinity of Salt Lake City and other localities in the Great Basin where flowing wells exist, except that the water-laid beds are covered with a lava sheet and probably have layers of lava interbedded with them.

If this hypothetical history of Snake River Desert be approximately correct, the more favorable localities for putting down deep borings with the hope of obtaining a surface flow of water would be at the entrances to the lateral valleys, as, for example, at Reno, or 2 or 3 miles southeast of that place, or near Howe. If successful wells should be obtained at these localities, it would strongly favor the probability of obtaining flowing wells in the central portion of the desert.

The following facts bear directly upon the artesian problem in this section: (1) The Market Lake craters threw out a large number of waterworn pebbles, showing that there is a bed or sheet of gravel beneath the surface lava flow. This sheet probably belongs to a buried alluvial fan of the East Fork of Snake River. (2) At Howe a well was drilled through lava to a depth of 200 feet, when water rose quickly 25 feet, or to within 175 feet of the surface. The casing in this well is not packed on the outside, and what the closed pressure of the water may be is unknown.

Another fact of interest is that the surface of the lava near Howe, and also in the vicinity of Reno, that is, well within the lateral valleys opening from the central basin on the west, is, by aneroid, 200 or 300 feet higher than the general level of Snake River Desert. As it is probable that the lava entered the lateral valleys from the central basin, the higher elevation of the last-formed sheet of basalt at Howe and Reno suggests that the sheets of hard rock beneath Snake River Desert may in reality have a basin shape. In this connection it may be suggested that a lava sheet occupying the broad desert area would be thicker in the central part than near the borders, and that on cool-

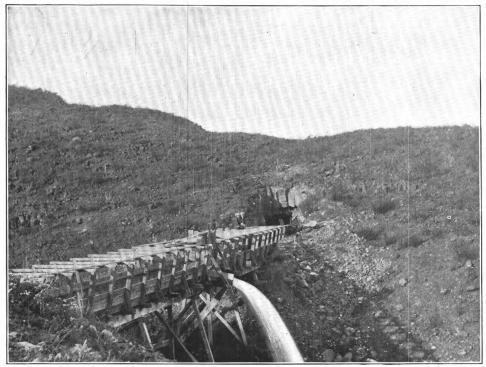
ing—the greatest amount of shrinkage occurring where the rock was thickest—it would acquire a concave surface. If this occurred in several superimposed lava flows between which porous beds were deposited, a veritable artesian basin might result.

Fremont County presents most interesting problems for the hydrographer and geologist, and surveys should yield results of great economic importance.

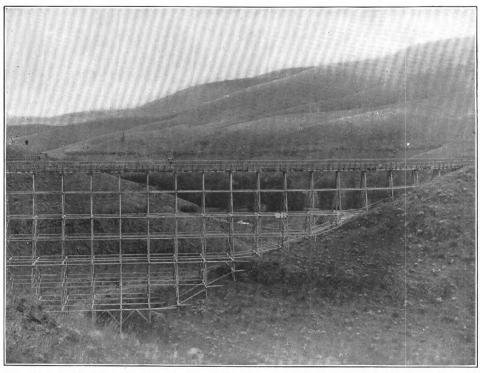
COLUMBIA RIVER.

Columbia River drains an area of 81,133 square miles, including parts of Washington, Oregon, Idaho, and Montana, the greater portion of the basin being in the arid region. Two of its principal tributaries are Snake and Pend Oreille rivers. Missoula, Blackfoot, and Bitterroot rivers are tributaries of the latter, and are gaged near Missoula, Mont. In the basin of Snake River stations are maintained on Boise River near Boise, Idaho, and on Weiser River near Weiser, Idaho. Other stations in the basin of the Columbia are as follows: Spokane River, at Spokane; Naches River, near North Yakima; Yakima River, at Union Gap and at Kiona; Palouse River, near Hooper, Wash.; and Umatilla River, at Gibbon, Oreg.

A great part of the water of Columbia River and its tributaries flows to waste, not being utilized for irrigation. This is due to the fact that the river has cut so deeply into the lava-covered plains that water can not be diverted except at points near the mountains, where the streams are of small size and have not vet entered the deeply incised canyon in the plateaus. One of the localities where water is used is in eastern Washington, in the vicinity of Clarkston, a town on the west side of Snake River, opposite Lewiston, Idaho, the system being known as the Vineland irrigation system. Pl. XXXI shows a portion of this system, a tunnel, flume, and wasteway being shown in A and a portion of the trestle (120 feet high) which carries the flume (600 feet long) being shown in B. A general description of this area and of the water problems has been given by Prof. I. C. Russell in Water-Supply Papers Nos. 53 and 54, entitled Geology and Water Resources of Nez Perce County, Idaho, Parts I and II. Pl. XXXII illustrates the system of water distribution used in this locality. In view A is shown a distributing ditch flowing along one of the principal roads. The grade is so steep that at short intervals small drops are introduced to prevent erosion. These drops also serve to back the water and assist in dividing it among the irrigators. View B of Pl. XXXII illustrates the method of carrying water through the orchards by means of temporary wooden boxes, in the sides of which are cut small openings about an inch square. The water is allowed to flow out of a series of these openings for a certain number of hours, and then the openings are closed by means of small tin gates



A. TUNNEL, FLUME, AND WASTEWAY IN VINELAND IRRIGATION SYSTEM, CLARKSTON, WASH.



B. TRESTLE CARRYING FLUME OF VINELAND IRRIGATION SYSTEM, CLARKSTON, WASH.
Length, 600 feet; height, 120 feet.

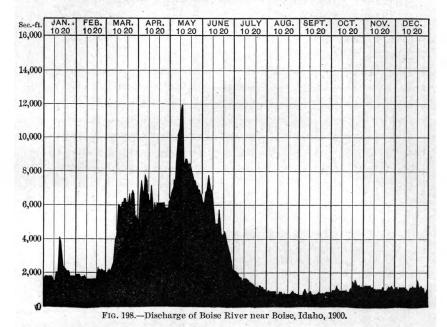
or shutters, and others are opened. In this way tiny rivulets are thrown into first one portion of the orchard and then into another. Pl. XXXIII, A, illustrates the results of irrigation on this fertile land. Pl. XXXIII, B, shows the large bridge stretching across Snake River from Lewiston, Idaho, to Clarkston, Wash. In the background are shown the sloping walls of Snake River, which rise to the plateau country, upon which, at elevations of 1,500 feet or more above sea level, wheat, oats, barley, flax, etc., are grown without water other than that absorbed and retained by the fine, porous soil. The yield from these crops is surprisingly large, but usually orchards do not thrive without irrigation. Wherever water can be had in the valleys and canyons along the streams peaches, pears, prunes, and similar fruits, as well as grapes, berries, and garden vegetables, all of excellent quality, are produced in great abundance.

Estimated monthly discharge of Boise River near Boise, Idaho.

[Drainage area, 2,450 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.				4		
January	4, 115	1,497	2,082	128, 017	0.85	0.98
February	2, 370	1,497	1,811	100, 578	0.74	0.77
March	6, 925	1,982	4,905	301, 597	2.00	2. 31
April	7,720	5, 085	6,342	377, 375	2. 59	2.89
May	11,960	6, 395	8, 241	506, 719	3.36	3.88
June	7, 852	2,273	4,992	297, 045	2.04	2. 27
July	2, 176	963	1,447	88, 973	0.59	0.68
August	915	721	793	48, 760	0.32	0.37
September	1,012	672	769	45, 759	0.31	0.35
October	1,545	818	1,056	64, 931	0.43	0.50
November	1, 206	915	1,075	63, 967	0.44	0.49
December	1,594	818	1,096	67, 390	0.45	0. 52
The year	11,960	672	2,884	2, 091, 111	1.18	16.01

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 428; discharge measurements, page 427; rating table in Paper No. 52, page 522. For hydrograph see page 432.

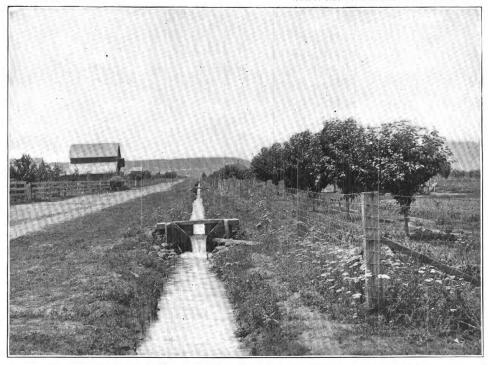


Estimated monthly discharge of Weiser River near Weiser, Idaho.

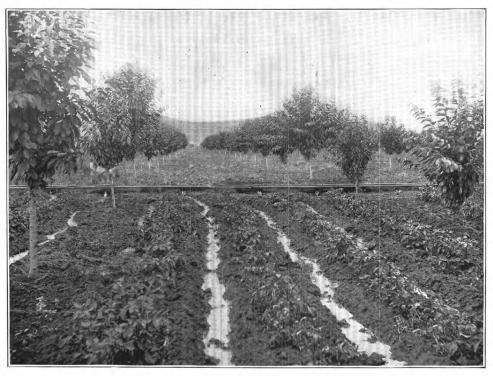
[Drainage area, 1,670 square miles.]

Month.	Dischar	rge in secon	nd-feet.	Total in acrefeet.	Run-off.	
	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
March	8, 120	1,955	3, 836	235, 866	2.30	2.66
April	2,990	1,840	2, 323	138, 228	1.39	1.55
May	-3, 935	1,840	2,786	171, 304	1.67	1.93
June	1,730	250	926	55, 101	0.55	0.61
July	250	55	135	8, 301	0.08	0.09
August	71	39	54	3, 320	0.03	0.03
September	105	71	90	5, 355	0.05	0.06
October	470	105	226	13, 896	0.14	0.16
November	330	250	287	17,078	0.17	0.19
December	4, 340	330	929	57, 122	0.56	0.65

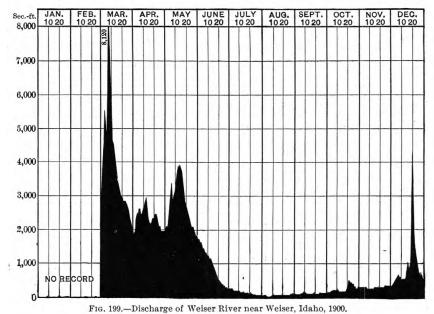
Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 430; rating table in Paper No. 52, page 522. For hydrograph see page 433.



 $\it A$ IRRIGATION LATERAL IN VINELAND IRRIGATION SYSTEM, CLARKSTON, WASH.



B. WATER DISTRIBUTION IN VINELAND ORCHARD, CLARKSTON, WASH.



rig. 199.—Discharge of Weiser River hear Weiser, Idaho, 1900.

Estimated monthly discharge of Blackfoot River near Bonner, Mont.

[Drainage area, 2,465 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile,	Depth in inches.
1900.						
January	945	662	787	48, 391	0.32	0.37
February	743	460	634	35, 211	0. 26	0. 27
March	3, 125	380	1,278	78, 581	0.52	0.60
April	3,749	1,310	2,707	161,078	1.10	1.23
May	12,559	3, 514	6, 566	403, 728	2.66	3.07
June	4,074	1,880	3, 116	185, 415	1.26	1.41
July	1,830	1,026	1,349	82, 947	0.55	0. 63
August	1,067	864	944	58, 044	0.38	0.44
September	986	743	859	51, 114	0.35	0.39
October	945	662	773	47, 530	0.31	0.36
November 1 to 19	824	662	760	45, 223	0.31	0.35
December 6 to 31	1,067	581	749	46, 054	0.30	0.35
The year	12,559	380	1,710	1, 243, 316	0.69	9.47

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 431; discharge measurements, page 430, rating table in Paper No. 52, page 522. For hydrograph see page 434.

²² GEOL, PT IV-01-28

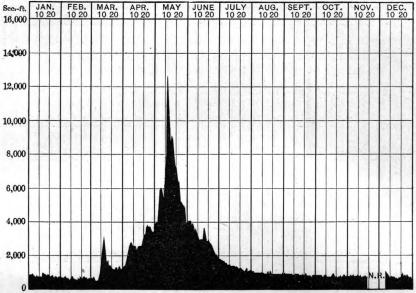


Fig. 200.-Discharge of Blackfoot River near Bonner, Mont., 1900.

MISSOULA RIVER.

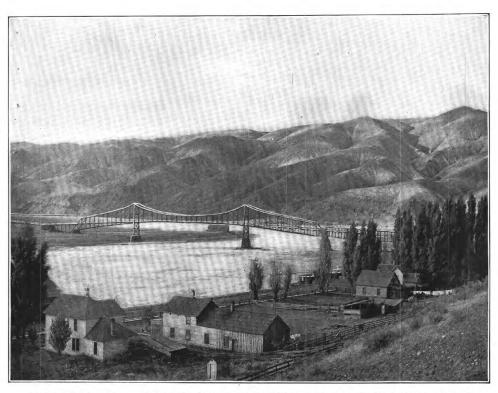
This river has its source in Silverbow County, Mont., and flows northerly until it receives the waters of Little Blackfoot River, when it takes a more northwesterly course. The name Missoula is usually applied to that portion of the river between the junction of Blackfoot and Hellgate rivers and the mouth of Pend Oreille River. From that point to its junction with Columbia River it is called Clark Fork of Columbia. Rattlesnake Creek and Bitterroot River are the important tributaries. In Pl. XXXIV, A, is shown a view of Hellgate Canyon and Missoula River near Missoula, taken from the summit of University Mountain, 5,000 feet high.

In the summer of 1900 a reconnaissance was made of the drainage basins of Mission and Post creeks, Mont., tributaries of the Missoula, the results of which are described on pages 436 to 441.

The results for 1900 of the observations on Missoula River at Missoula are given in the following table:



A. PEACH ORCHARD AT VINELAND, NEAR CLARKSTON, WASH., THREE YEARS AFTER SETTING.



B. SNAKE RIVER AT LEWISTON, IDAHO, SHOWING STEEL BRIDGE BETWEEN CLARKSTON AND LEWISTON (BUILT IN 1899).

Estimated monthly discharge of Missoula River at Missoula, Mont.

[Drainage area, 5,960 square miles.]

Month.	Discharge in second-feet.				Run-off,	
	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January 13 to 28	1,950	730	1,459	89, 710	0. 24	0. 28
February, 9 days			1,411	25, 188	0. 24	0.08
March	6, 950	980	2, 687	165, 217	0.45	0.52
April	6, 450	2,512	4,877	290, 202	0.82	0.92
May	23,600	6,600	12, 812	787, 779	2.15	2.48
June	9,400	3,500	6,361	378, 506	1.07	1.19
July	3,300	1,430	2,056	126, 419	0.34	0.39
August	1,430	1,030	1,268	77, 966	0. 21	0. 24
September	2,347	1, 245	1,494	88, 899	0. 25	0. 28
October	1,690	1,430	1,535	94, 383	0.26	0.30
November 1 to 17	1,690	1,430	1,560	92, 826	0.26	0. 29
December 5 to 30	1,885	980	1,466	90, 141	0. 25	0. 29

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 433; discharge measurements, page 432; rating table in Paper No. 52, page 522.

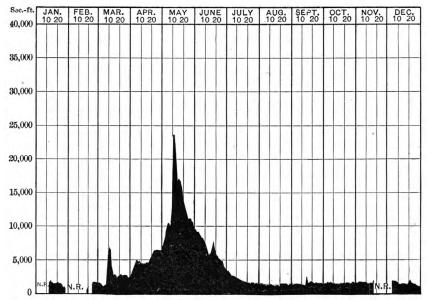


Fig. 201.—Discharge of Missoula River at Missoula, Mont. 1900.

RECONNAISSANCE OF DRAINAGE BASINS OF MISSION AND POST CREEKS, MONTANA.^a

The Mission Mountains, in western Montana, have a north-south extension of more than 75 miles, forming for a portion of their length the eastern boundary of the Flathead Indian Reservation. The upper end is smoothed by glacial action, the lower or southern end having the higher peaks. The range is important in connection with the water supply of the country, from the facts that the high summits retain much snow during the entire summer, and that from the mountains there come several large creeks which flow across the valley and into the Lower Flathead, or Pend Oreille, River to the west, their waters finally reaching Missoula River. At least two of these streams—Mission and Post creeks—leave small alpine lakes—McDonald Lake and St. Mary Lake—which are dammed in front by moraines, thus affording admirable opportunities for storing water.

The valley west of the range is 25 to 30 miles long and 10 to 15 miles wide. A large part of it is tillable, though being in the Flathead Indian Reservation little of it has been cultivated. Across it four creeks—Mission, Post, Crow, and Mud—make their way, all coming from the Mission Mountains. The two southern creeks—Mission and Post—unite before Flathead River is reached, as do also the two northern streams—Crow and Mud creeks.

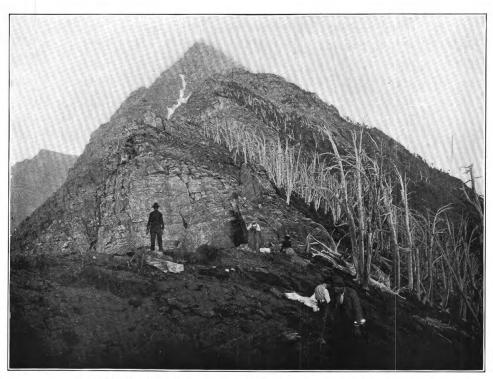
On June 30, 1900, the discharge of three of these streams was measured. Mission Creek was found to be carrying 412 second-feet 3 miles from the base of the mountains and within the limits of St. Ignatius Mission grounds; Post Creek carried 473 second-feet at a point on the main highway from Selish to Polson, 6 miles north of Mission Creek and 10 miles south of Crow Creek, the same being 6 or 7 miles from McDonald Lake, its source, and at an altitude of more than 900 feet below that of the lake, while Crow Creek carried 180 second-feet at the bridge on the main road mentioned, 2 miles south of the ranch of William Bell. Mud Creek, which is smaller than the other streams, has not been measured.

Lakes McDonald and St. Mary are about 15 miles apart, a branch of Mission Creek being the outlet of the latter and Post Creek being the outlet of the former. There are other lakes in the region which have not yet been studied. Mission Creek receives the water from the mountains south of McDonald Peak; Post Creek receives that from McDonald Peak and the spurs and peaks forming the amphitheater around McDonald Lake.

The Mission Range is broken at the south by Jocko River, which flows westward behind a range of hills lying east and west at the southern end of Mission Valley. The last high peak in the range north of Jocko River not having been named—this is true of most of the peaks



A. HELLGATE CANYON AND MISSOULA RIVER NEAR MISSOULA, MONT., FROM SUMMIT OF UNIVERSITY MOUNTAIN, 5,000 FEET ABOVE SEA LEVEL.



B. WESTERN SUMMIT OF McDONALD PEAK, MONTANA, LOOKING EAST. Main summit and glacier immediately behind peak. McDonald Lake receives drainage to the left.

in the Mission Mountains—it is here given the Indian name Sinyale-amin, meaning surrounded. This name was first applied by the Indians to what is now known as Mission Creek after a fight along that stream between the Flatheads and their enemies, the Blackfeet, when the latter were entirely surrounded and exterminated. Sinyaleamin Mountain is, therefore, the last peak on the southern end of the Mission Range next to Jocko River.

The peaks of the range are not the crests of the watershed, which is farther east. The water from the snow on the eastern slope of McDonald Peak and Sinyaleamin Mountain flows around the peaks to the westward, uniting with the streams from that side. This is also true of some of the other peaks. The snowfall on these mountains is therefore a very important item when the amount of water available for storage is to be considered.

At the southern base of Sinyaleamin Mountain a beautiful little alpine lake lies in the cradle created by the mountains, and from the nature of its location the name Sinyaleamin (surrounded) is most appropriate. Locally it is called St. Mary Lake, but the name Sinyaleamin would be much better, for there is a larger and more widely known St. Mary Lake in the northern part of the State, in the Blackfeet Indian Reservation.

The distance from St. Ignatius Mission to St. Mary Lake is given as 9 miles. The distance from the lake to the mouth of the canyon is about 3½ miles. The lake is hemmed in on all sides, only a small flat near the water affording a camping site. On the north the mountain rises abruptly from the water to a height, as recorded by an aneroid, of 9,200 feet—probably 200 feet in excess of the true elevation. At the time of the reconnaissance—July, 1900—an abundance of snow was on the summit. The lower mountain slopes are moderately wooded with small firs, while the upper heights are bare, jagged rocks, on which a few black pine alone have obtained a foothold. On the east and south the summits are lower, sloping gradually to the south and then to the west, where the ridge descends to almost the level of the lake and where the mountain sides are densely wooded with small trees. The western end of the lake is the only portion near open country, and this is dammed by a moraine, now covered with small trees and other vegetation. This moraine extends across the ravine, which here is about a quarter of a mile wide, and nearly a mile downstream.

The present outlet of the lake is at the southern end of the moraine. There are indications, however, that the outlet was formerly at the other end of the moraine, next the mountain side proper, and that the lake was formerly larger than at present. The configuration of the moraine makes the latter possible, and it is further suggested by the difference between the vegetation there and that of other portions of

the mountain and valley. The time that has elapsed since the change can not be great. When the lake occupied the larger area it was perhaps 40 or 50 feet deeper than it is now; and when the water first started to break through at the present outlet the cutting was very rapid, as is shown by the abrupt and narrow declivity, and resulted in lowering the lake level to its present height. It also seems possible that there may have been a lake outlet toward the south, through a canyon that led to Jocko River after crossing several small ponds which contain the same microscopic life as St. Mary Lake. Without leveling instruments this could not be determined, but there is little doubt that a survey will prove the correctness of the surmise and also that it is possible to raise the level of the lake so as to make the waters flow in two directions, viz, to the south toward Jocko River and to the west into Mission Creek and toward Mission Valley. There is no question that by damming the present outlet the level of the lake could be raised about 50 feet without overflowing the moraine.

St. Mary Lake is about 7,500 feet long east and west, and 2,500 feet wide north and south. It is deep, and the water is clear and cold—at 8 p. m. July 9, 1900, the temperature was 15° C.; and experiments show that the white net used for collecting entomostracan specimens could just be seen at a depth of 30 feet; the dark rocks on the bottom, however, could be seen only at a much less depth. The banks of the lake are precipitous, no shoals or swamps being found. The largest shallow place is on the western end of the southern side, where an area about 300 feet long by 50 feet wide slopes down from the shore. At the upper end, around the inlet, there has been some filling, but it has been slow. The depth a few hundred feet from the inlet was 30 feet, but it shot down rapidly to 115 feet, and finally to 250 feet, the deepest sounding recorded. This depth was found opposite the rocky cliff at the upper end, but the lake is everywhere deep. A few feet offshore at the southern end the depth was 165 feet.

The waters of the lake, notwithstanding the temperature and the depth, support an abundance of entomostracan life, as was determined by careful study, ten days being spent in the reconnaissance. There is but one inlet, at the upper end, draining the eastern slopes of Sinyaleamin Mountain and the Jocko Peaks, where there is an abundance of snow the year round. There are no small inlets save when the snow is melting off the hills in the spring, but there must be considerable underground seepage, for there is a great deal of water high up on the mountain sides that disappears before the stream reaches the lake. The creek forming the inlet comes through a canyon from the north, Sinyaleamin Mountain forming the western wall and one of the Jocko Peaks the eastern. For a quarter of a mile or more along this creek there is a rank growth of beautiful arbor vitæ trees. These continue until the canyon becomes so narrow that there

is room for only the stream, which tumbles over a cliff several hundred feet in height. This was followed for some distance, and as far as could be seen or heard the cascade continued.

On account of the landlocked position of the lake it is seldom disturbed by storms, although occasionally strong gusts blow in from the west. The surface is usually calm and smooth. Timber grows to the water's edge, but there is very little drift around the borders of the lake.

Three ridges, all of comparatively easy ascent, lead up from the lake, the altitude of which is 3,800 feet, to the summit of Sinyaleamin Mountain. The ascent of the mountain was made in a day, camp being reached again very late at night. The summit is really a long ridge extending southeast and northwest, culminating in two peaks and joined to the remainder of the range to the north by a low spur at the easternmost of the two peaks. On the north the drainage is into the main branch of Mission Creek; the western peak drains into the stream below St. Mary Lake; while the drainage from the country to the east and south is into the lake itself.

There can be no question regarding an abundant water supply for this lake, the surrounding peaks being covered with snow throughout the year. The wooded slopes on the south side retain the water until late in the spring. At the time of the reconnaissance the flow at the inlet of the lake was estimated to be between 60 and 80 second-feet, and the lake was doubtless at about its lowest stage.

From the summit of Sinyaleamin Mountain the view is indescribably grand. The eastern slope is a large, glacially eroded stretch, ending in more level valley country inclosing small lakes, five of which can be seen. One of these, at the base of the southern of the Jocko Peaks, was called Snow Lake, because when seen in July, 1900, it was apparently full of slush, snow, and ice. This lake is in the drainage system of St. Mary Lake. To the south Mount Lolo, in the Bitterroot Range and 75 miles away, is visible, while to the north Flathead Lake, 30 miles distant, can be seen.

McDonald Lake lies at the foot of McDonald Peak, on the north-west side. It is about 11 miles from St. Ignatius Mission and about 15 miles due north of St. Mary Lake. Like the latter it is hemmed in by mountains on all sides except the west, but the mountains are much higher, more picturesque, and steeper than those surrounding St. Mary Lake. The lake received its name back in the sixties, and on the ground of priority it should easily displace Terry Lake, above Kalispel and now also called McDonald, in proprietorship of the name.

The valley in which the lake is situated has been carved out by a glacier, the remnant of which still exists on the slopes of the peak, in plain sight from almost any place on the lake. The rocks along the sides of the peak have been ground smooth, and plainly show the marks

of the ice. At the outlet of the canyon is a large moraine, which, however, is not so advantageously situated for damming the waters as is the moraine at St. Mary Lake. In times past the water has evidently been much deeper than it now is, and at the upper end what is now a wooded valley was covered with water, being a part of the lake.

McDonald Lake is smaller than St. Mary Lake, and not nearly so deep. It is from a mile to a mile and a quarter long, with an average width of less than a quarter of a mile. On either side the mountains come abruptly to the water. At the upper end there is a small unexplored valley, abundantly wooded with large arbor vitæ and with species of fir, birch, and other small trees. The inlet divides above the lake, one branch receiving the water from the glacier, the other branch bringing toward the west the water from the amphitheater, which has for a drainage area not only the peaks visible but also the eastern slope of McDonald Peak. The bottom of the lake is comparatively level. Either the lake is much older than St. Mary Lake or it has filled faster. The depth from end to end is nearly uniform, the deepest part being 68 feet. The lower end is shallow, the outlet being crossed by a ford hub deep at the time of the examination in July, 1900. There is considerable shallow water at that end, and the bottom is mud of a dark-red color, apparently from the soft, decomposed rock on the north. Near the middle a ledge of rock projects from either side, making the lake at that point quite narrow. The rocks are precipitous, and the water a few feet from them is deep. These rocks are worn smooth by glaciation, and show numerous and deep glacial scratches. The rocks on the north are precipitous for about 2,000 feet. Four waterfalls with small streams tumble over them, the water disappearing in the loose talus at the base long before it reaches the lake. The southern slope is not so abrupt, and great masses of loose talus, with large bowlders, line the water's edge, making a spongy surface for the retention of moisture.

The life in the water is much the same as that in St. Mary Lake, the Entomostraca being as numerous, of nearly the same species, and showing the same peculiarities as those in the latter lake, descending to a depth of 25 or 30 feet during the daytime and coming to the surface at night.

The banks are so rough that it is almost impossible to climb along them. Exploration will very likely show that by increasing the depth of the lake the water surface will be greatly increased. On the northern side the forest growth is not dense, owing to the nature of the rocks, which are steep and afford poor foothold for timber. On the mountain above the precipitous rocks, however, the timber is rather heavy. The southern bank is well wooded, and the canyon at the head of the lake is densely forested, no entrance, either by road or trail, appearing to have yet been made. At the outlet and

along the moraine near the lake there is fine timber, much of which has been cut for rails and lumber. Everywhere there is much underbrush, making progress difficult. The upper slopes of the mountains are bare. Most of them have been covered with black pine, but it has been killed by fire.

The road from St. Ignatius to the lake is good, and there is considerable travel over it in summer, the lake, on account of the excellent fishing and the beautiful scenery, being a favorite resort of the Indians and of visitors to the reservation. There is no drift around the shores, nearly all of it having lodged in the outlet, where there is a rather large 'am, which could, however, be removed.

McDonald Peak is double, the western summit (see Pl. XXXIV, B) being a thousand feet lower than the eastern, and the two being connected by a saddle, or lower ridge. The main peak has three or four spurs projecting in different directions, behind which the snow lies in deep drifts, forming ice and remaining throughout the year. There is, however, little snow on the western peak, and its importance as a snow holder lies in the fact that if permits the snow blowing from the valley on the west to pile up between it and the main peak, making a glacier which is visible from almost every part of the valley. spurs referred to afford such protection that in three places on the mountain the snow piles in drifts which never melt, making three large glaciers, the water from which all flows into McDonald Lake. The peaks to the north of McDonald Peak and those to the north of the lake also give much of their waters to the lake. The supply is, therefore, abundant and never failing. The point at which Post Creek, the outlet of the lake, was measured on June 30, 1900, is 12 miles or more from the lake, and considerable water is taken out for irrigation between the lake and that point. As already stated, the creek carried 473 second-feet when measured.

BITTERROOT RIVER.

The source of this river is in the high mountains forming the boundary line between Montana and Idaho. It flows in a northerly direction, entering Missoula River a short distance below the city of Missoula. The tributaries on the east side drain comparatively low hills and contribute little to the supply of the river. The west side branches, on the contrary, are numerous, draining a precipitous and heavily wooded area. Their discharges are regulated by many small lakes fed by banks of snow, which continue far into the summer before disappearing altogether. From Hamilton to Missoula, a distance of 48 miles, the fall of the river is 350 feet, or 7.3 feet to the mile. The gaging station is at Missoula, Mont.

Estimated monthly discharge of Bitterroot River at Missoula, Mont. [Drainage area, 3,260 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	ı-off.
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	1 740	1 000	1 001	FF 0F 0	0.07	0.40
January	1,540	1,080	1, 221	75, 076	0.37	0.43
February 1 to 10	•••••		1,084	21, 501	0.33	0.12
March 4 to 31	2, 280	910	1,652	101, 578	0.51	0.59
April	4,600	1,930	3,626	215, 762	1.11	1.24
May	18, 150	6,400	9,871	606, 944	3.03	3.49
June	10,650	4,060	7, 352	437, 474	2.26	2. 52
July	3,570	980	1,820	111, 907	0.56	0.65
August	1,010	800	869	53, 433	0.27	0.31
September	1,350	950	1, 137	67,656	0.35	0.39
October	8, 250	1,010	2,828	173, 887	0.87	1.00
November, 24 days	1,930	1, 122	1,373	81, 699	0.42	0.47
December	1, 350	950	1,148	70, 588	0.35	0.40

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 434; discharge measurements, page 433; rating table in Paper No. 52, page 522.

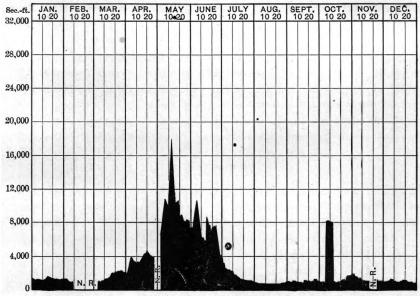


Fig. 202.—Discharge of Bitterroot River at Missoula, Mont., 1900.

SPOKANE RIVER.

This river rises in the northern part of Idaho, being an outlet of Lake Cœur d'Alene. It passes into Washington, flows in a northwest-erly direction, and enters Columbia River near latitude 47° 52′ north. It is about 120 miles long. The station, which was established October 17, 1896, is at Spokane, Wash.

Estimated monthly discharge of Spokane River at Spokane, Wash.

[Drainage area, 4,005 square miles.]

	Discha	rge in seco	nd-feet.		Rui	ı-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	V					
January	16, 173	8, 633	12, 191	749, 595	3.04	3. 51
February	10,957	6,059	7,609	422, 582	1.90	1.98
March	16,664	6,760	12,943	795, 834	3. 23	3. 72
April	17, 493	13, 786	16, 127	959, 623	4, 03	4. 49
May	13, 941	10,815	13, 198	811, 514	3. 30	3. 81
June	10,532	5,609	7, 529	448, 007	1.88	2. 10
July	5,609	2,937	4, 065	249, 947	1.01	1.16
August	2,937	2, 277	2, 494	153, 350	0.62	0.71
September	2, 436	2, 122	2,267	134, 896	0.57	0. 63
October	4, 141	2,356	2,867	176, 285	0.72	0.83
November	5,832	4, 141	5, 418	322, 393	1.35	1.51
December	14,568	5, 945	10, 456	642, 914	2.61	3. 01
The year	17, 493	2, 122	8, 097	5, 866, 940	2.02	27. 46

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 439; rating table in Paper No. 52, page 522.

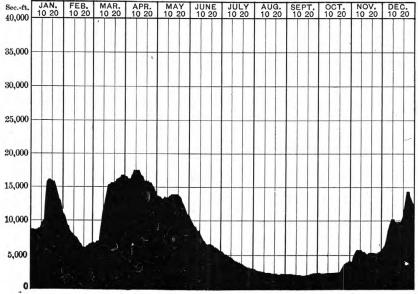


FIG 203.—Discharge of Spokane River at Spokane, Wash., 1900.

NACHES RIVER.

This river has its source on the eastern slope of the Cascade Mountains, in Yakima County, Wash. It flows in a general southeasterly direction, entering Yakima River a short distance above North Yakima. Irrigation is practiced in the narrow valley along the lower course of the river, but its waters are of greater value for the irrigation of lands west of North Yakima. The river has considerable fall and the water can easily be diverted by means of comparatively short canals. For this reason it is of more value for irrigation purposes than Yakima River, which has less fall. The station at North Yakima was originally established August 14, 1893, but was abandoned in 1897, and was reestablished February 1, 1898. The results for 1900 are given in the table on page 445.

Cowiche Creek, which flows into Naches River about 3 miles above North Yakima, is formed by two forks which in the vicinity of their junction have rather extensive alluvial bench lands. The headwaters of these forks do not reach back far enough to insure a constant supply of water, and on that account attempts have been made to devise a storage system. The plan adopted was the construction of a reservoir on the plateau between Cowiche Creek and Naches River. A natural depression in the surface of the hard andesitic lava flow was utilized and retaining dams were constructed, making a reservoir which can be filled during the flood season in the early spring, when an abundant supply of water is furnished by the North Fork of Cowiche Creek. This reservoir does not hold sufficient water to irrigate more than a very small portion of the Cowiche bottom lands, but it is of interest, as it is the first of its kind in the State.

On the South Fork of Cowiche Creek, in sec. 36, T. 14 N., R. 16 E., is an interesting weir, shown in Pl. XXXV, B. It extends across the stream from bank to bank, and the entire flow passes over it at all seasons of the year. It was constructed with the view to distributing the waters of the creek in accordance with a decision of the superior court awarding to the Cowiche Irrigation Ditch Company one-fifth of the entire flow of the creek. The weir board is of 3-inch planking, is beveled outward on top and made truly level from end to end, and the sharp edge forming the crest of the weir is protected from injury by a strip of stout iron nailed on the upstream side. The total length of the weir is 19 feet, with no end contraction. At right angles with and below the weir board and parallel with the stream there extends a high dividing board having a sharp edge toward the flow. As originally planned this dividing board cut off one-fifth of the total length of the weir, and diverted that portion of the flow to the Cowiche ditch. Changes in the location of the dividing board have recently been made, rendered necessary by the withdrawal of a portion of the water above the weir; but the principle of division remains the same. The weir and the method of subdivision give complete satisfaction to those interested. The structure is favorably situated, the flow being very tranquil at low stages, at which time only a fairly accurate division is required; at other times there is more than enough water for all. The weir is substantially constructed, with high wing walls, 30 feet in length, of stout piling and planking, with 3-inch flooring, all well calked, and with apron, etc. A vertical gage rod, graduated in tenths of a foot, is fixed at a suitable place above the weir, affording the means of ascertaining the total daily discharge of the creek, but so far no record has been kept.

Estimated monthly discharge of Naches River near North Yakima, Wash.

[Drainage area, 1,000 square miles.]

	Dischar	ge in secon	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	9,700	1,420	2,946	181, 142	2.95	3. 40
February	1,550	1,000	1, 199	66, 589	1.20	1. 25
March	4,310	1,090	2,720	167, 246	2.72	3. 14
April	5, 200	1,690	2, 953	175, 716	2.95	3. 29
May	5, 200	1,550	3, 166	194, 670	3.17	3.66
June	3,010	1,090	1,806	107, 464	1.81	2.02
July	1,000	470	636	39, 106	0.64	0.74
August	530	370	423	26,009	0.42	0.48
September	590	390	448	26, 658	0.45	0.50
October	2,000	390	721	44, 332	0.72	0.83
November	1,420	910	1, 189	70, 750	1.19	1. 33
December	5, 800	1,300	2, 711	166, 693	2.71	3. 13
The year	9, 700	370	1,743	1, 266, 375	1.74	23, 77

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 440; rating table in Paper No. 52, page 522. For hydrograph see page 446.

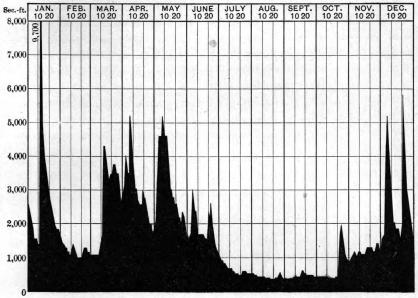


Fig. 204.—Discharge of Naches River near North Yakima, Wash., 1900.

YAKIMA RIVER.

This river has its source in Keechelus Lake, on the eastern slope of the Cascade Mountains, in Kittitas County, Wash. Within a short distance it receives the waters of Kachess Lake, and $2\frac{1}{2}$ miles above Clealum it receives the outlet of the last of the three large headwater lakes. It enters Columbia River 23 miles below Kiona, Wash. Two stations are maintained on the river, one at Union Gap and the other at Kiona. The results of the observations at these stations during 1900 are given in the tables on pages 447 and 448.

During the summer of 1900 reservoir surveys were made on Wenas Creek, a small tributary of Yakima River, as described on pages 449 to 450. On page 451 will be found a description of the Selah-Moxee Canal, which diverts water from Yakima River about 8 miles above North Yakima.

Estimated monthly discharge of Yakima River at Union Gap, Wash.

[Drainage area, 3,300 square miles.]

	Dischar	ge in seco	nd-feet.	-	Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	19, 150	4,000	8, 752	538, 139	2.65	3.06
February	4,800	3,000	3,770	209, 375	1.14	1.19
March	11, 450	3,500	7, 474	459, 558	2.26	2.61
April	11,800	4,800	7, 747	460, 978	2, 35	2. 62
May	10, 750	3,750	7,066	434, 471	2.14	2.47
June	4,800	2,800	3, 828	227, 782	1.16	1. 29
July	2,600	1, 150	1,635	100, 532	0.50	0.58
August	1, 150	650	876	53, 863	0.27	0.31
September	1,350	850	1,090	64, 859	0.33	0.37
October	6,600	950	2, 243	137, 917	0.68	0.78
November	4, 250	2,800	3, 472	206, 598	1.05	1.17
December	13, 550	4,250	7,092	436, 070	2.15	2.48
The year	19, 150	650	4, 587	3, 330, 142	1.39	18.93

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 442; discharge measurements page 441; rating table in Paper No. 52, page 522.

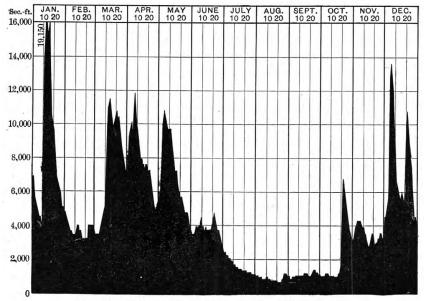


Fig. 205.—Discharge of Yakima River at Union Gap, Wash., 1900.

Estimated monthly discharge of Yakima River at Kiona, Wash.

[Drainage area, 5,230 square miles.]

	Dischar	ge in secon	id-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	18. 795	4, 370	7,914	486, 613	1.51	1.74
February	4,839	2,098	3, 965	220, 205	0.76	0.79
March	11, 457	3,660	7,559	464, 785	1.45	1.67
April	11, 170	4,556	7, 505	446, 579	1.43	1.60
May	9,073	3, 575	6, 398	393, 398	1. 22	1.41
June	4, 100	2, 459	3, 361	199, 993	0.64	0.71
July	2, 459	663	1, 224	75, 261	0. 23	0. 26
August	637	450	515	31,666	0.10	0.12
September	881	525	626	37, 250	0.12	0.13
October	2, 240	749	1, 187	72, 986	0. 23	0. 26
November	5, 130	2, 385	4, 213	250, 691	0.81	0.90
December	14, 895	5, 426	9, 393	577, 553	1.80	2.08
The year	18, 795	450	4, 485	3, 255, 017	0.86	11.67

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 443; discharge measurements, page 442; rating table in Paper No. 52, page 522.

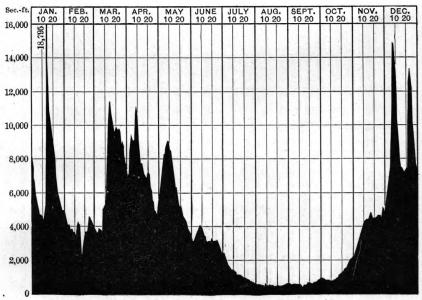


Fig. 206.—Discharge of Yakima River at Kiona, Wash., 1900.

RESERVOIR SURVEYS ON WENAS CREEK, WASHINGTON.

Wenas Creek is a small stream tributary to Yakima River, entering it about 7 miles north of North Yakima, Wash. Considerable irrigation is practiced in its basin, but the flow of the stream is insufficient for the needs of the irrigators. In order to ascertain whether reservoir sites exist in which flood waters could be stored by the construction of suitable dams, a reconnaissance of the basin was made in September, 1898, by Mr. Cyrus C. Babb. One site, known as the Sherman reservoir site, was surveyed, but the results were disappointing, the capacity of the site being too small to warrant the expense of construction. A detailed description of this site was published in the Twentieth Annual Report, Part IV, pages 505 and 506. The top length of the dam, at an elevation of 80 feet, would be 320 feet, and the capacity only 4,450 acre-feet.

In the summer of 1900 a further investigation of the basin was made by Mr. Sydney Arnold, and what is known as the O'Neil reservoir site was surveyed, the field work being executed with transit and stadia.

The bed of the creek at the dam site is the assumed zero of the survey, the barometric elevation of which is 2,205 feet above sea level. The length of the dam at the base would be 90 feet, and at the top, if carried 80 feet high, it would be 350 feet, and the capacity 1,753 acre-feet. If the dam were carried to a height of 100 feet the capacity would be 3,519 acre-feet. Results of the survey are disappointing, the total content of the reservoir being too small compared with the size of the dam required. The following table gives the capacity of the O'Neil site:

Contour.	Area.	Capacity.	Total capacity.	1		
Feet.	Acres.	Acre-feet.	Acre-feet.			
0	0.0	0	0			
10	1.8	1	1			
20	4.9	34	- 35			
30	9.0	70	105	•	,	
40	15.2	121	226			
50	25.0	201	427			
60	36.4	307	734			
70	50.1	432	1,166			
80	67.3	587	1,753			
90	87.6	774	2,527			
100	110.8	992	3,519			
			100			

Capacity of O'Neil reservoir site on Wenas Creek.

Pl. XXXV, A, is a view of the reservoir site from the east end of the dam site, looking northwesterly, upstream.

At the time of this reconnaissance Mr. Arnold also made a trip to

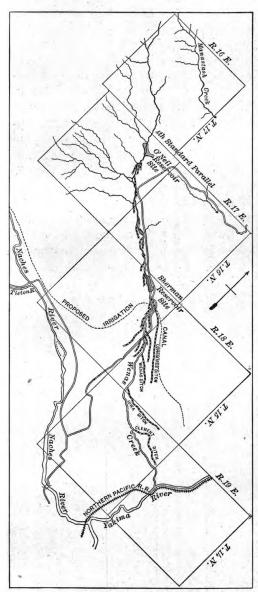


Fig. 207.—Map of basin of Wenas Creek, Washington, showing location of reservoir sites, ditches, and irrigation districts.

the headwaters of Wenas Creek, but a suitable reservoir site was not found.

Another plan for the improvement of the water supply of this valley is to bring the waters of Naches River to it by means of a The line of this canal. canal is shown on the accompanying map, fig. 207, which also shows the location of the reservoir sites mentioned and the various ditches diverting water from the creek. A large extent of country not at present cultivated, finest in Wenas Valley, however, would be served by the canal, and the project seems entirely feasible, although a survey has not yet been made. The cost would probably be considerable, for the canal would have to pass around the steep and rocky slopes of the lofty point known locally as Clemens Mountain and at a considerable elevation above its base.

Two measurements of discharge of Wenas Creek were made on May 7, 1900, as follows: One in sec. 33, T. 16 N., R. 17 E., a short distance above the upper end of the Sherman reservoir site, where the dis-

charge was 40 second-feet, and the other 3 miles below, immediately above the head of the Longmire ditch, where the discharge was 35 second-feet.



 ${\it A.}$ Wenas reservoir site, washington, looking northwest from East end of DAM site.



B. MEASURING WEIR ON SOUTH FORK OF COWICHE CREEK, WASHINGTON.

SELAH-MOXEE CANAL. a

This canal will derive its water supply from Yakima River, the head gates being on the left bank of the stream, about 8 miles above North Yakima, in the southeast quarter of the southeast quarter of sec. 8, T. 14 N., R. 19 E., W. M. Construction was commenced December 13, 1900, and is now (April, 1901) in progress, the work being well advanced. The canal is designed to irrigate desert lands in Selah and Moxee valleys, in Yakima County, Wash., amounting in all to about 5,000 acres. The water appropriation is about 500 cubic feet per second. For the first 5 miles the canal is in earth, having a bottom width of 15 feet and a maximum depth of water of 3 feet, with side slopes of $1\frac{1}{2}$ to 1. grade for the first 2 miles is 2 feet to the mile, and for the next 3 miles 1½ feet to the mile. Five miles from its head the canal leaves Selah Valley, and for the next 4½ miles the water will be conveyed in a flume along the rocky slopes leading to Moxee Valley. The flume is 6 feet wide and 4 feet high, with vertical sides of 1½-inch by 12-inch fir planks, and with 2-inch by 12-inch bottom planks, all with butt joints covered with 1-inch by 3-inch battens. The grade of the flume is 4 feet to the The remaining portion of the canal, 17 miles in length, is in The bottom widths of the ditch from the end of the flume are as follows: First 5 miles, 10 feet; next 5 miles, 8 feet; next 3½ miles, 7 feet; from latter point to the end, 5 feet. The side slopes are 2 to 1, and the grade 1½ feet to the mile, with a maximum depth of water of 3 feet.

PALOUSE RIVER.

The headwater tributaries of this stream have their sources in western Idaho. After passing into Washington the streams unite to form Palouse River, which has a general southwesterly course, through a rolling country. Six miles below Hooper, Wash., the river bends suddenly to the south and enters its canyon, through which it flows until its junction with Snake River. A short distance above the mouth of the river are the Palouse Falls, approximately 130 feet high. The gaging station, which was established September 9, 1897, is located near Hooper, Wash. The results for 1900 are given in the following table:

^{*} From report by Sydney Arnold.

Estimated monthly discharge of Palouse River near Hooper, Wash.

[Drainage area, 2,210 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	170					
April	1, 130	226	568	33, 798	0. 26	0. 29
May	866	271	392	24, 103	0.18	0. 21
June	295	50	142	8, 450	0.06	0.07
July	50	24	34	2,091	0.02	0.02
August	24	20	21	1, 291	0.01	0.01
September	22	17	20	1, 190	0.01	0.01
October	185	19	93	5, 718	0.04	0.05
November	320	18	89	5, 296	0.04	0.04
December	2,054	226	811	49, 866	0.37	0.43

Note.—Gage heights and discharge measurement for 1900 are given in Water-Supply Paper No. 51, page 444; rating table in Paper No. 52, page 522.

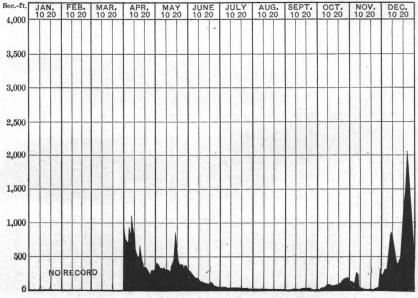


Fig. 208.—Discharge of Palouse River near Hooper, Wash., 1900.

UMATILLA RIVER.

This river rises in the well-wooded country in northeastern Oregon and flows in a general westerly direction, entering Columbia River below the mouth of Wallawalla River. The country north of Umatilla is high and rolling. Agriculture is practiced to a considerable extent, cereals being the principal crops raised. A number of canals divert water from the lower course of the stream to irrigate lands on either side. The gaging station is at Gibbon, Oreg. It was established July 22, 1896.

Estimated monthly discharge of Umatilla River at Gibbon, Oreg.

[Drainage area, 353 square miles.]

	Discharge in second-feet.				Run-off,	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet	Second- feet per square mile.	Depth in inches.
1900.						
April 15 to 30			1,312	41,637	3, 72	1.62
May	-1, 252	248	696	42, 795	1.97	2. 27
June	233	106	141	8, 390	0.40	0.45
July	106	83	90	5, 534	0. 25	0. 29
August	412	83	111	6, 825	0.31	0.36
September	233	92	123	7, 319	0.35	0.39
October	642	135	237	14, 573	0.67	0.77
November	694	298	466	27, 729	1.32	1.47
December	1,632	544	872	53, 617	2, 47	2.85

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 445; rating table in Paper No. 52, page 522.

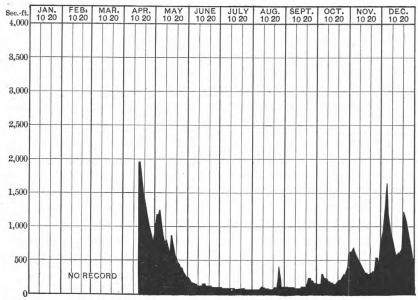


Fig. 209.—Discharge of Umatilla River at Gibbon, Oreg., 1900.

KLICKITAT RIVER BASIN.

The valley of Atanum Creek, southwest of North Yakima, was one of the first sections settled in that region. The supply of the creek is constant throughout the year, but is not nearly sufficient for the demands of the irrigators below. During the last few years the shortage has been seriously felt, and as a result numerous lawsuits have arisen. The valley has been described in the Nineteenth Annual Report, Part IV, pages 469 to 473.

In the Twentieth Annual Report, Part IV, page 505, were described the results of a reconnaissance trip made in September, 1898, by Mr. Cyrus C. Babb, for the purpose of thoroughly exploring the upper

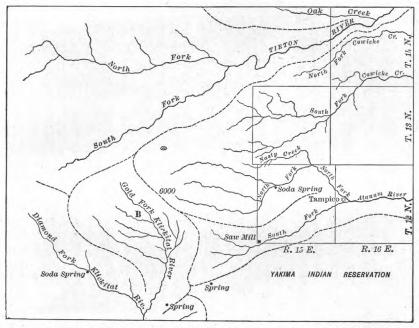


Fig. 210.—Map showing headwaters of Klickitat, Tieton, and Atanum rivers, Washington.

basin of the creek to ascertain whether there were any reservoir sites in which, by the construction of suitable dams, the spring freshets of the stream could be stored, to be used upon the irrigable lands below during times of low water. The results of this investigation were disappointing, no reservoir sites being found.

In order to further investigate the possibilities of increasing the water supply of Atanum Valley, in August, 1900, Mr. Sydney Arnold made a reconnaissance of the Klickitat Basin with the view to ascertaining whether some of the tributaries of Klickitat River could not be diverted across the divide into the Atanum Basin.



 $\it A$. GOLD FORK OF KLICKITAT RIVER, WASHINGTON.



B. ATANUM-KLICKITAT DIVIDE, WASHINGTON, FROM GOLD FORK OF KLICKITAT RIVER.

Fig. 210 shows the relative location of the headwaters of the various Diamond Fork of Klickitat River and the South Fork of Tieton River receive their waters from the peaks of the Goatrock Mountains, which are covered with snow throughout the year, thus insuring a constant supply. Gold Fork of Klickitat River drains a lower country, and has not so abundant a supply. The results of Mr. Arnold's investigation show the utter futility of any diversion from the Klickitat Basin into the Atanum Basin. The Gold Fork at the point marked B on the map (fig. 210) and shown in Pl. XXXVI, A, is approximately 1,000 feet below the Atanum ridge. The lowest point of the divide between Tieton River and the Gold Fork, as shown by leveling, is lower by several hundred feet than any point on the Atanum-Klickitat Divide, so that none of the waters of the Gold Fork, the only stream to be considered in this connection, could be carried over to the Atanum Basin. The divide between the two forks of Klickitat River has approximately the same elevation as the Atanum-Gold Fork Divide, with the Diamond Fork somewhere in the vicinity of 1,000 feet below the top of its divide. In Pl. XXXVI, B, is shown a view of the Atanum-Klickitat Divide taken from the banks of the Gold Fork. at the point marked B on the map. Pl. XXXVI, A, taken at the same point, shows, in the immediate foreground, a curve in the Gold Fork. When measured in August, 1900, the stream at the curve was discharging only about 5 second-feet.

The following is a list of the discharge measurements made in the Atanum and Klickitat basins by Mr. Arnold during his reconnaissance:

Date.	Stream.	Locality.	Dis- charge.
1900.	,		Secft.
August 15	North Fork of Atanum Creek	Sec. 18, T. 12 N., R. 16 E., near Tam- pico, Wash.	17
August 24	do	Sec. 12, T. 12 N., R. 15 E., near Tam- pico, Wash.	24
Do	South Fork of Atanum Creek	Sec. 32, T. 12 N., R. 15 E	9
August 18	Gold Fork of Klickitat River	Near mouth	48
Do	Diamond Fork of Klickitat River.	do	114

Discharge measurements in Atanum and Klickitat basins, Washington.

COWLITZ RIVER.

Cowlitz River is a glacier-fed stream rising in the Cascade Range, in the eastern part of Lewis County, Wash., through which it flows in a westerly and southwesterly direction, then flows southwesterly through Cowlitz County and enters Columbia River at Monticello. It is nearly 150 miles long, and is a large and rapid stream. Steamboats can ascend it nearly 40 miles. In the fall it is subject to great and sudden rises, which flood the bottom lands and often prove very

destructive. During a reconnaissance of the Mount Rainier Forest Reserve, made by Mr. Fred G. Plummer in 1899, the following interesting facts regarding the river and its drainage basin were collected.

In the fall of 1866 the Lower Cowlitz Valley was flooded. Ed. Davis, who drove the stage between Puget Sound and Columbia River, says he distinctly remembers the event, and that the accepted cause at that time was the warm chinook wind which followed the first fall of snow on the foothills. The Big Bottom, or Upper Cowlitz Valley, was not then settled, and the extent to which it was overflowed is only inferred from certain water marks dimly shown on the trees of the valley when in 1884 the pioneer settlers began their clearings.

On November 16, 1896, the river again suddenly overflowed its banks. At 1 o'clock a. m. it exceeded the ordinary high water, and in twenty hours had reached a height of 28 feet above its bed, or 10 feet above ordinary flood stage. At the center of sec. 20, T. 12 N., R. 7 E., there was 8 feet of water on the level, and at the center of section 18 there was 9 feet on the level. On November 18 to 19, 1897, the river again overflowed, reaching its extreme height at 3 a. m. on the latter day, at which time it was 1 foot lower than the flood of 1896. It is quite probable, however, that this flood contained more water than the flood of 1896, for it removed many drifts and other obstructions.

Almost synchronous with the overflow of 1896 Yakima River, on the eastern slope of the Cascade Mountains, rose 5 feet above its ordinary high stage. So far as known, this was an unprecedented rise for that stream.

The ordinary high stage of Cowlitz River is caused by the autumn rains and the melting snows and glaciers on its watershed immediately preceding the time of freezing. The fall of the stream succeeding this high stage is the result of the prevailing low temperature of winter, which permits the accumulation of snow and ice over large areas until the following spring, when melting produces a secondary high stage. If the winter season sets in early and a deep fall of snow is followed by rain succeeded by a warm chinook wind for several days, an unusual amount of drainage follows, and this at the season when the river is almost bank full, resulting in the flooding of a considerable area of the fertile bottom lands. These conditions are known to have existed in the years 1896 and 1897, when thermometers registered between 80 * and 90 degrees in the valley, which is partly protected from chinook winds. The testimony of the settlers is that it was noticeably and even uncomfortably warm at the time, a condition not unusual in the path of the chinook.

From data collected during the reconnaissance it appears that the watersheds of Cowlitz and Yakima rivers have the largest proportionate burnt and barren areas, and therefore the warm chinook winds are able to operate with greater effect than where the land is covered

with a protecting stand of timber. This is suggested as a contributory cause of the floods. The watersheds are in general so steep and their rock formations so impervious to water that the streams are very sensitive to varying temperatures and to precipitation. At Vance, near the western boundary of the Mount Rainier Forest Reserve and about 40 miles, by channel, from the head of Cowlitz River, the changes of level of the streams are very plainly apparent, the daily pulsation being from 6 inches to 1 foot during the time of melting snows. This pulsation is noticeable from the latter part of April to the middle of August, and reaches Vance at 5.00 a. m. of the day succeeding its start from the snow fields and glaciers. It may be assumed that the time of maximum melting is about 2.30 p. m., and the volume travels the 40 miles in $14\frac{1}{2}$ hours, or an average of almost 3 miles an hour.

Of course the upper valley is undergoing rapid erosion. This is noticeable as far down as Sulphur Springs. The swell butts of trees and often the exposed roots of the larger ones, the condition of the soil, and the river bars all bear testimony to this fact. Below Sulphur Springs the process is one of accretion, as shown by the exposed strata in wells and river banks, and by the fact that many of the trunks of the larger trees are buried 1 or 2 feet by river sands, the swell of the butt being partly lost. The upper stratum of scoriaceous sand which underlies this region is close to the surface near Sulphur Springs, but at Vance it is covered with a foot or more of sand containing loam and silt.

NORTHERN PACIFIC COAST DRAINAGE.

The measurement of four streams in that part of the State of Washington located between Puget Sound and the Pacific Ocean and known as the Olympic Peninsula has been continued during the year. The streams measured are Dungeness, Elwha, Calowa, and Soleduck rivers, all of which head in the Olympia Mountains, the first two flowing northwardly into the Strait of Juan de Fuca, and the last two flowing westwardly into the Pacific Ocean. They are measured at Dungeness, at McDonald, near Forks, and near Quillayute, respectively, with the results indicated in the following tables (pp. 458–461).

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neir

Estimated monthly discharge of Dungeness River at Dungeness, Wash.

[Drainage area, 145 square miles.]

tripe (**)	Dischar	rge in seco	nd-feet.		Ru	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	1, 144	392	667	41,012	4.60	5. 30
February	392	280	306	16, 994	2.11	2.19
March	3, 784	235	866	53, 248	5.98	6.89
April	1,336	392	667	39, 689	4.60	5.13
May	1,024	430	678	41, 689	4.68	5.39
June	1,912	568	918	54, 625	6.33	7.06
July	808	520	611	37, 569	4.21	4.85
August	544	268	359	22,074	2.48	2.86
September	280	218	244	14, 519	1.68	1.87
October	568	213	311	19, 123	2.14	2.47
November	496	235	281	16, 721	1.94	2.17
December	3, 928	373	1, 194	73, 416	8. 23	9.49
The year	3, 928	213	592	430, 679	4.08	55. 67

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 447; discharge measurements, page 446; rating table in Paper No. 52, page 522.

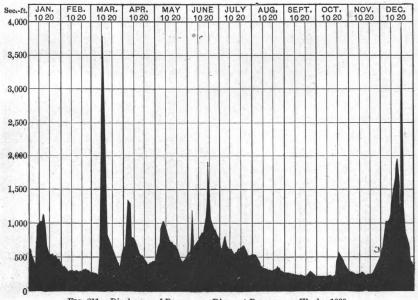


Fig. 211.—Discharge of Dungeness River at Dungeness, Wash., 1900.

Estimated monthly discharge of Elwha River at McDonald, Wash.

[Drainage area, 188 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	6,945	1,025	2,518	154, 826	13. 39	15. 44
February	1,566	690	920	51, 094	4.89	5. 09
March	14, 198	710	2,849	175, 178	15. 15	17.46
April	6, 945	930	1,744	103, 775	9. 28	10.35
May	2,951	1,100	1,918	117, 933	10. 20	11.76
June	8, 738	1,260	2, 789	165,957	14.83	16.55
July	1,892	810	1, 253	77, 044	6.67	7. 69
August	1, 310	650	941	57, 860	5.01	5. 77
September	1, 138	562	672	39, 987	3. 57	3. 99
October	5, 315	495	1, 327	81, 594	7.06	8.14
November	4,907	930	1,649	98,122	8.77	9.79
December	12, 242	1,566	4, 171	256, 465	22.19	25. 58
The year	14, 198	495	1,896	1, 379, 835	10.08	137. 61

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 448; discharge measurements, page 447; rating table in Paper No. 52, page 523.

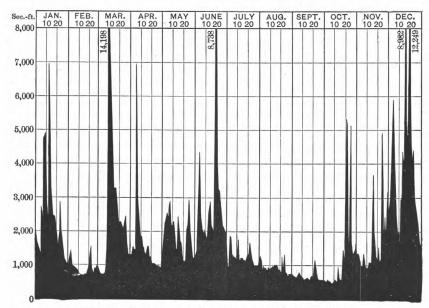


Fig. 212.—Discharge of Elwha River at McDonald, Wash., 1900.

Estimated monthly discharge of Calowa River near Forks, Wash.

[Drainage area, 213 square miles.]

	Dischar	ge in seco	nd-feet.		Rui	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.				3 3 4 1	5-35	
January	8,000	850	2, 943	180, 958	13.82	15.94
February	4,950	777	1,738	96, 523	8. 16	8. 49
March	12,600	665	2, 400	147, 570	11. 27	12.99
April	2, 475	237	762	45, 342	3.58	4.00
May	2,070	225	685	42, 119	3. 22	3. 71
June	6,600	330	-1,128	67, 121	5. 30	5. 91
July	687	190	460	28, 284	2. 16	2.49
August	507	110	169	10, 391	0.79	0.91
September	347	60	130	7,736	0.61	0.68
October	7,800	60	1,804	110, 924	8. 47	9.76
November	11,600	777	2, 307	137, 276	10.83	12.09
December	8, 100	1, 160	3, 111	191, 288	14.61	16. 84
The year	11,600	60	1,470	1, 065, 532	6. 90	93. 81

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 449; discharge measurements, page 448; rating table in Paper No. 52, page 523.

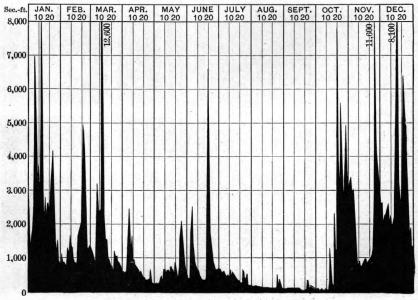


Fig. 213.—Discharge of Calowa River near Forks, Wash., 1900.

Estimated monthly discharge of Soleduck River near Quillayute, Wash.

[Drainage area, 272 square miles.]

	Dischar	ge in secon	nd-feet.	Total in acrefeet.	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
January	5,560	1, 180	2,597	159, 683	9.55	11.01
February	2,860	1,090	1,398	77, 641	5. 14	5. 35
March	12,580	1,045	2,663	163,742	9.79	11. 29
December 22 to 31			4, 419	87,650	16. 25	6.04

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 450; discharge measurements, page 449; rating table in Paper No. 52, page 523.

SAN FRANCISCO BAY DRAINAGE.

Sacramento River, rising in northern California and flowing south, and the San Joaquin, rising in the southern sierras and flowing northeast, drain the western slope of the Sierra Nevada, traverse what is often called the Valley of California, and meet near Suisun Bay, finally discharging their waters into the Pacific Ocean through San Francisco Bay. The Sacramento is measured at Jellys Ferry, and three of its tributaries are measured at favorable points along their courses, viz, North Yuba and Middle Yuba rivers near North San Juan, and Yuba River near Smartville. The following stations are also maintained: Stanislaus River near Oakdale, Tuolumne River at Lagrange, San Joaquin at Herndon, Kings near Red Mountain, and Kern River at First Point of Measurement. The results for 1900 are given in the following tables (pages 462 to 468) and illustrated in the accompanying hydrographs (figs. 214 to 217, inclusive).

462

PROGRESS OF STREAM MEASUREMENTS FOR 1900.

Estimated monthly discharge of Sacramento River at Jellys Ferry, Cal.

[Drainage area, 9,134 square miles.]

	Dischar	ge in secon	nd-feet.		Rui	n-off.
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January11	9,700	10, 400	30, 661	1, 885, 271	3. 36	- 3.88
February 2	24, 800	7,800	11,687	649, 063	1.28	1. 33
March	23,000	10,700	23, 288	1, 431, 923	2.55	2.94
April 1	16, 700	8,630	12,082	718, 929	1.32	1.47
May	19, 780	6, 265	9,572	588, 559	1.05	1. 21
June	6, 265	4,760	5, 477	325, 904	0.60	0. 67
July	4,760	3,805	4, 212	258, 986	0.46	0.53
August	3, 805	3, 805	3, 805	233, 960	0.42	0.48
September	5, 170	3,630	3, 981	236, 886	0.44	0.49
October	21,520	3,805	6, 381	392, 352	0.70	0.81
November	28, 800	4,560	8, 205	488, 231	0.90	1.00
December	80, 100	6,030	15, 553	956, 317	1.70	1.96
The year 12	23,000	3,630	11, 242	8, 166, 381	1.23	16. 77

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 451; discharge measurements, page 450; rating table in Paper No. 52, page 523.

Estimated monthly discharge of North Yuba River near North San Juan, Cal.

[Drainage area, 483 square miles.]

	Discharge in second-feet.				Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.	- 7					
July	630	350	460	28, 284	0.95	1.10
August	350	280	311	19, 123	0.64	0.74
September	355	265	286	17,018	0.59	0.66
October 1 to 13			493	12,712	1.02	0.49

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 451.

Estimated monthly discharge of Middle Yuba River near North San Juan, Cal.

[Drainage area, 205 square miles.]

	Dischar	ge in secon	id-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.		Second- feet per square mile.	Depth in inches.	
1900.						
July	191	80	128	7,870	0.62	0.71
August	80	68	74	4, 550	0.36	0. 42
September	100	60	67	3, 987	0.33	0.37
October 1 to 13			107	2,759	0.52	0. 25

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 452.

Estimated monthly discharge of Yuba River near Smartville, Cal.

[Drainage area, 1,211 square miles.]

	Dischar	ge in secon	id-feet.	Total in acrefeet.	Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.		Second- feet per square mile.	Depth in inches.
1900.						
July	1, 100	545	724	44, 517	0.60	0.69
August	580	400	480	29, 514	0.40	0.46
September	736	360	458	27, 253	0.38	0.42
October 1 to 13			1,538	39,658	1.27	0.61

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 453; discharge measurements, page 452.

Estimated monthly discharge of Stanislaus River near Oakdale, Cal.

[Drainage area, 1,051 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	7,050	820	1,944	119,532	1.85	2. 13
February	1, 100	540	700	38, 876	0.67	0.70
March	2,640	540	1,829	112, 461	1.74	2.01
April	3,000	1, 260	1, 761	104, 787	1.68	1.87
May	4, 377	1, 260	3, 343	205, 553	3. 18	3. 67
June	3, 125	960	1,863	110, 856	1.77	1.97
July	960	70	349	21, 459	0.33	0.38
August	110	30	64	3, 935	0.06	0.07
September	70	30	46	2,737	0.04	0.04
October	2, 760	70	448	27, 546	0.43	0.49
November	6,037	310	1, 220	72, 595	1.16	1. 29
December	1,640	610	871	53, 556	0.83	0.95
The year	7,050	30	1, 203	873, 893	1.15	15. 57

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 456; rating table in Paper No. 52, page 523.

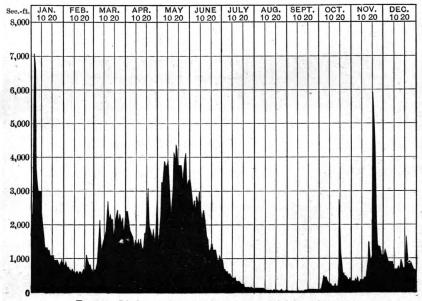


Fig. 214.—Discharge of Stanislaus River near Oakdale, Cal., 1900.

Estimated monthly discharge of Tuolumne River at Lagrange, Cal.

[Drainage area, 1,501 square miles.]

	Dischar	ge in secon	id-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	13, 160	1,060	2,384	146,586	1.59	1.83
February	1,300	750	967	53, 704	0.64	0.67
March	3, 100	950	2, 343	144,065	1.56	1.80
April	4, 320	1, 440	2,389	142, 155	1.59	1.77
May	9, 320	3, 100	6, 796	417, 870	4.53	5. 23
June	8,680	2, 285	5, 291	314, 836	3.53	3.94
July	1,740	140	694	42,672	0.46	0.53
August	140	0	43	2,644	0.03	0.03
September	110	0	11	655	0.01	0.01
October	5, 760	35	1,228	75, 507	0.82	0.94
November	14, 440	410	2,536	150, 902	1.69	1.89
December	2,080	850	1,332	81, 902	0.89	1.02
The year	14, 440	0	2, 160	1, 573, 498	1.45	19.66

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 457; rating table in Paper No. 52, page 523.

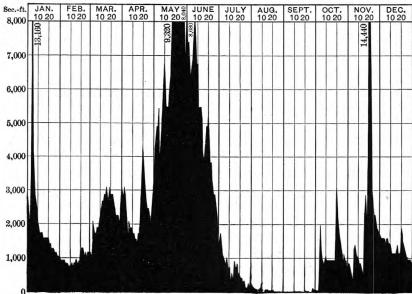


Fig. 215.—Discharge of Tuolumne River at Lagrange, Cal., 1900.

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Estimated monthly discharge of San Joaquin River at Herndon, Cal.
[Drainage area, 1,637 square miles.]

	Dischar	rge in secon	nd-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	15, 932	745	2, 244	137, 978	1.37	1.58
February	745	350	534	29, 657	0.33	0.34
March	2,780	640	1,748	107, 480	1.07	1.23
April	2,780	1,520	2,060	122, 578	1.26	1.41
May	9,730	2, 170	5, 725	352, 016	3.50	4.04
June	8,674	3,620	5, 728	340, 840	3.50	3.90
July	3, 445	630	1,642	100, 962	1.00	1.15
August	630	240	390	23, 980	0.24	0.28
September	240	180	204	12, 139	0.13	0 14
October	990	180	451	27, 730	0.28	0.32
November	20,780	240	1,834	109, 130	1.12	1.25
December	1, 285	745	1,033	63, 517	0.63	0.72
The year	20, 780	180	1,966	1, 428, 007	1. 20	16. 36

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 459; rating table in Paper No. 52, page 523.

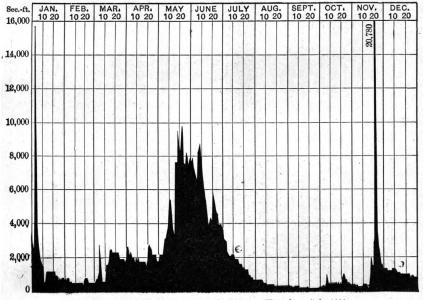


Fig. 216.—Discharge of San Joaquin River at Herndon, Cal., 1900.

Estimated monthly discharge of Kings River near Red Mountain, Cal. [Drainage area, 1,742 square miles.]

	Dischar	ge in secon	id-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	12,700	849	1,689	103,853	0.97	1.12
February	849	676	748	41,542	0.43	0.45
March	2, 584	728	1,712	105, 267	0.98	- 1. 13
April	2,852	1,546	2,098	124,840	1.20	1.34
May	9,400	1,930	5,881	361, 609	3.38	3.90
June	7,900	2,986	5, 127	305, 078	2.94	3. 27
July	2,584	572	1,278	78, 581	0.73	0.84
August	624	250	398	24, 472	0. 23	0. 26
September	520	215	301	17,911	0.17	0.19
October	440	215	309	19,000	0.18	0. 21
November	15, 700	250	1,310	77, 950	0.75	0.83
December	972	572	726	44, 640	0.42	0.48
The year	15,700	215	1,798	1, 304, 743	1.03	14.02

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 460; rating table in Paper No. 52, page 523.

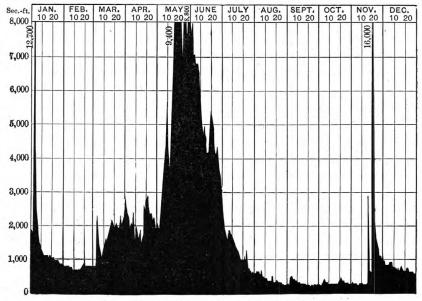


Fig. 217.—Discharge of Kings River near Red Mountain, Cal., 1900.

Estimated monthly discharge of Kern River, California, at First Point of Measurement.

[Drainage area, 2,345 square miles.]

	Dischar	ge in secon	id-feet.		Rur	n-off.
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.			16.2			
January	753	274	362	22, 258	0.15	0.17
February	313	250	280	15, 550	0.12	0.12
March	484	325	413	25, 394	0.18	0.21
April	567	395	472	28,086	0.20	0. 22
May	1,852	456	1, 111	68, 313	0.47	0.54
June	1,774	865	1, 283	76, 344	0.55	0.61
July	796	213	392	24, 103	0.17	0. 20
August	209	103	144	8,854	0.06	0.07
September	259	108	166	9,878	0.07	0.08
October	180	142	159	9,776	0.07	0.08
November	1,005	165	349	20, 767	0.15	0.17
December	430	299	373	22, 935	0.16	0.18
The year	1,852	103	459	332, 258	0. 20	2.65

Note.—Daily discharge for 1900 is given in Water-Supply Paper No. 51, page 463.

SALINAS RIVER.

Salinas River rises in the southern part of San Luis Obispo County, and flows northwest nearly parallel to the coast, draining the counties of San Luis Obispo and Monterey and emptying into Monterey Bay. A gaging station is maintained near the town of Salinas. For convenience it is considered in connection with the San Francisco Bay drainage.

Estimated monthly discharge of Salinas River near Salinas, Cal.

[Drainage area, 4,940 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January	2,700	223				
February	223	40	105	5, 831	0.02	0.02
March	223	25	73	4, 489	0.01	0.01
April	32	19	22	1,309	0.01	0.01
May	19	17	17	1,045	0.00	0.00
June	17	12	16	952	0.00	0.00
July	10	6	8	492	0.00	0.00
August	8	6	7	430	0.00	0.00
September	8	2	6	357	0.00	0.00
October	4	2	2	123	0.00	0.00
November	33,600	2	2, 413	143, 583	0.49	0.55
December	1,050	82	295	18, 139	0.06	0.07
The year	33, 600	2	318	228, 891	0.06	0.86

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 455; rating table in Paper No. 52, page 523.

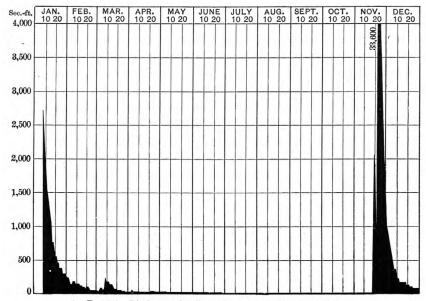


Fig. 218.—Discharge of Salinas River near Salinas, Cal., 1900.

RESERVOIR RECONNAISSANCES AND SURVEYS.1

During the year 1900 several detailed surveys were carried on within the watersheds of the rivers belonging to the San Francisco Bay drainage, in addition to the maintenance of systematic measurements of flow. The elaboration of this work was to a large extent made possible by cooperation on the part of the California Water and Forest Association. More than \$14,000 was devoted to the work, which included some investigations that were not completed until the spring of 1901. Of the sum mentioned, more than \$5,600 was contributed through the association.

The detailed surveys referred to were on Kings, San Joaquin, Kern, and Salinas rivers. Although the latter stream flows into the Pacific Ocean it has been considered in connection with the tributaries of San Francisco Bay. Examinations were also made on Yuba River, Stony Creek, and Cache Creek, all in the northern half of the central valley of California.

As a result of the work it has been developed that on the streams mentioned in the following table water can be made available for irrigation at an average cost of \$9.17 per acre-foot stored.

	Summary	of cost	of water-storage	and	power	plants.
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Stream,	Locality.	Capacity available.	Total cost.	Cost per acre-foot
		Acre-feet.		
Kings River	Pine Flat (140-foot dam)	78, 197	\$1,750,000	\$22.38
Do	Clarks Valley (105-foot dam)	. 217, 196	2, 206, 822	10.18
Do	Electric pumping plants (328 $\frac{1}{4}$ days' operation), for installation.	328, 500	1, 278, 629	3.89
Stony Creek	Briscoe	14, 435	218, 282	15.19
Do	East Park	25,000	206, 559	7.94
Do	Mill sites	44,000	698,000	15.87
Cache Creek	Little Indian Valley	40,000	453,000	11.38
Do	Clear Lake	80,000	452, 484	5.66
Salinas River	Foster (Arroyo Seco)	13,300	300, 475	22.60
Do	Currier (Arroyo Seco)	13,800	174, 800	12.6
. Do	Matthews (San Lorenzo)	8,000	193, 859	24. 20
Totals and average.		863, 428	7, 932, 910	9.19

a Plans and estimates to be revised.

It is believed that the addition of this amount of water for irrigation purposes in the interior valleys of California would increase the population there by 100,000 to 200,000, and that, deducting the cost of construction, it would result in a direct increase in land values of irrigated areas of fully \$20,000,000, irrespective of increase in value of town and city property, which would be a natural sequence.

The detailed reports of these surveys are being printed in the series of Water-Supply and Irrigation Papers, so that only a brief résumé

is here given of the principal facts developed by the field work and the subsequent computations. Immediately after the completion of the season's field work preliminary plans and estimates were prepared thereon for the California Water and Forest Association, subject to revision after the data had been more carefully worked up. This explains the minor differences which exist between the figures formerly given and those presented herewith.

KINGS RIVER.

During the winter, spring, and early summer there is obtainable from Kings River water in excess of that needed for the land under irrigation. If this surplus could be held for use during the dry season, many varieties of crops could be grown which are not cultivable under existing conditions, and it would be feasible to greatly extend the irrigated lands, especially along the foothills, where citrus and other high-priced fruits can be cultivated. It has been estimated that during 1900, under existing conditions, the profits from the irrigated districts around Fresno exceeded \$2,000,000. This shows what might be done by extending irrigation throughout the central valley.

The capacity of the canals diverting water from Kings River is approximately 4,000 cubic feet per second, and the low-water summer supply of the stream falls as low as 150 cubic feet per second. It is therefore evident that the late summer supply is wholly inadequate to the demands of the irrigators, and the division of it has resulted in much litigation. It is estimated that the canal companies have expended annually approximately \$40,000 in legal controversies over the water, representing 4 per cent interest on \$1,000,000, besides resulting in much bad feeling and no actual development. The Kings River canal companies have finally organized for the purpose of cooperating for the increase of the late summer supply of water, having decided that it is more profitable to expend money in construction than in litigation. They realize that they would be able to build a storage reservoir or a water-development plant for an annual interest charge not to exceed that now spent in litigation. In order to proportion the contributions for the investigation the canal companies deriving their water supply from the river stated the area covered by each canal as follows:

	Acres.
Fresno canal, whole system	160,000
Laguna canal	
Alta Irrigation Company's canal	50,000
People's canal	25,000
Last Chance canal	25,000
Centerville and Kingsburg canal	20,000
Murphy Slough Association canal	20,000
Lower Kings River	15,000
Fowler Switch canal	12,000

	Acres.
Stinson canal	12,000
Crescent cana!	12,000
Emigrants' canal	3,000
Liberty canal	
Total	379, 750

These figures probably are the total area irrigable under each canal instead of the areas actually irrigated.

RESERVOIR SITES.

The requisites of a reservoir site are numerous and exacting:

- (1) There must be an available water supply sufficient to fill the basin.
- (2) There must be a basin to hold this supply.
- (3) There must be a good dam site.
- (4) There must be suitable materials from which to make a dam.
- (5) The foundations must be able to satisfactorily sustain the dam.
- (6) There must be available lands upon which to put the water.
- (7) The entire project must be on a commercial basis.

There were on Kings River a large number of sites which were popularly supposed to be good, but which proved defective owing to the lack of some one of these vital requisites.

In the investigation of the large basin of the river, which was, from a scientific standpoint, practically unknown, two parties were equipped for the season's work. The first, a reconnaissance party, was placed in charge of Mr. E. G. Hamilton, topographer. The work of this party consisted chiefly of exploration. Mr. Hamilton was instructed to visit all portions of the drainage basin, to make instrumental examinations of all reservoir sites, and at the end of each month to report the character of the sites found. Where sites of merit were observed by the reconnaissance party they were noted. The second party was under the direction of Mr. H. E. Green, an engineer of extended experience in the construction of storage reservoirs, and its object was to make detailed surveys of the better sites found by the exploration party. The reconnaissance party visited and reported upon seven reservoir sites, four of which were surveyed by the surveying party.

The following instructions were given to the engineers for preliminary reports on the reservoir sites:

- 1. Give name of engineer in charge and date of survey.
- 2. Give name of locality.
- 3. Give streams tributary to site.
- 4. Give land title to site.
- 5. If possible, tie reservoir surveys to land surveys. The point of reservoir survey to be tied in is preferably the ends of the dam.
 - 6. If the land is not subdivided, tie reservoir survey to prominent natural objects.
 - 7. Estimate area of tributary drainage basin.
- 8. Give general statement of elevation of drainage basin and elevation of reservoir site.

- 9. State whether drainage basin is timbered or bare hills.
- 10. Compute water supply.
- 11. Give capacity of reservoir with various heights of dam.
- 12. State character of material for dam-earth, rock fill, or concrete.
- 13. For purposes of preliminary estimate consider-

Earthen dam.—Twenty feet wide on top, $2\frac{1}{2}$ to 1 slope on inner face, $1\frac{1}{2}$ to 1 on outer face. Describe the quality of the available earth, which should be a clay and sand; also give length of haul.

Rock fill.—Twenty feet wide on top; 1½ to 1 outer slope, 1 to 1 inner slope. State position of available rock supply; give probable cost of cement delivered on the ground, and available timber for inner face, and cost thereof.

Concrete dam.—State the proximity and relative elevation of quarries, the cost per barrel of cement delivered on the ground.

- 14. Report on probable foundations for dam.
- 15. Estimate on the cost of dam.
- 16. State cost per acre-foot of water stored and value per acre-foot of water stored.

The first part of the summer of 1900 was spent in exploring for reservoir sites in the higher portion of the Kings River drainage basin, but these investigations proved generally unsatisfactory.

The following sites were examined and wholly or partially surveyed. Long Meadow.—This reservoir site was surveyed in detail by Mr. Green. It is 5,200 feet above sea level, on Tenmile Creek, 4 miles above its junction with Kings River, in T. 13 S., R. 28 E., M. D. M. There are approximately 25 square miles of watershed. The reservoir site and most of the drainage basin are owned by the Sanger Lumber Company. The mean rainfall is estimated to be about 45.3 inches and the mean run-off 25,000 acre-feet, which is less than 50 per cent of the rainfall. On the basis of 2 second-feet per square mile, which is not unusual in drainage basins of this type, the run-off tributary to the dam site would be 36,500 acre-feet. A dam 170 feet high would give reservoir contents of 25,330 acre-feet. The most economical type of dam would be a rock-fill or loose rock dam with a plank face. The cost of the structure is estimated at \$713,715, or at the rate of \$28 per acre-foot of storage capacity. This is the cheapest type of dam that could be built here, and the high rate per acre-foot manifestly condemns the proposition for the present.

East Lake and Reflection Lake.—Several small lakes near the summit of the range were investigated during the season. East Lake was surveyed and found to have a capacity, within reasonable limits, of 4,554 acre-feet, and Reflection Lake, near by, of 700 acre-feet. These lakes apparently are formed by slides of loose rock, or glacial moraines, which have clogged the natural drainage lines. Water readily passes through this loose rock, and it is believed that it would not be practicable to obtain impervious foundations to bed rock on this class of material. The cost of delivering cement at these sites would be from \$15 to \$20 per barrel, owing to their inaccessibility, and they are condemned as impracticable.

Granite Basin.—This reservoir site, situated between the South and Middle forks of Kings River and between Kanawyer's store and Simpson Meadows, was visited and a preliminary survey was made. The elevation of the site is about 10,000 feet. There are two outlets from the basin requiring dams, one 750 feet long on top and 140 feet high, the other 900 feet long and 130 feet high. The capacity of the site would be 10,350 acre-feet. The drainage basin does not exceed 6 square miles, and the location is exceedingly difficult of access. It is therefore believed that the site is not one of merit.

Dusy Meadows.—This reservoir site is in Fresno County, on the North Fork of Kings River, in sec. 36, T. 10 S., R. 27 E., and sec. 31, T. 10 S., R. 28 E. The area of the watershed is 144 square miles. With a rainfall of 39 inches and a run-off of 33 per cent, there would, in average years, be available for storage 88,000 acre-feet. The elevation of the watershed is approximately 9,000 feet. The elevation of the dam site is 6,300 feet. Rock and lumber are available for a dam of the rock-fill type. A dam 125 feet high would store 16,850 acre-feet, and would cost approximately \$538,860, or \$32 per acre-foot. It is therefore not a site of value at present, in view of other possibilities on the river.

Clarks Valley.—This reservoir site is in Fresno County, 16 miles east of the Southern Pacific Railroad station at Sanger. It lies between low foothills and the main range, and commands in elevation all of the canals diverting water from Kings River except the Gould ditch. It is within 2 or 3 miles of the headworks of most of the canals, and the Alta Irrigation Company's canal passes within a mile of the proposed outlet from the reservoir. It is not upon the main stream. The local drainage line is known as Wahtoke Creek, which receives the run-off from 33 square miles of the western face of the sierras. The average elevation of the drainage basin is 1,000 feet. Assuming the average rainfall to be 20 inches and the run-off to be 12 per cent, we have 4,224 acre-feet of water locally available for storage. As the local drainage basin is small, and as the reservoir site would be filled by a diversion canal from the main river, the silt problem would be eliminated. The elevation at base of dam is 429 feet, as determined by levels from the Southern Pacific Railroad station at Sanger. capacity of the reservoir to the 80-foot flow line would be 120,499 acrefeet and to the 100-foot flow line 217,196 acre-feet.

The basin is known locally as Clarks Valley. Three dams will be necessary to close all of the openings. Earth dams have been estimated upon, as that material exists in abundance, largely in the nature of a reddish clay containing gravel and sand, a soil frequently found near the foothills of disintegrating granitic mountains.

It is estimated that the cost of the three dams—the rights of way, outlets, and diversion canal to control the 100-foot water level, giving

a storage capacity of 217,196 acre-feet—would be \$1,342,895. This is on a basis of dams with a maximum height of 105 feet, 20 feet wide on top, with slopes $2\frac{1}{2}$ to 1 on the inner face and $1\frac{1}{2}$ to 1 on the outer face, and containing 6,714,470 cubic yards of earth, which it is believed can be placed in position by mechanical devices at a cost ranging from 17 to 20 cents a yard.

It would be necessary to construct approximately 10 miles of diversion conduits from Kings River to the head of the reservoir site. As designed, the entrance to the site will be by means of a tunnel through an intervening granitic range. The line will consist of 7,000 feet of tunnel, with 3,600 feet of approaches, and 43,000 feet of canal, which will be partly in rock. The conduit should have a capacity of 1,250 cubic feet per second, or sufficient to deliver 2,500 acre-feet of water per day. Spillways, outlet tunnel, gates, and headworks are included in the estimate, which, with rights of way and sundry expenses, amounts to \$2,206,822, being \$10.15 per acre-foot stored.

Estimating the interest at 6 per cent, the taxes at eight-tenths of 1 per cent of the cost, and the maintenance at \$10,000 per annum, we have an annual charge against the plant of \$160,064. As this reservoir would be in the process of filling until approximately the first of July, and as the withdrawal for irrigation purposes would begin immediately thereafter, it is fair to assume that the loss by evaporation would not exceed 5 per cent, leaving available for distribution to the canal system about 206,336 acre-feet. With the annual charges at \$160,064 and the total amount delivered from the reservoir 206,336 acre-feet, the annual charge per acre-foot would amount to 78 cents.

During the greater portion of the irrigation season most of the canals of Kings River are carrying some water, and it is reasonable to assume that the larger part of the loss due to seepage would be met by this initial volume. The increased loss due to the delivery of a larger volume of water through the canals is problematical, depending on the distance which the water would have to be conveyed. A reasonable assumption might be that 15 per cent of the volume would be lost. The 78 cents per acre-foot would then represent 85 per cent of the ultimate cost of the water delivered to the irrigators, or 92 cents per acre-foot for water upon the field. It may be assumed that the cost of maintaining the distribution system would be the same whether water is run through it under present conditions or is regulated as described.

If the dams should be built to a maximum height of 85 feet, impounding water to the 80-foot level, the diversion canal to fill the reservoir should have a capacity of 525 second-feet. The lengths of the conduit would remain the same, but the cross section would be reduced, and the grade would admit of raising the dams to the higher level in case it were found desirable to do so in the future. The cost of works to

control the 80-foot level would be about \$1,331,025, and the resulting storage capacity 120,499 acre-feet, or at the rate of \$11.05 per acre-foot. Figuring the interest at 6 per cent, the taxes at eight-tenths of 1 per cent, and the maintenance at \$10,000, and assuming that the loss by evaporation will be 5 per cent, we have an annual charge of 88 cents per acre-foot stored. If 15 per cent of the volume stored is lost in transmission to the irrigated lands, the ultimate cost to the irrigator will be \$1.04 per acre-foot delivered.

With regard to the question of water supply it is assumed that 4,224 acre-feet of water will be furnished from the local drainage basin tributary to this site. The storage capacity of the reservoir with 105-foot dams is 217,196 acre-feet. Deducting the 4,224 acre-feet from local rainfall gives 212,972 acre-feet net to be supplied from Kings River. In order to determine whether a canal with a capacity of 1,250 second-feet would fill this reservoir, the following assumptions have been made: (1) That the flow of Kings River up to 1,250 secondfeet can be diverted to the reservoir during the months of November, December, January, and February; and (2) that the combined capacity of all canals diverting water from the river during the remaining months is 4,000 second-feet, and that any volumes in the river above that amount are available for storage, the amount thus diverted depending upon the size of the canal to the reservoir. During the last five years the Geological Survey has maintained a gaging station on the river near the proposed point of diversion. The period has been one of unusual drought, and it is believed that an estimate based thereon will be conservative for the future. From these records of discharge it is shown that during the season of 1897-98—which is the one of smallest flow and not likely to occur again in a generation-190,668 acre-feet could have been diverted by such a canal as the one proposed. If we add to this the supply from the local drainage, we have a total of 194,892 acre-feet. This is 22,304 acre-feet, or 9½ per cent, less than the maximum capacity of the reservoir. During the season of 1898-99, which was also one of great drought, there would have been available 205,819 acre-feet, or 5 per cent less than the maximum storage capacity. During the remaining three years the supply would have been ample. It is believed, however, that if a midsummer supply could be assured to the irrigators extensive irrigation would not begin as early as March or extend as late as November, and, consequently, that some water would be available for storage during those months. Under these conditions the supply would have been sufficient to completely fill the reservoir.

Proceeding on a similar basis, a canal with a capacity of 525 cubic feet per second would every year have filled the reservoir controlled by 85-foot dams without diverting any water during the months of October or March, except when the supply in the river was more than the combined capacity of all the canals.

It might be stated that the diversion of water for this reservoir would in no way interfere with the use of the water in Kings River for power purposes, a project which is discussed further on.

Summarizing, it has been shown (1) that it is feasible to construct a great storage reservoir at Clarks Valley, capable of supplying more than 200,000 acre-feet of water, and (2) that there is water to fill the reservoir. It is believed that this amount is greater than would be necessary to serve the lands now covered by canals under Kings River, and that many thousand acres not now irrigated could be thus brought under cultivation. These new lands should, preferably, be those along the foothills from Sanger toward Porterville, a locality favorable for the production of citrus fruits. These dry lands are now worth from \$20 to \$30 an acre, but with a reliable water right it is believed that their value would increase to from \$100 to \$150 an acre. If they could be furnished with water to the extent of 2 feet in depth at a cost of \$20 gross, or an annual charge of \$2 an acre, it will be seen that there would be a large profit in the undertaking. At present there is an ample supply of water to meet all demands on Kings River to the first of July. For approximately one hundred days thereafter, however, or during the growing season, there is a deficit, which the water from the reservoir could supply. If 217,196 acre-feet of water were withdrawn in one hundred days, it would be equivalent to a continuous flow during that period of 1,086 cubic feet per second.

It is believed that the productiveness of this irrigation district—the greatest in California—could be almost doubled by the erection of these works.

Pine Flat.—This reservoir site is on the main Kings River, just above the mouth of Mill Creek. Its elevation is such that its conversion into a reservoir would not interfere with the use of the river for generating power. The dam site is at practically the diversion point of the proposed canal to the Clarks Valley reservoir, and the site is of value not alone as a storage reservoir, but also as a regulating reservoir for the control of the flood waters and for their diversion to Clarks Valley. The elevation of the site is sufficient to command a large portion of the foothills north and south of the river, which are now entirely without a water supply, and upon which high-priced citrus fruits could be raised. The dam should be a long masonry overflow weir of the gravity type, with a maximum height of 140 feet, storing 78,197 acre-feet of water. The cost would be about \$1,750,000, or at the rate of \$23.38 per acre-foot stored. The reservoir would be filled each year. The water of Kings River is remarkably free from silt, and that problem would not, therefore, be a factor.

POWER DEVELOPMENT.

About August 15 Mr. Green was instructed to begin an investigation of the possibilities of developing a water power on Kings River to furnish electricity for pumping the underground waters around Fresno. At the same time Mr. Louis Mesmer was instructed to begin a study of the underground water in the district irrigated from the river, and Mr. Lewis A. Hicks, who has developed the pumping plant of the Kern County Land Company near Bakersfield, was employed to make estimates of the cost of pumping, on the assumption that power sufficient to raise 500 cubic feet of water per second, or 1,000 acre-feet per day, could be obtained from Kings River.

A vertical angle traverse was made of the canyon of the river from the mouth of Mill Creek to the junction of the Middle and South forks, and then up the Middle Fork to the Tehipiti, and for a mile up the South Fork. The grade of the main river to the junction is quite flat. The grade of the Middle Fork is steep, showing an available head of 650 feet in the first 14,000 feet of conduit above the junction. Probably as much or more power would be obtainable from the South Fork above its mouth, but the investigations upon that tributary were stopped by storms. The work done, however, shows that these results or better can be obtained; but additional stream measurements and surveys should be made before construction is begun.

The following preliminary estimate of the cost of a conduit to carry sufficient water out of Kings River to generate 6,250 horsepower, with a minimum water supply of 85 second-feet, embraces everything necessary, from the intake to the penstock. As planned, the works will be in one of the canyons of the river; the tunnels will be in granite, 6 feet by 6 feet in the clear, and unlined; the adits in the canyons will be arched over, allowing the storm waters free passage. The conduit upon which the estimates are based is designed to carry 180 cubic feet of water per second; the grades provided were 12.67 feet per mile. With 150 second-feet and an available head of 650 feet at the power house, it is estimated that there would be available 11,000 horsepower, and with 180 second-feet 13,330 horsepower. The cost of the works is estimated as follows:

Estimated cost of power plant on Kings River.

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Road into canyon, 6 miles at \$8,500	\$51,000
Bridge across South Fork	2,500
Trails, 6 miles at \$500.	
Tunnels (Burleigh work), 14,000 feet at \$12	
Headworks, including masonry diverting dam, shaft for inl	
tower, entrance gate, screen, etc	
Adits to tunnels, 14 at \$500.	
	236, 500
Engineering and contingencies, 15 per cent.	
Engineering and contingencies, 15 per cent	30, 470
Total	971 975

Observations at the Red Mountain gaging station on the main river, covering a period of fifteen months—July, August, and September of the years 1896 to 1900, inclusive—indicate that had the proposed tun-

nel conduit been in operation during that time it could have been filled from the Middle Fork to its maximum capacity of 180 second-feet during the whole of July of each year; that during the whole of August of the same years it could have been supplied with 100 second-feet of water; and that for 75 per cent of the time it could have had 150 second-feet. During September of the same five years three-fifths of the time a supply of 100 second-feet could have been obtained, and an average of 85 second-feet during the exceptionally dry years of 1898 and 1899. With a head of 650 feet the 85 second-feet would yield 6,250 horsepower. During all of the remaining months of the year the conduit would have been full, furnishing 13,300 horsepower.

UNDERGROUND WATERS.

Between September 24 and November 13, 1900, the district irrigated from the Kings River canals was inspected by Mr. Louis Mesmer, well observer, to determine the underground water supply. During that time more than 850 wells were visited, and the various features of interest concerning them were determined where possible, including an examination of the quality of the water, the strata through which the well passed, the depth to the water plane, the amount of water available, the general character of the well, its location, the owner's name, etc. A map has been prepared showing the location of each well in the area extending practically from San Joaquin River to 8 miles south of Hanford. This map and the data accumulated will be presented with the detailed report—Water-Supply Paper No. 58. The investigation shows that northerly and westerly from Fresno the water plane is at a depth of approximately 15 feet from the surface, between Fresno and Kings River it is at a depth of approximately 10 feet, and between Kings River and Hanford at a depth of about 15 feet. In the district lying under the Alta Irrigation Company's canal the water plane varies from a depth of 15 feet to a depth of 30 feet.

Throughout the locality the underlying soil is to a large extent granitic sand, which below a depth of 10 or 15 feet is thoroughly charged or saturated with water. The surface water is more or less alkaline, and it is not advisable to use it for irrigation. Water below a depth not to exceed 50 feet can, however, be considered satisfactory for the purpose. This is based on tests made of the wells in the district, some of them being in the sections where there were the strongest alkaline surface indications. In every case the lower water was found to be good, and when the surface strata are penetrated it rises to the elevation indicated in the preceding paragraph.

There have been but few attempts to pump water in larger quantity than that required for domestic purposes; but this supply is ample from a 2-inch screw pipe put down to an average depth of 50 feet, landing the pipe on a stratum of clay and then boring through the clay and allowing the water to come in from the bottom of the hole.

It is the common impression that by boring through two or three strata of clay or hardpan all of the surface water is shut off, thus exempting the consumers from one of the supposed causes of malaria. It should not be inferred that an abundant supply of wat r can not be obtained at 20 or 30 feet, for it can, but the quality is not so good.

One of the largest pumping plants in the district is that of the Fresno Domestic Water Company, the water supply for which is obtained from unperforated wells at a depth of 600 feet. In this case there is an ample supply for a city of 12,000 people from a lot 50 by 150 feet. A number of wells have also been put down in and around Fresno for street sprinkling. These wells are 8 inches in diameter, not more than 70 feet deep, and unperforated, except perhaps the lower joint or two of the pipe, so that practically all of the water comes from the bottom. Good wells have been thus obtained, and with a 2½-horsepower engine they fill a 1,250-gallon tank 9 feet above the surface in five minutes, or at the rate of 250 gallons per minute, lowering the water plane not to exceed 5 or 6 feet below the normal elevation in the well casing. A few small pumping plants have also been installed, one 5 miles east of Fresno, on Minnewawa ranch, several around Selma, and two near Wild Flower. In each case the yield is at least 0.5 second-foot to a 7-inch unperforated well not more than 20 feet deep, with a lift not exceeding 20 feet.

It is recommended that wells of 10-inch or 12-inch casing be put down to a depth of about 100 feet, and not be perforated under 50 feet, thereby shutting off all possible chance of drawing from the more or less alkaline surface water. It is probable that such wells would furnish 1 second-foot each. A well driller in Selma offers to put down wells 12 inches in diameter to a depth of 150 feet, guaranteed to furnish $1\frac{1}{2}$ second-feet to the well, without perforations, at a cost not to exceed \$300 each.

The permanent lowering of the water plane in the irrigation district between Fresno and Guernsey Station, south of Hanford, to a depth of about 20 feet from the surface, would largely check the accumulations of alkaline salts that are gathering every year and seriously injuring thousands of acres of good farming land. The application of the water to irrigation purposes would tend to carry down the salts, resulting in the redemption of most of this land.

To summarize, it may be stated that a water supply of ample quantity can be obtained generally throughout this district with an average lift not to exceed 15 feet, and it is believed that the supply would be satisfactory for irrigation purposes.

PUMPING PLANTS.

As already stated, Mr. Lewis A. Hicks was employed to prepare estimates of the cost of generating electric power from Kings River

and transmitting it to the valley for use in pumping the underground waters for irrigation. The following interesting facts are taken from his report.

The physical data as to area, elevation, and character of tributary watershed, the amount of run-off during the dry years just past, and the available fall that could be obtained by a development of short conduits and tunnels, indicate that sufficient power could be continuously generated at the proposed power-house site to provide the energy required for pumping and cover all losses incidental to its transmission and transformation.

Two pole lines have been laid out to Centerville, with distribution lines to Fresno and Hanford, through the center of the irrigated districts. The distances, climate factors, and voltage selected are all well within the attained limits of existing lines and experience elsewhere, as it has been considered desirable to select a medium line pressure which will permit the use of standard apparatus already developed. The grouping of pumps has been planned to attain the greatest economy in cost of transmission lines, step-down transformers, and motors, and also to permit the most economical use of the water from the combined flow from several pumps to obtain a satisfactory irrigating head.

The transmission voltage will extend to step-down transformers of suitable capacity for four pumping stations, a quarter of a mile or more apart, situated radially from the transformer house. Vertical 2,000-volt induction motors, direct coupled, will drive the centrifugal pumps, both motors and pumps being mounted in steel frames capable of adjustment in vertical and horizontal planes. Each station will be provided with mechanical devices for priming the pumps and with an automatic switch throw for cutting out the motors from the line in case of disturbance. The pits have been designed with a curbing of concrete panels reenforced with expanded metal and set in T steel frames, to remove from this usually perishable part of the plant the element of deterioration and fire risk.

The character of the deposits of gravel, sand, and clay which have been carried from the sierras by the lateral drainage entering San Joaquin Valley from the east is very similar throughout its length, and they constitute merely the repetition, on a large scale, of the familiar fan-shaped cone which can be seen wherever a small arroyo debouches from the hills into a wider valley of relatively flat gradients. The depth of these deposits in San Joaquin Valley is known to be more than 1,000 feet. In the process of deposition the surface drainage channels shifted radially from the mouth of the canyon, and the heavier cobblestones and gravel were soon deposited, while the finer sands and clays in suspension were carried on. As this process continued, and the water-borne detritus built up the levels of the valley,

the surface channels crossed and intersected the older channels beneath in every direction, so that while there is no continuity of strata laterally at the same depth, yet the whole country is so underlain with channels that wherever wells are bored water-bearing sand is sure to be encountered somewhere.

The delta of Kings River, comprising most of the irrigated territory covered by the associated canals, is characterized by remarkably thick superficial strata of clay, 15 to 60 feet in depth, underlain with fine sand, which yields a large amount of water through open-bottom wells. This formation is more favorable to the development of large quantities of water than are those farther south, where the clay strata are not of sufficient thickness to form a safe roof over the cavity produced in the sand by pumping, and where perforation must be resorted to. The slope of the Kings River district at right angles to the axis of San Joaquin Valley is from 5 to 20 feet per mile, and the gravel water storage thus afforded above the level of the valley supplies the underlying sand strata with water, which has a well-defined hydraulic grade and percolation toward the trough of the valley, where the heavy clay deposits cap the water-bearing sand and offer the requisite conditions for artesian pressure.

In dry years most of the run-off of Kings River, amounting to 800,000 acre-feet, is absorbed by seepage loss and the irrigation of its delta lands, and it is probable that the mean annual infiltration from river, canals, and irrigation exceeds 500,000 acre-feet. The storage capacity of the area affected by this infiltration above the level to which the water plane might be reduced by pumping continuously can not be less than 2,000,000 acre-feet. The experience in Kern County with pumping plants having a combined capacity of 75,000 acre-feet annually is that the water plane is maintained, notwithstanding continuous pumping, where the wells are in proximity to canals in use or where surface irrigation from gravity ditches takes place around the wells.

A careful study of the data furnished by the extensive survey of the water plane in the Kings River delta by Mr. Mesmer, together with the results of inquiries made of well borers familiar with the district and of much experience with conditions obtaining in connection with irrigation pumping on a large scale, warrant the statement that the water supply can be depended upon to furnish continuously 300,000 acre-feet per annum. It will be necessary to sink test wells wherever permanent plants are contemplated, and this expense has been considered in the estimates. Of 50 wells put down in Kern County only 30 were considered suitable for the installation of pumps.

The question of land purchases for sites for pumping stations has also been considered, on the basis that suitable locations can be obtained on lands owned by members of the association, who would be willing, for a nominal consideration, to grant ground room to the extent of a quarter of an acre for each station, together with right of way for pole lines and ditches connected therewith.

The total cost of hydraulic development, electrical equipment, transmission lines, and pumping stations, exclusive of local administration and interest charges during construction, might be stated as \$3.50 per acre-foot of developed capacity, on the basis of operation of the pumps throughout the entire year. For shorter periods of operation the cost per acre-foot of capacity would be proportionally greater. This figure furnishes a basis of comparison as to the relative amount of capital required to be invested to obtain the beneficial use of an acre of water by means of storage reservoirs and pumps. In making such a comparison it should be remembered that while the pumps provide an acre-foot of water very close to the point of use, the water from the most favorably located storage reservoir is subjected to a loss from seepage in the channels through which it is conveyed to the lands where used.

The estimated cost of operation of the plant is \$157,611 per annum, made up as follows:

Estimate of cost of operating power plant and pumping station.

Interest, 6 per cent on bonded indebtedness	\$76,718
Taxes, 2 per cent on 60 per cent valuation	
Depreciation and maintenance	
Operating expenses:	
Power house	
Pumping station 18,000	
	30,000
Administration and local expenses	5,000
Insurance and sundry expenses	5,000
Total	157, 611

This expense will remain substantially constant whether or not the pumps are operated, as less than 20 per cent of the total would be affected by discontinuing the operation of the plant.

The actual continuous operating time of all the pumps in a large system has been as high as 98 per cent, and that of the plant in contemplation may safely be estimated at 90 per cent, or 1,000 (acre-feet) $\times 365$ (days) $\times 0.9$ (time) = 328,500 acre-feet capacity, which divided into the annual expense gives 48 cents per acre-foot as the cost of operation.

In this estimate the item of depreciation has been calculated from a consideration of the relative life of the various perishable elements, and is ample to cover deterioration and provide for maintenance and the renewal of the plant when necessary. The item of operating expenses is a conservative estimate based on existing pumping plants and pumping stations.

The pumping plants have been designed for a daily capacity of 1,000 acre-feet, to meet the necessity of augmenting the midsummer and late summer supply, and if the beneficial use of the water is confined to that period the cost per acre-foot would increase to \$1.50. existence of a new supply of this magnitude would, however, insure the productive utilization of lands which are now without any assured rights to the benefits of prior appropriation, and it seems reasonable to assume that sufficient revenue would be received from country lighting and the wholesale disposal of power in Fresno and Hanford during periods when the river flow exceeds the diverting capacity of the canals to make the cost of pumping proportionate to the total capacity of the plant, or, say, 50 cents per acre-foot. It seems proper, however, to consider the matter in its worst aspect, and hence we may say that the cost of delivering stored reservoir water on the lands to be irrigated is the measure of unit prices which the irrigator can afford to pay for pumped water. If the pumping plants were shut down from February 1 until July 1, the period when the river flow is usually adequate, and no revenue received from any other source than pumping, the output and cost for the rest of the year would be 7 $(months) \times 30 (days) \times 1,000 (acre-feet) \times 0.9 (time) = 189,000 acre-feet,$ which divided into the annual expense would give 83 cents per acre-foot.

It may be said that this figure should be still further increased, because no beneficial use could be made of the water during the fall months; but, on the other hand, it is certain that the plant would never be shut down, for there would always be a demand for surplus power, and experience elsewhere in San Joaquin Valley demonstrates that forage crops are possible wherever water is available. These considerations lead to the conclusion that by the methods indicated the cost of pumped water on lands under the associated canals will not exceed 75 cents per acre-foot.

SALINAS RIVER.

During the months of May, June, July, and August, 1900, a reconnaissance survey was made, under the direction of Prof. Charles D. Marx, of Stanford University, of a portion of the drainage basin of Salinas River. During the investigation the following reservoir sites were examined: Foster, Currier, The Pools, Petit, Leigh, Pinkerton, and Matthews.

The reconnaissance by Professor Marx was followed, in the fall of 1900, by an examination of the wells of Salinas Valley by Mr. W. W. Cockins, jr., and a geologic and engineering investigation by Mr. Homer Hamlin, the work being under the general direction of Mr. J. B. Lippincott. Gaging stations were established on the Arroyo Seco, San Antonio, Nacimento, and San Lorenzo tributaries, and measurements of the trunk stream were made near Salinas, at the Monterey

road bridge. The latter examinations were extended through the year 1901. The investigations in the field and office have led to numerous revisions of the original plans and estimates, which were based upon a reconnaissance, and, as stated at that time, were conditional upon further study. In some instances dams of entirely different types and heights are now deemed desirable, and it is probable that additional examinations, which are necessary in some cases, will lead to other changes in the future. The California Water and Forest Association contributed \$500 toward these investigations, and through its efforts Monterey County allotted \$1,000 additional, while the Geological Survey has expended \$4,722.80 of its funds on the work.

The drainage basin of Salinas River contains 4,780 square miles. The problems encountered in determining a satisfactory method of increasing the available water supply were numerous and difficult. The streams are of a torrential nature, with few large and valuable reservoir sites, and offer unsatisfactory conditions for the generation of water power, which it was hoped could be applied to pumping from the flat valley lands, where an abundant supply of ground water exists. Geologic investigations of the bituminous shales that occur in many portions of the drainage basin were then made in the hope of finding oil in sufficient quantities to furnish a cheap fuel for prospective pumping plants, but these investigations led to an adverse report on the prospect of obtaining oil in commercial quantities. The details of the entire study will be printed in the series of Water-Supply and Irrigation Papers. The estimates given herewith are subject to further revision.

It is believed that the Currier, San Lorenzo, and Foster sites could be improved to advantage. Their aggregate annual yield would be 35,100 acre-feet, at a total cost of \$669,134, or at the rate of \$19.06 per acre-foot for installation. Considering interest, maintenance, and operation, the water could be delivered from the reservoirs at an annual cost of \$1.50 per acre-foot. The flow of the streams would probably be sufficient for diversion for winter irrigation, and the reservoir water could be held for late spring and summer irrigation. The amount of loss of the reservoir water in transit can not be stated, as data are not available, and it will depend upon the condition of the canal lining. In all probability the supply would be sufficient for at least one thorough late spring or summer irrigation of 35,100 acres. addition to the winter rains and irrigations, would insure such crops as are locally grown, eliminating the danger of the spring droughts which now often occur. It is believed that the construction here suggested offers the best solution of the irrigation problem of this valley, which possesses natural resources of a high order.

The Foster site is in sec. 23, T. 19 S., R. 5 E., M. D. M., on the Arroyo Seco and Piney Creek. The lands are held largely in private

ownership. There are 161 square miles of watershed tributary to the site. The dam estimated upon is of loose rock, 115 feet maximum height and 560 feet long, and would furnish 13,300 acre-feet of storage capacity at a cost of \$300,475, or at the rate of \$22.60 per acre-foot stored.

The Currier site is in sec. 19, T. 19 S., R. 6 E., M. D. M., on the Arroyo Seco. The lands are held in private ownership. There are 184 square miles of watershed tributary to the site, ranging from 400 to 6,000 feet above sea level. The dam would be made of loose rock, 420 feet long on top, and to the 100-foot level would have a storage capacity of 13,800 acre-feet. The cost would be \$174,800, or at the rate of \$12.67 per acre-foot of storage capacity. The water supply is estimated to be ample to fill the reservoir.

The site known as The Pools is in sec. 35, T. 19 S., R. 4 E., M. D. M., on the Arroyo Seco. The title vests in the Government. There are 74 square miles of tributary drainage basin. The site is of no value, as the storage capacity is only 660 acre-feet, and a 100-foot dam would cost \$115,800, or at the rate of \$175 per acre-foot stored.

The Petit site is in sec. 20, T. 19 S., R. 6 E., M. D. M., at the mouth of Vaqueros Creek. Title to the site is held by C. T. Romie. There are only 28 square miles of tributary drainage basin. The elevation of the basin ranges from 350 to 5,000 feet. A concrete dam 115 feet high would store only 1,040 acre-feet of water, and would cost \$99,000, or at the rate of \$95 per acre-foot of storage capacity.

The Leigh site is in sec. 9, T. 20 S., R. 6 E., M. D. M., on Vaqueros Creek. This is one of the best sites visited during the reconnaissance, but the tributary drainage basin is only 22.3 square miles, probably insufficient to supply the reservoir (except in years of good rainfall), which would have a capacity of 8,800 acre-feet, with a masonry dam 125 feet high costing \$127,000, or at the rate of \$14.40 per acre-foot.

The Pinkerton site is in T. 24 S., R. 10 E., M. D. M., on San Antonio Creek. The property is largely owned by W. J. Pinkerton. The area of the watershed is 322 square miles, ranging in elevation from 900 to 6,000 feet. A sandstone masonry dam 50 feet in elevation, with a maximum length of 900 feet, would furnish a storage capacity of 8,200 acre-feet, but at an excessive cost. There is not enough irrigable land for many miles below this site to justify the expense of constructing any type of dam at this locality.

The Matthews site is on San Lorenzo Creek, which enters Salinas Valley from the east. The title to the site vests in private parties. It has a watershed of 237 square miles, ranging from 400 to 2,000 feet above sea level. An earthen dam 110 feet high would store 16,131 acre-feet of water, and would cost \$193,859, or at the rate of \$12.02 per acre-foot of storage capacity. Water for irrigation in dry years must be held over from wet seasons. This reduces the effective capacity of the reservoir to 8,000 acre-feet, or \$24.20 per acre-foot of available capacity.

YUBA RIVER.

The California Water and Forest Association appropriated \$450 and the United States Geological Survey allotted a similar sum for the measurement of the midsummer low-water flow of Yuba River and its various tributaries during the season of 1900. This work was placed in charge of Dr. Marsden Manson, who deputized Mr. H. D. H. Connick to supervise the field work. Dr. Manson's detailed report on this investigation has been published in Water-Supply Paper No. 46.

KERN RIVER.

Mr. F. H. Olmsted, city engineer of Los Angeles, who has been connected with the survey of several power plants on Kern River and with investigations of the possibilities of storing water in the upper reaches of that basin, during the summer of 1900 extended his studies of the subject for the United States Geological Survey, and his detailed report has been published in Water-Supply Paper No. 46.

Mr. Olmsted found that a reservoir site of 47,000 acre-feet capacity exists on Salmon Creek, one of the tributaries of Kern River, but that the water supply is limited. It is proposed to use this water to supplement the low-water stages of the North Fork of Kern River, and hold it, if possible, at a minimum flow of 400 second-feet at the diversion point. This volume of water used through the proposed conduits would permit the generation and delivery at Los Angeles, 108 miles away, of 7,825 horsepower. The estimated cost of the work is \$1,333,-000. He also found that a 65-foot dam at Menache Meadows, on the South Fork of Kern River, would provide a storage capacity of 63,700 acre-feet, which in good years would be filled from its tributary drainage basin of 165 square miles. This reservoir would be used to regulate the flow of the South Fork and for the generation of power, which would be conveyed to Los Angeles, 120 miles distant. The dam estimated upon is a combined rock fill, with upper face of earth, and its cost would be \$130,000.

The regulation of the flood waters of Kern River by means of these storage reservoirs, which would be located at high elevations in the mountains, would manifestly be to the advantage of the lower irrigators.

STONY CREEK.

Stony Creek, which enters Sacramento River from the west side of Sacramento Valley, in Glenn County, has a drainage area, as determined from the best maps available, of about 700 square miles. In the investigation of its storage possibilities the main stream and all of its tributaries were visited. Immediately upon the completion of the surveys a preliminary report was made to the California Water and Forest

Association, accompanied by tentative estimates, which have been revised, as indicated below, after further field and office investigations.

The portions of the creek flowing north over the sedimentary rocks and against the natural fall of the country have an exceedingly low grade for a California mountain stream; for 40 miles (from Stony Ford near its upper end to the Stony Creek Buttes) it averages less than 20 feet per mile. At various places in the basin there is upturned a fairly hard conglomerate which has resisted erosion. Wherever this ridge has been cut by the streams dam sites of more or less merit exist. On Grindstone Creek, about 4 miles above where it joins Stony Creek, there is a narrow gap, but as the basin above is not broad and the canyon is very steep no surveys were made. On Salt Creek, at the Devils Gate, a similar condition exists. On the North Fork of Stony Creek, at the town of Newville, a reservoir site was found and surveved to the 60-foot contour. The contents were found to be 25,400 acre-feet, distributed over an area of 1,350 acres. The site includes the town of Newville and some of the most valuable lands in Glenn and Tehama counties. The foundation for the dam is not good, and the drainage area is not sufficient to fill the reservoir except in vears of extraordinary rainfall.

In sec. 30, T. 20 N., R. 6 W., M.D.M., Briscoe Creek breaks through the conglomerate bed in a gorge which in some places is only 3 feet wide at the bottom. The material is very compact—a sample taken weighed 143 pounds per cubic foot. Bed rock is upon the surface, and the walls of the canyon are good. It is proposed to erect here a dam of cyclopean rubble, 125 feet high, with a spillway and auxiliary dam at a low pass on the north side of the reservoir, which would impound 14,435 acre-feet of water. The cost of such a dam, built upon a conservative section and including all accessories, is estimated at \$218,282, or \$15.12 per acre-foot stored. It is believed that the drainage basin of Briscoe Creek would fill the reservoir during years of ordinary rainfall.

Below this point, in Stony Creek Valley, there is a large amount of agricultural land, at present used almost exclusively for grain farming, which if irrigated would successfully produce fruit and alfalfa at greater profit.

On Little Stony Creek, about 2 miles southeast of the town of Stony Ford, in Colusa County, a reservoir site was found and surveyed where an 85-foot dam would impound 26,000 acre-feet of water. The conditions here favor a concrete dam with gravity section. Such a dam, with its accessories and rights of way, would cost \$206,559, or at the rate of \$7.94 per acre-foot of storage capacity. The drainage area would supply 26,000 acre-feet in ordinary years. Owing to its great distance from the plains the water from this reservoir would have to be used largely in Stony Creek Valley, for the production of alfalfa and deciduous fruits.

At what is locally known as the Mill site, in sec. 1, T. 21 N., R. 6 W., M. D. M., the main stream intersects the conglomerate dike. Owing to its proximity to the Sacramento Valley foothill lands and to the large available water supply from more than 600 square miles, this site is important. The plans and estimates on this structure are not yet completed, but a tentative estimate is given here. feet high would impound 44,000 acre-feet of water, and the drainage basin should furnish that amount in even dry years. The dam site, however, is a very poor one, and a careful study, including borings to bed rock, would be necessary to determine the advisability of constructing the reservoir. The preliminary estimate considers a loose rock-fill dam with side slopes of 1 to 1 and 1½ to 1, on water and downstream faces, respectively, and 20 feet wide on top. The length would be 1,560 feet. It is estimated that such a dam, with all its accessories, would cost \$698,000, or at the rate of \$15.87 per acre-foot stored. The water for this reservoir would be available for the rich foothill lands on the west side of Sacramento Valley, near Orland and Corning, where it is possible to produce citrus fruits and olives. These lands would probably justify the construction of the dam, as they would probably be worth \$100 per acre with a secure water right, and without water they can not earn interest on any valuation.

The constructed portion of the central irrigation district system was visited during the reconnaissance. The water supply for this district will be derived from Sacramento River, which at this point is a navigable stream discharging many thousand second-feet of water. system is so planned as to command 156,550 acres of rich alluvial lands in Sacramento Valley between Willows and Williams and within the irrigation district. Most of the land is well suited for irrigation, and the water supply is ample and unfailing without any regulation by There has already been expended on the system approxireservoirs. mately \$500,000. Its completion was prevented by litigation which was started about 1891. It is believed that this system is the true solution of the irrigation problem for these valley lands of the Sacramento. Residents who have been interviewed apparently favor irrigation, but dread the effects of the Wright act. As matters now stand they have a debt hanging over their heads and no water for the improvement of the lands. The interest on the bonds is in default, and the situation is unjust to both the landowners and the investors. It is believed that if some adjustment could be made by means of which the holders of these securities could have delivered to them the works so far constructed, with the understanding that they will complete the plant and that the district will be relieved of its bonded indebtedness, a solution could be found for this most unsatisfactory situation that would be beneficial to all concerned. If such a contract were entered into, with the proviso that the plant could be purchased by the consumers at the end of twenty or thirty years of operation (after its success had been established and experience in its operation had been obtained), public ownership of these works would be the ultimate result. With \$500,000 expended on works which have great intrinsic value, and with 156,550 acres of exceedingly fertile land lying in a state of semidevelopment, the situation is distressing. At present there is in this district one inhabitant to approximately every 130 acres who is becoming bankrupt by dry wheat raising, and this on land where a score of scattered house gardens demonstrate the possibility of producing citrus fruits. Glenn County, which has wonderful natural resources, has only one school child to every 1,000 acres. With such a development as has been shown is possible in the irrigated districts of southern California—Riverside, for example, which, starting with a sheep pasture assessed under protest at 75 cents per acre in 1870, now supports about 10,000 inhabitants, or a citizen to every 1\frac{1}{3} acres irrigated, and during the last season shipped more than 4,000 carloads of citrus fruits—the population might be increased from fifty to a hundred fold. Under the existing law, however, it is impossible for an organized irrigation district to alienate any of its property, and it will be necessary to obtain such legislation as will provide for the transfer suggested.

Glenn and Colusa counties are exceedingly favored in natural resources. Reservoir sites have been found and surveyed which demonstrate the possibility of irrigating the mountain valleys of the former county on a conservative commercial basis, and it is confidently believed that it is possible to build up a great irrigation community by the completion of the works of the central irrigation district and the construction of the mountain reservoirs previously mentioned. This county is blessed with an abundant water supply, with arable lands of the finest quality, and with climatic conditions favorable to all varieties of horticulture and agriculture known in the State. Instead of being a sparsely settled district, with undeveloped resources, it is believed, from the investigations made, that if these natural resources were utilized it would support a population of more than 100,000.

A word in regard to the forests of the region. A large portion of the drainage basin near the heads of Stony Creek and its tributaries is heavily covered with commercial timber, 90 per cent of which is still on public domain, but several sawmills are located in the heart of the best forest. Sheep and cattle are permitted to graze unmolested over the entire area, and numerous forest fires, presumably of incendiary origin, were seen during the late summer and the fall of 1900. The forests, therefore, which are the greatest conservers of the water supply, are being rapidly destroyed. Their destruction would result in seriously increasing the amount of silt carried by the streams in flood, and would lead to the destruction of reservoirs that may be built. In

view of these conditions it is urged that a reserve be created of the public timbered lands. This can be done with very slight encroachment on private domains. In this connection, on November 17, 1900, the Sacramento Valley Development Association passed the following resolutions:

Whereas the waters of Stony Creek are now used for irrigation, and by their conservation and proper regulation a vast area may be brought to a much higher state of cultivation; and

Whereas the experts of the United States Geological Survey now conducting investigations along said creek report the existence of many excellent storage-reservoir sites thereon; and

Whereas the preservation of the forests along the headwaters of said creek is necessary to insure a permanent water supply, and also to moderate the flow of flood waters, thereby preventing the rapid filling with silt and detritus of any reservoirs that may hereafter be constructed along said Stony Creek or any of its tributaries: Therefore, be it

Resolved That we, the Sacramento Valley Development Association, earnestly petition the President of the United States to set aside as a forest reserve such of the public lands about the head of said Stony Creek and its tributaries as the experts of the Geological Survey shall recommend as necessary for the protection of the water supply of said creek.

Adopted at a meeting of the Sacramento Valley Development Association held in Oroville, Cal., November 17, 1900.

A similar resolution was adopted by the California Water and Forest Association at its annual meeting in San Francisco December 13 and 14, 1900.

The following boundaries for a forest reserve are suggested: Beginning at the northwest corner of T. 23 N., R. 6 W., M. D. M.; thence south to northwest corner of T. 20 N., R. 6 W.; thence west on township line to northwest corner of sec. 2, T. 20 N., R. 7 W.; thence south to southwest corner of section 26, township and range aforesaid; thence east to northwest corner of section 36, township and range aforesaid; thence south 1 mile; thence east to northeast corner of T. 19 N., R. 6 W.; thence south on range line 3 miles to southwest corner of sec. 18, T. 19 N., R. 6 W.; thence east to northeast corner of sec. 19, T. 19 N., R. 6 W.; thence south to southeast corner of section 31, township and range aforesaid; thence west to northwest corner of T. 18 N., R. 6 W.; thence south on range line between ranges 6 and 7 west, to southwest corner of sec. 6, T. 17 N., R. 6 W.; thence east to northeast corner of section 8, township and range last aforesaid; thence south to southeast corner of sec. 32, T. 16 N., R. 6 W.; thence west on township line between townships 15 and 16 north to southwest corner of T 16 N., R. 10 W.; thence north on range line between ranges 10 and 11 west to northwest corner of T. 23 N., R. 10 W.; thence easterly to northwest corner of T. 23 N., R. 6 W., the place of beginning; all Mount Diablo base and meridian.

CACHE CREEK.

During the last season (1900) a reconnaissance of the drainage basin of this creek was made by Prof. Albert E. Chandler, of the University of California, for the purpose of locating possible reservoir sites. The examination included the inspection of the Clear Lake reservoir site and the assemblage of many data that were obtained by previous surveys by the Geological Survey, the Southern Pacific Railroad, and certain power companies. Four sites were examined. Two of them were found to be meritorious, and they were surveyed. Although Professor Chandler's investigations were restricted to the engineering features of the work, in making the estimates along those lines suitable allowance was made for possible damages to private property.

It is believed that there is in this region a large area of land upon which water could be used to commercial advantage for the production of high-grade fruits, particularly in Capay Valley and underlying the reservoir sites which have been surveyed. Measurements were made on many of the streams, and a permanent gaging station was established near Lower Lake. A preliminary examination was also made of underground waters near Woodland, but most of the time and efforts were devoted to the investigation of reservoir sites, as follows:

The Twin Valleys site was inspected, and although the storage basin and dam site are fair, it was not considered of value, for there are only 5 square miles of tributary watershed.

Long Valley, on Long Creek, was also visited. This site is about 6 miles long, with an average width of approximately 1,000 feet. The drainage basin, however, is insufficient, containing only about 30 square miles, and the dam site is poor, and consequently it was rejected.

Little Indian Valley, on the North Fork of Cache Creek, was also surveved. This site is about 5 miles long and from a half to three-fourths of a mile wide. The land in the site is poor; about half of it is cultivated. The capacity at the 100-foot level would be 37,625 acre-feet; at the 125-foot level, 69,000 acre-feet. There are approximately 100 square miles of drainage basin. It is probable that this reservoir could not be filled to the 125-foot level during years of minimum rainfall, but by holding over 29,000 acre-feet of water from years of average and excessive precipitation it is believed that a supply of 40,000 acrefeet would be available. Judging from rainfall records in this drainage basin during the last fourteen years, there would have been twelve years of full supply, one year with a deficit of 6,000 acre-feet, and one year (1898, which was a dry year following a dry year) with a deficit of 23,000 acre-feet. The latter deficit is of course serious, but during the last five years it has been found that it is entirely possible to preserve, without serious injury, orchards and crops in southern California during one or two seasons of deficient supply, and it is believed to

be more economical to rely on tiding over an occasional shortage than to design works which, from a financial point of view, are practically prohibited, and which will not be called upon to perform full service oftener than once in twenty or thirty years, or so seldom as to entirely condemn the project. Forty thousand acre-feet are therefore considered the available supply from this site. Quarries of stone suitable for the construction of the dam are near at hand and at a higher elevation. The rock consists of hard slates. It is estimated that a concrete dam of 130 feet maximum height, which would impound water to the 125-foot level, could be built for \$453,000, or at the rate of \$6.56 per acre-foot of storage capacity. If the available supply is considered to be 40,000 acre-feet, the cost would be at the rate of \$11.33 per acre-foot stored. This is, therefore, a good reservoir site, and at some future time it will undoubtedly be utilized for irrigation purposes. For the raising of deciduous fruits and cereals probably 1½ acre-feet of water would be a sufficient annual supply, especially if during the months of March, April, and May one-third of that quantity could be obtained from the natural flow of the unregulated portions of the creek, and if 1 acre-foct were available from the reservoir for use during June, July, and August. In other words, 40,000 acre-feet would be sufficient to maintain a satisfactory water supply for 40,000 acres.

In considering the project of using Clear Lake for a reservoir the effort was made to plan the works so as to avoid large damages to property. Records of the lake's levels from 1874 to 1888, inclusive, have been kept by Captain Floyd, of Kono Tayee, who has kindly furnished them to the Geological Survey. Mr. F. H. Porter, of Kono Tayee, and Captain Rumsey and Captain Atherton, of Lakeport, have furnished records for the period from 1888 to 1900, inclusive. These records are of very great value, and were used as the basis of the computation of the available supply from the lake, checked by computations of run-off and other data.

To allow for 80,000 acre-feet for each and every irrigation season during the last twenty-six years the outlet would have to be fixed so as to control a minimum elevation of the lake of 90 feet and a maximum elevation of 106 feet above the assumed datum. In 1898 the surface of the lake fell to an elevation of 97.73 feet above this datum, and in March, 1876, it rose to an elevation of 110.02 feet, so that very little disturbance of the lake within these natural limits is expected. Two feet storage capacity would be sufficient under ordinary conditions to furnish the estimated supply.

The lake is 20 miles long, 7 miles wide (maximum width), from 35 to 50 feet deep, and has a surface area of 65 square miles. There are 417 square miles of tributary drainage area. The water is sufficiently pure for irrigation purposes. The storage capacity from the 106- to

the 110- foot levels is 180,671 acre-feet, equivalent to 499 cubic feet per second for an irrigation season of one hundred and eighty-two and one-half days. The evaporation, which from a body of water of so large area is an exceedingly important factor, has been estimated at 53½ inches. Further observations, however, are needed to determine this important fact, and a record is now being kept. From a careful study of the situation it is believed that 80,000 acre-feet could be relied upon, and it is possible that as much as 100,000 acre-feet would be available during the irrigation season.

Surveys of the outlet of the lake made by the Geological Survey in 1889 have been used as a basis for the computations of cost of storage works, which it is estimated can be built for \$452,484. Considering 80,000 acre-feet as the available supply, the cost would be at the rate of \$5.66 per acre-foot of storage capacity; if 100,000 acre-feet were obtained this unit would fall to \$4.52. These figures show that the Clear Lake reservoir site, economically considered, is one of the best storage sites in California.

Summarizing, Professor Chandler's report (published in full in Water-Supply Paper No. 45) shows that economical storage works can be constructed on Cache Creek as follows: Little Indian Valley, 40,000 acre-feet for \$453,000; Clear Lake, 80,000 acre-feet for \$452,484; making a total annual supply of 120,000 acre-feet for \$905,484, or at an average rate of \$7.55 per acre-foot. As dry lands in the locality are worth about \$30 an acre and irrigated lands from \$60 to \$100 an acre, the economy on the basis of land values alone is shown to be very great. On the basis of populations elsewhere in southern California it would not be an extreme statement to say that irrigation works of this size would provide support for an additional population of 60,000.

LOW-WATER MEASUREMENTS.

Measurements of the flow of San Joaquin, Kings, Stanislaus, and Tuolumne rivers were made August 9 to 11, 1900, by S. G. Bennett, assistant hydrographer, but as it was believed that the streams had not reached their lowest stages the work was discontinued until September 1, the time when the low-water measurements of 1899 were begun, in order that comparative measurements might be obtained. On September 1 San Joaquin River was gaged, and the next day Tule River was measured at the headworks of the Pioneer canal at the beginning of a local rain storm. The latter measurement represents the lowest stage of water for the year. The rain continued there on the night of September 2, and in the mountains on September 3. On the latter date Kaweah River was visited and gaged. It was rising slowly at the time, so that the measurement does not represent the lowest stage of that stream.

From a study of the rainfall reports of the Weather Bureau it is evident that the measurements obtained fairly represent the low-water stages for the year 1900 of the streams flowing into San Joaquin and Sacramento valleys, with the exception of Kaweah River. In tabulating the results it was deemed advisable, for purposes of comparison, to include the low-water measurements of the streams for the years 1898 and 1899, as it is believed that the three years represent a phenomenal low-water cycle. The following table gives the low-water measurements for these years:

Low-water measurements of streams flowing into Sacramento and San Joaquin valleys.

			I	Discharg	e.
Date.	Stream.	Locality.	1900.	1899.	1898.
			Secft.	Secft.	Secft.
Sept. 13	Sacramento River	Jellys Ferry		4,087.00	4, 152.00
Sept. 20	do	do	4, 105.00		
Sept. 22	Stony Creek	300 feet below Bridgeport bridge (1 mile below Elk Creek).	7.70		
Sept. 18	Feather River	½ mile above Oroville bridge	1, 123.00		
Oct. 7	Yuba River				a 0. 00
Aug 28	do	Parks Bar bridge, 1 mile below Smartville	b 474.00		
Aug. 29	North Fork of Yuba River.	Above Yuba Power Company's dam	ь 282. 00		
Sept. 18	MiddleYuba River	Freeman's bridge	ь 64.00		
Sept. 17	Bear River	1 mile south of Wheatland	12.00		
Oct. 7	American River	North and Middle forks, at head of North Fork ditch.			16.00
Sept. —	do	Folsom			34, 50
Sept. 16	do	Main stream, 1 mile above mouth of South Fork.		86.10	
Sept. 16	do	North Fork ditch, at road crossing $2\frac{1}{9}$ miles above Folsom.		19.64	
Sept. 14	do	Main stream, 1 mile above mouth of South Fork.	235, 00		
Sept. 14	do	North Fork ditch, at road crossing $2\frac{1}{2}$ miles above Folsom.	11.80		
Sept. 16	South Fork of American River.		·i	e 20. 00	
Sept. 16	,do	Natoma ditch		¢20.00	
Sept. 14	do	Iron road bridge near mouth	80.50		
Sept. 14	do	Natoma ditch, S. P. R. R. crossing 3 miles above Folsom.	35.00		
Sept. 23	Cache Creek	Rumsey road bridge	3.80		
Sept. 24	do	Road bridge crossing near Lower Lake	4.70		
Sept. 23	Putah Creek	6 miles above Winters, at Devils Gate	4.40		
Sept. 15	Cosumnes River	Bridge on Jackson-Latrobe road crossing		2.00	
Sept. 15	do	Michigan Bar ditch, Jackson-Latrobe road crossing.		2.00	
Sept. 12	do	Bridge on Jackson-Latrobe road crossing	1.70		
Sept. 12	do	Michigan Bar ditch, Jackson-Latrobe road crossing.	3. 70		
Sept. 14	Mokelumne River	$100{\rm feet}$ below bridge, Mokelumne Hill-Jackson road.	•••••	33.10	
Sept. 12	do	do	15.00		
Sept. 12	do	Amador ditch, below Butte ditch	37.00		
Sept. 12	do	Butte ditch	4.80		

^aDry, except for water from reservoir.

^b Measurement by H. D. H. Connick,

^c Estimated by Mr. Knight, superintendent of Folsom Power Company.

 $Low-water\ measurements\ of\ streams\ flowing\ into\ Sacramento\ and\ San\ Joaquin\ valleys-Continued.$

	Stream. Locality,		D	ischarge		
Date.	Stream.	Locality.	1900.	1899.	1898.	
			Secft.	Secft.	Secft.	
Sept. 14	Calaveras Creek	Bridge on San Andres-Jackson road		0.00		
Sept. 11	do	do	0.00			
Oct. 6	Stanislaus River	Oakdale			49.60	
Oct. 6	do	Stanislaus and San Joaquin canals			32.70	
Sept. 9	do	Oakdale		88.40		
Aug. 11	do	do	66,00			
Sept. 6	do	do	35.30			
Sept. 7	do	Stanislaus Water Company's canal, 100 feet below head gate 6 miles above Knights Ferry.	84.70			
Sept. 7	do	Below Stanislaus Water Company's intake	28.00			
Sept. 7	do	Total flow 6 miles above Knights Ferry	112.70			
Oct. 7	Tuolumne River .	Lagrange			82.70	
Oct. 7	do	Mining ditch.			24.00	
Oct. 7	do	Turlock canal		1-80	30.00	
Oct. 7					136.70	
	do	Total flow at Lagrange				
Sept. 11	do	1,000 feet below U. S. gaging station				
Sept. 11	do	Mining ditch				
Sept. 11	do	Turlock canal, flume No. 3	••••••	28.90		
Sept. 11	do	Total flow at Lagrange		65.00		
Aug. 11	do	Lagrange	17.00		.,	
Aug. 11	do	Mining ditch	12.00			
Aug. 11	do	Turlock canal	117.00			
Aug. 11	do	Total flow at Lagrange	146.00			
Sept. 8	do	1,000 feet below U. S. gaging station	10.90			
Sept. 8	do	Mining ditch	9.00			
Sept. 8	do	Turlock canal	35.00			
Sept. 8	do	Total flow at Lagrange	a 54. 90			
Sept. 11	Merced River	1 mile above head gate of Crocker-Hoffman canal.		35, 50		
Sept. 11	do	Valley Mills ditch		4.95		
Sept. 11	do	Total flow above Crocker-Hoffman dam		- 40.45		
Sept. 10	do	Total flow one-half mile above bridge at Merced Falls.	63.00			
Sept. 11	do	Snelling ditch		2,327		
Sept. 10	do	do	2.10			
Sept. 11	do	Crocker-Hoffman canal, 300 feet below head gate.		16.50		
Sept. 10	do	Crocker-Hoffman canal, at head gate	6.50			
Sept. 10	do	Merced River mill ditch, at mill	27.10	The state of the state of		
July 28	San Joaquin River.	Herndon			611.00	
Sept. 2	do	do			328.00	
Sept. 8	do	Pollasky, 500 feet above bridge		Mark Translation		
Sept. 8	do	Herndon		195.60		
Aug. 9	do	do	466.00	1,300 8 175		
Sept. 1	do	do	246.00	6.000.000		
Sept. 28	do	do	197.00			

^{*}It is said that a portion of the flow of Tuolumne River was being diverted at the time of this measurement for hydraulic mining in the gravel range 45 miles above Lagrange, and that after use the water reached Merced River.

b Estimated.

Low-water measurements of streams flowing into Sacramento and San Joaquin valleys—Continued.

2.14			D	Discharge.		
Date.	Stream.	Locality.	1900.	1899	1898.	
			Secft.	Secft.	Secft.	
Sept. 28	San Joaquin River	Pollasky, 500 feet above bridge	187.60			
Sept. 26	Salinas River	Gaging station near Salinas	1.70			
uly 27	Kings River	Red Mountain			503.0	
Aug. 31	do	do			243.8	
Sept. 4	do	do		206,00		
lug. 10	do	do	427.00			
Sept. 4	do	do	405.00			
Sept. 27	do	do	220.00			
Aug. 31	do	Church canal, check near Trimmer Springs road.			164.3	
Sept. 4	do	do	229.20	151.10		
Aug. 31	do	Seventy-six canal, at mouth of canyon			0.0	
Sept. 4	do	do	0.00	0.00		
Aug. 31	do	Kingsburg canal, at mouth of canyon			0.0	
Sept. 4	do	do	0.00	0.25		
Sept. 4	do	Gould canal, at mouth of canyon	84.00	2.00		
Aug. 31	do	Fowler Switch canal, at mouth of canyon			0.0	
Sept. 4	do	do	0,00	0.00		
Sept. 1	Kaweah River	One-half mile above Kaweah Irrigation Power Company's headworks.			35.3	
Sept. 6	do	do		40.90		
Sept. 3	do	do	100.00			
Sept. 1	do	Iron bridge above Watumna canal headworks.			17.9	
Sept. 6	do	do		33.30		
Sept. 3	do	do	86.60			
Sept. 1	do	Kaweah Irrigation and Power Company's ditch.			8. 5	
Sept. 6	do	do		1.49		
Sept. 3	do	do	8.10			
Sept. 1	do	Pogues ditch			4. 5	
Sept. 6	do	do		4.87		
Sept. 3	do	do	6, 67			
Sept. 3	do	Myers ditch	1.00			
Sept. 3	do	Watumna ditch, at headworks	15,00	4. 2. 2. 2. 2. 2. 2. 2. 2. 2.		
Sept. 1	do	North Fork, at mouth			0.5	
Sept. 6	do	do		1.12	1	
Sept. 1	do	South Fork, at mouth			0.0	
Sept. 6	do	do		1 18		
Sept. 1	Tule River	Headworks of Pioneer ditch		13. 12		
Sept. 1	do	Pioneer canal, 1 mile below head gate				
Sept. 2	do	Headworks of Pioneer ditch	9.05	100.00		
Aug. 29	Kern River	First Point of Measurement	9.05		115.6	
	do	do		99. 22		
Aug. 30	do	do	103.16			

a Estimated.

SOUTHERN CALIFORNIA DRAINAGE.

Of the streams in southern California systematic measurements have been made during the year of Mohave River at Victorville, the site of a proposed dam for storage; of San Gabriel River near Azusa; of Santa Ana River below Warmsprings; and of Mill Creek at Crafton headworks, with the results contained on pages 503-505.

The diurnal variation of several streams in southern California is illustrated in fig. 219, which gives the fluctuations through two complete days, from 7 a. m. on September 15, 1898, to 7 a. m. on September 17. The diagram shows that nearly all of the streams fell during

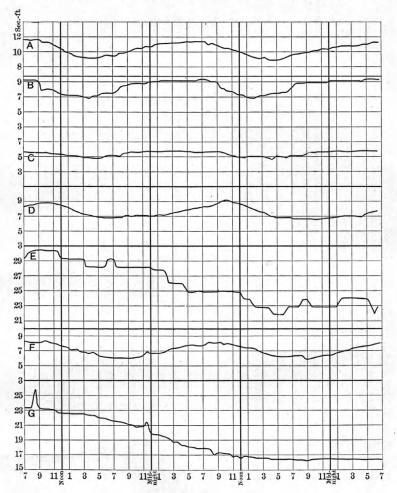


Fig. 219.—Diagram showing diurnal variation of southern California streams. A, Mill Creek below Mountain Home; B, Lytle Creek at Millers Narrows; C, San Antonio Creek at water company's weir; D, San Gabriel River at intake of San Gabriel Power Company; E, Santa Ana River above Keller Creek; F, Santa Ana River above Bear Creek; G, Bear Creek above Santa Ana River.

the afternoon of September 15, some of them rising after midnight and again falling the next afternoon. This is particularly notable in A, B, C, D, and F of the diagram. The record is of special interest, as it is the minimum summer flow of an exceedingly dry year.

The data are furnished through the courtesy of the Edison Electric Company.

A number of reservoir sites exist throughout the mountains in the southern part of the State. Several of these have been surveyed by Mr. J. B. Lippincott, resident hydrographer in California, four of which are illustrated in figs. 220, 221, 222, and 223, which show the character of the valleys available for storing water. The topographic surveys which are being made show the relative position of these and of other possible sites and the drainage areas tributary to them, but in order to determine the relative value or importance of the sites each must be examined in detail. The reclamation and ultimate development of the arid region rests to a large extent upon the utilization of all practicable reservoir sites.

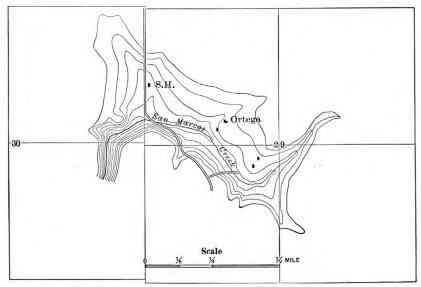


Fig. 220.—Fresno reservoir site, on San Marcos Creek, California.

The Fresno reservoir site on San Marcos Creek, shown in fig. 220, is in sec. 29, T. 12 S., R. 3 W., San Diego County, and has an area of 167 acres and reservoir content of 3,070 acre-feet (212 miners' inches, twelve months' flow), with a dam 69 feet high, 60 feet bottom length, and 285 feet top length. The contour interval of the map is 10 feet, the elevation of the top contour 365 feet above sea level.

The reservoir site on San Marcos Creek shown in fig. 221 is in secs. 16, 17, 20, and 21, T. 12 S., R. 3 W., San Diego County, and has an area of 290 acres and reservoir contents of 3,770 acre-feet, with a dam 50 feet high, 105 feet bottom length, and 264 feet top length. The contour interval of the map is 10 feet, the elevation of the water line 514 feet above sea level.

The Aliso reservoir site on Escondido Creek, shown in fig. 222, has an area of 158 acres and reservoir contents of 4,650 acre-feet (321 miners' inches), with a dam 103 feet high, 75 feet bottom length, and

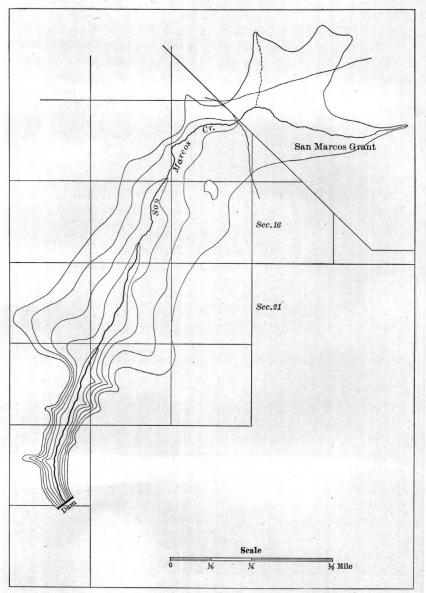


Fig. 221.—Reservoir site on San Marcos Creek, California.

317 feet top length. The contour interval of the map is 10 feet, the elevation of the top contour 420 feet above sea level.

The site on Sweetwater River, shown in fig. 223, has an area of 147 acres and reservoir contents of 3,470 acre-feet, with a dam 70 feet

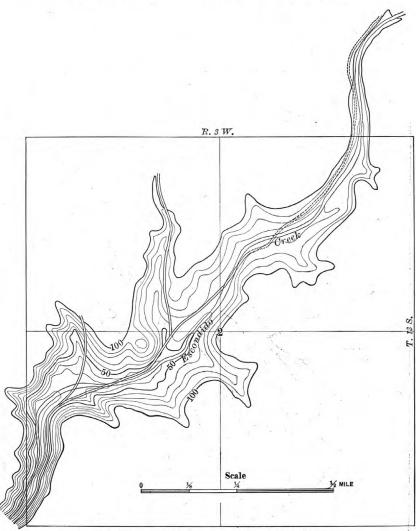
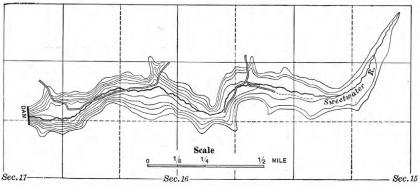


Fig. 222.—Aliso reservoir site, on Escondido Creek, California.



 ${\bf Fig.~223. - Reservoir~site~on~Sweetwater~River,~California.}$

high, 50 feet bottom length, and 320 feet top length. The contour interval of the map is 10 feet, the elevation of the water line 1,300 feet above sea level.

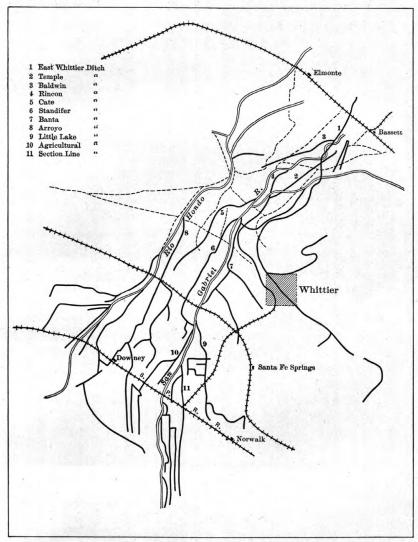


Fig. 224.—Canal diversion from San Gabriel River, California.

Fig. 224 illustrates the system of diversion ditches taking water from San Gabriel River, Rio Hondo, and other sources near Whittier, this being about 18 miles below the point of measurement noted on page 504.

Estimated monthly discharge of Mohave River at Victorville, Cal.

[Drainage area, 400 square miles.]

	Dischar	ge in secor	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefect.	Second- feet per square mile.	Depth in inches.	
1900.							
January	44	44	44	2,705	0.04	0.04	
February	60	44	49	2, 721	0.04	0.04	
March	80	44	57	3, 505	0.05	0.06	
April	44	33	35	2,083	0.03	0.03	
May	33	33	33	2,029	0.03	0.03	
June	33	25	30	1,785	0.02	0.02	
July	29	25	26	1,599	0.02	0.02	
August	29	29	29	1,783	0.02	0.02	
September	29	29	29	1,726	0.02	0.02	
October	33	29	32	1,968	0.03	0.03	
November	3, 200	33	139	8, 271	0.11	0. 12	
December	33	33	33	2,029	0.03	0.03	
The year	3, 200	25	45	32, 204	0.04	0.46	

Note.—Gage heights for 1900 are given in Water-Supply Paper No. 51, page 464, discharge measurements, page 463.

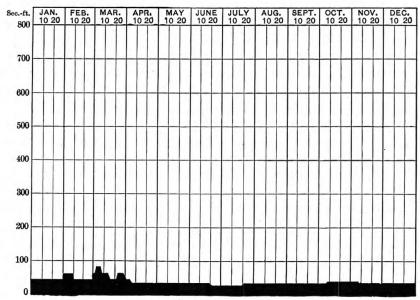


Fig. 225.—Discharge of Mohave River at Victorville, Cal., 1900.

Estimated monthly discharge of San Gabriel River and canals above Azusa, Cal.

[Drainage area, 222 square miles.]

	Dischar	ge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.							
January	89	22	32	1,968	0.14	0.16	
February	23	18	20	1, 150	0.09	0.09	
March	30	16	20	1, 230	0.09	0.10	
April	26	13	17	1,012	0.08	0.09	
May	86	16	37	2, 275	0.17	0.20	
June	22	8	15	893	0.07	0.08	
July	10	4	6	369	0.03	0.03	
August	5	4	4	246	0.02	0.02	
September	6	3	4	238	0.02	0.02	
October	. 6	4	5	307	0.02	0.02	
	Control of the last	The second second second					

Note.—Daily discharge of the river and canals for 1900 is given in Water-Supply Paper No. 51, pages 472 to 475.

Estimated monthly discharge of Santa Ana River below Warmsprings, Cal. a
[Drainage area, 188 square miles.]

	Discharge in second-feet.				Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1900.	- 131-3						
January	36	19	23	1,414	0.12	0.14	
February	23	20	22	1, 222	0.12	0.12	
March	28	20	23	1,414	0.12	0.14	
April	43	19	25	1,488	0.13	0.14	
May	250	20	57	3, 505	0.30	0.35	
June	25	19	22	1,309	0.12	0.13	
July	25	11	19	1, 168	0.10	0.12	
August	12	9	11	676	0.06	0.07	
September	16	11	12	714	0.06	0.07	
October	16	12	14	861	0.07	0.08	
November	1,564	14	107	6, 367	0.57	0.63	
December	31	25	28	1,722	0.15	0. 17	
The year	1, 564	9	30	21, 860	0.16	2. 16	

^{*}All of this water except 748 acre-feet which was wasted between May 7 and May 13, inclusive, was diverted by the Redlands and Highlands canals.

Note.—Gage heights and discharge measurements for 1900 are given in Water-Supply Paper No. 51, page 476; rating table in Paper No. 52, page 523. For hydrograph see page 505.

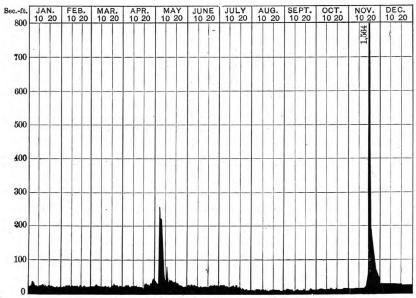


Fig. 226.—Discharge of Santa Ana River below Warmsprings, Cal., 1900.

Estimated monthly discharge of Mill Creek canals at Crafton headworks, California. ^a [Drainage area, 45 square miles.]

Month.	Discharge in second-feet.				Run-off.	
	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1900.						
January, 16 days	10.6	9.8	10	615	0. 22	0. 25
February	10.6	9.8	10	555	0. 22	0. 23
March	13.2	9.6	10	615	0. 22	0. 25
April	13.3	8.9	10	595	0. 22	0. 25
May	17.0	8. 2	12	738	0.27	0. 31
June	8.2	5.3	7	417	0.16	0.18
July	6.3	3.3	5	307	0.11	0. 13
August	5.7	4.3	5	307	0.11	0. 13
September	5.7	4.3	5	298	0.11	0. 12
October	5.8	3.8	5	307	0.11	0.13
November 1 to 17	8.5	5.1	5	298	0.11	0. 12

^a Exclusive of pumped water.

Note.—Daily discharge for 1900 is given in Water-Supply Paper No. 51, page 477.

A general description of the southern California drainage has been given in the preceding annual reports, notably in Part IV of the Nineteenth, where is given a paper upon the water supply of San Bernardino Valley, with a full description of the Santa Ana River, and the works of the Bear Valley Irrigation Company. Additional details are given in Parts IV of the Twentieth and Twenty-first annual reports, and also in Water-Supply and Irrigation Papers Nos. 59 and 60, which contain a description of the wells of southern California. In Water-Supply Paper No. 51 are contained the details of measurements made during the year 1900, particular attention having been given to lowwater flow.

The tables of precipitation at various mountain rainfall stations, mostly in southern California, which in the past have usually been given in the Annual Report, are printed for 1900 in Water-Supply Paper No. 52.

Note.—Owing to a change in the law concerning the Annual Report of the United States Geological Survey, the report of progress of stream measurements will not hereafter be printed as a part of the Annual Report of the Director, but will probably appear in the series of Water-Supply and Irrigation Papers.

HYDROGRAPHY OF THE AMERICAN ISTHMUS

BY

ARTHUR POWELL DAVIS

507

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HYDROGRAPHY OF THE AMERICAN ISTHMUS

By ARTHUR POWELL DAVIS.

GENERAL CHARACTERISTICS OF CENTRAL AMERICA. PHYSIOGRAPHY.

The geologic and topographic features of Central America are distinct from those of both North and South America.

The continental cordillera, or backbone of North America, abruptly terminates in southern Mexico, just north of the Isthmus of Tehuantepec, and if continued in its general direction, would extend into the Pacific Ocean, west of the American Isthmus. On the south, the Andean cordillera terminates in northern Colombia, far to the east of the isthmus. R. T. Hill describes this region as follows:

The Caribbean region, including Central America, the Antilles, and the Windward Islands, and most of the Venezuela and Colombian coast of South America, is one of east-and-west folded sedimentaries plus accumulations of volcanic intrusions and ejecta; but instead of dominating a continental region, practically constitutes a mountainous perimeter surrounding the depressed basin of the Caribbean. ^a

Thus, the natural division of Central America includes the region from the Isthmus of Tehuantepec to the point where the Isthmus of Darien joins the continental mass of South America. Besides the Mexican territory of Yucatan and the British Colony of Belize, it includes the five republics of Guatemala, Honduras, Salvador, Nicaragua, and Costa Rica. The narrowest part of the isthmus, from the southern boundary of Costa Rica to the South American continent, is a portion of the South American Republic of Colombia, and is properly known as the Isthmus of Panama.

Central America varies in width from 30 to 300 miles. It is mostly mountainous, the continental divide being usually nearer the Pacific than the Atlantic coast. Through Guatemala and Honduras, and for some distance into Nicaragua, the main chain of mountains trends northwest to southeast, and is from 30 to 50 miles from the Pacific. In northern Nicaragua this range bifurcates, and decreasing in altitude, one branch follows close to the Pacific, and the other passes to

^aGeological history of the Isthmus of Panama and portions of Costa Rica: Bull. Mus. Comp. Zool. Harvard Coll., Vol.XXVIII, No. 5.

the east of the center, and is cut through by the San Juan River. In Costa Rica the chains are again united in a high plateau studded with lofty peaks, which occupies the major portion of Costa Rica, and is almost as distinct from the lower range of the Isthmus of Panama as the latter is from the Andean system to the east. Hence, the mountain system of the Central American region may be divided into four groups, namely, the Guatemalan, the Nicaraguan, the Costa Rican, and the Panaman. The first and third are high and massive, the second low, divided, and broken, and the last, low and narrow. From this follows the location in Nicaragua and Panama of regions of canal possibilities.

Numerous marshes and lagoons are found on both coasts, and both are indented with occasional bays. The Bay of Honduras, on the east coast of Guatemala, is the largest. Many of the deep rivers offer good harbors, but the water is too shallow on the bars to admit large vessels. Boca del Toro and Chiriqui Lagoon are good harbors, but have little commerce. Limon Bay is merely an indentation of the coast, being entirely open to the north. It is used as a harbor for all shipping connecting with the Panama Railroad. The Gulf of San Blas, Caledonia Bay, and the Gulf of Darien occur to the east and south, the last being an extensive body of water.

There are also several gulfs and bays on the Pacific coast. The Gulf of Tehuantepec is the farthest north, and is merely a roadstead. The Bay of Fonseca is one of the fine harbors of the world, being 30 by 50 miles in extent. Its entrance is between the stately volcanoes of Couchagua and Conseguina. Several smaller islands assist in closing the bay. It serves as port for Salvador, Honduras, and Nicaragua, and is commercially very important.

Farther south the Bay of Corinto is a good harbor, and furnishes accommodation for the greater part of the foreign commerce of Nicaragua. San Juan del Sur, a few miles south of the Pacific end of the Nicaragua Canal route, is a small indentation with some commerce.

Salinas Bay lies at the Pacific terminus of the boundary line between Nicaragua and Costa Rica; it is partly within the jurisdiction of each of these countries.

The Gulf of Nicoya is an extensive body of water, and accommodates the Pacific coast commerce of Costa Rica through the port of Punta Arenas.

The Gulf of Dulce is a large landlocked arm of the Pacific in southern Costa Rica, and after passing the small bays of David and Montijo, we come finally to the great Gulf of Panama, over a hundred miles in diameter. Parita Bay is an indentation on the western margin of the gulf; Panama Bay, to the north, is the harbor of the Pacific terminus of the Panama Railway, and is also the terminus of the proposed Panama and San Blas canal routes. San Miguel Bay, on the eastern side of

the gulf, receives the waters of the Tuyra, and is the Pacific terminus of the once proposed Caledonian route.

Guatemala is well watered by numerous rivers and lakes. The largest river is the Matagua, which is over 250 miles long and is navigable for a considerable distance. The Polochic River is 180 miles long and is navigable for 20 miles. The principal lakes are the Flores, Izabel, Amatitlan, Guija, and Atitlan, the latter having no outlet.

The largest rivers in Honduras are the Ulna, in northern Honduras, and the Wanks, which forms the greater part of the boundary line between Honduras and Nicaragua, and is nearly 350 miles long.

The next streams of importance to the southward are the Grande and Bluefields rivers, which rise in the continental divide near the Pacific and drain the major part of northern Nicaragua.

We now come to the San Juan, which in total length and drainage is the largest in all Central America, though its discharge is less than the Ulna or the Wanks. From the source of the Viejo River to the mouth of the San Juan its total length is over 350 miles. This river is of especial interest, as it is the outlet of Lake Nicaragua and the course of the proposed Nicaraguan Canal.

The conditions which favor this region as a site for a canal consist of a large, deep lake 100 feet above sea level, separated from the Pacific Ocean by a narrow strip of land, containing the lowest depression in the continental divide between the Arctic Ocean and the Straits of Magellan, and a large, navigable stream carrying the surplus waters from the lake to the Caribbean Sea. This route is especially fortunate in having at its summit level a magnificent natural reservoir in Lake Nicaragua, fed by an ample drainage basin. This reservoir is useful not only for storing water for operating the locks of the canal, but also for controlling the great floods that could hardly be provided for at practicable cost without its aid. No other route enjoys advantages of this kind.

The high plateau of Costa Rica gives rise to numerous rivers, the San Carlos and Saripiqui flowing into the San Juan, and the Reventazon and several others into the Caribbean, while a number of smaller and relatively unimportant streams empty into the Pacific.

After passing a few insignificant streams we next come to the Chagres, celebrated as the site of the Panama Railroad and Canal. Its headwaters are near the Pacific, and it drains a long strip of the isthmus, flowing nearly parallel to the coast for two-thirds of its course, and emptying into Limon Bay on the Caribbean. Though the isthmus is less than 50 miles wide at its mouth, the Chagres River is over 120 miles long.

To the eastward the Bayana River drains an extensive area into Panama Bay. Like the Chagres, its course is parallel to the coast for most of its length, and it receives many tributaries. Its lower course occupies the narrowest part of the isthmus, and is the site of the proposed San Blas canal route. At this point the isthmus is only 30 miles in width.

The Tuyra River is the most important stream on the Isthmus of Panama. The drainage of its basin is extremely complicated. Its main branch rises near the Caribbean, and its course for about 80 miles is southeasterly; it then nearly doubles on itself and flows northwest into San Miguel Bay. At its great bend it receives several important tributaries from the south, and its basin covers nearly two degrees of latitude, joining the basin of the Atrato on the south and east.

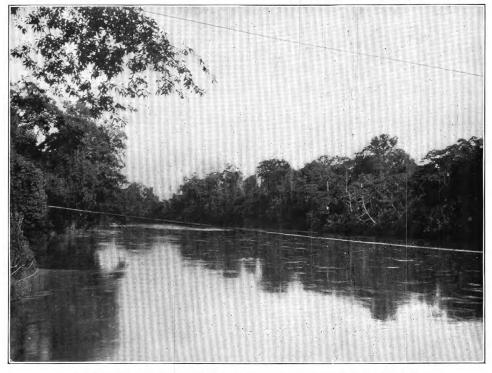
The Atrato River drains the western part of Colombia into the Gulf of Darien on the Caribbean. Its general course is nearly parallel and very close to the Pacific coast. It is the site of a proposed canal route which lies farther south than that of any other project.

Most of the streams on the Caribbean coast occupy a "drowned" or depressed topography for a considerable distance from the coast, and are consequently tidal in their nature. Though the Caribbean tide is less than a foot, it is plainly perceptible on Bluefields River at Rama, 60 miles from the mouth. The drowned bed of the San Juan extends to Machuca Rapids, over 70 miles from the coast, but the deep channel has been filled with sand by the San Carlos below the mouth of that river, so that it has lost its tidal nature. On the Chagres the tide is daily perceptible at Bohio Soldado, 15 miles from the coast.

TEMPERATURE.

Central America is in the torrid zone, lying entirely between 7° and 22° of north latitude. The climate is therefore tropical, except in the higher mountains, where it becomes cooler under the influence of altitude. In the lower regions, though the mean temperature is high, it is remarkably uniform, there being little change between day and night or with the seasons, and the heat is not excessive. This is especially true of the country near the Caribbean, which is blessed with almost constant trade winds, which have a tempering and very refreshing influence. The relative humidity is high, except on the Pacific slope in the dry season.

Some observations of temperature and relative humidity have been taken in the canal regions and are given in condensed form in the following tables:



A. SARAPIQUI RIVER, COSTA RICA, AT GAGING STATION 5 MILES ABOVE MOUTH.



B. INDIO RIVER, NICARAGUA, NEAR ITS MOUTH.

Temperature and relative humidity at Tola Gage Station, Nicaragua. [In degrees Fahrenheit.]

44.64		Temperature.			
Month,	Maximum.	Minimum.	Mean.	humidity.	
1900.					
January	85.0	74.0	79.0	81.0	
February	86.5	73.0	81.0	79. 6	
March	91.5	73.0	82.5	78. 2	
April	94.0	75.5	84.8	79.0	
May	93.0	73. 5	82.0	88. 2	
June	86. 5	72.0	80.5	86. 2	
July	87. 0	73.0	78.9	89.4	
August	88.0	75. 5	80.6	93. 2	
September	90.0	72.5	80.6	94.0	
October	88. 0	72.0	79.0	95. 2	
November	87.0	72.0	79.6	88. 6	
December	88.0	74.0	79.8	88. 6	

Temperature and relative humidity at Sapoa, Nicaragua.

Section 5		Temperature.		Mean relative humidity.
Month,	Maximum.	Minimum.	Mean.	
1899.		-0	-0.0	
August	87.0	72	79.6	87.8
September	96. 0	70	80.5	89.0
October	94.0	71	78.9	89. 4
November	86.0	70	78.5	89. 8
December	84. 0	72	80.3	87.0
1900.				45.4
January	84.5	73	77.9	88.6
February	86.0	73	79.0	87.8
March	89.0	73	80.3	85.0
April	94.0	75	80.4	82. 6
May	93.5	75	82.8	84. 6
June	91.5	72	81.3	88.4
July	89. 5	74	79.9	89. 8
August	87.5	74	80.8	90.0
September	88.0	74	79.8	92.0
October	86.0	71	78.9	94.0
November	86.0	71	78.9	91.8
December	86.0	72	79.1	91.4

Temperature and relative humidity at Las Lajas, near Rivas.

		Relative		
Month.	Maximum.	Minimum.	Mean.	humidity.
1898.				
February	- 80	75	77.7	81. 1
March	- 84	75	79.5	79. 8
April	. 86	77	80.8	79. 1
May	. 91	73	82.1	83. (
June	. 91	73	81.4	84. 8
July	. 85	74	79.7	86. 6
August	. 85	74	80.7	87.0
September	. 85	73	79.4	90.4
October				
November	. 86	73	79.3	89.7
December	. 83	73	78.3	91. 1

Temperature and relative humidity at Rivas, Nicaragua.

		Mean rela-		
Month.	Maximum.	Minimum.	Mean.	humidity.
1900.				
January	78.0	75	76.2	86. 2
February	79.0	73	77.4	80.8
March	81.5	74	78.5	78.6
April	83.0	79	81.0	80.8
May		77	80.0	85.4
June	81.0	75	78.6	89.8
July	80.5	75	77.8	89.4
August	81.0	76	79.0	86. 2
September		76	77.8	90. 2
October		74	77.0	91. (
November	80.0	73	77.4	89. (
December	79. 2	72	77.7	82.6

Temperature and relative humidity at San Ubaldo, Nicaragua.

Month.		Relative		
Month.	Maximum.	Minimum.	Mean.	humidity.
1899.				
September	95	72	81.7	88.0
October	91	72	79.8	91.0
November	91	72	80.0	88.6
December	88	67	78.5	84.6

Temperature and relative humidity at San Ubaldo, Nicaragua—Continued.

Year.		Relative		
Month.	Maximum.	Minimum.	Mean.	humidity.
1900.				
January	92	69	79.6	81.8
February	93	69	80.7	79. 4
March	99	68	82.9	76.8
April		72.	86.3	73.8
May		75	85.8	79.4
June	94	75	82.9	88.8
July	92	71	81.4	87. 2
August	93	73	83.0	84.0
September	93	73	83.1	84. 2
October		70	80.6	92. 4
November	90	71	80.3	85. 4
December	91	70	81.2	79. 2

Temperature and relative humidity at Fort San Carlos, Nicaragua.

2.7.2		Temperature.		Relative
Month.	Maximum.	Minimum.	Mean.	humidity.
1898.	2.0			
March	88.0	70.0	78.1	58.0
April	88. 5	70.5	78.5	79.1
May	91.0	73.0	80.0	85. 9
June	90.0	73.0	79.5	88.9
July	89.5	72.0	78.2	88.9
August	89.0	73.5	79.1	89.5
September	90.0	72.5	79.6	87.3
October	90.0	74.0	79.8	88.8
November	88.5	72.0	77.9	90.1
1899.				
January	84.0	69.0	75.9	90.5
February	85.0	66.0	76.9	87.5
March	90.0	70.0	77.6	83.7
April	93.0	69.0	79.6	80. 2
May	93.0	71.0	80.4	82. 2
June				
July	86.0	73.0	78.6	91.4
August	87.5	72.0	78.0	90.6
September	89.0	73.0	79.1	89.4
October	86.5	73.0	79.2	90.6
November	84.0	72.0	77.7	89.4
December	84.0	69.0	76.5	91.4
1900.	-			
January	85.0	72.0	77.6	90. 2
February	85.5	70.5	76.9	93.0

Temperature and relative humidity at Sabalos, Costa Rica.

[In degrees Fahrenheit.]

		Temperature.		Relative
Month.	Maximum.	Minimum.	Mean.	Relative humidity.
1898.				
February	90.0	67.0	75.5	87. 2
March	90.0	69.0	76.7	84. 8
April	89.0	66.0	76.8	85. 3
May	89.0	71.0	77.8	87. 8
June	89.0	71.0	77.7	90.0
July	89.0	71.0	77.1	92.0
August	87.0	70.0	77.5	91.0
September	90.0	71.0	78.0	87.4
October	90.0	.71.0	78.2	87.4
November	88.0	68. 0	77.0	90.4
1899.				
January	86.0	66.0	75. 2	90.7
February	86.0	64.0	76.0	87.6
March	90.0	68.0	77.1	85.0
April	91.0	67.5	78.2	83. 0
May	92.5	70.0	79.4	83.4
June		,		
July	88.0	74.0	78.3	91.0
August	92.0	71.5	77.8	91.0
September	91.0	71.5	78.4	89.9
October	91.0	71.0	78.9	89. 9
November	87.0	71.0	77.2	87.0
December	84.0	66.0	75. 1	91.0
1900.				
January	85.0	66.5	75.3	88. 8
February	87.0	68.0	76.0	85.0
March	89.0	67.0	76.8	85.0
April	96.0	67. 5	79.5	80.6
May	95.5	72.0	80. 4	83. 2
June	90.0	71.0	79.0	87.6
July	87.0	72.0	77.0	91. 4
August	86.5	72.5	77.0	91.4
September	92.0	72.0	78. 7	88.8
October	89.0	71.0	77.8	91.8
November	- 86.0	68.5	74.6	91.4
December	85.0	68.5	76.4	88. 2

Temperature and relative humidity at Ochoa, Costa Rica.

104.00		Reletive		
Month,	Maximum.	Minimum.	Mean.	Relative humidity.
1898.				
January	83.0	66.0	73.9	91. 6
February	85.0	66.0	73.3	90.4
March	87.0	67.0	75.1	87.6
April	80.0	66.0	75.8	88.8
May	94.0	72.0	78.3	90.0
June	90.0	71.0	77.5	90.7
July	89.0	70.0	76.6	91. 5
August	87.0	71.0	77.0	91.4
September	91.0	70.0	77.5	89. 6
October	95.0	71.0	78.2	89. 4
November	89.0	70.0	76.1	92.0
December	85. 0	67.0	75.1	91.0
1899.				
January	84. 5	67.0	74.8	93. 2
February	86.0	68.0	75.3	91.9
March	91.0	67.0	75.6	89. 7
April	88.5	68.0	76.6	87.0
May	89.5	70.0	77.9	90. 6
June	86.0	72.0	77.7	90. 2
July	85.5	72.5	77.3	92. 6
August	96.0	71.5	77.5	92. 2
September	90.0	72.0	78.4	89.8
October	88.5	72.5	79.0	89.0
November	87.0	72.0	77.4	91.4
December	84.5	68.0	75. 1	92. 6
1900.				
January	83.5	70.0	75. 7	90. 6
February	87.0	70.0	76.6	87.8
March	87.0	69.0	77.1	87.0
April	93.5	69.0	79.8	85. 4
May	92.5	74.0	80.4	87.0
June	91.0	73.0	79.6	88. 6
July	87.0	71.5	78.0	90. 6
August	86.0	73.5	77.9	92. 6
September	92.5	73.0	80.0	87. 0
October	87.5	72.5	78.6	89. 8
November	86.0	70.5	77.0	91.0
December	85.0	70.5	76.8	90. 6

Temperature and relative humidity at San Juan del Norte, Nicaragua.

		Temperature.						
Month.	Maximum.	Minimum.	Mean.	Relative humidity.				
1898.								
January	86	67	77.5	82.				
February	. 84	71	77.1	81.				
March	90	69	78.4	80.				
April	89	69	79.9	79.				
May	94	73	80.4	82.				
June	90	72	79.3	91.				
July	90	74	80.0	91.				
August	95	73	80.0	84.				
September	.96	72	81.2	85.				
October	96	72	81.4	84.				
November	92	72	79.7	87.				
December	91	72	78, 3	88.				
1899.								
January	86	69	77.8	87.				
February	88	66	77.2	87.				
March	90	72	79.7	80.				
April	92	70	80.6	78.				
May	98	72	81.0	84.				
June	89	74	79.5	85.				
July	88	73	78. 7	86.				
August	88	72	78.0	87.				
September	90	73	79.3	86.				
October	88	72	80.3	84.				
November	88	73	78. 2	88.				
December	85	70	76.0	88.				
1900.	07	71		. 07				
January	87	71	77.4	87.				
February	89	71	78.6	85.				
March	89	71	78.3	83.				
April	94	70 74	81.7	80.				
May	93		81. 2	85.				
June	92	75	81.1	83.				
July	91	73	78.6	87.				
August	89	75	80.0	86.				
September	92	74	80.9	84.				
October	91	73	79.3	87.				
November	88	72	77. 2	89.				
December	86	71	78.6	84.				

Monthly temperatures observed by the Panama Canal Company. [In degrees Fahrenheit.]

Alhajuela. La Boca. Month. Mini-Maxi-Mini-Maxi-Mean. Mean. mum. mum. mum. mum. 1899. 78.8 72 79.7 July 91 70 88 August 88 68 75.0 94 71 80.0 77.0 97 72 80.6 September..... 91 69 October 86 70 76.4 94 71 78.8 November 88 72 79.5 69 76.8 91 December 89 68 77.9 91 66 78.9 1900. 90 66 76.8 January 88 68 77.7 February 79.5 77.5 66 89 70 March..... 90 68 79.7 93 64 79.7 April..... 90 68 80.0 94 64 80.9 May 90 73 80.9 94 68 78.0 June 80.4 70 78.9 89 74 94 79.3 77.3 July 88 73 90 70

The following two tables are taken from the reports of the United States Weather Bureau:

91

91

88

89

91

72

72

72

73

68

80.3

80.6

79.4

78.8

80.2

79.6

90

92

89

89

70

70

69

69

78.4

76. 4 77. 7

77.3

August

September....

November

December

The year

October

Temperature observations at Gamboa.

ABSOLUTE MAXIMUM TEMPERATURES.

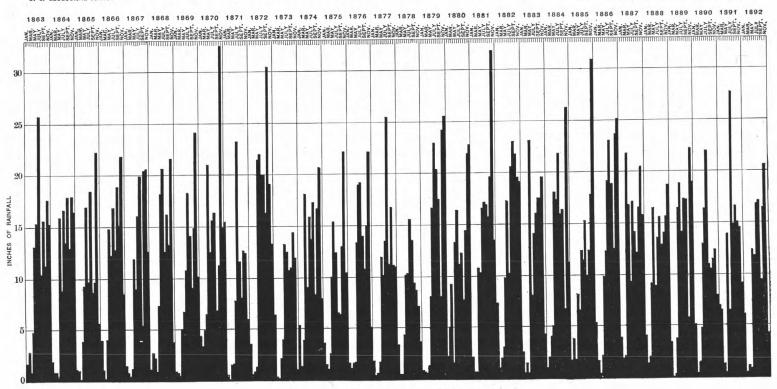
Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1882 1883			92.5	91.8	97.7	98.6	88.7	94.1	96.8	95.0	95.0	95.0	
1884	88.5	87.8	88.9	90.3	90.3	93.7	90.7	90.3	91.0	91.0	91.0	89.2	90. 3
1885	88.2	88.9	90.3	94.3	97.5	95.4	91.4	88.9	93.6	93.9	92.1	91.0	92.1
1886	92.8	90.0	92.5	97.2	95.4	91.8	94.6	92.3	95.7	93.2	92.5	93.6	93.4
1887	91.4	90.0	92.8	91.8	96.4	93.6	93.0	91.4	91.8	93.9	93.2	91.8	92. 3
Means	90.3	89.6	90.7	93.0	95.5	97.5	91.8	91.4	94.3	93.4	92.8	91.4	92.5

Temperature observations at Gamboa—Continued.

ABSOLUTE MINIMUM TEMPERATURES.

			BSOLU									v	
Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1882			62.6	53.6	63.0	59.0	71.6	66.2	66.2	66.6	64.4		
1883													
1884	60.4	59.0	58.6	61.2	65.8	66.6	68.0	65.8	66.9	65.8	66.2	59.0	63.7
1885	60.4	59.7	61.2	61.5	65.1	68.4	68.4	69.8	68.0	68.0	68.4	67.6	65. 5
1886	58.6	60.4	61.5	65.5	68.0	68.4	66.9	68.7	67.6	60.8	67.6	63.0	64.8
1887	62.2	58.3	57.2	61.2	63.3	68.5	67.6	70.9	71.2	70.2	72.0	71.2	66, 2
Means	60.4	59.4	60.3	60.6	65.1	66.2	68.5	68,4	68.0	66, 2	67.6	65.3	64.8
	,		1	MEAN	TEMI	PERAT	URES.	a					
1882–1887	75.4	74.5	75.6	76.8	80, 2	81.9	80.2	79.9	81.0	79.9	80.2	78.4	78.6
DE	PART	URES	OF TE	HE MO	NTHL	Y ME	ANS F	ROM	THE .	ANNU.	AL.		
1882–1887	-3.2	-4.1	-3.0	-1.8	+1.6	+3.3	+1.6	+1.3	+2.4	+1.3	+1.6	-0.2	
	^a Mea	an abso	olute n	naxim	um +	mean	absolu	te min	imum	÷ 2.			
						rvatio							
		A	ВЗОДО	IL M.	1	JM IE	MI EA	I	1			1	
Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1882	85.3	87.1	84.9	87.8	88.7	88.5	88.2	89.6	91.8	92.1	88.9	89.2	88.8
1883	88.9	87.8	88.2	89.2	89.6	89.6	89.2	89.2	89.6	88.9	89.2	86.0	88.7
1884	86.4	85, 6	86.4	87.8	89.6	89.6	90.7	91.4	90.5	91.2	95.9	92.1	89.8
1885	90.3	90.7	90.7	89.2	92.1	90.7	90.3	91.4	92.8	94.3		98.2	91.9
1886	98.2	92.8	98.2	96.8	93.9	93.9	93.2	93.9	93.9	96.1	95.7	94.6	95.2
1887	96.8	93.2	91.4	92.1	93.2	92.3	91.8	91.4	90.7	89.2	87.4	89.6	91.6
Means	90.9	89.6	90.0	90.5	91.2	90.9	90.5	91.2	91.6	91.9	91.4	91.6	90.9
18.01		A	BSOLU	TE M	INIMU	M TE	MPER	ATURE	s.				
1882	71.6	69.1	70.2	68.0	68.7	69.4	68.7	63.1	66.2	66.6	66.2	66.6	67.8
1883	68.0	70.5	64.4	65.5	69.4	68.0	68.4	66.2	69.8	68.4	63.7	66.9	66. 5
1884	65.8	67.6	64.4	66.2	64.4	65.8	67.6	59.4	57.6	76.3	70.7	66.2	66.0
1885	71.2	66.9	72.7	70.2	72.0	70.5	71.6	70.2	70.5	71.2	71.2	70.2	70.7
1886	65.8	71.6	67.1	71.6	69.1	70.5	69.4	69.4	68.7	69.1	67.3	65.8	68.7
1887	67.6	69.4	66.6	69.1	68.0	70.3	70.5	73.0	74.5	72.3	73.8	73.4	70.7
Means	68.4	69.3	68.7	68.4	68.5	69.1	69.3	66.9	69.4	70.5	68.7	70.0	68.7
Tactaris	00.1	00.0	00.7	00.4	00.0	05.1	03.8	00. 8	03.4	70.5	00.7	10.0	00.
				MEAN	TEM	PERAT	URES.	8.					
1882–1887	79.5	79.5	79.3	79.5	79.9	79.9	79.9	79.2	80.6	81.3	80.1	79.9	79.9
DE	PART	URES	OF TE	HE MO	ONTHI	Y ME	ANS F	ROM	THE .	ANNU.	AL.		
1882–1887	-0.4	-0.4	-0.6	-0.4	0.0	0.0	1	1	+0.7	+1.4		1	

^{*} Mean absolute maximum + mean absolute minimum $\div 2$.



MONTHLY RAINFALL AT COLON, ON THE CARIBBEAN.

RAINFALL.

Considering the earth as a whole, no water can fall as rain except that which has previously been evaporated from its surface. The rainfall must, in the long run, therefore, be nearly equal to the evaporation, the temporary departures from such equality being due and equal to the fluctuating atmospheric humidity. The potential evaporation from the earth's surface varies from a few inches in polar regions to perhaps 100 inches in arid tropical localities, the mean being probably between 40 and 50 inches. But as about one-fourth of the earth's surface is land, upon which potential evaporation can not exercise its full possibilities for lack of water to evaporate, the average evaporation that actually takes place, and, hence, also, the mean rainfall of the world, is probably less than 40 inches.

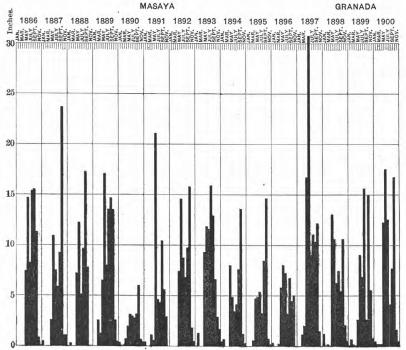


Fig. 227.—Monthly rainfall at Masaya and Granada, Nicaragua.

Considered by this standard, the greater part of Central America may be classed as a region of heavy rainfall, some of it excessively so. Although the Isthmus is narrow, the contrast between the two coasts is great, both as to the quantity and distribution of rainfall. On the Pacific side, where the greater part of the population is concentrated, the year is distinctly divided into two seasons—the wet and the dry—as distinctly defined and contrasting as strongly in rainfall as those seasons on the coast of California. There is some variation from year

to year in the dates of beginning and ending of these seasons, but the five months from December to April are dry, November and May are variable, and June to October are rainy months; the rainy season being usually a few weeks longer than the dry. In this region the annual precipitation varies from 30 to 90 inches, the mean being mostly between 50 and 60.

On the Caribbean side of the Isthmus the rainfall is greater and the dry season shorter and less definite. Here the relative humidity is uniformly high and no month in the year is entirely free from rain, though the months of February, March, and April are relatively dry months. These characteristics are shown on Pl. XXXVIII and fig. 227.

One of the most remarkable features of Isthmian climate is the limited region of excessive rainfall, of which the nucleus seems to be in the neighborhood of San Juan del Norte, Nicaragua. This is more fully discussed under heading "Hydrography of Nicaragua Canal route," page 546.

The general distribution of rain, so far as known, is shown in Pl. XXXIX.

The following tables give in condensed form some of the more important observations of rainfall on the Isthmus:

Annual rainfalls in Central America.

Year.	San Jose, Costa Rica.	Colon, Colom- bia.	Masaya, Nicara- gua.	Granada, Nicara- gua.		San Anto- nio plan- tation, Nicara- gua.	Bas Obispo, Panama.	Gamboa, Panama.	Bohio, Panama.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1863		134.31							
1864		123.43							
1865		106.14							
1866	63.93	129.71							
1867	73.47	[119.52]							
1868	56.09	120.03							
1869	62.92	114.78							
1870	75.09	149.64							
1871	75.56	99.58							
1872	86.78	168.50							
1873	55.84	87.12							
1874	60.83	137.70							
1875	59.76								
1876	50.43								
1877	53.42			61.34					
1878	60. 29								
1879	86.37								
1880	61.50								
1881		[104.39]							
1882		124.10						77.29	
1883		115.34		47.43					
1884	19.49	86.54		35.98			74.71	94.59	
1885	69.60	146.29					81.23	97.48	
1886	154.30	137, 17			23. 25. 25. 25. 25. 25.		91.00	102.87	

RAINFALL.

Annual rainfalls in Central America—Continued.

Year.	San Jose, Costa Rica.	Colon, Colom- bia.	Masaya, Nicara- gua.	Granada, Nicara- gua.		San Anto- nio plan- tation, Nicara- gua.	Bas Obispo, Panama.	Gamboa, Panama.	Bohio, Panama.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1887	71.48	154.88	61.22				98.27	136.19	
1888	59.21		58.70				66.72	102.64	
1889	85.18		78.78				77.53	75.72	
1890	71.78	154.38	20.52		296.94		92.16	105.03	
1891	65.18	124.73	49.98		214.27		83.82	77.67	
1892	91.55	145.27	64.54		291.20		105,07	104.37	
1893	97.90	131.89	72.86				123.00	117.81	
1894	58.23	153.69	42.88					90.60	
1895	76.75	151.54	41.26			69.83			
1896	64.76	131.51	39.64			65.50			
1897	74.97	138.03		93.62		98.26		107.91	181.65
1898	78.43	115.55	[50.73]	55.59	201.64	81.05		82.60	204.61
1899		133.02	45. 24	56.93	285.93	67.22		80.00	118.98
1900		116.06	59.75	72.07	266.10	95.68		78.60	131.93
Mean.	70.70	129. 25	54.20	60.42	259.35	79.59	89.26	87.28	159. 29

Rainfall in Costa Rica previous to 1898.

[The stations in italic are on the Caribbean side of the main cordillera.]

	Longitude west of Greenwich.	Lat. N.	Alti- tude.	Yearsof obser- vation.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual.
			Feet.		Inches.	Inches											
Boca Banana	83° 01′ 51″	90 56'	10	3	14.1	5.7	6.9	21.8	7.4	7.8	11.3	12.4	3.0	6.8	9.6	14.6	121.
Port Limon	83° 03′	10° 00′	10	2	8.9	8.3	8.9	10.2	11.4	8.1	20.9	9.7	3.9	3.9	14.0	10.4	117.
Matima	83° 22′	10° 06′	131	3	20.1	10.8	5.1	20.0	9.1	8.1	12.2	10.0	3.7	4.3	11.7	19.4	134.
Jimenez	± 83° 48′	±10° 14′	820	1	18.0	5.3	8.8	11.2	16.6	10.2	8.1	15.4	7.2	17.9	9.4	25.0	153.
Turrialba	± 83° 47′	± 9° 55′	2,110	5	9.1	2.1	3.1	10.6	9.4	12.4	9.1	10.0	10.0	9.4	7.5	17.8	110.
Tuis	± 83° 38′	± 9° 51′	2,133	2	6.7	3.7	2.1	10.5	12.0	10.6	9.3	5.9	10.9	7.9	7.8	18.5	105.
Juan Viñas	± 83° 45′	± 9° 55′	3,740	21/9	13.1	3.3	4.6	5.0	7.2	7.5	6.6	8.7	7.3	7.9	6.8	14.0	91.
Cartago	± 83° 55′	± 9° 55′	4,842	3	3.7	1.7	1.0	2.7	7.1	5.1	3.2	6.3	7.2	11.1	3.5	3.4	56.
Aguacaliente	± 83° 57′	± 9° 55′	4, 475	2	1.7	0.4	1.4	1.6	7.5	5.3	4.3	7.4	7.2	10.5	1.4	6.0	54.
Fres Rios	± 83° 57′	± 9° 56′	4, 265	7	0.4	0.0	0.2	2.9	1.4	10.3	6.7	9.7	13.2	17.2	6.7	2.0	83.
La Verbena	± 84° 04′	± 9° 55′	3,740	2	0.0	0.0	1.0	2.3	14.0	14.3	7.4	- 9.1	12.5	14.7	7.4	1.9	84
San Jose	84° 03′	9° 56′	3,806	30	0.6	0.1	0.7	1.8	8.8	9.3	8.2	9.5	12.5	11.8	5.9	1.5	70.
San Francisco	± 84° 03′	± 9° 57′	3,937	3	1.0	0.0	0.4	2.9	9.4	10.8	7.3	11.1	11.2	12.0	6.9	1.3	74.
Heredia	± 84° 09′	± 9° 59′	3,871	3	1.6	0.3	0.0	0.8	2.2	8.9	8.7	5.7	5.4	9.2	14.1	4.1	61.
La Palma, on the divide	± 83° 59′	±10° 03′	4,790	-2	18.5	3.0	2.7	7.4	10.0	16.9	11.3	10.6	9.2	9.3	11.0	24.9	134.
San Carlos	± 84° 31'	±10° 24′	164	1 2	7.7							13.0	13.2	13.4	15.3	6.1	

Monthly rainfall in Costa Rica, 1898 to 1900.

1898.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Boca Banana	18.74	5.20	7.87	8.43	10.12	7.52	8.98	4.49	1.38	3.74	8.86	7.05	92.38
Limon		2.16	11.37	9.35	15, 55	6.89	7.76		1.41	2.99	13.62	6.22	
Swamp Mouth				13.58	8.82	6.65	12.44	5.11	1.38				
Gute Hoffnung	27.32	7.68	6.61	7.91	7.87	11.49	10.83	1.29	1.88	2.51	12.67	9.06	107.12
Rio Honda	34. 25	7.68	6.89	8.97			10.98	8.82	4.48	4.48	10.15		
Siquirres	21.06	11.18	6.54	12.04	9.88	11.81	9.13	7. 95		5.43		4.13	
Peralta				8.22	15.90	21.96	9.96	10.0	-8.74	6.02	9.84	6.81	
Turrialba	10, 23	2.4	5.43	7.32	7.99	15.98	5.67	4.72	9.72	7.36	8.03	3, 89	88.74
Juan Vinas	7.87	2.0	7.52	5.75	6.89	7.83	8.39	8.27	8.98	8.98	7.09	3.66	83.26
San Rafael de Car- tago	3.11	1.25	0.82	1.14	8.19	9.47	4.41	7.56	1.38	13.42	3.42	0.47	67.06
San Diego	0.47		0.11	1.65	7.79	13.07	6.11	11.96	21.18	15.74	7.05		
La Palma	17.71	5. 89	5.39	6.77	9.88	17.79	9.02	9.92					
San Francisco Guadalupe	1.43		0.27	1.14	9.61	16.02	7.68	11.57	15. 27	12.08	5.28	0.078	79.428
San Jose	0.35		0.27	9.61	8.58	15.59	8.92	13.42	13.62	11.69	4.65	0.078	86.778
Hacienda La Ver- bena							13.3	12.12	15.70	24.05	10.35		
Sarapiqui coffee estates							16.81	17.48	19.4	19.28	21.73	5.16	
Nuestro Amo	0.00					11.57	5. 24	11.80	14.92	8.15	5.19	1000	
San Carlos								13.03	1 20 10 20 1				
1899.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
4	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Boca Banana	12.91	15.55	5, 55	8.74	9.29	6.57	25.00	11.68	6.81	1.33	12.37	12.36	128.16
Limon			5.28	8.03	14.52		29. 29			3.93	11.22	13.14	
Swamp Mouth	12.00	8.62	8.62	4.65									
Gute Hoffnung	10.11	12.87	5.08	5.87	4.76	6.11	22.36	6.49	4.13	5.51	14.64	14.13	112.06
Peralta	8.61	7.72	3.34	6.02					7.05	7.58	9.69	10.19	
Aragon	8.39	4.17	3.42										
Juan Vinas	6.54	3.77	2.04	4.76	5.47	4.69	16.73	6.97	4.76	8.89	7.56	13.81	85.99
San Rafael de Car- tago						5. 24	9.92	3.22	2.32	7.28	8.74		
San Diego	0.86	0.66	0.23	1.18	1.92	10.19	12.12	6.61	4.57	15.51	8.19	0.157	62. 191
	1.57	0.31	1.57	1.81	2.55	9.13	14.44	6.81	6.65	7.59	7.36	0.196	59.86
San Francisco Guadalupe	100	0.196	1.45	1.25	2.55	8.35	15. 86	0.392					
Guadalupe	1.69			1000		1							
	1.69		0.86	0.039	1.96	8.26	13.81	6.61	6.69	7.36	8.19	0.196	55.895
Guadalupe San Jose Hacienda La Ver-			0,86	0.039 0.66	1.96 4.25	1			6.69 7.44	1000		0.196	55. 898
Guadalupe San Jose Hacienda La Ver- bena	1.37		0.86 3.22	0.66		8.66	7.68			1000	8.31		180. 20

22 geol, pt iv-01-34

Monthly rainfal	l in Costo	a Rica, 189.	8 to 1900-	-Continued.
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1900.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Boca Banana	6, 65	4.84	9.84	9.88	5.12	2.87	7.1	21.6	8.98	6.18	9.72	12.16	104.94
Limon		8.3	9.57	10.27	3, 58	3.82	8.27		10.9	3.98	8.07	13.74	
Swamp Mouth									9.41	2.6		12.63	
Gute Hoffnung	4.57	4.61	9.09	12.16	8.19	4.57	10.19	26.26	9.84	10.31	11.73	10.67	122.19
Siquirres			9.61	9.57		9.25		18.3	7.85	8, 82	0.23	9.53	
Guapiles							4.61	30.9	16.1		25.6	14.56	
Las Lomas								15.9	11.37	13, 22	19.96	14.4	
Peralta	4.49	1.9	7.05	9.25	21.53	13.58	13.11	13.81	14.64	16.26	11.77	14.4	141.79
Juan Vinas	2.48	3.66										7.52	
San Diego	0.19		0.11	2, 59	14.64	13.34	15.43	3.48	12.12	11.53	6.77	0.66	80.86
San Francisco													
Guadalupe	0.078		0.55	2.55	7.01	19.25	14.13	3.31	10.75	17.32	6.34	0.51	81.789
San Jose	0.039		0.82	2.76	6.93	19.88	15.59	3.11	10.23	16.29	6.54	1.1	83. 289
Hacienda la Ver-													
bena			0.29	0.94	8.62	14.08	8.78	3.74	12.08	16.22	5.87		70.62
Nuestro Amo			3, 85	1.25	11.1	12.67	16.33	3.42	12.4	22, 12	7.95		91.09
Alajuela									11.53	24.13	9.45		
Sarapiqui	8.31	8.31	4.02	10.55	20.35	25, 35	22.75	8.86	15.7	27.75	27.4	11.81	191.16
San Carlos	.8. 03	3.78	3.11	5, 43	14.96	7.95	17.12	13.5	12.87	19.88	21.69	10.23	138.55

WIND MOVEMENT.

One point of interest in the consideration of the Isthmian canal is the strength and persistence of winds, considered as motive force for sailing vessels, and as annoyance to the navigation of the canal and to ships entering and leaving port.

The persistence of the trade winds has frequently been mentioned in discussions of the Nicaragua Canal route. In 1898, it being necessary to take gage readings at Las Lajas, on the western margin of the lake, for transferring the level line across the lake, a camp with an observer was established here and the gage height of the lake was observed at 6 and 9 a. m., 12 noon, 3 and 6 p. m. Note of the condition of the lake surface was made at each observation, and from January 19, 1898, when the observations began, until the 1st of May a heavy surf was beating on the beach at this point at every observation, due to the persistence of the trade winds. A few days of calm occurred in May and at later periods during the rainy season.

On May 16, 1900, an anemometer was installed at San Juan del Norte and observed at 8 a.m., 12 noon, and 6 p. m. each day, and the record was kept practically continuous to the end of the year. In all this time not a single day occurred without wind movement; the highest velocity recorded being something over 40 miles per hour, and this occurred on only one day, November 13. The mean for that day was 24.5.



The results of the observations are shown in the following table:

Anemometer record at San Juan del Norte, Nicaragua.

			May.					June.		
Day.	Anemo	meter re	eadings.	Mi	les.	Anemo	meter re	adings.	Mi	les.
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1						677.4	786.1	754.5	127.4	5.8
2						804.5	922.9	980.9	121.8	5, 1
3						926.3	950.8	3.2	118.8	4.
4						45.1	81.5	100.4	154.9	6.
5						200.0	222.8	278.9	195.7	8.
6						395.7	413.5	431.0	94.5	3. 8
7						490.2	525.0	562.4	133.5	5.0
8					-	623.7	659.1	694.0	106.3	4.4
9						730.0	754.0	801.0	102.1	4.
						832.1	835.0	842.5	99.4	4.
1						931.5	973.1	19.0	123.8	5.
2						55.3	111.0	133.0	114.7	4.
3						170.0	193. 2	221.5	81.0	3.
4						251.0	283. 0	315. 2	101.1	4.
5						352.1	370.7	416.3	97.7	4.
6	78.0	93.6	117.2	68.7	2.9	449.8	473.1	499.0	75.8	3.
7	146.7	178.0	212.1	99. 4	1	525.6	554.1	569.0	78.4	3.
	246.1	271.0	313.6	127.1	4.1		620. 2	653.6	128.0	5.
9	373. 2	399.0	403.3	62.3	5.3	604. 0 732. 0	751.6	784.1	93.7	3.
			30000	0.000	2.6				1	
20	435.5	450.3	497.5	97.6	4.1	825.7	837.2	855. 2	79.3	3.
21	533.1	553.4	589.0	85.2	3.6	905.0	832.0	953. 2	82.1	3.
22	618.3	639.3	688.6	105.0	4.4	987.1	10.7	45. 2	78.7	3.3
23	723.3	755.5	801.2	99. 9	4.2	65.8	81.2	186.7	146.3	6.
24	823. 2	869.0	916.1	119.8	5.0	212.1	237.3	307.2	117.0	4.
25	943.0	984.1	41.7	139.5	5.8	329.1	343. 3	378.8	72.5	3.
26	82.5	95.5	130.9	91.1	3.8	401.6	419.1	470.0	98.4	4.
27	173.6	195. 2	226, 0	115.2	4.8	500.0	515.5	567. 2	103.0	4.
28	288, 8	317.8	353.5	129.8	5.8	603.0	624. 2	664.0	129.0	5.
29	418.6	438.8	467.7	84.7	3.5	732.0	744.2	822.5	147.0	6.
30	503.3	521.1	549.1	101.7	4.2	879.0	897.6	967.0	155.1	6.8
31	605.0	626.2	652.1	72.4	3.0					

HYDROGRAPHY OF THE AMERICAN ISTHMUS.

Anemometer record at San Juan del Norte, Nicaragua—Continued.

			July.					August.		
Day.	Anemo	meter re	eadings.	Mi	les.	Anemo	meter re	eadings.	Mi	les.
	8 a.m.	12 m.	6 p. m.	Per day.	Per hour.	8 a.m.	12 m.	6 p. m.	Per day.	Per hour.
1	34.1	50.0	69.1	77.8	3.2	200.0	215.8	250.0	127.2	5.
2	111.9	152.2	172.4	97.1	4.1	327.2	339.3	381.2	93.8	3.9
3	209.0	219.1	235.8	54.2	2.3	421.0	433.6	552.7	230.5	9.
4	263. 2	281.0	328.4	113.9	4.7	651.5	663.7	700.0	71.6	3.0
5	377.1	397.4	463.5	140.9	5.9	723.1	732.4	778.3	85.9	3.
6	518.0	532.1	568.9	99.0	4.2	809.0	838.7	874.0	104.2	4.
7	617.0	625.1	683.1	167.8	7.0	913.2	924.2	950.0	86.8	3.
8,	784.8	806.1	843.2	88.4	3.7	1,000.0	9.2	29.0	120.7	5.0
9	873.2	890.5	920.1	94.8	3.9	120.7	141.9	196.0	119.5	5.0
10	968.0	995.2	62.5	102.0	4.3	240.2	252,1	284.8	148.8	6.5
11	70.0	83.2	105.2	58.1	2.4	389.0	415.0	487.6	215.5	8.
12	128.1	140.2	169.7	85.7	3.6	604.5	612.0	625.2	74.2	3.
13	213.8	230.0	275.5	96.3	4.1	678.7	700.2	734.5	48.0	2.
14	310.1	349.2	395.0	153.9	6.5	726.7	820.0	867.5	216.7	9.
15	464.0	478.0	502.5	108.2	4.5	943.4	975.0	32.5	118.9	4.
16	572.2	590.0	664.5	145.8	6.1	62.3	79.6	116.1	93.3	3.9
17	718.0	733.0	761.5	102.2	4.3	155, 6	182.3	246.8	141.4	5.
18	820.2	860.1	895.0	142.8	5.9	297.0	312.4	349.5	101.1	4.
19.:	963.0	991.5	47.0	121.6	5.1	398.1	416.2	446.7	97.1	4.0
20	84.6	91.2	116.0	62.5	2.6	495.2	506.4	549.0	102.1	4.
21	147.1	166.5	182.3	84.4	3.5	597.3	646.6	680.0	102.0	4.5
22	231.5	246.2	276.0	73.6	3.1	699.3	718.7	743.2	75.8	3.
23	305.1	330.0	363.2	83.4	3.5	775.1	787.4	818.1	78.6	3.
24	388.5	406.5	438.0	83.5	3.5	853.7	877.4	944.2	138.6	5.8
25	472.0	490.1	543.2	107.0	4.4	992.3	18.7	65.5	114.3	4.
26	579.0	602.1	650.8	134.0	5.6	106.6	117.8	141.2	84.2	3.
27	713.0	725.8	758.0	81.0	3.4	190.8	214.6	261.0	137.2	5.
28	794.0	836.0	889.2	135.0	5.6	328.0	346.2	409.0	138.1	5.
29	929.0	941.3	994.0	84.5	3.5	466.1	424.5	511.9	74.9	3.5
30	13.5	24.1	55.2	76.0	3.2	541.0	552.7	536.2	140.0	5.
31	89.5	102.3	156.2	110.5	4.0	681.0	698.3	739.6	87.4	3.

Anemometer record at San Juan del Norte, Nicaragua—Continued.

-		S	eptember					October.		
Day.	Anemo	meter re	eadings.	Mi	les.	Anemo	meter r	eadings.	Mil	es.
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	768.4	782.0	799.3	70.7	2.9	127.8	162.2	203.7	108,5	4.8
2	839.1	848.3	890.1	81.4	3.4	236.3	251.2	300.0	96.7	4.0
3	920.5	947.2	999.0	79.5	3.3	333.0	347.1	406.4	114.2	4.8
4	1000.0	19.9	76.5	102.0	4.3	447.2	472, 3	557.9	150.9	6.8
5	102.0	120.2	163.8	97.2	4.1	598.1	623.0	693.2	131.2	5.4
6	199.2	211.1	250.4	108.2	4.5	729.3	747.8	795.9	101.8	4.2
7	307.4	326.4	369.0	89.6	3.7	831.1	846.2	880.0	70.1	2.9
8	397.0	411.5	461.0	89.7	3.8	901.2	923.6	1000.0	130.1	5.4
9	486.7	507.2	553.6	114.7	4.8	31.3	57.6	111.1	85.8	3.6
0	601.4	621.0	673.1	99.9	4.2	117.1	122.5	202.6	111.9	4.7
1	701.3	719.5	763.3	101.8	4.2	229.0	246.4	273.1	69.4	2.9
2	803.1	815.7	845.0	57.6	2.4	298.4	316.2	359.6	87.6	3.6
3	860.7	873.4	911.6	81.0	3.4	386.0	399.4	427.1	52.6	2.2
4	941.7	953.1	1000.0	95.5	4.0	438.6	463.1	556.9	152.5	6.4
5	37.2	52.1	102.3	109.5	4.5	591.1	608.7	648.6	87.9	3.6
6	146.7	160.5	223.2	145.5	6.1	679.0	699.3	753, 2	118.3	4.9
7	292.2	321.6	401.3	159.8	6.6	797.3	812,5	860.0	104.7	4.4
8	452.0	472.1	501.3	71.0	3.0	902.0	912.3	995.1	115.3	4.8
9	523.0	540.8	601.2	91.2	3.8	17.3	38.2	76.1	92.0	3.8
20	614.2	632.4	681.1	150.9	6.3	109. °	125, 2	198.6	107.8	4.5
21	765.1	783.9	830.5	119.6	5.0	217.1	232.0	275.4	104.0	4.8
22	884.7	899.0	948.9	111.3	4.6	321.1	339.2	381.2	122.2	5.1
23	996.0	15.6	49.5	86.3	3.6	443.3	477.0	488.2	51.4	2.1
24	82.3	100.2	161.1	149.2	6.2	494.7	516.2	578.3	117.3	4.9
25	231.5	243.5	299.4	105.9	4.4	612.0	650.0	700.3	157.4	6.6
26	337.4	361.2	433.1	197.3	8.2	769. 4	805.1	867.4		
27	534.7	553.1	612.2	140.8	5.9)				200000
28	675.5	693.3	759.1	125.8	5.2					
29	801.3	824.4	900.0	184.7	7.7	(a)				
30	986.0	20.1	97.3	141.8	5.9					

a No record.

HYDROGRAPHY OF THE AMERICAN ISTHMUS.

Anemometer record at San Juan del Norte, Nicaragua—Continued.

		1	Novembe	er.			1	Decembe	er.	
Day.	Anemo	meter re	eadings.	Mi	les.	Anemo	meter re	eadings.	Mi	les.
	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.	8 a. m.	12 m.	6 p. m.	Per day.	Per hour.
1	319.5	326.1	515. 2	255.0	10.6	610.5	674.2	760.1		
2	574.5	593.0	631.9	119.2	5.0					
3	693.7	716.5	694.0	113.6	4.7	835.1	866.4	902.8	128.3	5.
4	807.3	912.0	980.9	201.4	8.4	963.4	21.0	49.2	143.4	16.
5	8,7	25.8	125.6	84.2	3.5	106.8	150.1	187.6	155.2	6.
6	92.9	74.5	118.2			261.0	296.5	330.0	249.0	10.
7						510.0	646.3	741.0	288.4	12.
8	453.0	403.0	480.5	210.6	8.8	798.4	824.0	866.2	95.6	4.
9	663.6	694.0	747.8	197.1	8.2	894.0	976.5	997.0	198.3	8.
10	860.7	907.1	955.2	236.4	9.9	92.3	141.6	188.9	117.2	4.
1	97.1	145.3	136.6	148.9	6.2	209.5	261.2	278.6	85.2	3.
12	246.0	234.6	227.9	178.2	7.4	294.7	312.1	329.6	106.5	4.
13	424.2	608.5	870.0	588.6	24.5	401.2	419.5	439.2	64.9	2.
14	12.8	81.1	87.4	71.5	3.0	466.1	484.6	504.9	70.0	2.
15	84.3	94.7	135.7	210.4	8.8	536.1	581.2	601.4	95.4	4.0
16	294.7	213.6	355.2	63.9	2.7	631.5	649.0	684.0	130.3	5.
17	358.6	411.0	428.2	79.3	3.3	761.8	794.0	822.6	132.2	5.
18	437.9	490.4	499.0	125.1	5.3	894.0	931.4	962.0	103.1	4.
19	563.0	592.8	640.7	139.5	5.8	997.1	42.4	87.6	145.8	6.
20	702.5	740.6	794.3	157.6	6.6	142.9	186.1	241.0	153.4	6.
21	860.1	878.0	921.6	78.8	3.3	296.3	361.2	398.0	183.9	7.
22	938.9	963.4	986.0	55.3	2.3	480.2	511.2	531.4	118.4	4.
23	994.2	14.8	132.5	196.8	8.3	598.6	623.9	641.7	94.4	3.
24	191.0	214.6	384.0	313.2	13.0	693.0	768.2	802.0	167.1	7.
25	504.2	524.0	557.7	116.7	4.9	860.1				
26	620.9	769.8	798.3	199.5	8.3		978.0	61.7		
27	820.4	846.2	910.1	115.8	4.8	92.8	111.4	137.5	75.4	3.
28	936.2	958.7	971.6	55.8	2.3	168. 2	179.0	194.7	53.2	2.
29	992.0	210.5	401.6	466.6	19.4	221.4	236.0	252.3	68.2	2.
30	458.6	521.4	539.0	151.9	6.3	289.6	302.5	319.8	48.6	2.
31				1		338.2	356.4	379.6	74.2	3.

Observations of wind velocity at Ochoa station for 1899.

[Representing estimated mean velocity of wind, in miles per hour, for daytime only.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	May. June. July.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7	00	O1 -	00	00	4	o	7	ω	4	ಲ	۵.
2	16	00	ೞ	13	٥,	ಀ	01	22	4	లు	ಀ	0
3	11	ಲ	ಀ	-1	లు	οι	O1	7	တ	Ö	0	3
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Observations of wind velocity at Ochoa station in 1900.

[Representing estimated mean velocity of wind, in miles per hour, for daytime only,]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7	- 8	7	7	8	8	0	0	0	0	28	3
2	11	7	0	13	7	5	4	0	1	0	0	3
3	7	5	8	13	0	8	0	0	- 3	7	5	3
4	3	7	18	5	13	5	4	0	4	7	0	3
5	0	5	4	13	8	0	. 0	3	0	5	4	4
6	8	13	18	13	0	5	8	0	3	8	5	3
7	7	3	13	3	8	4	4	3	5	13	0	3
8	7	- 13	13	8	0	4	8	0	3	7	0	0
9	18	5	3	8	3	3	4	0	5	5	4	3
10	7	7	0	0	7	0	4	. 3	4	0	5	1
11	4	18	3	0	3	8	0	0	- 0	- 0	11	0
12	3	13	5	5	5	5	4	0	5	5	3	. 1
13	11	18	7	13	0	0	0	3	5	0	4	5
14	18	13	0	13	8	7	3	3	3	. 2	7	1
15	4	3	5	18	8	4	0	5	4	0	5	3
16	7	11	3	16	8	0	3	8	7	3	11	5
17	3	11	13	18	8	0	3	5	0	4	7	8
18	4	8	18	11	5	0	0	. 4	0	3	8	0
19	7	0	18	22	13	0	8	3	3	4	7	11
20	7	3	8	5	7	0	7	5	7	6	7	5
21	7	8	18	13	0	3	3	7	4	0	4	7
22	0	8	. 18	8	15	1	0	0	7	0	5	3
23	0	5	8	4	1	5	0	. 6	0	0	3	5
24	4	5	3	0	4	5	4	8	7	2	0	0
25	4	8	8	0	2	7	5	7	4	2	3	. 7
26	4	0	7	0		8	3	3	8	7	4	7
27	0	8	0	8		5	0	8	4	0	3	5
28	7	8	.5	5	0	8	0	0	7	0	7	11
29	3		8	3	2	4	3	7	15	11	4	. 5
30	3		8	8	0	9	0	0	0	8	7	7
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THE ISTHMIAN CANAL PROBLEM.

The project of connecting the oceans by a waterway across the American Isthmus has attracted the attention of the world ever since the existence of the Isthmus became known. More than a dozen various routes have been advocated from time to time, the most northerly and one of the earlier being the Tehuantepec route, since famous as the ship-railway route of Captain Eads. An ordinary railway now crosses at this place.

The projects occupying most attention are the Nicaragua, Panama, Atrato, San Blas, and Caledonian.

ATRATO ROUTES.

The Gulf of Darien, an arm of the Caribbean Sea at the point where the Isthmus joins the main continent of South America, receives the waters of Atrato River, a navigable stream which flows due north about 200 miles into the gulf. Its watershed is bounded on the west by the continental divide, which here hugs the Pacific coast very closely, and has several passes of moderate altitude.

Various projects have been proposed to utilize this river and its tributaries to approach the Pacific coast as nearly as possible, and then cut through the range to the sea. Of these projects the two that have received the most favor and attention are those which utilize the Napipi and Truando rivers, tributaries of the Atrato. Neither of these has been regarded with as much favor as the more northerly routes.

SAN BLAS ROUTE.

The San Blas route lies between the Gulf of San Blas in the Caribbean Sea and the mouth of the Bayano River on the Pacific. It is the narrowest part of the entire Isthmus, being only 30 miles from ocean to ocean. It is proposed that the level of the water in this canal be that of ordinary high tide in the Pacific Ocean. This route requires the construction of a tunnel several miles long, which it is proposed shall be 80 feet wide at the surface of the water and 140 feet high from the canal bottom.

CALEDONIA ROUTE.

A route across the Isthmus from Caledonia Bay was proposed and advocated by Dr. Cullen about 1850, but there was very little actual knowledge on which to base his opinions, and later examinations failed to confirm them.

The present Isthmian Canal Commission has caused a reconnaissance to be made of the entire Isthmus of Darien, which has resulted in the conviction that no other route compares in practicability with the Panama and Nicaragua routes.

PANAMA ROUTE.

The Panama route, though not in the narrowest part of the Isthmus, has a natural harbor on each coast, with a depression in the backbone of the cordillera only 363 feet above sea level. These natural advantages led to the construction in 1851 of the Panama Railway, from Colon on the Caribbean to Panama on the Pacific, to accommodate the heavy traffic consequent upon the discovery of gold in California. In 1878 De Lesseps inaugurated his celebrated attempt to cut a sea-level canal through this region without having made an adequate estimate of the cost, or even of the physical obstructions to be overcome. A large amount of work was actually done, the canal being practically completed for 7 miles on its northern end, and quantities of heavy excavation made in the upper and southern portions of the route. The sums actually subscribed and put into this work are variously stated as more or less than \$260,000,000, not more than one-fourth of

which is represented by actual construction, the balance being squandered in corrupt and reckless extravagance; and the scandals occasioned thereby led to the bankruptcy of the company and the suspension of the work.

On the reorganization of the company a subscription of about \$11,000,000 was obtained for surveys and construction. The new company very wisely sought the advice of a "Comité technique," composed of 14 eminent engineers, 7 of whom were French, and 7 elected from Germany, England, Russia, Colombia, and the United States, the latter being represented by Gen. Henry L. Abbot, United States Army, and Alphonse Fteley, chief engineer of the New York Aqueduct Commission. Under the direction of the "Comité technique" more complete surveys were made, the sea-level plan was abandoned, and plans were drawn up for a lock canal, which is to be supplied with water from reservoirs to be constructed on the Chagres River. A small force is, and has been for several years, at work on construction.

The Panama Canal follows the line originally adopted by the old company from Colon to Panama, is about 49 miles long from deep water to deep water, and is to have four locks on each side, with summit level at 98 feet. There is to be a large storage reservoir constructed at Alhajuela, on the Upper Chagres, 12 miles from the canal line, and a large aqueduct is to convey feed water from the reservoir to the summit level. Surplus waters are to be stored until safely discharged.

NICARAGUA ROUTE.

The same influence which prompted the construction of the Panama Railway led to the establishment of a transit route across Nicaragua, partly by water and partly by stage road, and surveys were made along this route for a ship canal by the transit company, and afterwards by the United States Government under Commander Lull. Later the Maritime Canal Company modified the plans, extended the surveys, and began construction on a ship canal. Financial difficulties, however, stopped the work before it was fairly under way, and agitation was carried on for some years to induce the United States Government to finance the project.

In 1895 Congress provided for a board of engineers to ascertain the feasibility, permanence, and cost of the canal, and appropriated the sum of \$20,000 for the purpose. Col. William Ludlow, of the Army, Civil Engineer M. T. Endicott, of the Navy, and Mr. Alfred Noble, were appointed by President Cleveland to constitute it. Considering the time and funds at their disposal, this board made a very thorough examination of the route, the data, and the estimates, all of which were freely discussed and criticised. They reported that while the

canal was feasible the information collected was entirely inadequate as a basis upon which to make final estimates of cost, or even to determine approximate plans. They recommended, therefore, that an appropriation of \$350,000 be made for further surveys and investigations. Accordingly a commission was appointed by President McKinlev, consisting of Rear-Admiral J. G. Walker, Col. Peter C. Hains, and Lewis M. Haupt, for the further survey and examination of the canal route. This Commission inaugurated thorough surveys, which demonstrated the impracticability of certain features of the company's plans, and before its work was completed Congress provided in 1899 for increasing the Commission, and appropriated funds for the thorough examination, survey, and comparison of all the possible routes for an interoceanic canal across the Isthmus. The engineering portion of the Commission was reenforced by Col. O. H. Ernst, Alfred Noble, George S. Morison, and William H. Burr. Prof. Emory R. Johnson and Hon. Samuel Pasco were appointed as experts, respectively, on the commercial and political aspects of the problem. Explorations were made of the lower isthmus, east and south of Panama, which added largely to the topographic information there, but failed to reveal any favorable canal route, so that the problem was finally narrowed down to a comparison of the Panama and Nicaragua routes.

The route adopted by the Isthmian Canal Commission starts near San Juan del Norte on the Caribbean, runs in a general southwesterly direction across the swamps and lowlands north of Lake Silico, along the San Juanillo, and reaches the left bank of the San Juan River, near the head of the San Juanillo, about 20 miles from San Juan del Norte; it then follows on the left side of the river, but not in it, to Conchuda, about 3 miles above the mouth of the Rio San Carlos, passing through three locks on the way. A high dam near this point will raise the waters of the San Juan to the level of Lake Nicaragua, and the canal will enter the basin through two locks and follow the course of the river for the most part to Lake Nicaragua. Several cut-offs on the natural course of the river will be made, and above Castillo a large amount of dredging will have to be done to secure the required depth, and this will be continued far out into Lake Nicaragua. West of the lake the line runs by way of the valley of Las Lajas, cuts through the divide, and follows the Rio Grande Valley through four locks to the Pacific, where a harbor is to be constructed. The total length is about 187 miles, of which 49 miles is deep water in Lake Nicaragua, 17 miles in river not requiring improvement, leaving 121 miles of canalized river and canal proper. It is to have nine locks; the level of Lake Nicaragua and all the canal between Boca San Carlos and Bueno Retiro, the extremities of the summit level, are to be controlled between the limits of 104 and 111 feet above sea level, the surplus water being discharged into the Caribbean by way of the San Juan River.

The comparative length and direction of the Nicaragua and Panama canals is shown in Pl. XL.

COMPARISON OF CANAL ROUTES.

The value of an isthmian canal depends upon the difference between the tolls charged by the canal and the expense it saves in shortened voyages and transfers of freight. To be a public benefit its tolls must be less than the cost of transferring freight to the Panama Railroad, hauling it across the 47 miles of that line and reloading it on the other side.

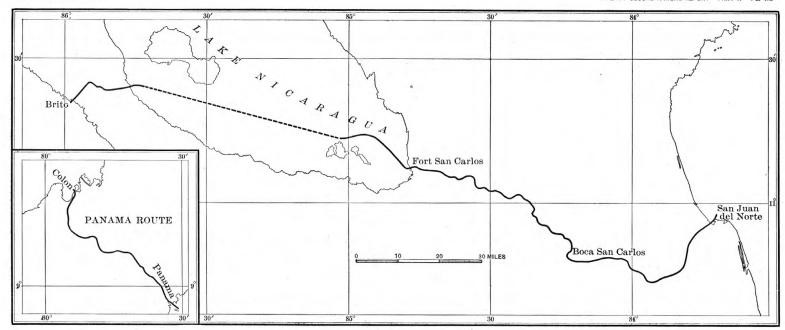
The canal will be compelled also to compete with the Tehuantepec Railway, 190 miles in length, on a route very much shorter between points in the northern hemisphere than by way of either canal. For these reasons to be successful the interoceanic canal must not only be a first-class canal, operated at low rates, but must be located on the most favorable route.

Investigations have shown that there are only two practicable routes, the Panama and Nicaragua. While both these routes involve engineering feats of great magnitude and difficulty, they are both entirely feasible. Both have ample and certain water supplies, and can control their surplus waters with certainty and safety. Both can be constructed in about ten years, and can be maintained in a high state of efficiency. In all these respects the routes are about equal.

No construction work has been done in Nicaragua, while in Panama about \$60,000,000 worth of work has been done, but the partly constructed canal with its concession belongs to a French company which is prohibited from transferring it to any government. It might, however, relinquish its rights for a sufficient consideration, thus leaving the Colombian Government free to negotiate a new concession with the United States. The Isthmian Canal Commission in its preliminary report estimates that a canal of 35 feet depth, 150 feet bottom width, and duplicate locks of large dimensions, would cost \$46,000,000 more at Nicaragua than the completion of the Panama Canal on a similar basis. We will assume that this figure represents the present value of the Panama Canal and that the works could be purchased and a satisfactory concession could be obtained from Colombia for that amount, making the completed canal cost the same as the Nicaragua.

It then remains to compare the canals as to cost of operation and maintenance and relative utility. In making this comparison we will adopt the plans recommended by the Isthmian Canal Commission and accept, as far as they go, the official estimates and figures.

It may be presumed that the tolls charged will be regulated according to the cost of maintenance and operation. To arrive at the cost of maintaining and operating the canal we have recourse to comparison



COMPARATIVE LENGTH OF PANAMA AND NICARAGUA CANALS.

Plans drawn to same scale.

with other canals already constructed and in operation. The following table shows the traffic and expenses for recent years of the principal canals of the world, according to their official reports:

Traffic and cost of operation of ship canals.

Year.	Traffic in tons.	Annual cost.	Cost per ton-mile.
Manchester, 35.5 miles:			
1898	2, 595, 585	\$861,976	\$0.0093
1899	2,778,108	927, 140	0.0094
1900	3,060,516	1,004,333	0.0092
Mean cost per ton-mile			0.0093
Suez, 80 miles:			
1898	9, 238, 603	1, 592, 834	0.0022
1899	9, 895, 630	1,661,042	0.0021
1900	9, 738, 152	1,742,717	0.0022
Mean			0, 0022
Kiel, 61.6 miles:			
1898	3, 117, 840	492,080	0.0026
1899	3, 488, 767	540, 128	0.0025
Mean			0.0025
Sault Ste. Marie, 1.6 miles:			
1897	17, 619, 933	78, 104	0.0028
1898	18, 622, 754	58, 890	0.0020
1899	21, 958, 347	90, 307	0.0026
1900	22,315,834	79, 293	0.0022
Mean			0.0024

Average cost per ton-mile of all four, \$0.0041.

These figures show a wide divergence in traffic cost, which may be explained in part by examination of the following table comparing the canals in length, alignment, locks, traffic, etc.:

Comparison of ship canals.

	Suez.	Manches- ter.	Kiel.	Panama.	Nicara- gua.	Sault Ste.Marie.
Length, miles	88	35. 5	61.6	49	184	1.6
In natural lakes	8	0	4	0	42	0
Bottom width, feet	122	120	72	150	150	108
Depth, feet	28	26	29.5	35	35	21
Cost-million dollars	115	76	37	184	189	7.85
Number of locks	0	5	2	5	9	1
Maximum lift, feet	0	16.5	16	43	37	18
Radius of sharpest curve, in feet	5,900	1,980	3,280	6, 234	4,045	Infinite
Percentage straight		56	63	57		100
Traffic began	1870.	1894.	1895.			1855.
Traffic, 1899, in thousand tons	9,985	2,778	3,489			21,958
Degrees of curvature				772	2,340	0

It will be noted that the Manchester has by far the shortest radius of curvature, and to this is largely due its excessive cost of operation. When a large vessel in a canal draws nearly as much water as the available depth she will not obey her rudder and it becomes impossible to steer her around short curves. For this reason when a very large vessel is taken through the Manchester Canal she is attended by two small tugs, one at the stern and one at the bow, to conduct her along the tortuous channel. The Suez Canal was constructed with curves of 2,300 feet radius, but these caused such annoyance that they were afterwards eliminated, and its shortest radius is now nearly three times that of Manchester. The Manchester also has 5 locks, or one to every 7 miles, and the smallest tonnage of all. These facts all tend to make up the high rate per ton-mile; but it is undoubtedly operated with economy, for it is at the very doors of the merchants who own it and are losing money on it every year. It may be assumed that they watch its expenditures with a jealous eve.

The Sault Ste. Marie, which shows very low figures, has one lock in its 1.6 miles, but it has no curvature, and its enormous traffic helps to keep down the rate. Still the low cost shows good management.

The Kiel Canal has nearly as low a rate as the Sault, with only onesixth the traffic. Its two locks are only tidal locks with low average lift, and it must have been well constructed to keep its cost of maintenance down to a nominal sum.

The Suez Canal has gentler curves than the Kiel, a traffic nearly three times as large, and no locks at all. In all of these respects it has important advantages over the Kiel, and should, it would seem, show far smaller cost of operation, yet this is nearly as great. Several reasons for this suggest themselves. The Kiel, Manchester, and Sault canals are located near centers of manufacture and commerce, where materials and skilled labor can be obtained to the best advantage, while the Suez is relatively remote from such essentials, and drifting sands also increase the cost of its maintenance. The chief cause of the small cost of operation of the Kiel Canal may be that it is operated and maintained with wonderful economy, for which the credit is due to the thrifty German management, which, in its construction, furnished the world with one of the few examples of a gigantic and difficult engineering feat accomplished within the time and cost estimated, and did the work so well as to leave a low cost of maintenance. The Suez Canal may be taken as furnishing the minimum cost of operation and maintenance, and one which can not be equaled by the American canals, since it has no locks and they have They will also cost more than the Kiel, for it has one lock to 30 miles of canal, while Nicaragua has about one to 15 miles, and Panama one to 9 miles. This will increase the relative cost of the American canals, which will be augmented by their remoteness from centers of commerce. They can not hope to have more than one-third or one-fourth the traffic of the Sault Ste. Marie, and consequently can not approach its rate. Being straighter and having relatively fewer locks than the Manchester the expenses can be kept below those of the latter.

The mean cost of the four canals given is 4.1 mills per ton mile, and is useful in estimating the cost of maintaining and operating an American canal.

The great cost of maintenance and operation of the Manchester, and the low cost of that of the Kiel, together with the complication of length, locks, and curvature on both, make it difficult to use their data in estimating the relative influence of each feature on the total annual cost. In the Sault, however, we have a canal without curvature, only 1.6 miles long, and with only one lock. Its cost is, therefore, chiefly the maintenance and operation of that lock, and is thus of value for comparison with the Isthmian canal locks. Though it handles a very much heavier traffic than the Isthmian canal will ever have, the latter will have to contend with a wet, tropical climate, and is remote from commercial centers, and these conditions will tend to increase its cost. We may, then, without important error, take \$60,000 per annum as the cost of maintaining and operating each lock on the Isthmus.

The Suez Canal has no locks, has very gentle curvature, and carries a traffic similar in character and magnitude to that expected for an Isthmian canal. It is, therefore, of value in estimating the annual cost due to length only. It is greatly annoyed by drifting sands, which increase its cost. But, on the other hand, the Panama Canal receives the waters of the Upper Chagres into Lake Bohio, which, though not a muddy stream, may in the future require some attention, while the Nicaragua route receives the waters of a large number of small tributaries, and Greytown harbor will require constant dredging to counteract the tendency to close up under the littoral action on the sands. But these difficulties are not nearly so important as the drifting sands at Suez, and a much smaller figure should be taken for the American canals. From the above table we find the cost on Suez to average about \$19,000 per mile. Adopting \$15,000 for the mileage cost of the American canals, and \$60,000 each for the locks, we have figures which should approximately satisfy the conditions on the Isthmian canals. They give results somewhat too small when applied to the Manchester, but large when applied to the Kiel.

The total length of the Nicaragua route is 184 miles, of which 42 are in the deep water of the lake, where vessels can travel at full speed, and are not properly part of the canal, leaving 142 miles of river and canal proper. Eighteen miles of the river require no improvement other than the construction of the dam, and will require little attention for

maintenance, but will require lighting, attendance of tugs, telegraph service, etc., and will be included in cost of operation and maintenance, while the lake will be excluded, though it will also require some lights, and telegraph wires must go around it.

The length of the Panama Canal is about 49 miles, of which 10 are in lake Bohio, which is really the Chagres River impounded by the Bohio dam; but being of the same nature as the 18 miles of San Juan River on the Nicaragua route it will, like that, be charged for operation and maintenance.

Taking these lengths, 142 miles for Nicaragua and 49 for Panama, on the above assumptions for cost of operation and maintenance, we obtain the following table:

Cost of operating Nicaragua and Panama canals.

For Nicaragua:	
Length, 142 miles, at \$15,000 per mile	\$2, 130, 000
Eight locks, at \$60,000	
Total annual cost	2,610,000
For Panama:	
Length, 49 miles, at \$15,000 per mile.	735,000
Five locks, at \$60,000	300,000
Total annual cost	1, 035, 000

Assuming a traffic of 8,000,000 tons per annum, this would be nearly 33 cents per ton for Nicaragua and 13 cents for Panama, without including any allowance for Panama's advantage in curvature, which, as the table on page 541 shows, is considerable.

It now remains to compare, in view of the above, their respective advantages to commerce. A vessel can not, with a given power, move so rapidly through a canal as through deep water, and if she could it would not be safe to do so. It is essentially correct to assume that on an average vessels will move through the canal at half the speed they would accomplish at sea. To allow for this we will, in comparing distances through the canals, add 40 nautical miles to those via Panama and 120 to those via Nicaragua, and this will compensate for their difference in length, since this is about the length in nautical miles, in each case, which is equivalent to the delay by the canal proper. By comparison of distances computed on this basis we can determine their relative advantages to commerce.

No trade between Europe and the Orient can profitably use either the Panama or Nicaragua canal, the distance being very much shorter via Suez. Vessels from New York, bound for ports south of Hongkong, will go via Suez or Good Hope; but for Shanghai, Yokohama, or Manila, they can save time via the American canal, while Hongkong is so nearly equal as to bring into play the advantage offered by the Suez route of more frequent ports available for coaling and repairs,

and the Suez Canal would obtain the traffic unless a lower rate were offered by way of the American Isthmus.

It is estimated by good authorities that the average cost for carrying freight over long ocean voyages is one mill per ton-mile, of which one-half is for shore expenses, loading and unloading, warehouse, insurance, etc., leaving one-half mill per ton-mile for moving freight through the water.

There are eight typical routes of travel that would use an Isthmian canal. The following table shows the relative distances saved for these eight classes of traffic, allowing for delay in transit, due to canal length, as above indicated. The last column shows the amount per ton that vessels would save by going via Panama, on the assumption that both canals are open to traffic, and the tolls fixed to just cover cost of maintenance and operation, computed as above:

Comparison of	distances	saved	by	Nicaragua	and	Panama	canals.
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From—	то—	Via Nicaragua,	Via Panama.	Saving v	Net advantage of Pana- ma.	
		Miles.	Miles.	Miles.	Per ton.	Per ton.
San Francisco	New York	5,040	5, 340	300	\$0.15	\$0.05
Do	Liverpool	7,770	8,080	310	.16	.04
Do	New Orleans	4,240	4,740	500	. 25	05
Yokohama	New York	10,870	11,050	180	.09	11
Do	New Orleans	10,070	10,450	380	.19	. 01
				Saving via	Panama.	
Guayaquil, Ecuador	New York	3,370	2,910	460	0.23	.43
Do	Liverpool	6,100	5,650	450	.22	. 42
Do	New Orleans	2,560	2,300	260	. 13	. 33

The fact is well established that Nicaragua is far more favorably located for the use of sailing vessels, being in the region of trade winds, while the Bay of Panama is subject to calms so prolonged as to seriously interfere with the arrival and departure of sailing ships, and it is not likely that such vessels would use the Panama Canal. About 8 per cent of the carrying trade of the world is done in sailing vessels, but, as pointed out in the preliminary report of the Commission, this is decreasing and likely to decrease in future, especially for Isthmian traffic. From one-third to one-fourth of such traffic would be with the west coast of South America, in which Panama's advantage in distance and tolls would offset her disadvantage in winds.

To sum up, sailing vessels to and from the North, or say 5 per cent of the total traffic, would prefer Nicaragua; steam vessels from Gulf ports to the west coast of North America, or perhaps 25 per cent of the total, would prefer Nicaragua, but might use either route with nearly equal advantage; while all the rest, or 70 per cent, would prefer Panama; and the traffic to and from the west coast of South America in steam vessels, or about 30 per cent, would, by way of Panama, save

an average of nearly 400 miles in distance and 20 cents per ton in tolls—always assuming that these are to be based on expenses.

There are many other questions to be considered in comparing these routes, the most important being those of health and facilities for local development. The Panama region is notorious for its liability to yellow fever and other tropical ailments, while, for a tropical region, Nicaragua is peculiarly healthy, and epidemics of yellow fever are unknown, though frequent both to the north and south. This adds importance to the further fact that in the vicinity of the Nicaragua Canal is a vast wilderness of immense agricultural and horticultural resources comparable in area and possible development with the State of Ohio, with a present population less than the city of Toledo.

The construction of the canal would furnish much-needed transportation facilities, to which Lake Nicaragua, San Carlos River and many smaller streams would become feeders, and the result would be an immense influx of American settlement and capital, the rapid development of agriculture, and the culture of bananas, coffee, rubber, and cacao. In a very short time American interests would unquestionably dominate.

There is no tropical region on the face of the earth so favorable for Caucasian immigration as the Nicaragua Canal region, on account of its cool trade winds and its remarkable healthfulness. With these conditions it combines an especially luxuriant vegetation, owing to the heaviest rainfall of any part of the Western Continent. There is thus a splendid opportunity to bring the highest type of civilization to a tropical gem of unsurpassed splendor. No such opportunity is presented at Panama.

HYDROGRAPHY OF NICARAGUA CANAL ROUTE.

The hydrographic investigations made for the Nicaragua Canal Commission were described in the Twentieth Annual Report of the Geological Survey, Part IV. The Isthmian Canal Commission being instructed to examine all possible routes, and "especially those known as the Panama and Nicaragua routes," the hydrographic inquiry was accordingly extended, and the writer was placed in charge of all such investigations on the Isthmus.

The hydrographic observations of the Isthmian Canal Commission consisted in the main of a continuation of those inaugurated by the Nicaragua Canal Commission, some extension of rainfall observations in the basin tributary to Lake Nicaragua being the principal difference.

The information required relates to the solution of four principal problems:

First. Water supply for the use of the canal and to replace loss by leakage and evaporation.

Second. The quantity of rainfall and volume of streams considered as obstacles to construction.

Third. The volume and habit of excessive floods with reference to their permanent control and discharge without injury to the canal or other property.

Fourth. The evaporation from Lake Nicaragua, this being the prin-

cipal draft upon the water supply.

The desired information therefore required an investigation of the discharge of all streams of importance which it was proposed to control during construction, or for which it was necessary to provide diversion channels or spillways and measurements of rainfall at points as widely distributed as possible throughout the basin of Lake Nicaragua, San Juan River, and the adjacent region.

It also required an approximate determination of the rate of evaporation on Lake Nicaragua and some investigation of the sediment carried by the larger rivers.

The methods used in observing the discharge of streams were similar to those employed by the Geological Survey in the United States, cross sections being taken with sounding line and velocities usually measured by current meter.

PACIFIC SLOPE.

All streams with which the canal is concerned flow eventually into the Atlantic, except the Grande and its tributaries. This stream rises in the hills of the continental divide, and empties into the Pacific Ocean at Brito. The canal line follows its valley from the deep divide cut to the sea. The principal tributary is the Tola River, which enters from the north and which formerly, in common with the other headwaters of the Grande, flowed into Lake Nicaragua. The recession of the continental divide toward the lake turned them toward the Pacific, and the proposed canal cut through the divide is the site of the former stream bed of this drainage.

GRANDE AND TOLA RIVERS AT THEIR JUNCTION.

A gage was kept on the Grande River a short distance below the junction of the Tola, and the latter river was observed about a mile above its mouth.

During a portion of the dry season the Grande is entirely dry above the mouth of the Tola, and the waters of the latter are ponded for some distance up the Grande.

A perceptible quantity of the water is lost by evaporation and seepage from this pond, so that for a time the discharge of the Tola at the station was slightly greater than that of the Grande below the mouth of the Tola.

The largest flood yet observed at this station occurred on the 22d day of October, 1900, when 5,450 cubic feet per second was flowing in the Grande below the Tola.

Estimated monthly discharge of Grande River below mouth of Tola River.

	Disch	Total in		
Month.	Maximum,	Minimum.	Mean.	acre-feet.
1898.				
January 6 to 31	75	60	69	3, 340
February	55	41	49	2, 720
March	40	25	35	2, 150
April	35	17	25	1, 490
May	.85	17	28	1,720
June	1,990	17	110	6, 550
July	2,030	55	121	7, 440
August	145	45	67	4, 120
September	2,975	55	253	15, 050
October	2,065	260	596	36, 650
November	1,028	190	282	16, 780
December	190	97	130	7, 990
Total	2, 975	17	148	106, 000
1899.				
August 13 to 31	37	7	11	401
September	18	6	8	496
October	2,081	5	113	6, 954
November	385	26	44	2, 646
December	68	19	32	1, 954
The year	2,081	5	44	12, 451
January	17	12	12	765
February	11	6	9	482
March	7	4	6	343
April	5	2	3	185
May	216	2	19	1, 196
June	953	16	63	3, 74
July	1,272	48	123	7, 569
August	59	29	36	2, 22
September	5,400	26	238	14, 166
October	5, 450	260	603	37, 068
November	382	144	197	11,746
December	142	69	105	6, 434
The year	5, 450	2	. 119	85, 918
1901.	70	47		9 505
January	73	41	57	3, 505
February	41	22	31	1,722
March	22	18	19	1, 168

Estimated monthly discharge of Tola River one mile above its mouth.

	Disch	Totalin		
Month.	Maximum.	Minimum.	Mean.	Total in acre-feet.
1898.	1100			
June 9 to 30	355. 0	12.0	53	2, 310
July	163.0	21.0	46	2,830
August	57.0	20.0	30	1,840
September	364.0	39.0	112	6, 660
October	452.0	130.0	246	15, 125
November	270.0	100.0	160	9, 520
December	100.0	65, 0	79	4, 860
Total	452.0	12.0	106	43, 145
1899.				
August 13 to 31	26.0	2.0	13	496
September	17.0	8.5	14	841
October	408. 0	8.0	49	2, 993
November	173.0	18.0	30	1,759
December	41.0	15.0	20	1, 256
Total	408.0	2.0	26	7, 345
1900.				
January	15.3	10.0	13	770
February	11.7	7.0	8	428
March	9.5	5.0	6	381
April	5.3	4.0	5	276
May	89.0	11.0	19	1, 182
June	187.3	15.0	40	2, 384
July	99.0	28.0	62	3,840
August	47.0	24.0	34	2,023
September		28.0	120	7,154
October	3,047.0	145. 0	370	22, 765
November	291.0	111.0	179	10, 679
December	113.0	66.0	89	5, 496
The year	3, 047. 0	4.0	77	57, 378
1901.				
January	66.0	31.0	47	2,890
February	31.0	20.0	25	1, 388
March	20.0	16.0	17	1,045

LAKE NICARAGUA.

Lake Nicaragua is one of the notable fresh-water lakes of the world. It has an area of 2,975 square miles. Its greatest length is from northwest to southeast, and is about 100 miles. Its extreme width is about 45 miles.

West of the center is an island occupied by the volcanoes Ometepe and Madera, which stand about 5,000 feet above the lake level, adding greatly to the scenic beauty.

The prevailing easterly trade winds cause a moderately heavy surf to beat almost constantly on the western shore, causing the formation of a decided beach on that side, while on the eastern shore aquatic vegetation grows far out into the water. This shore is flat and muddy, with no well-marked beach.

Except in the southeastern portion the lake is deep, reaching in one point near the southern foot of Madera a depth of 200 feet.

Lake Nicaragua receives the waters of a large number of tributaries, the most important being Frio and Pisote rivers, on the southern end, which rise in the high mountains of Costa Rica and maintain some flow throughout the dry season, and Malacatolla and Tipitapa on the northern end, the latter bringing the waters of Lake Managua. The drainage area, as estimated from the best information obtainable, is as follows:

Drainage area of Lake Nicaragua.

S	q. miles.
Area of land surface draining directly to Lake Nicaragua	6,640
Area of Lake Nicaragua	2,975
Lake Managua and tributary basin	3, 035
Total	12, 450

STATION AT TIPITAPA.

The gage in this river is about 100 yards above Tipitapa Falls, and serves both to register the stage of the river and the height of Lake Managua, upon which the stage of the river depends. During low water the river was too sluggish above the falls for accurate measurement with current meter, and gagings were made from the bridge below the falls. As the river rose it became very turbulent and swift at the bridge, but at the same time the velocity in the upper river increased and good measurements were made above the falls. Observations of rainfall and evaporation were also made at this point.

Lake Managua lies to the northwest of Lake Nicaragua and drains into the latter through Tipitapa River. Its area is about 438 square miles.

Estimated monthly discharge of Tipitapa River at Tipitapa.

	Disch	Total in		
Month.	Maximum.	Minimum.	Mean.	acre-feet.
1898.				
February	125	37.0	77.0	4, 275
March	36	3.0	16.6	1,020
April	4	0.0	0.5	29
May	18	0.0	3.8	234
June	700	13.0	121.0	7, 200
July	922	280.0	662.0	40, 700
August	930	487.0	626.0	38, 490
September	3, 230	910.0	2,045.0	121, 690
October	5, 580	2, 910. 0	4, 040. 0	248, 410
November	5,500	2, 150. 0	3, 640. 0	216, 600
December	2,630	1, 470. 0	1, 950. 0	119, 900
. 1899.				,
January 1 to 23	1,470	950.0	1,210.0	55, 200
The year	5, 580	0.0	1, 208. 0	853, 748
August 20 to 31	5	3.0	4.0	97
September	7	2.0	4.5	266
October	631	2.0	101.5	6, 244
November	824	517.0	612.7	36, 459
December	824	308.0	545.0	33, 505
Total	824	2.0	291. 0	76, 571
1900.				
January	316	148.0	223.0	13, 724
February	137	58.0	94.0	5, 232
March	55	5.7	25.0	1, 515
April	13	0.4	8.0	474
May	17	0.2	5.0	309
June	358	12.0	173.0	10, 277
July	1,275	284.0	919.0	56, 500
August	1, 348	749.0	974.0	59, 900
September	866	762.0	801.0	47, 667
October	2, 804	832.0	1,527.0	93, 917
Total	2,804	0.2	400.0	289, 515

STATION AT FORT SAN CARLOS.

A gage was established at this point by Lieutenant Hanus, United States Navy, January 4, 1898. It was simply a graduated stick driven in the sand in shallow water and supported by two stakes in the form of braces. On March 13 a more substantial gage was placed in deeper water and firmly fastened to the iron remains of an old wreck of a Vanderbilt steamer about a quarter of a mile north of the town of San Carlos. It was driven as far as possible into the mud and fastened with bolts and cable to the iron wreck.

Bench mark No. 1 is on the highest point of the shore end of the stranded boiler and is 12.933 feet above the zero of the gage last described and 9.78 feet above the zero of gage established by Lieutenant Hanus. From the 8th of March, when a special observer was stationed at San Carlos, rainfall, evaporation, temperature, and humidity observations were taken.

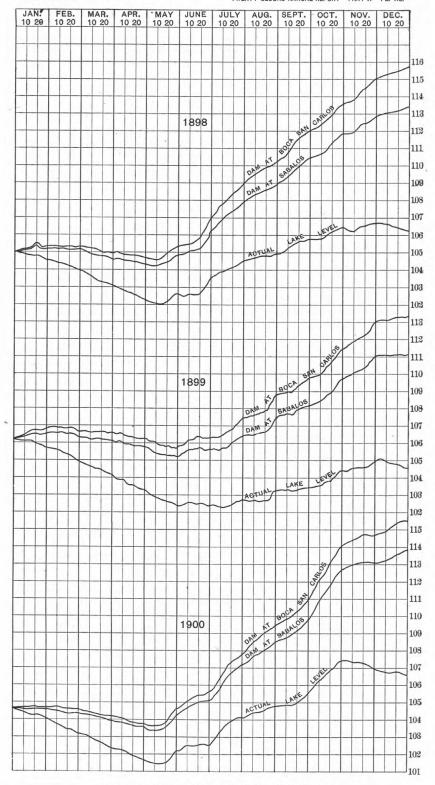
ELEVATION OF THE LAKE.

The rise and fall of the lake is the most important element in the measurement of the water supply for the summit level of the canal, the rate of inflow, and of evaporation. To obtain this element with the greatest possible accuracy, four gage rods were established at approximately equal intervals on the margin of the lake—at Sapoa, Granada, San Ubaldo, and Fort San Carlos—upon which daily observations were taken.

Daily elevation of Lake Nicaragua in 1898.

[Computed from gage-rod readings at Fort San Carlos, Jan. 4, 1898, to Dec. 31, 1898; Las Lajas, Feb. 8, 1898, to Dec. 31, 1898; Morrito, Apr. 9, 1898, to Sept. 21, 1898.]

	1			1		-		-	6 1	- 1		-
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		104, 49	103, 86	103.02	102. 29	102.48	103.50	104, 56	104. 96	105.66	106.41	106.64
2		104.42	103.89	103.02	102.24	102.49	103.47	104.51	104.97	105.74	106.37	106.68
3		104.52	103.82	102.98	102.23	102.44	103.55	104.51	104.95	105.76	106.31	106.59
4	. 104.92	104.48	103.86	102.96	102.21	102.39	103.70	104.58	104.94	105.74	106.26	106.68
5	. 104.96	104.51	103.78	102.92	102.20	102.42	103.62	104.61	104.97	105.75	106.22	106.67
6	. 105.02	104.43	103.75	102.96	102.20	102.45	103.78	104.57	105.05	105.73	106.26	106.62
7	. 104.93	104.43	103.76	102.92	102.14	102.52	103.79	104.60	105.02	105.75	106.22	106.6
8	. 104.94	104, 43	103.73	102.86	102.12	102.49	103.82	104.70	105.05	105.79	106.19	106.5
9	. 104.88	104.42	103.72	102.83	102.11	102.48	103.90	104.67	105.05	105.73	106.22	106.5
10	. 104.79	104.32	103.62	102.77	102.09	102.48	103.89	104.65	105.11	105.73	106.21	106, 58
11	. 104.85	104.30	103.64	102.81	102.08	102, 48	103.96	104.65	105.19	105.71	106.26	106.5
12	. 104.87	104.31	103.62	102.81	102.04	102.54	103.99	104.59	105.29	105.75	106.34	106.5
13	. 104.80	104.41	103.61	102.76	101.96	102.51	103.98	104.74	105.44	105.75	106.46	106.49
14	. 104.76	104.32	103.52	102.74	102.03	102.47	103.98	104.73	105.45	105.84	106.42	106.49
15	. 104.75	104.29	103.57	102.69	101.97	102.48	104.03	104.78	105.48	105.88	106.47	106.4
16	. 104.79	104.23		102.68	102.05	102.44	104.07	104.80	105.53	105.86	106.50	106.50
17	104.78	104.21		102.68	102.01	102.47	104.04	104.83	105.58	105.92	106.50	106. 4
18	. 104.83	104.21		102.65	102.13	102.47	104.07	104.78	105.57	106.08	106.57	106.44
19	. 104.84	104.16	103.26	102.61	102.10	102.59	104.16	104.78	105.57	106.14	106.51	106.39



Daily elevation of Lake Nicaragua in 1898—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	104.97	104.14	103.30	102, 55	102.11	102.65	104.25	104.78	105.58	106.15	106, 44	106, 41
21	104, 90	104.08	103.33	102.59	102.15	102.70	104.17	104.82	105.65	106.13	106.62	106.37
22	104.82	104.04	103.14	102.56	102, 43	102.91	104.25	104.83	105.71	106.24	106, 56	106.32
23	104.73	104.00	103.27	102.53	102.40	102.97	104.23	104.77	105.66	106.28		106.37
24	104.64	104.08	103, 29	102, 45	102, 51	103.01	104.32	104.80	105.74	106.36		106.39
25	104.71	104.04	103.30	102.43	102.57	103.09	104.33	104.81	105.72	106.35		106.35
26	104.70	104.06	102.99	102.44	102.55	103.04	104.35	104.78	105.68	106.36	106.54	106.33
27	104.69	103.94	103.19	102.42	102.59	103.16	104.39	104.83	105.63	106.38	106.59	106.29
28	104.67	103.93	103.12	102.37	102.56	103.30	104.46	104.82	105, 74	106.34	106.62	106.27
29	104.52		103.09	102.33	102.46	103.42	104.38	104.94	105.76	106, 44	106.63	106.38
30	104.64		103.10	102.32	102, 55	103.47	104.54	104.95	105.75	106.41	106.70	106.37
31	104.57		102.97		102.50		104.51	104.96		106.38		106, 44

Daily elevations of Lake Nicaragua in 1899.

[Obtained by averaging the daily elevation as indicated by gages at San Carlos, Granada, San Ubaldo, and Sapoa.*]

					4.4	-						
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	106, 23	105, 73	105.01	104.10	103, 25	102.41	102.35	102, 69	103, 35	103.46	104.37	105.02
2	106.08	105.70	104.88	104.03	103.29	102.45	102.35	102.69	103.33	103.41	104.35	105.05
3	106.19	105.69	104.85	104.02	103.31	102.43	102.38	102,70	103.33	103.46	104.33	105.09
4	105.97	105.68	104.90	103.93	103.19	102.35	102.44	102.66	103.31	103.44	104.33	105.01
5	106.10	105.64	104.85	103.95	103.24	102.38	102.41	102,68	103, 32	103.44	104.38	105.03
6	106.15	105.68	104.79	104.01	103.02	102.48	102.37	102.69	103.32	103.46	104.37	104.99
7	106.00	105.68	104.92	103.99	103.09	102.45	102.35	102.70	103.31	103.48	104.36	104.92
8	106.05	105.66	104.73	103.94	103.06	102.53	102.36	102.63	103.32	103.47	104, 41	104.91
9	106.09	105.56	104.65	103.78	102.97	102.46	102.27	102.64	103.32	103.47	104.58	104.96
10	106,06	105, 58	104.66	103.86	102.89	102.48	102.31	102.64	103, 29	103.48	104.57	104, 96
11	106.08	105.55	104, 58	103.82	102, 89	100 M	102, 28	102.71	103.29	103.52	104.59	104.94
12	106.04	105.61	104.54		102.88		102, 21	102.67	103, 26	103.55	104.58	104.90
13	106,02	105.39		103.62		Part and Sept.	102.24	102,65	103, 24	103.57	104.58	104.89
14	106.00		104.57	103.70		102.52	102.36		103.25	103.73	104.54	104.91
15	106.01	105.30	104.58	103.62	102.72	102.53	102.38	102.62	103. 21	103.89	104.54	104.90
16	105, 92	105, 40	104.49	103.59	102, 72	102.56	102.38	102.63	103, 15	103.88	104.49	104.91
17	105.98	105, 40	104, 45	103.63		102.46	102, 33	102.59	103, 14	103.86	104.53	104.89
18	106.09	105.30	104.53		1000	Section 1975	102.36	102.63	103.17	103.80	104.54	104.86
19	105.99	105, 26	104, 47	103.60			102.44	102.67	103.18	103.81	104.58	104.78
20	106.04	105.32	104.50	103.57	102.61	102.75	102.41	102.68	103.36	103.84	104.58	104.82
21	105.92	105, 20	104.44	0.000.00	102.64	2000	102.54	102.67	103.31	103.86	104.57	104.75
22	105.93		104.34	103.46		100000	102.53	102.69	103.33	103.95	104.60	104.72
23	105.89	105.14	104.38	103.47	102.60			102.73	103.37	104.01	104.64	104.73
24	105.78	105.18	104.32	103.40	102, 56			102.80	103.38	104.07	104.65	104.71
25	105.76	105.11	104.29	103.37	102.52	102.49	102.58	102.86	103.39	104.10		104.63
26	105.74	AAA (17.00)	104. 23	103.33	102.56		102.60	103.07	103.45	104.14	104.67	104.65
27	105.74		104.15	103.34	102.53	102.45	102.67	103. 22	103.42	104.24	104.72	104.62
28	105.75	22.00	104. 20	103.32	102.57	102.36	100000000000000000000000000000000000000	103. 22	103.41	104.37	104.79	104.59
29			104.19	103, 32	102.42		1000	103. 27	103, 41		104.80	104.57
30			104.17	103. 24		102.44		103.31	103, 42	1.00	104.98	104.52
31	43.45	- Acres and a		1	200	100000000000000000000000000000000000000	102.73	0.501.33	1000000	104.39	200	104.53
31	105.75		104.19		102.35		102.73	103. 29		104.39		104

^aJan. 1–23, San Carlos gage; Jan. 24–June 17, average of San Carlos and Granada gages; June 18–July 15, average of gages at San Carlos, Granada, and San Ubaldo; July 16–Dec. 31, averages of gages at San Carlos, Granada, San Ubaldo, and Sapoa.

Daily elevation of Lake Nicaragua in 1900.

[Obtained by averaging the daily elevation as indicated by gages at San Carlos, Granada, San Ubaldo. and Sapoa.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	104. 55	103.96	103.28	102.42	101.75	102.14	102.66	104.12	104.73	105. 49	107.42	106.9
2	104.50	103.95	103.23	102.37	101.72	102.16	102.71	104.10	104.71	105.70	107.42	106.90
3	104.46	103.91	103.23	102.33	101.69	102.17	102.79	104.11	104.75	105.78	107.38	106.8
4	104.43	103.92	103.17	102.28	101.63	102.17	102.80	104.11	104.79	105.89	107.36	106.8
5	104.44	103.92	103.09	102.27	101.59	102.17	102.73	104.22	104.83	105.91	107.36	106.8
6	104.44	103.87	103.14	102.30	101.66	102.22	102.87	104.31	104.82	105.98	107.33	106.8
7	104.40	103.85	103.12	102.27	101.56	102.21	102.95	104.33	104.79	106.20	107.32	106.8
8	104.38	103.87	103.13	102.29	101.52	102.32	102.93	104.32	104.81	106.18	107.34	106.79
9	104.42	103.80	103.09	102, 25	101.56	102.40	103.03	104.36	104.85	106.18	107.32	106.74
0	104.37	103.78	103.06	102.21	101.53	102.48	103, 21	104.38	104.84	106.20	107.30	106.78
1	104.39	103.74	103, 03	102.17	101.50	102.48	103.33	104.43	104.83	106.31	107.35	106.79
12	104.37	103.74	103.00	102.16	101.42	102.48	103.43	104.45	104.85	106.37	107.35	106.78
3	104.40	103.70	103.01	102.09	101.47	102.45	103.42	104.46	104.84	106.43	107.33	106.80
14	104.30	103.69	102.99	102.11	101.48	102.48	103.58	104.51	104.81	106.44	107.34	106.78
15	104.32	103.61	102.97	102.10	101.43	102.45	103.69	104.48	104.81	106.47	107.32	106.76
16	104.30	103.59	102.92	102.09	101.37	102.47	103.66	104.47	104.89	106.50	107.30	106.76
7	104.27	103.53	102.89	101.'94	101.38	102.50	103.78	104.52	104.91	106.63	107. 29	106.71
18	104.28	103.52	102.82	101.98	101.33	102.54	103.78	104.51	104.94	106.66	107.30	106.68
9	104.25	103.43	102.77	101.97	101.35	102.56	103.89	104.48	104.94	106.69	107.27	106.76
20	104.21	103.45	102.77	101.94	101.51	102.55	103.89	104.57	105.03	106.75	107.22	106.77
21	104.20	103.45	102.69	101.94	101.41	102.60	103.97	104.56	105.06	106, 95	107.22	106.78
22	104.18	103.42	102.67	101.91	101.49	102.63	103.95	104.62	105.05	107.07	107.17	106. 7
23	104.17	103.43	102.67	101.90	101.46	102.63	104.02	104.65	105.09	107.24	107.16	106.71
24	104.16	103.51	102.62	101.87	101.48	102.67	103.99	104.66	105.14	107.32	107.12	106.69
25	104.18	103.41	102.62	101.85	101.58	102.61	104.03	104.62	105.17	107.37	107.12	106, 69
26	104.15	103.29	102.66	101.86	101.72	102.63	104.05	104.71	105.19	107.37	107.11	106.67
27	104.12	103.35	102.61	101.85	101.87	102.60	104.04	104.70	105.18	107.42	107.05	106.61
28	104.10	103.28	102.73	101.80	101.87	102.65	104.05	104.70	105.20	107.41	107.05	106.68
29	104.00		102.51	101.75	101.99	102.64	104.04	104.72	105.32	107.41	107.03	106.64
30	103.90		102.52	101.75	102.09	102.53	104.09	104.73	105.43	107.39	106.99	106.68
31	103.99		102.45		102.12		104.09	104.75		107.39		106.59

Daily elevation of Lake Nicaragua in 1901.

[Obtained by averaging the daily elevation as indicated by the gages at San Carlos, San Ubaldo, Granada, and Tortuga.*]

Day.	Jan.	Feb.	Mar.	Apr.
1	106.52	105: 50	104.81	104.04
2	106.51	105.53	104.80	104.11
3	106, 50	105.46	104.90	104.05
4	106.41	105.49	104, 78	104.11
5	106.41	105.48	104.74	103.98
6	106.38	105.39	104.70	103.90
7	106.36	105.35	104.69	103.84
8	106.33	105.35	104.79	103, 85
9	106.31	105.33	104.76	103.89
10	106.35	105. 29	104.72	103.75
11	106.34	105. 26	104.69	103.82
12	106.30	105. 25	104.66	103.66
13	106.26	105.22	104.63	103.72
14	106.30	105. 21	104.61	103.63

a San Ubaldo discontinued on February 24; Tortuga discontinued February 28.

Daily elevation of Lake Nicaragua in 1901—Continued.

Day.	Jan.	Feb.	Mar.	Apr.
15	106.28	105.15	104.59	103. 43
16	106.20	105.13	104.49	103.48
17	106.16	105.12	104.44	103.46
18	106.09	105.18	104.40	103. 38
19	105.96	105.18	104.44	103.33
20	105, 93	105.15	104.48	103. 23
21	105.89	105.03	104.42	103. 28
22	105.94	105.03	104, 45	103.33
23	105.87	104.98	104.34	103.30
24	105.83	104.95	104.46	103. 28
25	105.80	104.95	104.31	103. 35
26	105.78	104.92	104.34	103.16
27	105.74	104.82	104.40	103.16
28	105.70	104.86	104.29	103. 28
29	105.65		104.21	103.04
30	105.63		104.20	103.04
31	105.62		104.18	

Estimated monthly flow into Lake Nicaragua in excess of evaporation.

Month.	Acre-feet stored in lake.	Acre-feet outflow.	Total in acre-feet.	Net inflow in second-feet.
1898.				
January 4 to 31, inclusive.	- 666, 400	+ 1,032,400	+ 366,000	+6,590
February	-1,218,600	+ 923, 800	- 294, 800	-5,310
March	-1,827,800	+ 863,600	- 964, 200	-15,680
April	-1,237,600	+ 724, 100	- 513, 500	- 8,630
May	+ 342, 700	+ 723, 300	+ 1,066,000	+17,340
June	+1,846,900	+ 841,600	+2,688,500	+45,200
July	+1,980,200	+ 1, 190, 900	+ 3, 171, 100	+51,570
August	+ 856,800	+ 1, 202, 200	+ 2,059,000	+33,490
September	+1,504,200	+ 1, 313, 600	+2,817,800	+47,350
October	+1,199,500	+ 1,440,600	2, 640, 100	+42,960
November	+ 609, 300	+ 1,512,000	+ 2, 121, 300	+35,650
December	- 495,000	+ 1,540,000	+ 1,045,000	+16,990
The year			+16, 202, 300	
1899.				
January	-1,313,760	+ 1, 443, 254	+ 129, 494	2, 106
February	-1,637,440	+ 1, 154, 774	- 482, 666	- 8,691
March	-1,332,800	+ 1, 103, 500	- 229, 300	-3,729
April	-1,808,800	+ 896,008	- 912, 792	-15,341
May	-1,694,560	+ 788, 584	- 905, 976	-14,735
June	+ 171,360	+ 765, 329	+ 936, 689	15, 743
July	+ 552, 160	+ 881,716	+ 1,433,876	23, 319

Estimated monthly flow into Lake Nicaragua in excess of evaporation—Continued.

Month.	Acre-feet stored in lake.	Acre-feet outflow	Total in acre-feet.	Net inflow in second-feet.
1899.	*			
August	+1,066,240	+ 944, 463	+ 2,010,703	32, 537
September	+ 247, 520	+ 1,021,693	+1,269,213	21, 331
October	+1,846,880	+ 1, 115, 681	+ 2,962,561	48, 179
November	+1,123,360	+ 1,211,088	+2,334,448	39, 234
December	- 856, 800	+1,250,254	+ 393, 454	6, 399
The year	-3,636,640	+12, 576, 344	+ 8,939,704	
1900.			- /	
January	-1,028,160	+ 1,083,292	+ 55, 132	897
February	-1,351,840	+ 836, 958	- 514, 882	-9,270
March	-1,580,320	+ 755, 503	- 824, 817	-13,413
April	-1,332,800	+ 662, 265	- 670, 535	- 1, 295
May	+ 704, 480	+ 671, 212	+1,375,692	22, 372
June	+ 780,640	+ 741,117	+1,521,757	25, 575
July	+2,970,240	+ 1,073,149	+ 4,043,389	65, 756
August	+1,256,640	+1,288,735	+2,545,375	41, 395
September	+1,294,720	+ 1, 266, 473	+2,561,193	43, 045
October	+3,731,840	+1,752,367	+ 5, 484, 207	89, 189
November	- 761,600	+ 1, 679, 231	+ 917,631	15,422
December	- 761,600	+1,653,969	+ 892, 369	14,512
The year	+3,922,240	+13, 464, 271	+17, 386, 511	
1901.				
January	-1,846,880	+ 1,446,800	- 400,080	-6,510
February	-1,447,040	+ 1, 117, 300	- 329, 740	-5,940
March	-1,294,720	+ 1,068,470	- 226, 250	- 3,680
April	-2, 170, 560	+ 838, 470	- 1, 332, 090	-22,390

SAN JUAN RIVER.

The San Juan River is the sole outlet of Lake Nicaragua and its tributary drainage basin. Its total length from the lake to the sea is 122 miles, and it is usually navigable for light-draft river steamers. It leaves the lake at Fort San Carlos at an altitude varying from about 97 feet to about 110. Its course for a distance of 27 miles is through a low, swampy country, relieved by occasional hills. Through this portion the river is sluggish and receives several tributaries of small discharge, which in the dry season are practically still water. The principal of these are the Melchora, Medio Queso, Palo de Arco, and Negro. The first tributary of importance to the San Juan River is

the Sabalos, which enters from the north and empties 27 miles east of Fort San Carlos. About half a mile below the mouth of the Sabalos are the first rapids, called Toro Rapids. These rapids are caused by bowlders and gravel, probably brought into the river by the Sabalos in former times, but do not seriously obstruct navigation except in times of extremely low water. Below this point the San Juan receives the waters of a few streams, the principal of which are the Poco Sol and the Santa Cruz. Ten miles below Toro Rapids occur the largest rapids on the river, at Castillo Viejo. At this point the river falls about 5 feet in a few hundred feet, and steamers are seldom taken over the rapids except in high water. A railroad about 2,000 feet long is provided for the portage of freight and passengers on the right bank of the river.

Below Castillo are the Diamond, Balas, and Machuca rapids, the latter being 12 miles from Castillo. All of these rapids admit the passage of river steamers except at extreme low water. Below Machuca there are no more rapids. The river is deep and sluggish for a distance of about 15 miles to the point where it receives the waters and sediment of the San Carlos. This river is the largest tributary of the San Juan, rising far to the southward in the mountains of Costa Rica, and bearing such a volume of sediment that a delta has been built up at its mouth, and from this point to the sea the San Juan is a shallow stream with sandy, shifting bed. Twenty-five miles farther down the Sarapiqui empties into the San Juan from Costa Rica, being the second tributary in size to the San Carlos, and, like the latter, bearing large quantities of sediment in times of flood. Eight miles below the mouth of the Sarapiqui the San Juan assumes decidedly the character of a deltaic stream and sends out a small tributary known as the San Juanillo, which meanders through the swamps to the northward and, after receiving the drainage of the Deseado, reenters the San Juan 4 miles above its mouth. Five miles below the exit of the San Juanillo, or 103 miles from Lake Nicaragua, the main stream of the San Juan separates into two large distributaries, the larger, called the Colorado, flowing eastward directly to the Caribbean, and the smaller, or Lower San Juan, meandering to the northeast and finding its exit into the ocean at San Juan del Norte. Between the mouth of the Colorado and the Lower San Juan another distributary, called the Taura, finds its way from the Lower San Juan to the sea.

The principal obstructions to free navigation of light-draft river craft from San Juan del Norte to Fort San Carlos are due to the shoal character of the Lower San Juan, especially in times of low water, and to the rapids lying between Machuca and the mouth of the Sabalos. For purposes of a ship canal the river also requires deepening below the mouth of the San Carlos and between the Sabalos and Fort San Carlos.

The only portion of the river which is suitable in its present state for a ship canal is the part from Machuca to a point a short distance above Boca San Carlos, or about 15 miles out of 122, and even here some dredging must be done and two sharp bends eliminated to permit the safe passage of the largest ships.

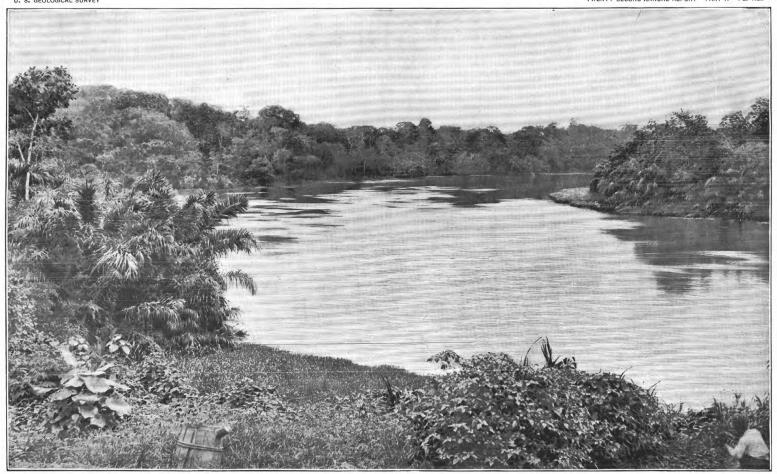
Rating	table for	San	Juan	River	at	Fort	San	Carlos.

Lake height.	Dis- charge.	Lake height.	Dis- charge.	Lake height.	Dis- charge.	Lake height.	Dis- charge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet
96.0	3,000	99.0	6,770	102.0	11,500	105.0	19, 325
96.2	3, 230	99.2	7,050	102.2	11,850	105.2	19,980
96.4	3,460	99.4	7,330	102.4	12, 215	105.4	20,680
96.6	3,690	99.6	7,620	102.6	12,590	105.6	21,435
96.8	3,930	99.8	7,920	102.8	13,000	105.8	22, 195
97.0	4,170	100.0	8,220	103.0	13,450	106.0	22, 995
97.2	4,410	100.2	8,530	103.2	13,910	106.2	23, 795
97.4	4,660	100.4	8,840	103.4	14, 410	106.4	24,790
97.6	4,910	100.6	9,155	103.6	14,950	106.6	26, 290
97.8	5,160	100.8	9, 475	103.8	15, 490	106.8	27,920
98.0	5,420	101.0	9,795	104.0	16,080	107.0	28,560
98.2	5,680	101.2	10,115	104.2	16,725	107.2	29, 200
98.4	5,945	101.4	10,450	104.4	17,375	107.4	29,900
98.6	6,215	101.6	10,800	104.6	18,025	107.5	30, 250
98.8	6,490	101.8	11, 150	104.8	18,675		

SAN JUAN RIVER ABOVE LOS SABALOS.

A record has been kept of the discharge of the river at this point ever since January, 1898. The station used during 1898 and a portion of 1899 was found objectionable in some respects, especially showing evidence at times of being affected by high water in the Sabalos River, which enters the San Juan half a mile below. In October, 1899, a gage was placed farther up the river, at the mouth of an insignificant tributary called Farina. The discharge at this point is the same as that previously occupied, there being no tributaries between. This gage was connected with the bench mark of the precise levels, showing the zero of the rod to be at elevation 90.794 feet above sea level.

In October, 1899, a gage rod was placed on the right bank of the San Juan one-half mile below the east end of Isla Grande, near station 121 of the river survey. The zero of this is 95.29 feet above sea level. Occasional readings were taken of this gage when convenient to compare with those observed at Los Sabalos for determining the slope of the river between the gages. Eight cross sections were measured between these points at known gage heights by Mr. H. C. Hurd, showing the average cross section of 8,714 square feet with the Isla Grande gage rod at 4.9. Cross section No. 3, which occurs just above Isla Chica, a mile below the upper slope rod, gives an area of 8,799 square feet.



SAN JUAN RIVER, LOOKING UPSTREAM FROM LOS SABALOS.

Estimated monthly discharge of San Juan River at Station Sabalos.

	Disch	arge in second	-feet.	Total in acre-
Month.	Maximum.	Minimum.	Mean.	feet.
1899.	25 100	01 010	99 479	1 440 05
January	25, 100	21, 810	23, 472	1, 443, 254
February	21, 720	19, 480	20, 792	1, 154, 774
March	19, 480	16, 560	17, 946	1, 103, 500
April	16, 618	13, 780	15, 658	896, 008
May	14, 421	12, 176	12, 825	788, 584
June	13, 730	11,942	12, 862	765, 329
July	17, 519	12, 418	14, 193	881, 716
August	19, 904	13,680	15, 360	944, 463
September	25, 310	15, 134	17, 170	1, 021, 698
October	20, 593	15, 469	18, 144	1, 115, 681
November	21, 865	16, 135	20,353	1, 211, 088
December	21, 653	17, 213	20,333	1, 250, 254
The year	25, 310	11, 942	17, 370	12, 576, 344
1900.	10.010	10.000		1 000 000
January	18, 943	16, 600	17, 618	1, 083, 292
February	16, 320	13, 800	15,070	836, 958
March	13, 635	11,520	12,287	755, 503
April	11,540	10, 407	11, 128	662, 265
May	12, 588	10, 263	10, 916	671, 212
June	15, 536	11, 420	12,455	741, 117
July	22, 816	12, 368	17,453	1, 073, 149
August	27, 968	17, 649	20,959	1, 288, 735
September	25, 784	19, 338	21,283	1, 266, 473
October	34, 800	23, 466	28,499	1, 752, 367
November	29, 200	25, 345	28, 220	1, 679, 231
December	28, 640	25, 168	26,915	1, 653, 969
The year	34, 800	10, 263	18,600	13, 464, 271
1901.	05 110	01 010	00 500	1 440 000
January	25, 110	21, 810	23, 530	1, 446, 800
February	21, 470	18, 560	20, 118	1, 117, 300
March	19, 110	15, 980	17, 377	1, 068, 470
April	15, 880	12,530	14,091	838, 470

OCHOA STATION ON SAN JUAN RIVER.

A camp was continued at this point under charge of Mr. H. S. Reed, keeping rainfall and temperature records and rod readings on the river. Measurements of discharge were made from a boat, its position at each observation being determined by stadia from shore.

From this station records were kept for the Machado River.

Records were also kept of gage height, discharge, rainfall, and sediment at the station on San Carlos River.

From the time when the camp on the San Carlos was removed August 31, 1898, to May, 1901, daily trips were made to the San Carlos station, never omitting a day. Therefore, we have over three years'

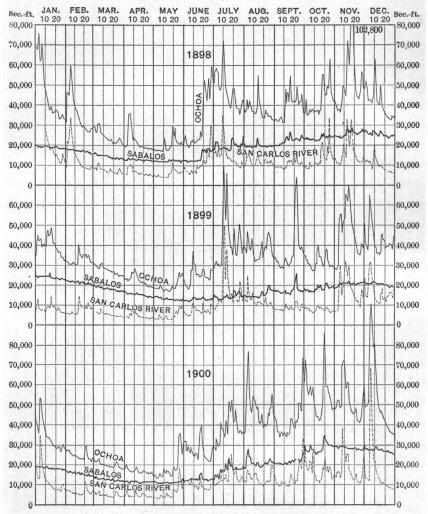


Fig. 228.—Comparative discharge of San Juan and San Carlos rivers.

complete record of discharge for both the San Carlos near its mouth and the San Juan at Ochoa. By taking the difference between them we obtain the discharge of the San Juan above Boca San Carlos, and by deducting from this the discharge measured at Sabalos we obtain the discharge of the tributaries between Sabalos and Boca San Carlos. The comparative flow of the San Carlos and the San Juan at Ochoa and at Sabalos is shown in fig. 228.

List of discharge measurements made on San Juan River at Ochoa.
[By H. S. Reed with Price meter No. 65.]

Date.	Gage height.	Area of section.	Mean velocity.	Dis- charge.	Wetted perim- eter.	Hydrau- lic radius.	Slope.	"n."
1899.	Feet.	Sq. ft.	Ft.per sec.	Secft.	Feet.			
October 5	7.90	9, 204	3.55	32,693	866	10.63	0.000187	0.02
October 6	7.31	8,713	3.41	29,731	865	10.07	0.000190	0.02
October 10	6.84	8,079	3.40	27, 453	864	9, 35	0.000197	0.02
October 28	7.21	8,554	3.46	29,633	865	9.89	0.000206	0.02
November 5	11.21	12,617	4.16	52,476	878	14.37	0.000190	0.08
November 6	13.38	-15, 301	4.63	70,870	886	17.27	0.000192	0.0
November 8	10.49	12, 147	3.94	47,868	875	13.88	0.000185	0.08
November 15	14.31	16,678	4.50	74,882	896	18.63	0.000160	0.0
November 25	8.51	10,373	3.52	36,500	868	11.96	0.000180	0.0
December 1	10.97	12,964	3.86	50,057	875	14.82	0.000183	0.0
December 6	12, 14	13,864	4.33	60, 105	877	15.81	0.000180	0.0
December 12	9.24	11,006	3.64	40,020	863	12.74	0.000178	0.08
December 16 1900.	8, 31	10,099	3.54	35, 735	867	11.65	0.000176	0.0
January 4	8.63	10, 289	3.73	38, 346	860	11.97	0.000180	0.0
January 6	11.28	12,742	4.10	52, 194	876	14.55	0.000173	0.0
January 24	7.01	8,621	3. 29	28, 396	863	9.99	0.000173	0.0
January 27	7, 17	8,721	3.42	29, 824	863	10.11	0.000180	0.0
January 30	6.89	8, 366	3.37	28, 164	862	9.71	0.000176	0.0
February 15	5, 81	7, 219	3.15	22,746	862	8.37	0.000183	0.0
February 26	5.57	7, 223	3. 03	21, 913	861	8.39	0.000180	0.0
March 9	5.16	6,926	2.98	20, 647	857	8.08	0.000182	0.0
March 16	4. 97	6,467	2.90	18,711	857	7.55	0.000176	0.0
March 30	4. 63	6, 317	2.86	18, 085	855	7.39	0.000166	0.0
April 5	4.55	6, 116	2.84	17, 358	855	7.16	0.000173	0.0
April 12	4. 36	5, 930	2.77	16, 551	853	6.95	0.000173	0.0
April 25	3, 97	5, 980	2.79	16,694	850	7.03	0.000173	0.0
April 28	4.02	5,622	2.77	15,550	851	6, 61	0.000169	0.0
May 1	3, 85	5, 453	2.77	15,079	850	6.42	0.000169	0.0
May 5	3.48	5,048	2.69	13,560	847	5.96	0.000176	0.0
May 21	4.74	6, 280	3.04	19, 101	859	7.31	0.000178	0.0
May 28	8. 60	10,000	3.59	35, 880	860	11.64	0.000173	0.0
June 2	6.48	8,305	3.21	26, 685	865	9.60	0.000187	0.0
June 11	6.07	7,872	3.16	24, 843	863	9.12	0.000187	0.0
June 18	8. 96	10,503	3.66	38, 405	862	12.18	0.000176	0.0
June 21	6.40	7,994	3.16	25, 272	864	9. 24	0.000183	0.0
June 28	5, 59	7,316	3.10	22,702	863	8.48	0.000187	0.0
July 2	6.79	8,629	3.41	29, 407	867	9.96	0.000187	0.0
July 12	8. 20	9, 497	3, 66	34, 758	867	10.95	0.000182	0.0
July 14	9.47	10, 473	3.90	40,800	865	12.11	0.000173	0.0
July 16	10.92	11,804	4.28	50, 513	874	13. 51	0.000189	0.0
August 4	12.47	13,923	4.38	61,026	879	15.84	0.000190	0.0
August 7	11.64	13, 223	4.09	54, 128	877	15.08	0.000173	0.0
August 12	10.97	12, 142	4.11	49, 880	875	13. 87	0.000190	0.0
August 30	11.36	12, 698	4.11	53,523	876	14.50	0.000180	0.0
September 4	8.60	10, 169	3.55	36, 064	860	11.82	0.000183	0.0
September 18	10.08	11,582	3.78	43, 791	869	13.33	0.000178	0.0
September 21	9.00	10,475	3.60	37,709	862	12.15	0.000178	0.0
September 29	12.05	13, 287	4. 29	57, 035	878	15. 13	0.000180	0.0
September 30	14.83	16, 501	4. 29	77, 429	897	18.40	0.000169	0.0
October 3	14. 85	15, 395	4. 72	72, 721	893	17. 24	0.000167	0.0
October 10	13.05	14, 333	4. 72	62, 427	884	16.21	0.000187	0.0

Note.—Slope rod established October 4, 1899.

Estimated monthly discharge of San Juan River at Ochoa.

Month.	Discharge in second-feet.			Total in sere
	Maximum.	Minimum.	Mean.	Total in acrefeet.
1898.				
January	75, 200	32, 240	45, 250	2, 782, 300
February	58, 530	26, 080	35, 400	1,966,000
March	30,650	20, 140	23, 800	1, 463, 400
April	40, 380	17, 290	21, 150	1, 258, 510
May	34, 880	16, 300	19,640	1, 207, 600
June	60, 180	18, 890	33, 140	1, 971, 970
July	78,050	35, 540	46, 810	2, 878, 200
August	54, 100	32, 020	37, 230	2, 289, 200
September	54, 100	30, 920	39, 530	2, 352, 200
October	67, 625	34,600	42, 200	2, 594, 800
November	107,000	37,080	51, 890	3, 087, 670
December	65,000	32, 790	40, 850	2, 511, 770
The year	107, 000	16, 300	36, 408	26, 363, 620
1899.				
January	49, 100	32,000	39,665	2, 438, 900
February	41, 120	29, 840	32,540	1, 807, 180
March	31, 300	23, 900	26, 940	1, 656, 480
April	28, 834	18, 500	21,987	1, 308, 222
May	27, 294	16, 780	19, 533	1, 201, 079
June	36, 399	17,900	24, 624	1, 465, 351
July	80,626	28,050	42,783	2, 630, 648
August	58,624	31,900	37, 931	2, 332, 348
September	77, 321	29,050	35,963	2, 139, 978
October	39,000	27, 350	31, 769	1, 953, 350
November	74, 882	27, 800	46, 133	2, 746, 154
December	64, 190	34, 950	42, 763	2, 629, 458
The year	80, 626	16, 780	33, 553	24, 309, 145
1900.				5
January	53, 280	27, 150	33, 968	2, 089, 746
February	29, 300	21,750	24, 235	1, 345, 993
March	22, 065	17, 220	19,664	1, 209, 122
April	19, 725	14, 680	16, 469	979, 978
May	36, 050	13, 245	18, 413	1, 132, 212
June	39, 400	20, 850	26,386	1, 570, 119
July	53, 100	29, 200	38, 494	2, 366, 930
August	76, 470	36, 050	47, 131	2, 898, 042
September	77, 429	33, 950	41,039	2, 442, 026



GAGING SAN JUAN RIVER AT OCHOA.



 $A.\$ MOUTH OF DANTA ON SAN JUAN RIVER. Boat entering the Dante.



B. SAN JUAN RIVER NEAR PUNTA PETACA.

Estimated monthly discharge of San Juan River at Ochoa—Continued.

Month.	Disch	Total in acre-		
Monun.	Maximum.	Minimum.	Mean.	feet.
1900.				
October	87, 696	42, 965	55,259	3, 298, 815
November	72,680	41, 300	51,838	3, 084, 600
December	106,600	35, 300	52, 889	3, 252, 040
The year	106, 600	13, 245	35, 484	25, 669, 630
1901.				
January	61,900	30, 350	35, 310	2, 171, 130
February	31, 810	23, 710	26, 910	1, 494, 500
March	24, 900	19,800	22,180	1, 363, 800
April	19,680	16,600	17,900	1,065,120

Estimated monthly discharge of San Carlos River 3 miles above its mouth.

[Drainage area, 1,450 square miles, approximately.]

1	Discha	rge in seco	nd-feet.		Rur	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1898.							
January 10-31	28,000	10, 560	16,055	700, 582	11.10	9.09	
February	34, 300	7,400	13,530	751, 380	9. 30	9.68	
March	11, 341	5, 140	7,030	432, 260	4.80	5. 53	7.52
April	10,080	4, 220	6,038	359, 285	4. 20	4.69	11.66
May	11,880	4,100	5, 560	341, 870	3.80	4.38	20.12
June	32, 250	5, 200	10,720	637, 880	7.40	8. 26	20.79
July	41,600	8, 400	14,094	866, 605	9.70	11.18	18. 26
August	15, 730	8,800	10,990	675, 750	7.6	8.76	11.68
September	14, 200	7,420	10, 319	614, 023	7.1	7.92	
October	32,500	8, 180	12,880	791, 960	8.9	10. 26	
November	32, 260	9,680	15, 440	918, 750	10.6	11.88	
December	19,920	5, 850	9, 290	571, 220	6.4	7.38	
The year	41,600	4, 100	10, 996	7, 661, 565			
1899.							
January	14, 200	5,720	7, 865	483, 600	5. 42	6. 25	
February	17, 340	4,940	7, 360	408, 750	5.08	5. 29	
March	8,060	4, 300	5, 400	332, 030	3.72	4. 29	
April	7, 280	3, 120	4,410	262, 457	3.04	3.39	

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HYDROGRAPHY OF THE AMERICAN ISTHMUS.

Estimated monthly discharge of San Carlos River 3 miles above its mouth—Continued.

	Discha	rge in seco	nd-feet.		Rur	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean,	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1899.							-11
May	10, 100	2,800	4,559	280, 308	3.14	3.62	
June	12, 314	4, 360	7, 381	439, 206	5, 09	5.68	
July	50, 130	8,700	16, 909	1,039,701	11.66	13.44	
August	24, 360	8, 290	11,678	718, 067	8.05	9. 28	
September	12, 100	6,560	8, 467	500, 829	5.84	6.52	
October	9,757	6, 440	7, 808	480, 701	5.38	6. 20	a 6. 03
November	34, 737	6, 320	17, 106	1, 027, 893	11.79	13. 15	20. 32
December	31, 480	10, 380	16, 057	991, 347	11.07	12.76	16.03
The year	50, 130	2,800	9, 583	6, 967, 889			
1900.							TO STATE OF
January	35,457	6,776	11,670	717, 543	8.05	9. 28	8.79
February	10,783	4, 580	5, 946	330, 249	4. 10	4. 27	4.96
March	5,840	3, 520	4, 525	278, 257	3.05	3. 52	6. 56
April	6, 752	3, 320	4, 316	256, 835	2.98	3.32	3.00
May	18,000	2,848	5, 844	369, 353	4.03	4.65	15. 42
June	14, 496	6, 560	9,530	567, 079	6.57	7. 33	11.26
July	26,074	9, 596	13, 665	840, 358	9.42	10.86	15. 53
August	20, 120	9,512	13, 187	817, 815	9.10	10.49	22.72
September	34,608	8,924	12, 936	769, 784	8.92	9.95	21.36
October	27, 840	11, 276	17, 202	1, 057, 745	11.86	13. 67	6.45
November	38, 432	10, 524	17, 380	1, 034, 237	11.98	13. 36	16.56
December	66, 820	7, 320	16, 256	999, 545	11. 21	13.02	24.69
The year .	66, 820	2,848	11, 038	8, 038, 800			
1901.			1				
January	38, 300	5, 610	10,057	618, 380	6. 94	8.00	
February	9, 230	4, 300	6, 116	338, 660	4. 22	4. 39	
March	5,920	3, 580	4, 376	269, 070	3.02	3.48	
April	4, 450	2,830	3, 417	203, 330	2.36	2.63	

a From October 12 to 31, inclusive.

Estimated monthly discharge of San Juan River above the mouth of the San Carlos.

[This is obtained by subtracting the discharge of the San Carlos from that of the San Juan at Ochoa.]

20.00	Disch	Total in acre-		
Month.	Maximum.	Minimum.	Mean.	feet.
1898.				
January 10 to 31	23, 270	19,500	21,030	917, 650
February	34,900	18,500	22,080	1, 226, 260
March	22,000	14,600	16,850	1, 036, 070
April	25, 800	12,900	15, 120	899, 700
May	19, 200	11,700	14, 130	868 820
June	39, 200	13,000	22, 410	1, 333, 500
July	43, 100	26, 200	32,720	2, 011, 870
August	38, 400	23,000	26, 170	1, 609, 130
September	41, 300	22, 800	29, 210	1, 738, 120
October	37,600	24, 700	29, 320	1, 802, 820
November	70, 500	26, 800	36, 460	2, 169, 520
December	41,800	26, 300	31, 570	1, 941, 160
The year	70,500	11,700	24, 756	17, 554, 620
1899.				
January	38, 900	26, 300	31,800	1, 955, 300
February	28, 200	23, 100	25, 180	1, 398, 430
March	23, 100	19,600	21,540	1, 324, 450
April	20,880	15, 388	17, 575	1, 045, 77
May	16, 740	13, 390	14, 981	920, 979
June	30, 580	13, 540	17,229	1, 025, 23
July	38, 030	17,000	25,777	1, 586, 008
August	35, 900	21, 050	26, 253	1, 614, 28
September	56, 900	21, 250	27,472	1, 634, 74
October	29, 320	20, 910	25,548	1, 471, 747
November	41,720	21, 460	28, 959	1, 723, 175
December	32, 710	23, 450	26, 706	1, 642, 110
The year	56,900	13, 540	24, 085	17, 342, 226
1900.				
January	26, 854	19,640	21, 994	1, 352, 370
February	19, 832	16, 597	18,292	1,025,928
March	16, 633	13, 520	15, 133	930, 498
April	13, 620	11, 122	12,186	725, 12
May	22,750	10, 188	12,569	772, 860
June	22,060	11, 144	16,524	983, 23
July	34, 730	17, 554	24,496	1, 406, 245
August	59,082	23, 770	33, 946	2, 087, 339

Estimated monthly discharge of San Juan River above the mouth of the San Carlos-C't'd.

	Discharge in second-feet.				
Month.	Maximum.	Minimum.	Mean.	feet.	
1900.					
September	38, 892	24, 628	28, 156	1, 675, 415	
October	61, 528	30, 512	37, 999	2, 336, 492	
November	43, 820	30, 098	34,277	2, 039, 652	
December	55, 742	27, 980	36, 633	2, 252, 502	
The year	61, 528	10, 188	24, 380	17, 587, 656	
1901.					
January	28, 320	22, 740	25, 253	1, 552, 750	
February	22, 330	19,410	20, 794	1, 154, 840	
March	19, 330	16, 190	17,804	1,094,720	
April	16, 140	13, 120	14, 483	861, 800	

SMALL TRIBUTARIES OF SAN JUAN RIVER.

Occasional measurements were made of the small tributaries to San Juan River to determine approximately their relative importance in the maintenance and operation of the canal. The following table shows the maximum, minimum, and mean discharge at the time of such measurements, but must not be taken as representing continuous observations. Some of the streams happened to be visited in times of flood while others were not, and due allowance should be made for this fact:

Estimated monthly discharge of tributaries of San Juan River between Boca San Carlos and Los Sabalos station.

[Drainage area, 750 square miles (approximately).]

	Discha	rge in seco	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1898.							
January 10-31	5, 100	900	2,630	114, 770	3.51	2.87	
February	17,600	2,700	5, 450	302, 680	7. 27	7.57	
March	6,600	1, 300	2,820	173, 400	3.76	4.34	
April	12,700	1, 100	2,960	176, 130	3.95	4.40	
May	7,000	500	2, 380	146, 340	3. 17	3.66	
June	21,000	1,000	8,270	492, 100	11.03	12. 31	
July	21,600	7,800	13, 350	820, 860	17.80	20.52	

Estimated monthly discharge of tributaries of San Juan River between Boca San Carlos and Los Sabalos station—Continued.

	Dischar	ge in secon	nd-feet.		Run-off.		
Month.	Maxi- mum.	Mini- mum,	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	
1898.	10 100	9, 100	0.500	404 500	2 ===	10.11	
August	16, 100	3, 400	6, 580	404, 590	8.77	10.11	
September	15, 900	2,600	7, 140	424, 860	9. 52	10.62	
October	11,900	2,000	6,050	373,000	8. 04	9. 30	
November	45,000	2,800	11,080	659, 360	14. 76	16. 47	
December	15,600	2,900	6, 540	402, 150	8.72	10.05	
The year	45,000	500	6, 270	4, 490, 240			
1899. January	14, 400	4, 300	8, 330	512, 190	11, 10	12. 80	
February	7, 100	3, 200	4, 390	243, 810	5. 85	6. 09	
March	4, 400	2,800	3,590	220, 750	4.80	5. 58	
April	5, 481	1,600	2,517	149, 772	3. 36	3. 75	
May	5, 773	972	2, 156	132, 573	2.87	3, 31	
June	11, 446	1, 296	4, 367	259, 862	5. 82	6, 49	
July	22, 970	4, 430	11, 585	712, 309	15, 45	17. 8	
August	15, 833	7,067	10, 892	669, 818	14.52	16. 74	
September	31, 590	5, 795	10, 362	616, 619	13. 82	15. 45	
October	9, 704	3, 048	5, 790	356, 056	7.72	8. 90	
November	19, 855	2,008	8,604	511, 967	11. 47	12. 80	
December	11,853	3,604	6, 373	391, 649	8. 50	9.80	
The year	31, 590	972	6, 580	4, 777, 375			
1900. January	8, 574	2,977	4,574	281, 262	6. 10	7.08	
February	5, 008	2,517	3, 186	176, 984	4. 25	4.4	
March	4,010	2,000	2,845	164, 965	3. 79	4. 3	
April	2, 258	446	1, 124	66, 877	1.50	1.6	
May	11, 270	90	1,886	116, 025	2. 51	2. 89	
June	8, 884	2, 124	4, 214	250, 778	5. 62	6. 20	
July	11, 914	2, 802	7, 365	452, 885	9, 82	11. 3	
August	31, 114	5,042	12,983	798, 317	17. 31	19.9	
September	14, 574	4, 170	6, 922	411, 870	9. 23	10. 30	
October	26, 728	2,320	9,559	587, 739	12.75	14.70	
November	14, 620	3, 524	6, 234	370, 954	8. 31	9. 2	
December	28, 222	2,712	9, 715	597, 335	12.96	14. 8	
The year	31, 114	90	5, 884	4, 275, 991			

 $^{^{\}rm a}$ This is the difference between the discharge of the San Juan above Boca San Carlos and at Sabalos station.

Discharge of small tributaries of San Juan River above Boca San Carlos, 1899–1900.

Change	Disch	Discharge in second-feet.				
Stream.	Maximum.	Minimum.	Mean.	measure- ments.		
Melchora	287	. 0	78	10		
Medio Queso	1, 160	0	525	12		
Palo de Arco	227	0	106	9		
Caño Chico	540	0	242	8		
Caño Negro	1, 277	0	168	43		
Los Sabalos	12, 134	23	581	115		
Poco Sal	2,651	34	1,120	17		
Santa Cruz	10, 301	36	881	17		
Santa Crucita	623	0	287	8		
Bartula	2, 437	40	357	16		
Infiernito	2, 449	80	898	16		
Machuca	573	27	161	17		
La Crucita del Norte	108	0	32	. 6		
La Crucita del Sur	152	0	95	4		
La Cruz del Norte	293	0	96	13		
La Cruz del Sur	77	0	38	2		
El Jardin	742	25	166	23		
La Tigre	560	17	88	22		
			1			

Discharge of small tributaries of San Juan River below Boca San Carlos, 1899–1900.

	Disch	Number of		
Stream.	Maximum.	Minimum.	Mean.	measure- ments.
Cureña	1, 145	43	394	17
Danta	355	24	140	17
Tambor Grande	111	9	43	10
San Geronimo	117	3	10	4
Tamborcito	661	17	302	14
Copalchi	769	17	233	15
Guasimo	234	13	66	16
Caño Maria	565	134	269	4
Sucio	100	. 4	31	8
La Tigre	894	41	368	16
San Juanillo (at mouth)	587	380	483	2

Estimated monthly discharge of Machado River.

[From triweekly observations.]

	Discha	Total in		
Month.	Maximum.	Minimum.	Mean.	acre-feet.
1899.				
January	339	98	214	13, 178
February	150	68	97	5, 405
March	300	56	118	7, 252
April	213	60	101	6,030
May	424	53	160	9, 854
June	251	95	159	9, 471
July	1,035	170	337	20, 570
August	930	198	334	20, 747
September	1, 158	180	302	17, 994
October	225	100	154	9, 471
November	1, 252	79	309	18, 373
December	1, 464	110	338	20, 797
The year	1, 464	53	219	159, 142
1900.				
January	258	95	146	9,011
February	311	73	120	6,665
March	105	62	77	4, 740
April	83	37	55	3,255
May	221	30	94	5, 796
June	196	79	112	6,653
July	472	101	258	15, 862
August	989	209	528	32, 490
September	648	170	337	20, 025
October	355	80	169	10, 378
November	375	113	267	12, 327
December	2,602	168	600	36, 538
The year	2,602	30	230	163, 740

SAN FRANCISCO RIVER.

The most important stream that will be intercepted by a canal line from Boca San Carlos to San Juan del Norte, on the left bank of the San Juan, is the San Francisco. Its principal branch is the Chanchos. Above the Chanchos a smaller tributary is called Nicholson Creek. These tributaries and the San Francisco above their junction were measured in 1898. From these observations a summary of monthly

discharge of the San Francisco at its mouth was made for 1898, and is here given. The discharge measurements in 1899 and 1900 follow:

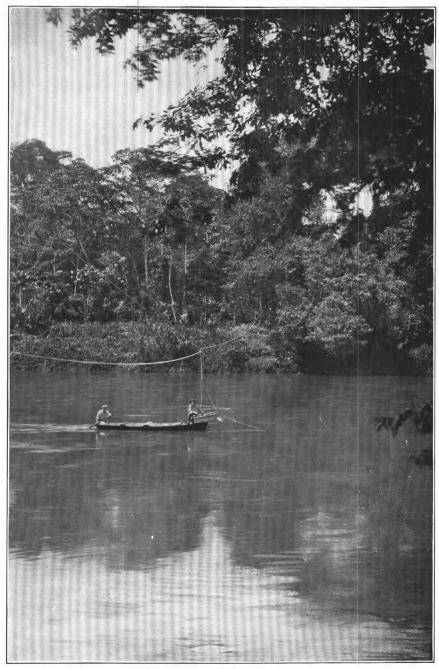
Estimated monthly discharge of San Francisco River at its mouth.

[Obtained by combining observations taken on the Upper San Francisco and Chanchos rivers and Nicholson Creek.]

	Disch	Total in acre-		
Month.	Maximum.	Minimum.	Mean.	feet.
1898.				
January	1,270	230	583	35, 850
February	1, 360	170	489	27, 160
March	390	120	199	12, 240
April	1, 260	110	254	15, 110
May	560	125	232	14, 260
June	1, 100	115	373	22, 200
July	1,890	270	684	42,060
August	800	185	364	22, 380
September	1, 280	150	382	22, 730
October	510	130	274	16, 850
November	1,520	100	502	29, 870
December	1,090	160	398	24, 470
The year	1,890	100	394	285, 180

Discharge measurements made on San Francisco River.

Date	e.	Hydrographer.	Meter number.	Area of section.	Mean velocity.	Discharge.
1899).			Square feet.	Ft. per sec.	Second-feet.
Oct.	9	H. W. Durham	Price No. 34	491	0.52	256
Nov.	7	do	do	1,083	1.12	1, 212
Nov.	28	do	do	834	0.30	247
190	0.					
Jan.	24	H. G. Heisler	Price No. 63	662	0.64	429
Feb.	16	H. C. Hurd	Price No. 34	503	0. 26	131
Mar.	18	do	do	415	0.36	148
Apr.	29	do	Price No. 35	270	0.10	27
May	21		The part of the second	348	0.36	126
June	4	do	do	508	0.64	326
June	27	do	do	417	0.42	176
Aug.	1	do	do	810	0.57	465
Aug.	16	do	do	842	1.15	968
Aug.	30	do	do	978	1.21	1, 187
Sept.	11	do		625	0.54	340
Sept.	24	do	do	751	0.73	554



SEDIMENT TRAP ON SARAPIQUI.

SARAPIQUI RIVER.

A station for the measurement of rainfall, sediment, and discharge on the Sarapiqui was maintained about 6 miles above the mouth of that river from August, 1898, to the end of the year 1899, and the record is complete for that period. A native observer took rainfall and gageheight observations throughout 1900, and approximate results for that year also are given.

Estimated monthly discharge of Sarapiqui River 5 miles above its mouth.

[Drainage area, 1,100 square miles, approximately.]

200.00	Discha	arge in second	-feet.	Total in acre-	
Month,	Maximum.	Minimum.	Mean.	feet.	
1899.	99,077	9,000	F 400	999 966	
January	22, 077	3,000	5, 420	333, 260	
February	27, 100	2,710	5, 200	288, 800	
March	8, 972	2, 240	3, 350	205, 980	
April	6, 481	1,928	3, 173	188, 835	
May	18, 054	1,694	4, 357	267, 905	
June	16, 766	3, 753	6, 553	399, 916	
July	61, 479	5, 223	14,173	871, 488	
August	23, 347	5,020	8,094	497, 708	
September	15,076	4, 474	6,418	381, 931	
October	15, 670	3,778	5, 920	363, 982	
November	26, 678	4, 219	11,605	691, 724	
December	42, 110	6, 876	11,512	685, 012	
The year	61, 479	1,694	7, 150	5, 176, 541	
1900.	99 697	9 691	7 450	450 575	
January	33, 637	3,631	7, 458	458, 575	
February	7,598	1,025	3,598	199, 828	
March	6, 464	800	1,726	106, 119	
April	14, 180	2,500	4,055	241, 065	
May	14, 852	1,944	5, 472	336, 441	
June	11, 991	4,530	7,041	418, 997	
July	27, 038	6, 547	9, 880	607, 532	
August	21, 077	5, 566	10,257	630, 690	
September	28, 946	3, 753	7,652	455, 340	
October	23, 498	5, 800	11,094	682, 211	
November	41, 808	6, 298	14,258	848, 406	
December	62, 236	4, 194	13,624	837, 713	
The year	62, 236	800	8,043	5, 822, 917	
1901. January	38, 500	3, 390	8, 624	530, 270	
February	9,650	2,900	4, 448	247, 030	

SAN JUANILLO RIVER.

Lull route, variants I, II, and III, all require that the San Juanillo River be diverted below the mouth of the Deseado River and conducted to the sea north of the canal line. To obtain data on this problem, a gage was established on that river January 1, 1900. Daily readings of the gage and occasional measurements of discharge were made, the results of which are as follows:

Estimated monthly discharge of San Juanillo River below the mouth of the Deseado.

******	Disch	arge in second	-feet.	Total in acre-	
Month.	Maximum.	Minimum.	Mean.	feet.	
1900.					
January	2,520	925	1,603	98, 596	
February	1,616	507	904	50, 181	
March	1,044	325	626	38, 508	
April	460	260	311	18, 534	
May	1,405	245	744	45, 765	
June	729	440	619	36, 828	
July	1,883	934	1,421	87, 458	
August	2,500	1,489	2, 184	134, 305	
September	2, 225	1, 215	1,786	106, 292	
October	2, 260	1, 268	1,794	110, 330	
Total	2, 520	245	1, 211	726, 797	

DISTRIBUTARIES OF SAN JUAN RIVER.

The waters of the San Juan River have two principal outlets, the southern called the Colorado River, and the northern called the lower San Juan. The later stream sends out two other distributaries which empty into the ocean between the two larger, and are called the Parado and Taura. It seems, however, that a portion of the course of the Taura is, during the season of low water, higher than the water in the San Juan, and it becomes a tributary of the latter. It was visited on May 6, 1898, and was at that time discharging 25 cubic feet per second into the San Juan. On the same day the discharge of the San Juan below the Taura was 1,112 cubic feet per second. The discharge at Ochoa on the same date was 16,950 cubic feet per second.

On July 13 the Taura was flowing away from the San Juan, and its volume 200 yards below its exit was 2,234 cubic feet per second. On this day the discharge of the San Juan at Ochoa was 46,000 cubic feet per second.

On March 19, 1900, the Taura was observed to be discharging 8

cubic feet per second, and on April 30, 1900, 3 cubic feet per second, into the San Juan.

The condition of the Taura flowing toward the San Juan is abnormal, its normal condition being that of a minor distributary of the San Juan.

Measurements of	discharge	of distributaries	of San	Juan	River.
-----------------	-----------	-------------------	--------	------	--------

QL	Disch	arge in second	-feet.	Number of	
Stream.	Maximum.	Minimum.	Mean.	measure- ments.	
San Juanillo	199	4	80	18	
Colorado	39, 034	22, 336	30, 685	2	
Lower San Juan	22, 337	559	5,721	10	
Parado	265	34	124	11	
Tauro	1,669	0	730	18	

RAINFALL.

Observations of rainfall were made at each river station, the form of gage used at most of the stations being a metal funnel which caught the rain and discharged it into a bottle, from which it was measured in a graduate bearing a known relation to the diameter of the funnel. The gage was always placed in a position as exposed as possible, but nearly always this was a small clearing in the forest, which was still well sheltered from the wind.

One of the most remarkable characteristics of Nicaragua is its rainfall, and there are radical and striking differences in the climate of the east and west coasts with reference to it.

From the records it will be seen that there is no definite dry season on the eastern coast, but that rain may be expected any day in the year, and the expectation will seldom be disappointed.

On the Pacific coast, on the contrary, there is little rain from the beginning of January till the middle of May, when the rainy season begins, but the region is subject to violent downpours during the rainy season, the precipitation for a single day being often several inches. Mr. William Climie reports a rainfall of 9 inches in nine hours at Nandaime, a small town south of Granada.

No less remarkable is the excessive aggregate of rainfall in a limited district of which the nucleus seems to be in the vicinity of San Juan del Norte. The annual precipitation at this point, as deduced from the mean of six years' observation, is about 260 inches, while that at Bluefields, 73 miles north also on the Caribbean, is only about 105; that of Port Limon, an equal distance south, is 118; that of Colon, the Caribbean end of the Panama Canal, is 124, and that of Ochoa, 54 miles west of San Juan del Norte, is 168. A short record at Lake

Silico, near San Juan del Norte, seems to show a still heavier rainfall, and from this neighborhood the precipitation seems to decrease in all directions.

The heaviest fall of rain observed in Nicaragua was reported by Mr. Howard Scharschmidt, at Silico station on Lake Silico, November 4, 1899, 10.5 inches in six hours, or an average of 1\frac{3}{4} inches per hour. On the same date, Mr. Charles D. Scott, at San Juan del Norte, observed 12.48 inches in twenty-four hours, of which 8 inches fell in about six hours. These are the heaviest falls for a single day yet observed. The heaviest monthly rainfall observed on the Isthmus by the Commission was at San Juan del Norte for November, 1900—55.38 inches.

Rainfall at San Juan del Norte, Nicaragua, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual.
1890	26.80	6.36	5. 93	18.11	4.93	46.84	52.55	35.72	8.14	24.36	25.55	41.65	296. 94
1891	20.30	2.57	1.95	10.40	13.78	26.95	23.57	19.49	14.16	20.21	28.15	32.74	214.27
1892	28, 57	11,38	4.98	18.38	50.88	13.42	38.96	23,63	11.47	27.95	36.93	24.65	291.20
1893	17.70	7.53	3.93	9.99	2.77								
1898	19.44	25.17	10.16	7.82	9.37	19.52	24, 63	16.38	7.24	12.50	32.35	17.06	201.64
1899	23.49	11.69	8.33	9.09	21.24	20.97	39.62	29.50	36.95	12.44	40.36	32.25	285. 93
1900	21, 20	10.72	7, 47	4.62	22,06	11.43	27.13	38, 96	26, 45	22.44	55.38	18.24	266.10
Mean	22.50	10.77	6.11	11.20	17.86	23.19	34.41	27.28	17.40	19.98	36.45	27.76	259. 35

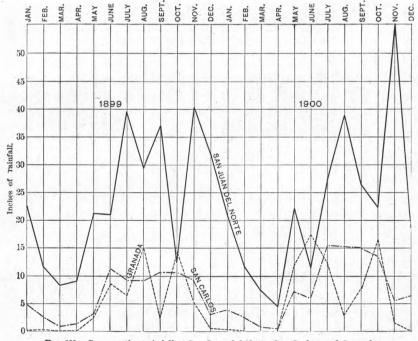


Fig. 229.—Comparative rainfall at San Juan del Norte, San Carlos, and Granada.

Rainfall at San Antonio plantation, in inches.

[Latitude, 12° 32' N. Longitude, 86° 59' W. Elevation, 66 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug,	Sept.	Oct.	Nov.	Dec.	Total.
1895	0.00	0.00	0.00		7.98	6.29	3.36	5.07	21.68	21.71	3.42	0.32	69. 83
1896	0.00	0.00	0.00	0.20	12.20	10.50	7.54	4.71	13, 39	11.22	4.76	0.98	65, 50
1897	0.00	0.00	1.26	0.59	18.23	14.53	6.81	13.86	10.94	31.06	0.98	0.00	98. 26
1898	0.24	0.00	0.00	0.00	16,00	11.60	8.37	14.85	16.71	7.60	5.64	0.04	81.05
1899	0.00	0.44	0.00	0.00	2.12	9.82	8.08	9, 60	5.50	26.85	4.81	0.00	67. 22
1900	0.00	0.00	0.55	1.02	6.05	22, 46	18.81	6.80	13.69	24.45	1.85	0.00	95. 68

Rainfall at Valle Menier, in inches.

[Latitude, 11° 46' N. Longitude, 85° 57' W. Elevation, 492 feet.]

Year.	Jan,	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1880	0.00	0.00	0.00	0.00	13, 48	9. 92	2, 24	9, 96	6.77	13.46	2.72	C.00	58.55
1881	0.55	0.00	0.00	0.00	9.94	12.88	7.52	8,86	9.10	22.68	9.33	0.98	81.84
1882	0.00	0.00	0.00	0.00	1.93	12	. 87	6.30	4.92	19.13	2.76	0.00	47.91
1883	0.00	0.00	0.00	0.00	1.35	7.44	3.94						
1899	0.00	0.00	0.00	0.00					2.04	15.95	6.11	0.00	
1900	0.00	0.00	0.00	0.31	10.36	11.00	9, 94	44.64	17.46	11.54			

Rainfall at Managua, in inches.

[Latitude, 12° 7' N. Longitude, 86° 16' W. Elevation, 148 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1891	0.00	0.00	0.00	0.00	1.08	14.00	5.04	3.04	8, 43	9.64	7, 24	0.43	48. 90
1892	0.00	0.00	0.00	0.00	8.58	11.34	6.35	7.98	9.24	20.55	3.09		67.18
1899									2.21	18.59	2.79	0.11	
1900	0.00	0.00	0.00	0.00	6.62	8.54	7.97	3.83	7.57	17.48	1.37	0.17	53. 53

Rainfall in Nicaragua and Costa Rica in 1898, in inches.

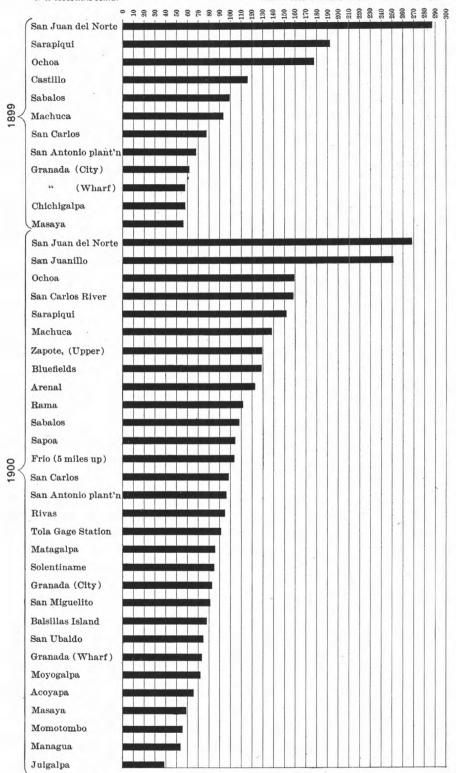
Station.	Jan,	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Brito and Tola	0, 25	0.00	0.08	0.08	11.30	14.86	11.42	6.17	16.60	25.70	6. 01	2.41	94. 88
Rivas	1.07	0.12	0.10	0.00	16.17	18.95	13,65	11.85	13.99	20.83	8.19	3.14	108.06
Las Lajas	0.25	0.05	1.34	0.28	10.60	13.50	10.64	8.44	6.79	16.19	4.41	2.26	74.75
Rio Viejo		0.01	0.66	0.00	13.78	13.45	4.01	11.66	7.28	8.99	0.61	0.17	60.62
Tipitapa		0.00	0.26	0 00	8.56	16.88	6.24	7.82	11.25	7.12	0.93	0.17	59.23
Morrito				0.07	8.92	14.05	13.84	10.20					
Fort San Carlos			1.21	3.00	8, 22	15.56	13.35	8.00	10.56	8.93	9.86	5.62	84.31
Sabalos			2.10	6.00	11.69	17.13	20.69	11.33	11.42	11.81	12.17	10.20	114.54
Castillo							18.92	11.46	16.22	4.64	14.04	11.64	
Machuca								6, 52	12.86	9.83	15.65	6.75	
Rio San Carlos		4 400 - 0 -	100		100000000000000000000000000000000000000	1 hand 1 h	1000000	100	1000	100			
Ochoa		1000000	1.000				15 - F. S		100				170.84
San Francisco	15.33	18.43		The second	100000000000000000000000000000000000000		(FEE 6 5	1000		100	1. 1		172.17
Sarapiqui					The second		Lanca Control						
Deseado b		The same of the same	100000000000000000000000000000000000000	34, -400	10000		26.86	W. 11. 11. 11. 11. 11. 11. 11. 11. 11. 1			100	95 7.50	210.63
Greytown		1			7	1000	24.63	1	10000			700	201.64

^aRecord incomplete from January 1-5, inclusive, and from December 29-31, inclusive; so the rainfall at Ochoa for those days is added.

 $^{^{\}rm b}$ Rainfall not observed from December 25–31, 1898; so the record was completed by including the corresponding days of 1897.

Rainfall in Nicaragua and Costa Rica during 1899, in inches.

Lecation.	Observer.	Total inches.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Estab- lished.
Acoyapa	Modesto Cuadra									9.60	3.30	15.32	8.95	1.20	Aug. 10
Balsillas	Sherwood Wilson										0.49	5.95	9.22	1.96	Sept. 26
Bluefields	T. W. Waters									2.18	29.11	8.10	9.55	9.75	Aug. 26
Castillo	John Augustine	114.50	10.32	6.47	2.02	2.21	5.90	9.29	18.11	17.73	12.01	8.21	15.33	6.90	
Chichigalpa	S. H. Young	58. 20	0.00	0.00	0.00	0.60	0.88	4.56	5.13	6.88	4.06	32, 29	3.80	0.00	
Colorado	H. Scharschmidt			10.72	11.83	13.17	19.11		43, 99	29.78		11.92			
rio River	Sherwood Wilson											0.90	8.36	3.53	Oct. 2
ranada	S. Vargas	56.93	0.00	0.52	0.11	0.02	2.43	8.78	6.64	15.44	2.39	14.79	5, 24	0.57	Jan. 25
Franada	Nicaragua sugar estates	60.33	0.36	0.43	0.00	0.00	2.48	10.19	7.47	14.77	3.78	15.13	4.85	0.87	
ndio (Negro)	S. H. Harris											0.25	18.55	18.65	Oct. 2
avali Mine	W. H. S. Grigsby										5.60	8.81	7.65	4.78	Sept. 17
uigalpa	J. J. Sequeira			The state of the state of	Contract of the			Mark Control		4.25	0.83	12.97	10.26	0.60	Aug. 19
a Libertad	Pelayo Porto									7.05	2.85	8.33	9.12	5.46	Aug. 16
Iachuca	A. Faris	93.08	12.96	4.61	1.65	5. 61	7.08	8.58	18.33	18.79	5.69	1.91	4.09	3.78	
Ianagua	T. Bird.										2.21	18.59	2.79	0.11	Sept. 16
Iasaya	J. Weist	45. 24	0.50	0.48	0.07	0.00	2.02	8.62	4.19	9.47	2.80	10.35	5, 54	1.20	11000
Iatagalpa	W. K. Henley										1.43	15.88	5, 29	1.18	Sept. 1:
Iomotombo	A. Peterson		Property of the second								0.97	26.55	5.30	0.62	Sept. 16
Ioyogalpa	K. B. Luna										3.08	18.32	5.99	7.03	Sept. 1
Ochoa	H. S. Reed		14.02	7.96	5, 80	7.09	12.60	15.69	30. 20	17.50	15.49	7.85	20.58	22.13	
inon	Fernando Loredo	100000	100000000000000000000000000000000000000	201633							4.94	9.11	5.24	2.02	Sept. 13
Rama	T. W. White.									2, 65	11.58	10.90	13.42	8.33	Aug. 18
Rivas	Earl Flint		0,85	1.70	0, 65	0.00	1.62	7.53	10.69	9, 26	5.15	20.39	9.06	0.92	
Rivas	J. O. Jones	100000											5.91	0.57	Nov.
abalos	R. H. Morrin	98, 55	9, 82	4, 33	2.73	2.65	5, 50	11.31	15.87	12.15	14.70	6.67	8.09	4.73	
an Antonio Plantation	Nicaragua sugar estates	67.22	0.00	0.44	0.00	0.00	2.12	9, 82	8, 08	9,60	5, 50	26, 85	4.81	0.00	
an Carlos	E. Humphreys	75.5	4.99	2.79	1.05	1.48	3.18	11.24	9.28	9.23	10.67	10,66	9.43	3, 20	
an Carlos River	H. S. Reed	0.00.000										6.03	20.32	18.03	Oct. 1
an Francisco	T. Merriman										0.82	1.60	6.82	3.00	Sept. 2
an Juan del Norte	Chas, D. Scott		23, 49	11.69	8.33	9.09	21.24	20, 97	39.62	29.50	36. 95	12,44	40.36	32. 25	
an Miguelito		TORSE STORY		22.00	0.00	2.00			00.00		22100	8.13	6.95	2.78	Oct.



Rainfall in Nicaragua and Costa Rica during 1899, in inches—Continued.

22	Location.	Observer.	Total inches.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Estab- lished.
2	San Ubaldo	Frank Trap							1.80	4.30	9.45	6.22	11.10	9.31	1.87	June 21
E	Sapoa	M. C. Hogan								5.42	8.74	5.34	6.45	8.59	1.98	July 16
10	Sarapiqui	T. F. Boltz et al	190.40	16.57	7.77	5.67	9.13	14.78	12.90	24.89	21.05	17.05	10.55	29, 29	20.75	
,		T. Montiel												11.59	1.71	Nov. 1
PT	Sucia (Boca)								,			13.72	13.95	30, 32	19.88	Sept. 17
I		F. Davis et al										2.57	11.69	. 5.42	0.44	(a)
V	Tola Gage Station	J. O. Jones									4.81	3.35	29.49	5.48	0.52	Aug. 13
	Valle Menier	V. Gavinet										2.04	15.95	6.11	0.00	Sept. 2
ĭ	Viejo	Fred Davis									1.39	2.27	16.91	2.29	0.08	Aug. 18
	Zapote	J. G. Kennedy								12.33	11.63	9.45	8.04	16.23	6.18	July 3
ಯ	Zapote	G. B. Zampieri											10.57	14.78	7.09	Oct. 3

a Discontinued January 24; reestablished August 20.

Rainfall in Nicaragua and Costa Rica during 1900, in inches.

	v													
Location.	Observer.	Total.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Acoyapa, Nicaragua	Modesto Cuadra	65.04	0.58	0.21	0.22	0.16	11.31	10.19	12.91	4.76	9.36	12, 96	1,12	1.26
Arenal, Costa Ricas	Godfrey Hahn	- 121.70	4.45	2.73	3.18	4.25	17.35	7.11	15.95	13.71	15.42	11.61	13.64	12.30
Basillas Island, Nicaragua	S. Wilson et al	77.10	1.78	1.04	0.52	0.34	9.54	4.49	10.67	14.05	12.48	14.45	2.97	4.77
Boca Sucia, Costa Rica			9.65	0.80										
Bluefields, Costa Rica	Thomas W. Waters	127.63	5.70	6.95	3.55	1.05	10.40	8.90	14.60	23, 55	11.20	12, 32	14.90	14.51
Castillo, Costa Rica	John Augustine			4.37	2.22	2.32	18.04	9.82	18.42	33.83	15.24	21.38	6.86	16.93
Frio (5 miles up), Costa Rica	Fred Davis	102.66	3.17	2.31	0.92	0.75	13.61	11.68	13.29	12.21	11.76	20.15	6, 19	6.62
Granada Wharf, Nicaragua	Stephen Vargas	72.10	0.26	0.00	0.03	0.02	12.06	17.63	12.40	3.93	7.60	16.70	1.42	0.05
Granada City, Nicaragua	Nicaragua sugar estates	82.46	0.45	0.00	0.00	0.10	16.01	19.74	13.40	5,58	9.46	15, 90	1,60	0,22
Juigalpa, Nicaragua	J. Jesus Sequeira	37.73	0.05	0.12	0.18	0.22	6, 49	2,05	3, 42	3.77	9.79	10.56	0.63	0.45
Las Haciendas, Nicaragua	R. de Hennin						8.95	7.58	16.45	12.05	20.61	22.14	5,58	
Machuca, Nicaragua	J. S. Martinez et al	137.88	1.37	1.67	2.05	2.39	17.70	7.46	22.65	25.80	18.20	10.68	12.35	15.56

^{*}Upper San Carlos River.

Rainfall in Nicaragua and Costa Rica during 1900, in inches—Continued.

Location.	Observer.	Total.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Managua, Nicaragua	T. Bird	53, 55	0.00	0.00	0.00	0.00	6, 62	8, 54	7.97	3.83	7.57	17.48	1.37	0.1
Masaya, Nicaragua	J. Wiest	59.70	0.00	0.00	0.00	0.00	8.66	15.52	10.27	4.70	7.23	11.24	1.91	(17)
Matagalpa, Nicaragua	W. K. Henley et al	85.68	0.24	0.36	0.87	1.09	16.06	14.49	13.13	5.12	10.40	17.35	4.27	2.3
Momotombo, Nicaragua	A. Peterson	55. 21	0.00	0.00	0.00	0.00	6.67	13.48	6.96	0.90	5.63	18.78	2.06	0.7
Məyogalpa, Nicaragua	K. B. Luna	71.70	0.13	0.03	0.22	0.05	13.59	11.46	8,28	7.95	12, 44	15.63	1.58	0.3
Negro (Indio), Nicaragua	S. H. Harris		12.32	12,69	5.50	2.51	18.13	10.41	12.67	40.15	12.85	,		
Ochoa, Costa Rica	H. S. Reed	158.83	9.12	4.49	7.58	4.29	13.36	11.24	16.45	26, 46	16.66	8.53	15.69	24.9
Palo Seco, Costa Rica a	A. Quintania			4.37	5.47	3.62	16.01	13.98	15.15	24.96	18.34	11.18	18.12	25. 8
Rama, Nicaragua	G. W. White et al	110.35	2, 52	3.31	3. 20	1.48	12.70	6.73	16.30	19.56	19.58	10.97	7.61	6.39
Rivas, Nicaragua	Earl Flint	94.68	0.19	0.02	0.11	0.02	11, 19	16.38	10.61	9.16	22.58	21.93	1.18	1.3
Rivas, Nicaragua ^b	Charles Hayman							5.07	6.93	6.82	16.86	18.12	0.87	0.65
Sabalos, Nicaragua	Thomas F. Boltz	107.34	3.19	3.84	1.69	0.64	8.57	8.37	16.89	20.40	11.24	16.34	6.72	9.4
San Antonio Plantation, Nicaragua		95.68	0.00	0.00	0.55	1.02	6.05	22.46	18.81	6.80	13.69	24.45	1.85	0.00
San Carlos River, Costa Rica	H. S. Reed	157.30	8.79	4.96	6.56	3.00	15.42	11.26	15.53	22.72	21.36	6, 45	16.56	24.6
San Carlos, Nicaragua	Fred Davis et al	98.34	3.09	2.66	0.81	0.41	14.19	6.04	15, 44	15.29	15.02	13.59	5.42	6. 3
San Juan del Norte, Nicaragua	Charles D. Scott	266.10	21, 20	10.72	7.47	4.62	22.06	11.43	27.13	38.96	26.45	22.44	55.38	18.2
San Juanillo, Nicaragua	Fred Appleby	249.20	18.79	11.79	7.18	2.28	17.18	6.53	22.66	41.01	28.18	24.84	43.34	25. 4
San Miguelito, Nicaragua	J. F. Cuadra	81.11	1.38	1.02	0.49	1.40	13.58	10.19	15.83	8.46	7.20	13.41	4.71	3.4
San Ubaldo, Nicaragua	G. C. W. Magruder	74.26	1.22	0.19	0.27	0.09	7.44	9.85	24.91	5.32	14.08	8.91	1.43	0.5
Sapoa, Nicaragua ·	M. C. Hogan	103.60	1.11	0.57	0.63	0.54	10.21	12.85	14.74	10.70	23.75	22.28	3.91	2.3
					1.08	2.69	15.81	8.72	6.28					
Sarapiqui, Costa Rica	Paulino Gonzalez	151.48	9.65	5.00	10.76	2.63	10.54	9.84	22.24	23.48	6.99	11.08	24.86	24.8
Sardinas, Nicaragua	Tomas Montiel		1.89	2.73	0.61	0.20								
Solentiname, Nicaragua	J. M. Boniche		1.66	1.95	1.10	1.40	12.47	5.31	8.63	14.21	15.43	14.89	4.04	3.5
Tipitapa, Nicaragua f	L. Roy Cannon		0.00	0.02	0.00	0. 15	13.53	12.60	12.58	6.04	8.32	15.00		
	J. O. Jones		0.17	0.00	C. 01	0.33	12.91	12.29	15.67	4.53	24.15	18.46	0.87	0.6
Valle Menier, Nicaragua			0.00	0.00	0.00	0.31	10.36	11.00	9.94	4.64	11.54	17.46		
Zapote (Upper), Costa Rica	G. B. Zampieri		4.09	2, 62	2, 29	1.44	12.13	7.11	17.55	14.50	23.93	18, 22	13, 43	11.3

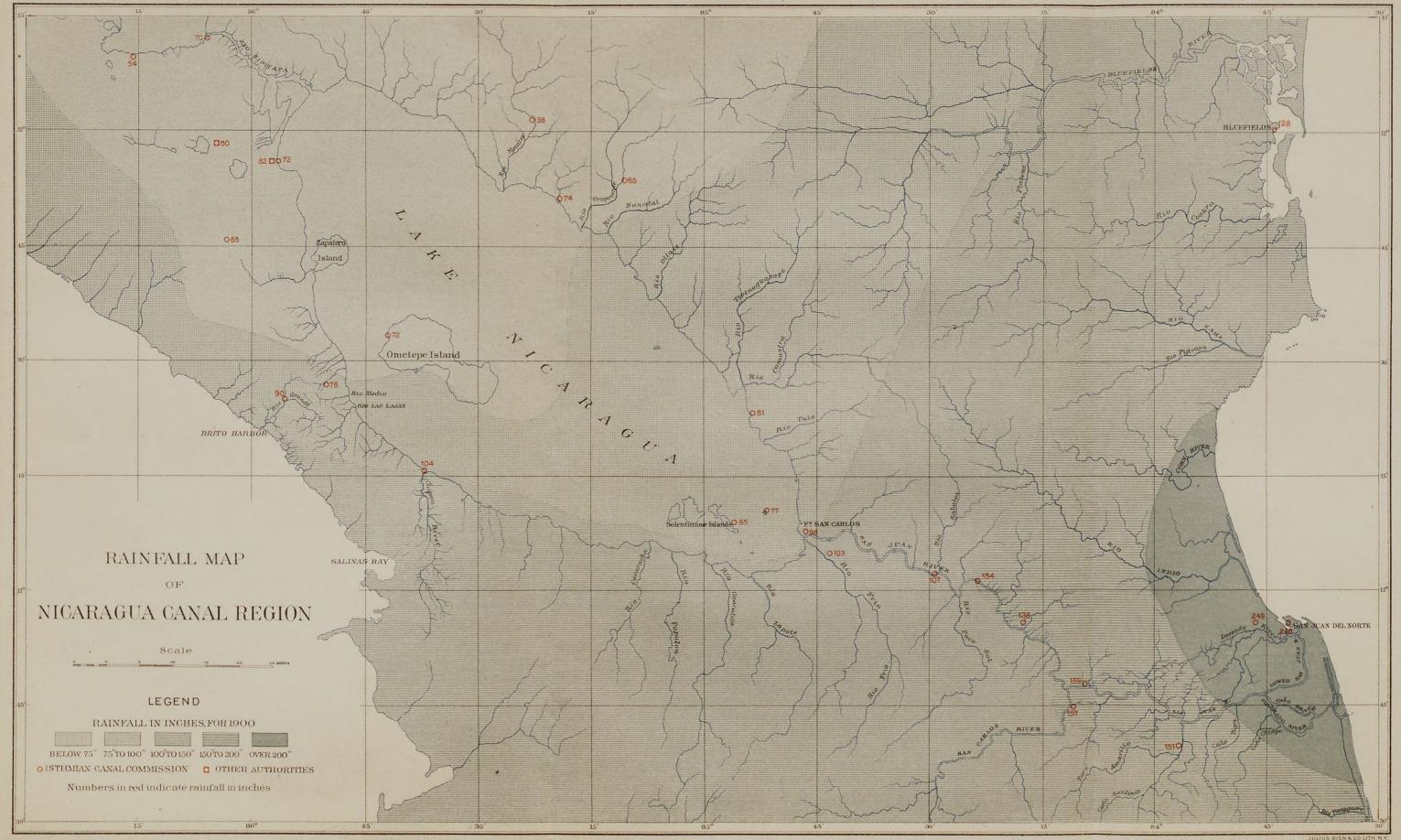
a Established February 7.

b Established June 15.

[°] Removed to Tortuga July 16. d Established March 22; discontinued July 9.

[•] Isla Venado, Lake Nicaragua.

Discontinued October 30.



Rainfall in Nicaragua and Costa Rica in 1901, in inches.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Fort San Carlos	2.59	0.99	1.31	0.93							
Granada	0.00	0.00	0.00	0.00	1.14	14.67	13.36	13.96	15.62	12.84	0.45
Ochoa	10.25	2.61	5.26	5.57							
San Juan del Norte	29.92	4.32	6.47	11.06	3.52	14.69	18.54	18.36	5.46	38.89	4.81
San Ubaldo	0.45	0.02	0.12	0.00							
Tortuga	1.38	0.10	0.20	0.14							
Solentiname Island	2.00	0.83									

Rainfall at Grancda, Nicaragua, in inches.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1876					5.77	13.65	26.61	4.96					
1877	0.00	0.00	0.00	0.00	11.57	10.24	10.12	5.32	17.36	5.27	0.87	0.59	61.34
1883	0.35	0.00	0.00	0.18	0.28	5.20	2.66	5.47	9.74	19.91	3, 64	0.00	47.48
1884	0.00	0.00	0.00	0.00	0.00	8.25	3.99	3.75	8.82	8.63	2.28	0.26	35. 98
1897	0.00	0.00	0.97	1.77	16.63	30.79	8.88	10.87	10.21	11.97	1.25	0.28	93.62
1898	1.07	0.00	0.02	0.00	12.82	10.44	6.09	7.30	5.25	10.49	1.87	0.24	55.59
1899	0.00	0.52	0.11	0.02	2.43	8.78	6.64	15.44	2.39	14.79	5.24	0.57	56.98
1900	0.26	0.00	0.03	0.02	12.06	17.43	12.40	3.93	7.60	16.70	1.42	0.22	72.07
1901	0.00	0.00	0.00	0.00	1.14	14.67	13.36	13.96	15.62	12.84	0.45	0.00	72.04
Mean	0.21	0.07	0.14	0.25	6.97	13, 27	10.08	7.89	9.62	12.57	2.13	0.27	63. 47

1876, Ramon Espinola; 1877, Dr. Earl Flint; 1883–4, National Institute: 1897–98, William Climie; 1899–1900, Stephen Vargas; 1901, Nicaragua Sugar Estates, Limited.

EVAPORATION.

The observation of evaporation by means of pans floating in the water was carried on under both the Nicaragua and Isthmian Canal commissions.

The inherent obstacles to accurate work by this method are great at all times, and, as might be expected, results are rather discordant. They are summarized in the tables following:

Monthly evaporation of Lake Nicaragua, in inches.

1898.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
San Ubaldo				6.42	6. 26	5.19	5.08	4.87				
Las Lajas			5.77	8.13	5.98	4.35	3.38	3.41	2.73	2.73	3.00	3.01
Fort San Carlos				4.92	4.56	4.20	3.84	3.69	3, 54	4.09	3.39	4.08
Mean			5. 25	6.49	5.60	4,58	4.10	3.99	3.13	3.41	3. 20	3. 52
				18	99.							
Las Lajas:	3.40	3.39	4.25									
Fort San Carlos	3.72	3.28	4.34	5.01		100000	1		100 251	2.85	2.23	2.70
San Ubaldo							3.87	3.87	3.78	4.40	3.72	3.71
Sapoa										3.56	3.24	3.91
Tipitapa									5.58	5.42	3.97	5.79
Mean									3.79	4.06	3.29	4.08

Monthly evaporation of Lake Nicaragua-Continued.

1900.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
San Carlos	2.89	3.16	4.36	4.62	4.34	3.93	2.63	2.24	3.24	2.35	3.39	3.04
San Ubaldo	4.57	4.24	5.47	5.79	7.59	4.95	5, 46	5.05	4.74	4.64	3.90	4.03
Sapoa	4.36	5.40	6.33	6.41	5.12	3, 19	2.54	2.30	3.36			
Tipitapa	3.28	4.02	5.89	6.66	7.28	5.16	4.49	4.25	4.89	5.18		
Mean	3.78	4. 21	5. 61	5.87	6.08	4.31	3.78	3.46	4.06	4.06	3.64	3.53

Allowance must be made in the use of these results for the fact that the conditions prevalent on the lake can not be duplicated in the evaporating pan. During the greater part of the year the trade winds blow strongly from the eastern side of the lake to the western. Except along the eastern shore the surface of the lake is blown into billows, the waves often attaining a considerable height and being crowned with whitecaps, and the total water surface in contact with the wind is much greater than the level surface of the lake. Most of the lake surface must therefore lose by evaporation a greater depth of water than the pan. The amount of evaporation during the dry season was obtainable by another method. The fluctuations of the lake were observed, and by applying to this the observations of rainfall upon the lake, the inflow from streams, and the discharge of San Juan River, the evaporation actually taking place upon the lake was obtained. During April, 1898, the evaporation was found by this method to be 6.12 inches. The results for 1900 and 1901 are given in the following table:

Evaporation from Lake Nicaragua.

[Evaporation = fall of lake + rainfall + inflow - outflow.]

	T-11 - 6	Rainfall	T= 0	metal.	040	Evapo	oration.	T
Month.	Fall of lake, feet.	on sur- face of lake, feet.	Inflow, feet.	Total, feet.	Outflow, feet.	Feet.	Inches.	Inches, per day.
1900.								
February	0.71	0.08	0.14	0.93	0.44	0.49	5.88	0.21
March	0.83	0.04	0.10	0.97	0.40	0.57	6.84	0.22
April	0.70	0.04	0.07	0.81	0,35	0.46	5, 52	0.18
May 1 to 15	0.32	0.08	0.03	0.43	0, 17	0.26	3.12	0.21
1901.								
February	0.69	0.03	0.14	0.86	0.58	0.28	3.36	0.12
March	0.77	0.03	0.10	0.90	0.56	0.34	4.08	0.13
April	1.00	0.02	0.07	1.09	0.44	0.65	7.80	. 0.26

Area of lake, 1,904,000 acres.

Rainfall on surface of lake is an average of the rainfall at Basillas, Granada, Mayogalpa, San Carlos, San Miguelito, San Ubaldo, Sapoa, and Solentiname.

REGULATION OF LAKE NICARAGUA.

Lake Nicaragua being the summit level upon which the water supply for the canal depends, and from which the surplus water must be discharged, its history, and especially the extreme variations of its supply, are important. Its fluctuation depends upon four factors:

1. The inflow, which is a function of the amount and character of

rainfall in the basin.

2. The storage capacity of the lake.

3. The evaporation, which varies with the seasons.

4. The outflow, which varies with the elevation of the lake.

The problem of the storage capacity is simple, and its solution is known with all desirable accuracy. The area of the lake is 2,975 square miles, or 1,904,000 acres.

The evaporation from the lake has been fairly well determined and can be allowed for without important error. It is given in the table, page 579–580.

The outflow was observed during 1898, 1899, and 1900, at Camp Farina, above Sabalos River, which is the first important tributary to the river.

The inflow has been observed by noting the fluctuation of the lake surface at four stations, San Carlos, San Ubaldo, Granada, and Sapoa. The fluctuation, after allowing for evaporation and outflow, gives the inflow.

It has not been possible to fix with certainty the limits of the natural fluctuation of Lake Nicaragua, but the best information obtainable indicates that the range is about 14 feet, from 97 as the minimum to 111 as the maximum.

The maximum stage was estimated as follows:

All the oldest inhabitants in the vicinity of the lake agree that a stage attained in 1861 was higher than any since reached. No more definite statement could be established than that it was "nearly up to the top of the wharf at Granada." The top of the wharf in the lowest place is at elevation 111.24 feet above sea level. If the mean lake level was within 6 inches of the top of the wharf during the customary breeze in that region, it is probable that the waves would wash over the wharf and the report would be that the water was over the top of the wharf. It is thought that the facts indicate 111 as about the elevation of the stage reported as nearly as it can be determined.

The low-water limit of 97 feet is taken on the information of Mr. William Climie, who testifies that the lake was lower in 1886 than it has been since, and all obtainable evidence on the subject is to the effect that no lower stage has occurred within the memory of persons now living.

All available testimony, and especially that of the engineman on the steamer *Victoria*, who has been in continuous service for sixteen years, is to the effect that the steamer *Victoria* has in that period always been able to discharge her cargo directly upon the wharf, but at times of extreme low water, occurring at very rare intervals, she could not come alongside, but had to lie off the end of the wharf, touching only her bow. This was the condition in May, 1897. A diagram of the wharf was made when the water stood at 5.8 reading on the gage rod, or 104.24 feet above sea level. It shows the bottom of the lake to be at an elevation of about 93 feet near the end of the wharf, and somewhat lower, say 92 feet, off the end where the steamer lay at low water. The boat draws from 4 feet of water when empty to 7 feet when fully loaded. Allowing her 6 feet of water in May, 1897, the stage of the lake was about 98 feet above sea level, or at least it could not have been lower than this.

If the lake were 1 foot lower than this in 1886, it would give a stage of 97, and this is probably near the true minimum.

These data fix the natural limit of fluctuation at 14 feet, though no fluctuation approaching this amount occurs in any one year, nor even in any two. The low water of 1886 was preceded by three successive years of low rainfall, as shown by the Granada record for 1883 and 1884 and by the Rivas record for 1885, the latter being the lowest in the Rivas record of twenty years with one exception. A study of the rainfall tables indicates another stage of extremely low lake just before the rainy season of 1897, this being preceded by three years of less than normal rainfall. This indication is confirmed by popular reports of an extremely low lake level at that time, and accounts for the fact that the heaviest rainfall of the record, 1897, did not produce as high a lake as had occurred in other years. Though no observations of the lake were made in 1897, those of 1898, considered with the rainfall record of 1897, indicate that the lake did not reach stage 107. diagram, fig. 230.) Its stage at the end of 1897 is known to have been about 105 by observations of the Nicaragua Canal Commission.

Judging from the table of rainfall, considered in the light of known facts, the lake has passed through minimum stages in May of the years 1886, 1891, and 1897; and maximum in the autumns of 1889, 1893, and 1900. None of these stages are exactly known except that of 1900, in which year the lake reached a maximum stage of 107.42 feet on the 27th day of October, and maintained about the same elevation for one week.

In this discussion we are concerned mainly with the years of maximum and minimum rainfall as giving the extreme conditions under which Lake Nicaragua must be controlled. All the records and traditions at hand indicate that the year 1897 was the year of greatest precipitation in this vicinity ever recorded. Dr. Flint gives for Rivas

a total for that year 123.43 inches, a rainfall of over 15 inches greater than any other in his record, while the report of Mr. Climie, for Granada, substantially confirmed by that of the sugar company, gives 93.62 inches for that year, being greater than any other year in either Granada or Masaya records. It may therefore be taken as the year of maximum rainfall within the range of the records. It is fortunate that this is the case, for we then have direct comparison by the same observer of the rainfall for 1897 with that for the three years covered by the observations of the fluctuations of Lake Nicaragua by this The year of minimum rainfall occurs in the Masaya commission. record for 1890, being only 20.52 inches, and being but little more than half of that for 1896, which is the next driest year in the Masaya The year is also the year of smallest precipitation in Dr. Flint's record at Rivas, and gives very much less rainfall than he gives for any other year covered by the Masava record. It seems safe to conclude, therefore, that 1890 was actually the year of smallest precipitation within the records.

The Rivas record is the longest and most continuous, and is nearly on the canal line and nearly on the lake shore. In all these respects it promises very desirable and valuable information, completely covering the period from 1880 to date. An examination of this record, however, is somewhat disappointing. During the year 1898 Mr. J. A. Bull, an observer of the Nicaragua Canal Commission, was stationed at Las Lajas, near the point where the canal line leaves the shore of the lake. This point is only about 5 miles from Rivas, not greatly different in elevation or surrounding conditions that might affect the rainfall, and yet the precipitation recorded at Rivas exceeded that observed at Las Lajas by the percentages shown in the following table:

Rainfall at Las Lajas and Rivas, in inches.

Month.	Las Lajas.	Rivas.	Excess, per cent.
May	10.60	16. 17	52. 5
June	13.50	18.95	40.4
July	10.64	13.65	28.3
August	8.44	11.85	40.4
September	6.79	13.99	106.03
October	16. 19	20.83	28.7
November	4.41	8.19	85.7
December	2. 26	3.14	38.9
Total	72.83	106.77	46.6

This table indicates that the Rivas record is too large. Comparing it year by year with the recent records at Granada and Masaya also tends to confirm the result indicated above:

Rainfall, in inches, at Granada, Masaya, and Rivas.

Year.		Masaya.	Rivas.	Excess, per cent.
1890		20.50	31. 81	50.3
1891		49.98	66.03	32. 1
1892		64. 54	78. 27	21.3
1893		72.86	106.13	45.7
1894		42.88	47.32	10.3
1895		41. 26	47.68	15. 56
1896		39.64	47.80	20.6
1897	93.62		123, 43	31.8
1898	55. 59		108.06	94.4
1899	56.93		67.82	19. 10
1900	71, 80		94.68	31.8

While Granada and Masaya are at considerable distance from Rivas and under somewhat different topographic conditions, there is no obvious reason why they should have less rainfall, and this evidence, so far as it goes, tends to confirm the indication of the Las Lajas record that the record at Rivas is too large. A similar result is obtained by a comparison of the Rivas record with the movements of Lake Nicaragua. Many months occur in which the rise of the lake, if all water had been held by a dam on the Rio San Juan and evaporation eliminated, would have been much less than the reported rainfall at Rivas, proving that the rainfall on the surface of Lake Nicaragua is less than recorded at Rivas.

These facts, coupled with the great importance of the accuracy of any record on which estimates are to depend, led to the establishment in June, 1900, of a rainfall observer in Rivas, whose gage is located not more than 300 yards from that upon which the long record has been taken. The observer employed by the commission was Mr. Charles Hayman, who thoroughly understood the work and who was cautioned to be extremely careful. The comparison of the observations is given on page 585. It shows that the record of Dr. Flint exceeded that taken by Mr. Hayman in every month, and seems to establish the fact that the results reported by Dr. Flint are too large.

Comparison of rainfall observations made at Rivas, Nicaragua, in 1900, by Dr. Earl Flint and the observer of the Isthmian Canal Commission.

	-				[In in	ches.]						
	Ju	ne.	Ju	ly.	. Aug	gust.	Septe	mber.	Oct	ober.	Nove	mber.
Day.	Dr. Flint.	Com- mis- sion.										
1			0.99	0.79	0.18	0.04	0.75	0.01	0.17	0.10	0.00	0.00
2			0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.98	0.00	0.03
3			0.20	1.01	0.60	0.47	0.00	0.00	1.50	1.26	0.05	0.09
4			1.55	0.15	0.40	0.24	0.71	0.52	1.30	1,20	0.00	0.00
5			0.85	0.38	0.14	0.35	0.14	0.21	0.92	0.27	0.00	0.00
6			0.55	0.35	0.46	0.10	0.00	0.03	1.29	1.43	0.00	0.00
7			0.20	0.15	0.07	0.02	2.70	2.53	2.00	0.98	0.06	0.00
8			0.26	0.35	0.00	Tr.	0.63	0.37	0.13	0.07	0.08	0.05
9			0.66	0.36	0.48	0.35	0.16	Tr.	0.00	0.00	0.08	0.06
10			0.21	0.28	0.00	0.02	0.40	0.17	0.00	0.02	0.00	0.00
11			0.87	0.45	0.02	0.20	0.09	0.00	0.00	0.01	0.00	0.02
12			0.30	1.07	0.30	Tr.	0.74	0.69	0.50	0.39	0.02	0.00
13			1.49	0.04	0.00	0.00	0.20	0.03	0.11	0.11	0.08	0.00
14			0.07	0.06	1.60	1.10	0.06	0.00	0.33	0.11	0.00	0.00
15	0.00	0.01	0.00	0.17	0.13	0.02	0.00	0.98	0.02	0.04	0.00	0.04
16	0.70	0.04	0.40	0.16	0.03	0.01	1.70	0.44	0.31	0.17	0.30	0.39
17	0.60	0.99	0.20	0.16	0.00	Tr.	0.40	0.13	0.80	0.60	0.28	0.00
18	0.60	0.01	0.80	0.44	0.00	0.00	0.07	0.00	0.30	0.44	0.04	0.01
19	0.00	0.00	0.30	0.10	0.00	0.15	1.97	1.95	0.79	0.33	0.00	0.01
20	1.26	0.92	0.05	0.01	0.10	0.20	0.50	0.00	0.01	1.95	0.08	0.04
21	1.50	1.18	0.00	0.02	0.49	0.02	0.00	0.00	3.15	3.50	0.00	0.00
22	0.00	0.18	0.10	0.00	1.61	0.34	1.70	1.42	4.80	2.71	0.00	0.00
23	0.30	Tr.	0.07	0.00	0.50	1.35	1.42	1.07	0.31	0.19	0.00	0.00
24	1.48	1.19	0.04	0.10	0.90	0.59	0.57	0.37	0.90	0.65	0.00	0.00
25	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.99	0.61	0.01	0.00
26	0.00	0.00	0.00	0.00	0.43	0.70	0.08	0.05	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.70	0.13	0.00	0.00	0.00	0.00	0.11	0.06
28	0.07	0.03	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.37	0.02	0.00	0.00	4.18	3.40	0.00	0.00	0.00	0.00
30	0.75	0, 51	0.08	0.06	0.00	0.00	3.41	2.48	0.00	0.00	0.00	0.07
31			0.00	0.07	0.00	0.43			0.00	0.00		
	7.26	5.07	10.61	6.93	9.16	6.84	22.58	16.86	21.93	18.12	1.19	0.87
Excess	43 per	cent.	53 per	cent.	34 per	cent.	34 per	cent.	21 per	cent.	37 per	cent.

These comparisons show that the record of Dr. Flint exceeded that taken for the Commission in every month, the average excess being about 37 per cent, confirming the indications previously referred to.

For these reasons it is deemed safer at present to eliminate the Rivas records from consideration in estimating the probable relation between the recorded rainfall and the action of Lake Nicaragua. We have then left available for comparison only those records for Masaya and Granada. Some of these are published in the report of the Nicaragua Canal Commission, pages 280 and 281, and comprise a complete record at Granada for 1877, taken by Dr. Flint, and complete records for 1883–84, observed by the National Institute at Granada. From the end of 1884 to the beginning of 1897 we have no records for

Granada, but for 1887 to 1896, inclusive, we have a complete record for the town of Masaya, taken by Mr. William Climie. This record is believed to be entirely reliable, but is not coincident with any observations of Lake Nicaragua. Early in 1897 Mr. Climie removed his gage to Granada, and gives the record for 1897 and 1898 at that place. The rainfall was also observed in 1897 by the officials of the Nicaragua Sugar Estates in the city of Granada, and their record continues up to the present time. It gives about 2 per cent less rainfall for 1897 than that of Mr. Climie, but the results are sufficiently accordant to confirm the substantial accuracy of both. During 1899 and 1900 a gage was maintained by this Commission at Granada, and these observations also serve to confirm the substantial accuracy of those furnished by the sugar company. We therefore have a continuous record from 1887 to date, the worst feature of which is that during the first ten years it was taken at Masaya and the last four years at Masaya is at an elevation of nearly 600 feet above Granada and is not on the drainage of Lake Nicaragua, but lies in a small basin which drains into Lake Masava. Observations taken under the direction of Mr. Jacob Wiest in Masava are at hand, covering the period from June 11, 1898, to November 30, 1899, which includes the major portion of three rainy seasons coincident with observations taken in The distance from Masaya to Granada is about 10 miles, which precludes comparison day by day, but a monthly comparison is given below, which shows considerable difference from the precipitation observed at Granada, that at Masaya being less.

Comparison of Granada and Masaya rainfall records, 1899 and 1900.

[In inches.] 1899 1900. Month. Month. Differ-Differ-Granada. Masaya. Granada. Masaya. ences. ences. Jan. 25-31 0.00 0.50 0.50 January 0.26 0.00 0.26 February 0.52 0.04 February 0.48 0.00 0.00 0.00 March.... 0.11 0.07 0.04 March 0.03 0.00 0.03 April..... 0.02 0.00 0.02 April..... 0.02 0.00 0.02 May 2.43 2.02 0.41 May 12.06 8.66 3.40 June 8.78 8.62 0.16 June 17.63 15.522.11 12,40 July 6.64 4.19 2.45 July 10.27 2.13 August 5.97 August 4.70 15.44 9.47 3.93 0.77 2.39 2.80 September ... 7.60 7.23 September.... 0.410.37 October 14.79 10.35 4.44 October 16.70 11.24 5.46 November 5.24 5.54 0.30 November ... 1.42 1.91 0.49 December ... 0.57 0.63 December ... 0.05 (a) 1.20 (a) Total.. 56.93 45.24 11.69 Total .. 72.10 59.53 12.57

MAXIMUM SUPPLY TO LAKE NICARAGUA.

To obtain the probable inflow to the lake during the season of greatest rainfall, 1897, we compare the rainfall at Granada for that year with the rainfall at the same place for some year during which the behavior of Lake Nicaragua was observed. For the purpose of this comparison the diagram (fig. 231) has been prepared. It shows three lines, each of which represents the relation of Granada rainfall to the run-off from the basin for one rainy season, the lines being plotted with the Granada rainfall as ordinates and the fluctuation of Lake Nicaragua that would have occurred if there had been neither outflow nor evaporation as abscissæ. This diagram is essentially accurate, involving no errors excepting those of observation. Appar-

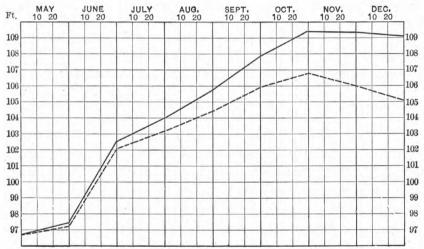
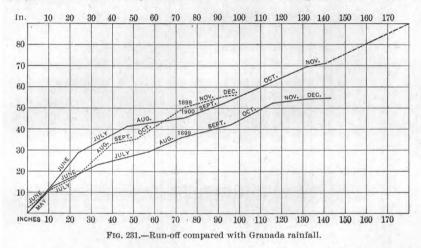


Fig. 230.—Estimated inflow into Lake Nicaraugua during 1897.

ently the two years of observation most suitable for comparing with 1897 are the years of 1898 and 1900, these being the years of greatest rainfall of the three observed. A diagram was plotted in which the line for 1898 was used as the basis for estimating the run-off corresponding to rainfalls observed in 1897. On this basis the fluctuation of the lake in 1897 would, if all water had been held, have amounted to nearly 14 feet, bringing the elevation of the lake in the spring of 1897 below 92 feet. There is abundant evidence that this stage of lake did not occur, and that the indication of the observations of 1898 is therefore erroneous, giving a much greater fluctuation than really occurred. This could be the case only if the rainfall for 1898 was lower in proportion to the run-off of the basin than that of 1897. That this was really the case is indicated by an examination of the annual total rainfall for Granada and Rivas on page 584. These show that whereas the record for Granada exceeded that for Rivas by 32 per cent in 1897, 19 per cent in 1899, and 31 per cent in 1900, in 1898 the excess was 94.4 per cent. Though the rainfall record of Rivas is rejected as inaccurate, the above indication is significant when taken in connection with the known facts of the fluctuation of Lake Nicaragua.

The estimate of run-off for 1897 was next made, the observations of 1900 being used as the basis. The results were obtained by months, by taking the run-off indicated by the given rainfall from the 1900 line on the diagram forming fig. 231 and adding thereto the evaporation corresponding to the period covered. The result is taken as the fluctuation of the lake due to the rainfall, and considered with evaporation in full play and with a dam in the river preventing outflow. This result is shown by the continuous line in fig. 230. The dotted



line in the same diagram shows the fluctuation of the lake on the assumption that the outflow to the San Juan River was that occurring in the state of nature due to the altitude of the lake. It therefore represents the actual changes that took place in the lake surface during 1897, as inferred from the observations of 1900.

The rainfall in 1897 was greater than that for 1900, and it was necessary to extrapolate the line indicated in fig. 231 for 1900. This is shown by the discontinuous line for 1900 on that figure.

The fluctuation of the lake as indicated by this method is about 10 feet in the aggregate, or a little over 8 feet net. The stage of January 4 having been observed by the Nicaragua Canal Commission, it is known that the lake stood at about 105 at the end of December, 1897. The elevation indicated for May, 1897, 96.7, is somewhat lower than that indicated by the estimates made on page 581, and by reports of people who were in Nicaragua at that time, notably Mr. William Climie. But if this is the case the errors are on the side of safety, and the indications of the diagram may safely be taken as correct.

THE SEASON OF MINIMUM SUPPLY.

To obtain the probable fluctuation of the lake during the period of nineteen months ending May, 1901, which, as has been shown, includes two dry seasons, and the driest rainy season in all the records at hand, comparison is made between the rainfall for that period at Masaya and the rainfall for 1900 at the same place when the behavior of the lake was observed. The only two years available for this comparison are 1899 and 1900, the former being not quite complete. The relation of rainfall at Masaya to the fluctuation of the lake is shown in fig. 232, two lines being plotted, for 1899 and 1900, respectively, as indicated, on the same basis as fig. 231, already described.

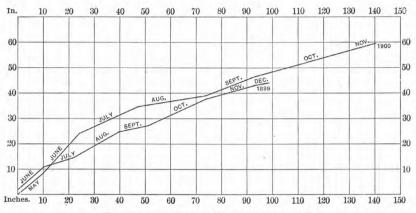


Fig. 232.—Run-off compared with Masaya rainfall.

It will be seen from the diagram that by taking 1900 as the basis of comparison we obtain more conservative results than if 1899 were used; that is, a given rainfall at Masaya corresponds to less inflow to the lake than in 1899, this difference being for a dry season on the side of safety.

On both diagrams it will be noticed that in the latter part of the year the line tends to approach a horizontal position, there being a considerable run-off during the months of November and December with little or no rainfall, this, of course, being due to the rainfall of previous months. During 1890 there were only 20.52 inches of rainfall at Masaya, and this quantity corresponds to the rainfall plotted in the diagram before the end of June, at a time when the rainy season had only endured a little over a month and when considerable rain had fallen that had not yet reached the lake, but which did so later on. This introduces an actual error into the assumption which may be important, but the magnitude of which can not be accurately estimated. Against this error must be placed the well-known fact that for a large

rainfall the percentage of run-off is greater than for a small one on an average, or, in other words, the percentage of run-off to rainfall in 1900 was in the aggregate greater than in 1890. How far these two errors balance each other can not, of course, be known, but it is practically certain that their resultant is to an important degree an error on the side of safety.

The result is shown in fig. 233, and indicates the fall of the lake from the 1st of November, 1889, to the end of May, 1891, the driest consecutive period of nineteen months of which we have record. It indicates that if all water had been held by a dam at the outlet of the lake, and 1,000 cubic feet per second had been used for canal purposes throughout that period, the surface of the lake would have declined 6.2 feet. No resistance can be offered to the decline of the lake during a dry period except to keep all sluices closed, and therefore we may expect an unavoidable decline under extreme conditions of 6.2 feet in nineteen months.

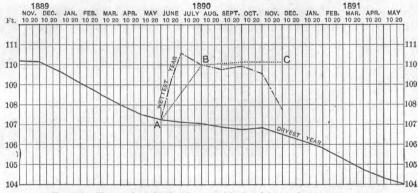


Fig. 233.—Fluctuation of Lake Nicaragua during driest and wettest seasons.

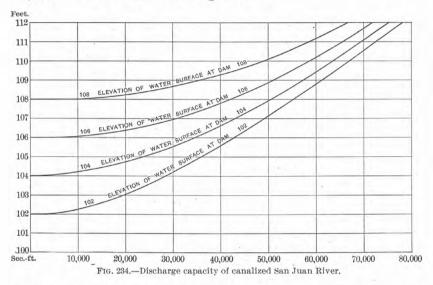
The rise of the lake in seasons of excessive rainfall can be resisted by the discharge of water through the dam at Boca San Carlos and into the valley of Grande River on the west side.

It is not permissible to use the latter outlet extensively, owing to the danger of carrying to the sea an excessive quantity of detritus, and thereby obstructing the harbor at Brito. It is necessary, therefore, that the surplus waters be discharged to the eastward through the San Juan River.

If adjustable sluices be provided at Boca San Carlos, to discharge any desired quantity of water, the problem resolves itself into the estimation of the capacity of the canalized San Juan River. This is a function of the cross section, roughness, and slope, the latter depending upon the stage of the lake.

To determine the coefficient of roughness, computations were made of the value of the factor "n" in Kutter's formula, using measured slope, velocity, cross section, and discharge of the San Juan River. These computations, which were exceedingly laborious, were made by Mr. S. H. Woodard, and the resulting mean values of "n" varied from .022 to .024. Applying the latter value to the canalized river, its discharging capacity was computed for the various elevations at the lake and at Boca San Carlos. The accompanying diagram (fig. 234) has been constructed by Mr. Woodard, showing his results. It shows that with water at the dam held at 104 the discharging capacity varies from zero to 63,000 cubic feet per second, while the lake level rises from 104 to 110.

Applying these facts to the lake supply, shown in figs. 231 and 232, we obtain results shown in fig. 233.



That is, if the canal had been constructed and the lake surface was at 107.3 on the 1st of June, 1897, the lake would have risen to 110.6 by the end of June in spite of the discharge through the river with sluices left open, holding the water level at 104 at the dam. During July and August the discharge would have been greater than the inflow, and the lake might have been drawn down to 109.8. It would have risen slightly in September and receded again in October. But after June the discharge would have been checked, because it is necessary to hold the lake at 110.2 at the end of October to provide against exceptional drought. The aim would have been, therefore, to hold the lake as nearly as possible to the line A B C, and after the end of June this could have been accomplished.

If, instead of the very wet year 1897, the driest year in the record, 1890, had occurred, the sluices would have remained closed, and the lake surface would have declined 3.3 feet under the combined influence

of inflow, evaporation, and the consumption of 1,000 cubic feet per second, from 107.3 to 104, by the opening of the following rainy season, when the lake may be expected to rise.

If the elevation of 104 feet be adopted as the minimum summit level to be permitted, the lake must be at a stage not lower than 107.3 feet at the beginning of the rainy season, as it may be a season of minimum precipitation, so that the lake will decline 3.3 feet in the ensuing twelve months. To do this, each rainy season must be closed with the lake at 110.2, as the unavoidable loss during the dry season is 2.9 feet, as shown by fig. 233. Should the following wet season be one of heavy rainfall, like 1897, the lake will rise to about 110.6 in spite of all the discharge of which the river is capable. If, instead of a very wet season, the rainfall should be slight, like that of 1890, the lake would decline to 104 by the opening of the next rainy season, with all the sluices closed.

Our present information indicates, therefore, that the lake can be kept within limits of 6.6 feet, provided two minimum years do not occur in succession, which seems to be a safe assumption.

As neither the maximum nor minimum years have been actually observed, there is necessarily some uncertainty in any estimates that can be made for such years. It has been the effort to make the estimates conservative, as indicated in the discussion. If actual conditions should occur which are more extreme than those we have considered, it might be necessary to allow a greater fluctuation than 6.6 feet. a season of greater inflow than that estimated for 1897 should occur, it would be necessary to allow the lake to stand temporarily at a higher level than 110.6. If experience should show a season of less inflow than that estimated for 1890, it would be necessary to begin each rainy season with the lake surface higher than 107.3 and to close it with the lake above 110.2 in order to prevent its decline below 104. A very slight increase in the upper limit allowed is a great relief to the conditions, since this not only increases the allowable fluctuations, but also increases the discharge capacity of the river. If the lake should reach a height of 111 feet it would only be repeating the conditions that have actually occurred in its natural state. The water might rise to a height of 112 feet, or even higher, without doing any great amount of damage, and it is probable that permission to allow this could, without difficulty, be included in the concession. We could then begin each month of June with the lake at elevation 108; if the rainy season should furnish 20 per cent more water than that estimated for 1897 we could still control the lake within the 112-foot limit. If, instead, the rainy season should furnish only one-half the supply estimated for 1890, the lake would fall to just 104 by the opening of the next rainy season. This is certainly a very wide margin of safety.

HYDROGRAPHY OF PANAMA ROUTE.

The hydrographic problem of the Panama canal project requires a knowledge of the magnitude and habit of the flood discharge of the Chagres River, and also in a minor degree of the tributaries of the Chagres and of the Grande River on the southern end of the line. It also requires a knowledge of the minimum flow of the Chagres River considered as a feeder to the summit level and the locks of the canal. Incidental to these matters the determination of rainfall is important, considered both as a source of water supply and as a hindrance to con-Some observations upon these points were taken by the old Panama Canal Company, and since the organization of the new company the records of the discharge of the Chagres at Gamboa and Bohio have been much more thorough and complete. Since April, 1899, measurements have also been made at Alhajuela, where it is proposed by the canal company to construct a reservoir to serve as a regulator of the floods of the river and to store water for the use of the canal.

The work undertaken by the Isthmian Canal Commission consists mainly in an examination of the observations and results already obtained by the company, of a verification of their methods by actual field observations, and of an extension of the rainfall information, as far as possible, over the basin of the Chagres River.

These latter operations were undertaken in November, 1899, and placed in charge of Mr. W. W. Schlecht. In July and August, 1900, the writer made a personal inspection of the records of the old and new companies at the office of the Panama Canal Company, in Paris, obtaining many details of value regarding the methods and data employed in arriving at the conclusion published by the company. It was found that the data obtained by the old company prior to the organization of the new were very fragmentary and incomplete, considerable periods being entirely skipped. The most serious lack of information was with respect to the magnitude of the great floods that have been observed upon the isthmus, especially the maximum flood The observations taken by the new company are far more complete and satisfactory, but, unfortunately, they do not include any flood discharge as great as those that occurred under the régime of the old company.

At present all stream measurements by the Panama Canal Company are confined to the Chagres River, which really presents the only important hydrographic problems relative to an interoceanic canal on the Isthmus of Panama. In order to obtain the daily mean gage height, and a record of the rapid fluctuations of the river, the canal company has installed continuous self-registering river gages or "fluviographs," with an observer at each. The scale of the fluvio-

graph record is 1 millimeter (vertical) = 2 centimeters of rise, and 5 millimeters (horizontal) = 1 hour, so that each centimeter of rise and each ten minutes of time may be easily read. These readings were checked each day at 6 a. m. and 6 p. m., and, with very few exceptions, no material errors were found.

The measurements for the discharge are made by the company by means of floats of 1 to 3 feet immersion and 2 to 3 inches diameter, the latter size being used only at times of flood, so all may be considered as surface floats, and a length of course of 60 meters at Alhajuela and Gamboa and 80 meters at Bohio. Cross sections of the courses are taken 10 meters apart, and from these a table of mean sectional areas for different stages of the river is computed for each station. Following are the instructions to the observers concerning the method of obtaining the discharge, which are carefully followed:

The observations should be made in calm weather. The floats should have but a small portion exposed above the surface of the water. The float should be liberated a short distance above the first profile, so that at the moment it crosses that section it will have attained the velocity of the water. The observer will note the moment of passage at the first section, and then go to the lower section and note its passage at that section.

The discharge is then obtained by means of the formula—

D = 0.80 A V.

D = discharge; A = mean sectional area; V = the mean velocity of the floats.

CHAGRES RIVER.

The main trunk of the Chagres is formed by two principal branches. The Pequeni rises near the Caribbean coast and flows nearly south until it meets the Chagres proper, a short distance above Alhajuela. The general course of the Upper Chagres from its source is southwest, and it continues in the same general direction after receiving the waters of the Pequeni to the mouth of the Obispo, where the proposed canal line leaves its valley. Its course is then westward to Tavernilla, and from that point to its mouth its course is nearly northwesterly. Its total length is over 120 miles, without including minor bends, although the width of the isthmus at its mouth is less than 50 miles.

The district below Bohio drained by the Chagres and its tributaries consists mainly of low hills and swamps. The river is sluggish, the effect of the tide being plainly perceptible at Bohio at low water, although the tidal fluctuations of the Caribbean are very slight. Above this point there is some modification, the declivity being greater and the country higher and less swampy. Several rapids occur in this portion of the river, and above Obispo rapids are frequent and the river is swift. The Upper Chagres is flanked by steep, rocky hills, clothed with luxuriant vegetation; rapids are frequent; and the water is

everywhere swift and is very clear except in times of freshet. The stream is sinuous in many parts and is frequently bordered by rock cliffs, lending variety to the scene, which is everywhere one of surpassing beauty. In some cases the convex curve of the stream with its swift current has undermined the limestone cliffs, leaving overhanging ledges and producing caverns of considerable extent.

The drainage area of the Chagres River above Bohio is only approx-

imately known, and depends upon the following data:

Totten's "Map of the Isthmus of Panama" gives that portion of the divide lying between latitude 9° 0′ and 9° 20′ north and longitude 80° 30′ and 80° 50′ west. It also gives the divide of the Boqueron River—i. e., the northwestern extremity of the drainage area. The survey of the Mandinga River by this Commission gives the eastern divide at longitude 79° 15′ west.

The survey of the Chagres River above Santa Barbara gives the northeastern extremity of the drainage basin at latitude 9° 25′ north, longitude 79° 15′ west. It also gives an idea of the size and general direction of the tributaries.

The northern and southern portions of the divide, not included in Totten's map, have been approximately determined from the Atlantic and Pacific oceans, and in these parts the greatest probable error exists.

The various drainage areas are about as follows:

Drainage areas in watershed of Chagres River.

Square	miles.
Total area of Chagres drainage basin	1,400
Upper Chagres (above Pequeni)	300
Rio Pequeni	175
Above Alhajuela	505
Between Alhajuela and Gamboa	130
Above Gamboa	635
Rio Obispo	38
Between Gamboa and Bohio	245
Above Bohio	880
Between Alhajuela and Bohio	375
Below Bohio	520
Lower Gatun	145

ALHAJUELA STATION, ON CHAGRES RIVER.

This is the point on the Chagres, about 11 miles above Gamboa, where the Panama Canal Company proposes to build a high masonry dam to impound water for the use of the canal and to assist in the storage of floods. The dam site is about 7 miles by the bends of the river below "Dos Bocas," the junction of the two main branches of the Chagres, the gaging station being about half a mile below the dam site. The river here has high, steep banks on each side, a width of about 250 feet, and at normal stage a mean depth of 4 or 5 feet; it

is on a slight bend, and the cross sections along the course differ considerably in area and conformation. About 60 feet above the upper range a three-fourths-inch cable is stretched across the river with marks giving at normal stage the one-fourth, one-half, and three-fourths points of the width of the river; these marks are used to show the points at which to release the floats. The fluviograph is 200 yards below, and a secondary rod divided into centimeters is firmly set in the bank at the gaging station. The reading of this rod is used as the argument in the table giving the mean area.

On October 31, 1899, a No. 8 telegraph wire was stretched across the river, about 60 feet above the canal company's cable. This was divided into 10-foot lengths and was used to hold the boat in a fixed position while the velocity was being measured. The wire could be readily lowered while in use so that a man in the bow could seize it and hold the boat in the desired position, and when not in use it was raised 20 or 25 feet above the surface of the river, beyond the reach of floods.

The first current-meter measurement was made on October 31, 1899, with new "Small Price Electric Meter No. 35." Two simultaneous determinations of the discharge were made, the first by measuring the velocity at 0.6 foot depth below the surface at each station, and the second by measuring the velocity at each foot of depth at the same stations and then taking the mean as the mean velocity at that station. The river was divided into twelve sections, varying from 10 feet wide near the banks, where the velocity across the stream changes rapidly, to 30 feet near the center, where it is more uniform.

Following are the results:

Fluviograph = 28.565 meters.

1st method. Mean velocity = 1.92 feet per second.

Discharge = 2,280 second-feet.

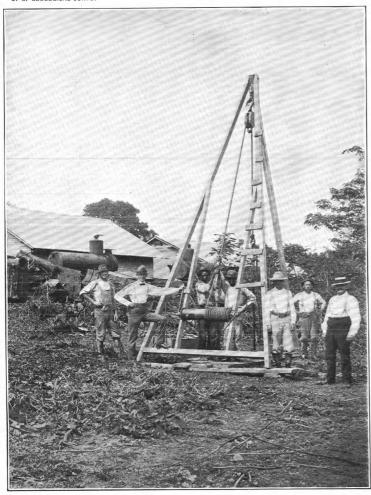
2d method. Mean velocity = 1.90 feet per second.

Discharge = 2,257 second-feet.

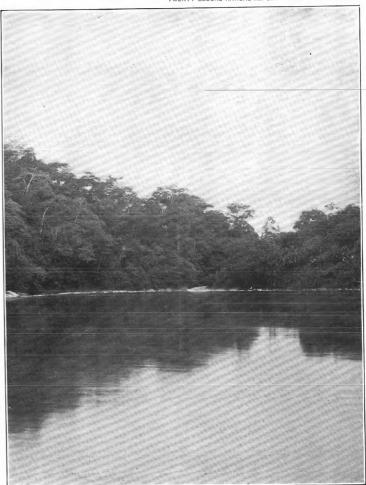
From the above we see that at Alhajuela the velocity at 0.6 foot depth below the surface gives the mean velocity of the section, with an error of about 1 per cent.

Gagings made by this method gave results almost uniformly 20 per cent greater than those obtained by the company, thus justifying General Abbot's criticism of their method of using the coefficient 0.8, this factor being too small. Another error of 3 to 5 per cent is introduced by taking as the mean velocity the quotient of the length of the course by the mean time of the floats. The proper method is to compute the velocity of each float separately and apply it only to its own section.

Seventy-four measurements were made for the Commission at Alhajuela, and monthly estimates of discharge were computed for 1900. The



A. BORING PARTY AT PANAMA.



B. ALHAJUELA DAM SITE, SHOWING ROCK AT WATER'S EDGE.

results obtained by the company since the station was established, in April, 1899, as well as those obtained by the Commission, are given below.

Estimated monthly discharge of Chagres River at Alhajuela, from observations of the Panama Canal Company.

[Drainage area, 505 square miles.]

	Discha	rge in secon	nd-feet.		Rur		
Month.	Month. Maximum. Minimum. Mean. Total in acr		Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall in basin, inches.	
1899.							
April 15 to 30	1,024	600	706	22, 400			
May	28, 420	494	1,590	97, 760	3.15	3. 63	
June	4, 200	1, 165	2, 150	127, 930	4. 26	4. 75	
July	15,640	1, 235	2, 220	136, 500	4.40	5.07	
August	27, 430	1,660	3, 280	201, 680	6.50	7.49	
September	11, 160	1,450	2,400	142, 800	4.75	5. 30	
October	9, 990	1,590	2,650	162, 940	5. 25	6.05	
November	28,660	1,520	2,930	174, 350	5.80	6.47	
December	11, 160	1,380	2,260	138, 960	4.47	5. 15	
The year .	28, 660		2, 430	1, 205, 320		43. 91	
1900.							
January	11, 150	1,020	1,590	97, 760	3. 15	3.63	2. 27
February	1, 130	565	812	45, 100	1.60	1.67	0.38
March	777	425	530	32,590	1.05	1.21	0. 32
April	2,050	318	565	33, 620	1.12	1. 25	4.06
May	13,770	388	1,340	82, 400	2.65	3.06	11. 88
June	7, 730	880	1,550	92, 230	3.07	3.42	16.57
July	18, 180	1, 230	2, 190	134, 660	4.33	4.99	14.64
August	20,400	1,520	2,820	173,400	5.58	6.43	13. 01
September	11,650	1,270	2, 150	127, 930	4. 26	4.75	15.60
October	24,780	1,730	3,210	197,380	6. 36	7.33	16. 39
November	14,680	1,620	2,290	140, 800	5. 87	6. 55	14. 92
December	20,540	1, 130	2, 290	140, 800	4. 53	5. 22	3. 76
The year	24, 780	318	1,840	1, 334, 300	3. 64	49.51	113. 80

Estimated monthly discharge of Chagres River at Alhajuela, from observations of the Isthmian Canal Commission.

[Drafnage area, 505 square miles.]

	Dischar	ge in secon	nd-feet.		Rur			
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall in basin, inches.	
1900.				The second of			100	
January	14, 535	1, 230	1,941	119, 350	3. 84	4.43	2. 27	
February	1, 365	652	916	50, 870	1.81	1.88	0.38	
March	849	497	608	37, 380	1.20	1.38	0.32	
April	2,032	395	631	37, 550	1. 25	1.39	4.06	
May	17, 460	476	1,588	97, 640	3. 14	3. 62	11.88	
June	10, 395	1,025	1,934	115, 080	3. 83	4. 27	16.57	
July	21, 950	1,814	3, 148	193, 560	6, 23	7.18	14.64	
August	27, 400	2, 157	4, 094	251, 730	8. 11	9.35	13.01	
September	17,065	1,720	3, 101	184, 520	6. 14	6.85	15.60	
October	31, 740	2, 710	4, 889	300, 610	9.68	11.16	16.39	
November	20,670	2, 223	4,504	268, 010	8, 92	9.95	14.92	
December	28, 020	1,396	3, 286	202, 050	6.50	7.49	3. 76	
The year	31, 740	395	2, 567	1, 858, 350		68.95	113. 80	

Ratio of run-off to rainfall = 60 per cent.

The following experiments with rod floats were made at Alhajuela, by Mr. W. W. Schlecht, to find the relation between the surface velocities and the mean velocity in a vertical section.

Float experiments made August 22, 1900.—Fluviograph=28.81.

I. Full-depth rod floats of 2 to 3 inches uniform diameter.

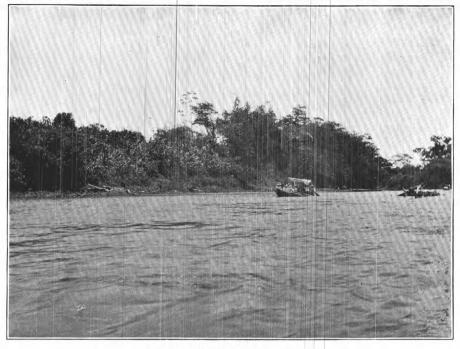
	-	-	1	1	-	-			1	1	
Distance from right bank (feet)	. 20	40	60	80	100	120	140	160	180	200	220
Length of floats (feet)	7.5	5,0	5.0	5.0	3.5	3.5	3.5	3.5	3.5	3.5	2.0
Elapsed time (seconds)	. 87	78	78	77	75	57	55	55	59	64	93
Velocity (feet per second)	2.27	2.53	2,53	2.56	2.63	3.46	3.58	3.58	3.34	3.08	2.12

Mean=2.88 feet per second.

II. FLOATS OF 11/2 FEET LENGTH, 2 INCHES UNIFORM DIAMETER.

				-	7				1		
Distance from right bank (feet).	20	40	60	80	100	120	140	160	180	200	220
Elapsed time (seconds)	72	75	70	68	63	53	50	45	51	58	71
Velocity (feet per second)	2.74	2.63	2.81	2.90	3.13	3.72	3.94	4.38	3.86	3.40	2.77

Mean=3.30 feet per second. Ratio= $2.88 \div 3.30 = 0.87$.



A. CHAGRES RIVER BELOW ALHAJUELA.



B. CHAGRES RIVER NEAR GORGONA.

The discharge obtained by using 2.88 as the mean velocity is 4,040 second-feet, which compares very favorably with discharges obtained by means of current meters.

SANTA BARBARA STATION ON CHAGRES RIVER.

The gage height of the Chagres River at Santa Barbara was read by C. Clauzel at 6 a. m. and 6 p. m. and at times of important fluctuations. The discharge measurements were made with current meters and surface floats. After comparing several float measurements with simultaneous current meter measurements a coefficient of 0.85 was adopted to reduce the observed velocity of the floats to the mean velocity of the cross section. Thirty-five current-meter and 110 float measurements were made, from which a rating table was constructed, and the following table of discharges was computed:

Estimated monthly discharge of Chagres River at Sa; ta Barbara
[Drainage area, 300 square miles,]

	Dischar	Discharge in second-feet.			Rui		
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall in basin, inches.
1900.							
January	8, 360	700	1, 205	74, 090	4.02	4.63	1.34
February	1,020	390	542	30, 100	1.81	1, 88	0. 21
March	415	320	369	22, 690	1.23	1.41	0.10
April	8,570	300	430	25, 590	1.43	1.60	5. 52
May	16, 625	310	1,003	61, 670	3. 34	3.88	13. 15
June	6,510	610	1,338	79, 620	4.46	4.98	21.51
July	19,875	802	1,900	116, 830	6.33	7.31	13, 53
August	18, 250	1,020	2,348	144, 370	7.83	9.02	11. 22
September	13,055	965	1,717	102, 170	5. 72	6.38	16, 08
October	33,600	1, 365	3,601	221, 420	12.00	13.84	17.00

TRIBUTARIES BETWEEN ALHAJUELA AND GAMBOA.

The mean monthly discharge of all the tributaries between Alhajuela and Gamboa was obtained by subtracting the discharge at the former station from the discharge at the latter, month by month.

Estimated monthly discharge of tributaries to the Chagres River between Alhajuela and Gamboa.

[Drainage area, 130 square miles.]

			Rui			
Month,	Mean dis- charge in second- feet.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.	
1900.						
January	85	5, 226	0.65	0.75	1.41	
February	54	2,999	0.42	0.44	0.10	
March	33	2,029	0. 25	0.29	0.08	
April	6	357	0.05	0.06	3, 66	
May	27	1,660	0. 21	0.24	8.46	
June	492	29, 276	3.78	4. 20	14. 97	
July	956	58, 782	7. 35	8.46	16.58	
August	598	36, 769	4.60	5.30	9.74	
September	.649	38, 620	4.99	5.74	13. 22	
October	957	58, 840	7.36	8.47	12.68	
November	911	54, 210	7.01	7.82	12.01	
December	94	5, 780	0.72	0.83	0.97	
The year	407	294, 548		42.60	93. 88	

Ratio of run-off to rainfall = 45 per cent.

The chief tributaries between Alhajuela and Gamboa are the Chilibre and the Gatuncillo. Weekly gagings of these were made and their gage height was read three times a week. These observations in a general way furnished the relation of the discharge of each one to the total increase of discharge between the stations, which is as follows:

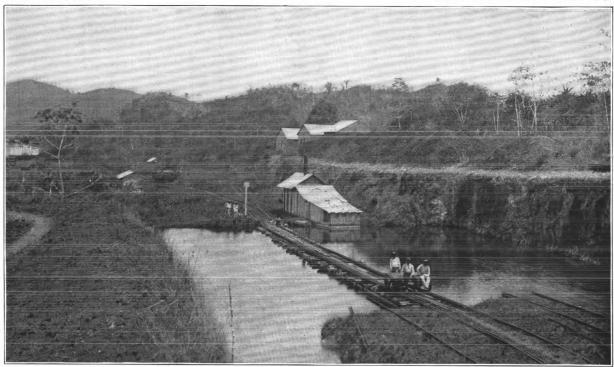
	Per cent.
Chilibre	36
Gatuneillo	26
Other sources	38
Total	100

The highest observed gage height on the Chilibre was 22 feet, giving a computed discharge of 3,700 second-feet. On the Gatuncillo the highest observed gage height was 16 feet, giving a computed discharge of 2,500 second-feet.

GAMBOA STATION ON CHAGRES RIVER.

This is the station of longest record of any on the Isthmus. It is near the point where the canal line leaves the valley of the Chagres, the river valley ascending from this point to the northeast, while the

a Mean of observations Alhajuela and Gamboa.



SITE OF OBISPO LOCKS, PANAMA.

Used as rating station for current meters by Isthmian Canal Commission.

canal line proceeds to the southeast to cut through the continental divide to the Pacific. It was at one time proposed to construct a dam at this point, and the old canal company began observations here, but a careful examination of the records by the writer, in Paris, failed to bring to light any continuous record of river stages prior to 1892, although a number of discharge measurements for 1889–1891 were obtained.

The canal company's gaging station at Gamboa is about 100 yards above the mouth of the Obispo River, or about 300 yards below the proposed dam site. Although by no means an ideal station on account of the tributary just below it, which may at times produce backwater, and also on account of the broken water produced by a whirlpool above it, still it is the best section within several miles on each side of it. The banks are fairly high and the course is straight. Floods rising over gage height 18 meters will cover the left bank, and some water will flow through the channel dug for the canal, and thus will not be included in the discharge measured at the gaging station. It then becomes necessary to make the measurement at Gorgona, where, although the discharge of the Obispo is added, better results are obtained. The fluviograph, which is similar to the one at Alhajuela, is one-half mile above the gaging station. Discharge measurements are made with floats in the same way as at Alhajuela.

Annual summary of discharge measurements made by the Panama Canal Company at Gamboa.

Year.					Ru		
	Maximum.	Minimum.	Mean.	Total in acrefect.	Second- feet per square mile.	Depth in inches.	Rainfall at Colon.
	Secft.	Secft.	Secft.				
1892	42,000						
1893	51,100	759	3,610	2, 612, 607	5.69	77.14	131, 89
1894	26, 190	530	3,770	2,732,284	5,94	80.68	153.69
1895	27,990	565	2,880	2, 083, 740	4.53	61.55	151.54
1896			2,880	2,093,910	4.53	61.83	131, 51
1897	42, 190		3,880	2, 806, 070	6.11	82, 84	138, 03
1898	28,770	777	3,000	2, 169, 630	4.72	64.05	115, 55
1899	26, 190	706	2,580	1,870,500	4.06	55.23	133. 02
1900	23, 720	388	2,360	1,705,100	3.72	50, 35	a 108. 01

a Mean rainfall on basin.

Discharge measurements made on Chagres River at Gamboa in 1889.

	September.			October.		November.		
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
27	15.4	4, 448	2	15.7	5, 154	2	15.4	5, 366
30	15.4	4, 977	5	15.8	5, 613	6	15.2	4, 236
			9	15.1	3, 954	9	15.4	4, 942
	- 11		12	15.4	5, 330	14	15.0	3, 812
			15	15.0	3, 459	16	15.4	4, 765
			19	15.9	6, 107	20	15. 2	4,660
			23	15.4	4, 977	22	17.1	11, 614
			26	15.1	3,600	30	15.1	3,600
			30	15, 2	4, 165			
Mean			Mean	4, 7	07	Mean	5, 5	374

Discharge measurements made on Chagres River at Gamboa in 1890.

	January.		1	February.			March.	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
13	16.8	9, 531	14	14.5	1, 412	1	14.3	1, 270
1			21	14.4	1,412	6	14.2	1,094
			27	14.3	1, 236	11	14.2	882
						19	14.2	882
						27	14.4	1, 341
Mean	9, 5	531	Mean	1, 8	353	Mean	1,	094
	April.			May.			June.	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
S. Land	Meters.	Secft.	21 :4 :1	Meters.	Sec.:ft.		Meters.	Secft.
8	14.2	812	3	17.6	14, 470	3	15.4	4, 463
10	14.1	600	6	14.8	3, 530	6	15.6	4, 518
14	14.1	600	9	14.4	1, 165	7	16.8	10, 307
17	14.1	565	12	15.8	6, 707	10	16.4	8, 472
19	14.1	600	16	16.1	8, 013	13	14.8	2, 471
22	14.1	586	20	15. 2	3, 990	17	16.6	11, 120
25	14.1	777	23	14.8	2,824	20	15.5	4, 730
29	14.4	1,306	27	15.2	3,990	24	15.1	3, 636
			30	14.8	2, 753	27	15. 2	3, 777
Mean	73	31	Mean	5,	271	Mean	5,	946

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Discharge measurements made on Chagres River at Gamboa in 1890.

	July.			August.			Septembe	r.
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
1	15.4	4, 483	1	14.8	2,400	5	15.4	4, 977
7	15. 2	3, 954	5	15.4	4, 624	9	15.2	4, 130
8	15. 2	3,636	8	15.3	4, 377	12	15.6	5, 330
8	17.2	11, 331	12	15.8	5,720	13	17.7	15, 890
16	15.6	5,013	14	16.2	7,554	16	16.0	6, 920
18	15.4	4, 518	19	15.3	4, 306	19	15.5	5, 083
22	15. 2	3,777	22	15. 2	4,060	21	16.3	8, 225
25	16.6	8, 930	26	15.9	6,954	26	15.4	4, 342
29	15.0	3,000	29	15.3	4, 448	30	15.9	6, 460
			31	17.1	12, 320			
Mean	5, 4	104	Mean	5, 6	76	Mean	6,	817
	October.		November.				December.	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
3	15.4	4, 518	4	15. 2	3,777	2	18.0	14, 296
7	15.4	4,660	7	15.1	3, 565	5	15.6	5, 471
10	15.9	5, 825	11	15.4	4,412	9	15.6	6, 178
14	15.3	3,742	14	15. 2	3,990	12	15. 2	3,600
17	15. 2	4,024	18	15.0	3,018	16	15.4	4, 554
21	15.1	3,600	22	15.6	5, 048	19	15.5	5, 295
24	17.1	10, 307	25	15.4	4, 589	23	15.4	4, 836
	18.4	17,900	29	15.1	3, 248	26	15.4	5, 013
						30	15. 2	3, 990
25 31	15.3	3, 777				30	10. 2	5, 550

HYDROGRAPHY OF THE AMERICAN ISTHMUS.

Discharge measurements made on Chagres River at Gamboa in 1891.

	January.		1	February.			March.	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
2	15.1	3, 353	3	14.5	1, 236	3	14.3	720
6	14.9	2,612	6	14.5	988	6	14.3	681
9	15.1	3, 177	10	14.4	1,130	10	14.3	745
13	14.7	1,836	13	14.5	1,024	13	14.3	582
16	14.7	1,765	17	14.4	847	17	14.2	540
20	14.6	1,482	20	14.4	928	20	14.2	551
23	14.6	1, 353	24	14.3	709	24	14.2	600
27	14.6	1,341	27	14.3	709	27	14.2	434
30	14.5	1,341				31	14.2	515
Mean		. 2,051	Mean		946	Mean		596
	April.			May.			June.	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge.
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
3	14.2	572	1	14. 2	512	2	14.7	2,051
7	14.1	568	4	18.2	18, 285	5	14.7	2, 365
10	14.1	547	8	14.5	1,701	9	14.7	2, 230
14	14.1	441	12	14.1	618	12	14.3	1,097
17	14.1	614	15	14.1	512	16	14.5	1,750
21	14.2	522	19	15.0	3,036	19	15.8	6,080
24	14.1	544	22	14.4	1, 423	23	14.7	1,860
28	14.1	473	26	14.7	2, 404	26	14.4	1, 377
			29	14.8	2,580	30	14.8	2, 602
						-	-	

	July.			August.		8	September	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
3	14.5	1,518	4	14.9	2, 683	1	15.4	4, 130
7	14.6	1,871	7	15.2	3,777	4	15. 1	3,000
8	17.5	11,967	11	14.9	2,577	8	15.3	4, 342
3	16.0	5, 825	14	14.7	2, 259	11	14.8	2, 259
7	14.7	1,977	18	15.0	3, 142	15	14.7	2, 083
21	15.0	3,000	21	14.8	2, 330	18	14.7	1, 518
24	14.7	1,588	25	15.0	3, 354	21	15.7	4, 590
28	15.5	4, 483	28	14.7	2, 120	29	14.8	2, 330
31	14.7	1,906						
Mean		. 3, 793	Mean		. 2,780	Mean		3, 032
	October.		ı	November.			December	
Day.	Height.	Dis- charge.	Day.	Height.	Dis- charge.	Day.	Height.	Discharge
	Meters.	Secft.		Meters.	Secft.		Meters.	Secft.
2	14.9	2, 316	3	15.1	3, 142	1	16.9	9, 955
6	14.7	2, 120	6	15.5	4, 377	4	15.6	4, 907
9	14.6	1,870	10	15, 4	3, 636	8	17.5	12, 885
3	15.1	3, 390	13	15.2	3, 565	11	15.1	2,930
6	16.4	6, 848	17	14.9	2, 294	15	15.0	2,790
200	15.4	4, 095	19	19.2	26, 475	18	14.8	2, 153
23	15.6	4,836	24	15.3	3, 848	22	14.8	3,083
27	15.5	4,695	27	17.5	12, 637	27	14.7	1,730
80	15.4	3, 954				29	14.6	1,590
31	17.0	10, 555						
Mean		4,468	Mean		7 497	Mean		4,670

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company.

[Drainage area, 635 square miles.]

	Discha	arge in seco	nd-feet.		Ru	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Colon rainfall, inches.
1892.							
May	28, 770	2, 345	5, 311	326, 561	8.36	9.64	18.03
June	17, 930	2, 260	3, 590	213, 620	5. 65	6.30	16. 97
July	27, 320	2, 232	7, 114	437, 423	11. 20	12.91	21.77
August	25, 910	3, 531	5, 950	363, 084	9.37	10.80	15.98
September	7, 275	3, 178	4, 476	266, 341	7.05	7.87	16. 26
October	19,840	3, 284	5, 848	359, 580	9. 21	10.62	6.69
November	42,000	3, 990	6, 715	399, 570	10.57	11.80	26. 30
December	25, 200	2,860	5, 968	366, 958	9. 40	10.84	11.30
The year	42,000			2, 733, 137			
1893.				11/1/1			
January	2,892	1,865	2, 293	140, 991	3. 61	4.16	1.73
February	3, 563	1,423	1,993	110, 686	3. 13	3. 26	3. 82
March	6, 512	759	1, 134	69, 727	1.79	2.06	1.81
April	23, 102	1, 201	3, 190	189, 818	5. 02	5. 60	8.07
May	26, 620	1,497	3, 045	187, 229	4. 80	5. 53	6.56
June	6,039	2, 147	3, 200	190, 410	5.04	5. 62	12. 32
July	17, 300	2,034	3, 472	213, 484	5.47	6. 31	11.50
August	21, 140	3, 146	4,538	279, 031	7.15	8. 24	15. 12
September	10, 389	2, 430	3, 813	226, 890	6.00	6.69	9.92
October	9, 535	2, 260	3, 733	229, 533	5.88	6.78	12. 28
November	19,840	3, 249	4, 494	267, 412	7.08	7.90	17.80
December	51, 100	3, 178	8, 252	507, 396	13.00	14. 99	30. 94
The year	51, 100	759	3, 610	2, 612, 607	5. 69	77.14	131. 89
1894.				11-1-1-1			
January	26, 189	2, 175	3, 858	237,219	6.08	7. 01	5. 35
February	2, 260	1, 201	1,633	90, 692	2.57	. 2.68	1.65
March	1, 225	742	948	58, 290	1.50	1.73	0.35
April	2, 317	572	760	45, 223	1.20	1.34	2. 16
May	13, 278	530	1, 358	83, 500	2.14	2.47	9.85
June	7, 190	798	2, 180	129, 719	3. 43	3.82	12. 24
July	18, 222	1, 349	4, 199	258, 186	6. 61	7.62	19.10
August	14, 804	2,670	3, 864	237, 588	6.09	7.02	23. 03
September	18, 462	2,486	4, 402	261, 937	6. 93	7.73	18.78

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company—Continued.

	Dischar	ged in seco	ond feet.		Run	ı-off.	
Month.	Maxi- mum.			Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Colon rainfall, inches.
1894.							
October	6,039	2,860	a 4, 690	288, 370	7.38	8.51	12.40
November	21,780		a 6, 530	388, 560	10.28	11.47	23.66
December	32, 510		a 10, 620	653,000	16. 72	19. 28	25. 12
The year	32, 510	530	3, 770	2, 732, 284	5. 94	80.68	153. 69
1895.							
January	14,610	1,910	3,530	217, 050	5.56	6.41	3. 86
February	3, 350	1,160	1,480	82, 200	2.33	2.43	1.89
March	3, 210	850	1,200	73, 790	1.89	2.18	2.09
April	14, 120	565	1, 130	67,240	1.78	1.99	21.78
May	12, 430	1,760	3, 210	197, 380	5.06	5.83	16. 77
June	25, 560	1,690	2,930	174, 350	4.61	5. 14	9. 25
July	21,000	1,410	2,860	175, 850	4.50	5.19	17.09
August	19, 340	2,050	3,740	229, 960	5. 89	6.79	14, 13
September	12, 140	600	3, 140	186, 840	4.95	5.52	12.09
October	27,990	1,690	4,590	282, 230	7. 23	8.34	16.46
November			3, 280	195, 170	5. 17	5.77	20. 47
December			3, 280	201, 680	5. 17	5. 96	15. 71
The year	27, 990	565	2,880	2, 083, 740	4.53	61.55	151. 54
1896.							
January			2, 220	136,500	3.50	4.04	4. 02
February			1, 130	65,000	1.78	1.92	1.30
March			a 630	38, 740	0.99	1.14	2.01
April			3,070	182,680	4.84	5.40	9.02
May			3, 280	201, 680	5.17	5. 96	16.46
June			3, 810	226, 710	6.00	6.69	8.50
July			2,720	167, 250	4.28	4.94	13. 58
August			2,580	158, 640	4.06	4.68	15. 51
September			3, 420	203, 500	5.39	6.01	12. 84
October			3, 180	195, 530	5.00	5. 76	13. 98
November			4, 980	296, 330	7.84	8.75	15, 68
December			3,600	221, 350	5. 67	6. 54	18.66
The year			2,880	2,093,910	4. 53	61, 83	131. 51

^a These means are obtained by averaging the discharge measurements.

Note.—Number of days lacking: In January, 5; February, 9; March, 31; April, 18; May, 7; August, 23; September, 8; October, 1; November, 9; December, 6.

Estimated monthly discharge of Chagres River at Gamboa, from measurements by the Panama Canal Company—Continued.

	Dischar	rge in secon	nd-feet.		Run	-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Colon rainfall, inches.
1897.							
January			5, 120	314, 800	8.06	9. 29	3. 42
February			1,130	62, 760	1.78	1.85	0.04
March			777	47, 780	1.22	1.41	0, 28
April			670	39, 870	1.06	1.18	3.74
May	42, 190	2,050	6, 710	412, 580	10.57	12. 19	16. 34
June	12, 110	3, 920	6,570	390, 940	10.35	11.55	18. 82
July	13, 480	4, 270	5, 360	329, 570	8.44	9.73	14.06
August			a 4, 090	251, 480	6.44	7.42	17. 24
September			a 3, 850	229, 090	6.06	6.76	17. 20
October	13,870	2,050	3,560	218,900	5.60	6. 46	5. 83
November	18, 250	3,070	4, 130	245, 750	6.50	7. 25	22.16
December	20, 020	1, 450	4, 270	262, 550	6.72	7.75	18.90
The year	42, 190		3, 880	2, 806, 070	6. 11	82.84	138. 03
1898.		***************************************					
January	27, 710	2,010	4, 310	265, 010	6.80	7.84	5.04
February	2,930	1,130	1,480	82, 200	2.33	2.43	0.35
March	2,540	777	1,020	62,720	1.60	1.84	1.58
April	28,770	777	1,840	109, 490	2.90	3. 24	4.72
May	9,920	1,340	2,470	151, 870	3.89	4.48	12.83
June	11,650	1,380	2,860	170, 180	4.50	5.02	16.38
July	18, 960	2,330	4, 240	260, 700	6.68	7.70	21.89
August	14,510	2,470	4, 130	253, 940	6.50	7.49	10.91
September	7, 270	1,660	2,540	151, 140	4.00	4.46	10. 24
October	20, 470	1,340	3, 460	212, 750	5. 45	6.28	11. 38
November	27,600	1,020	5, 190	308, 830	8.17	9.12	12. 28
December	5, 790	1,690	2, 290	140, 800	3.60	4.15	7.95
The year	28, 770	777	3,000	2, 169, 630	4.72	64.05	115.55
1899.	1776	melal			T. Indian	119	
January	22,060	1,730	3, 490	214,600	5. 50	6.34	6.93
February			950	52, 760	1.50	1.56	6. 49
March			950	58, 410	1.50	1.73	1. 26
April	6, 740	706	1,060	63, 070	1.67	1.86	0.43
May	20, 470	706	1,910	117, 440	3.00	3, 46	13.90
June	14, 120	1, 310	2,470	146, 970	3.89	4.34	6.41

^{*}These means are obtained by averaging the discharge measurements.

 $\label{lem:extracted} Estimated\ monthly\ discharge\ of\ Chagres\ River\ at\ Gamboa,\ from\ measurements\ by\ the\ Panama\ Canal\ Company—Continued.$

	Dischar	ge in secon	id-feet.		Run	-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acre-feet.	Second- feet per square mile.	Depth in inches.	Colon rainfall, inches.
1899.							
July	14, 120	1,340	2,820	173, 400	4.44	5. 12	27.68
August	26, 190	1,870	4, 240	260, 700	6.68	7.70	14.80
September	11,750	1,660	3, 180	189, 220	5.00	5.58	16.55
October	13, 730	1,840	3, 390	208, 440	5.34	6.16	15.04
November	23, 890	1,870	3, 740	222,550	5.89	6.57	14.49
December	13, 200	1,620	2,650	162,940	4.17	4.81	9.04
The year	26, 190	706	2,580	1, 870, 500	4.06	55. 23	133. 02
1900.							
January	12,920	1,060	1,690	103, 910	2.66	3.07	2.09
February	1, 165	600	810	44, 980	1.28	1.33	0.35
March	670	424	530	32,590	0.83	0.96	0. 29
April	1,870	388	565	33,620	0.89	0.99	3. 94
May	12, 320	424	1,340	82, 400	2.11	2.43	11.15
June	10,020	918	1,940	115, 440	3.06	3.41	15.94
July	16, 910	1,480	3, 350	205,980	5. 27	6.08	14.47
August	20,620	1,620	3, 565	219,200	5. 61	6.47	12.43
September	16,060	1,450	3,070	182, 680	4.83	5.39	14.69
October	23, 720	2,050	4, 520	277, 920	7.12	8. 21	15. 78
November	17, 540	1,910	4,060	241,590	6.40	7.14	13.86
December	21, 920	1,160	2,680	164, 790	4. 22	4.87	3.02
The year	23, 720	388	2, 360	1, 705, 100	3.72	50.35	108.01

²² GEOL, PT IV-01-39

Estimated monthly discharge of Chagres River at Gamboa, from observations of the Isthmian Canal Commission.

[Drainage area, 635 square miles.]

	Dischar	ge in secon	nd-feet.		Rur	ı-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfa. in basin, inches.
1900.							3
January	14, 030	889	2,026	124, 570	J. 19	3. 66	2, 09
February	1,420	726	970	53, 870	1.53	1.59	0.35
March	805	509	641	39, 410	1.01	1.16	0. 29
April	1,745	443	637	37, 900	1.00	1.11	3.94
May	15, 900	492	1,615	99, 300	2.54	2.91	11.15
June	12,550	1, 205	2, 426	144, 360	3.82	4. 25	15.94
July	21, 980	2,058	4, 104	252, 350	6.62	7.62	14. 47
August	26, 300	2, 222	4, 692	288, 500	7.39	8.51	12.43
September	20,060	1,899	3,750	223, 140	5. 91	6.59	14.69
October	29, 900	2, 795	5, 846	359, 460	9. 21	10.61	15. 78
November	22, 760	2, 461	5, 415	322, 220	8. 53	9.52	13.86
December	27, 900	1,509	3, 380	207, 830	5. 32	6. 13	3. 02
The year	29, 900	443	2,974	2, 152, 910		63. 66	108. 01

Ratio of run-off to rainfall=59 per cent.

TRIBUTARIES BETWEEN BOHIO AND GAMBOA.

The largest tributary between Bohio and Gamboa is the Caña Quebrada. Minor tributaries in order of their size are the Obispo, Gigante, Frijoles, and Frijolitos, and Agua Salud. By subtracting the mean monthly discharge of the Chagres at Gamboa from the discharge at Bohio the discharge of all the tributaries was obtained.

Estimated monthly discharge of tributaries to the Chagres River between Gamboa and Bohio.

[Drainage area, 245 square miles.]

	Mean dis-	121	Run	-off.		
Month,	charge in second-feet.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.	^a Rainfall, inches.	
1900.						
January	177	10,890	0.72	0.83	3, 57	
February	82	4,550	0.33	0.34	0. 26	
March	40	2,460	0.17	0.20	0.46	
April	15	900	0.06	0.07	3.08	
May	55	3, 380	0.22	0.25	7.08	
June	759	45, 160	3.10	3.46	11.01	
July	1,856	114, 120	7.57	8.73	16.99	
August	1, 188	73,050	4.85	5. 59	11.33	
September	1,440	85, 690	5.88	6.56	11.96	
October	2, 374	145, 970	9.69	11.17	15. 27	
November	2, 125	126, 440	8.68	9.68	17.82	
December	720	44, 270	2.94	3.39	2.40	
The year	908	656, 880		50. 27	101. 23	

^a Mean of observations at Bohio, Gorgona, and Gamboa.

Ratio of run-off to rainfall=50 per cent.

The tributaries named below were gaged on an average of once a week, and the following table depends upon these data:

Measurements of flow of tributaries of Chagres River.

River.	Maximum measured discharge.	Minimum measured discharge.	Mean.	Per cent of total discharge. a
	Sec. ft.	Sec. ft.	Sec. ft.	
Caña Quebrada	1,640	17	335	37
Obispo	1, 177	1	90	10
Gigante	281	0	65	7
Frijoles and Frijolitos	219	5	55	6
Agua Salud	90	3	33	4
Other sources			330	36
Total			908	100

^a The last column indicates the per cent of the total inflow between Gamboa and Bohio contributed by each stream.

BOHIO STATION ON CHAGRES RIVER.

The present plans of both the Isthmian Canal Commission and the Panama Canal Company provide for a dam at Bohio. The company established a fluviograph here in 1895 and a record of discharge has been kept ever since.

The Canal Company's gaging station is at Buena Vista, about one-half mile above the proposed dam site. It is on a long, straight stretch of the river, 220 feet wide, with high, steep banks. The cross sections are very similar and the velocities across the stream are very uniform. It is almost an ideal station for discharge measurements, its sole defect being that at times of extreme low water the tides of the Atlantic may slightly affect the velocity.

The fluviograph is at Bohio and is the counterpart of the one at Alhajuela, but the tides are noticeable whenever the height of the river is less than 0.5 meter, so that below this stage a rating table may give slightly erroneous results, as the same gage height at different times may not correspond to the same discharge. A gage rod divided into centimeters is firmly set in the bank at the gaging station. The reading of this is used in obtaining the mean area of cross section.

Annual summary of discharge measurements made by the Panama Canal Company at Bohio.

		-		10.0	Rur		
Year.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall at Colon.
	Secft.	Secft.	Secft.				
1895	27, 750	710	4, 510	3, 263, 810	5. 12	69. 52	151.54
1896	28, 950	600	4, 220	3, 062, 960	4.80	65. 28	131.51
1897	38, 790	495	4,850	3, 514, 390	5. 51	74.88	138. 03
1898	27, 890	780	3, 960	2, 865, 730	4.50	61.07	115.55
1899	25, 870	600	3, 400	2, 458, 420	3.86	52, 40	133.02
1900	23, 860	490	3,520	2, 551, 810	4.00	54. 38	108.67

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company.

[Drainage area, 880 square miles.]

	Discha	rge in seco	nd-feet.		Rui	n-off.
Months.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1895.						
January	20, 721	2, 290	a 4, 550	279, 770	5. 17	5. 96
February	2,930	1; 900	a 1, 380	76, 640	1.57	1.63
March			a 1,060	65, 180	1. 20	1, 38
April	11,540	710	a 1, 060	63,070	1. 20	1.34
May	13, 830	1,380	a 4, 170	256, 400	4.74	5.46
June	10,770	2, 290	a 4, 310	256, 460	4.89	5. 46
July	19,980	1,910	a 4, 590	282, 230	5. 22	6.02
August	15, 500	1,940	a 6, 920	. 425, 500	7.86	9.06
September	21, 320	2,540	a 5, 790	344, 530	6.58	7.34
October	27, 750	2,610	a 6, 920	425, 500	7.86	9.06
November	18, 640	4,020	a 6, 070	361, 190	6.90	7.70
December	27, 180	2,610	a 6, 950	427, 340	7.90	9.11
The year	27, 750	710	4, 510	3, 263, 810	5. 12	69. 52
1896.	10)	-				
January	10,450	1,910	a 4, 730	290, 840	5.38	6. 20
February	2,470	1,020	a 1,550	89, 160	1.76	1.90
March	1,940	740	a 880	54, 110	1.00	1.15
April	25, 030	600	a 1, 690	100, 570	1.92	2.14
May	16, 270	1,730	a 4, 940	303, 750	5. 61	6.47
June	13, 240	2,080	a 4, 200	249, 920	4.77	5. 32
July	22,950	2, 430	a 3, 140	193, 070	3.57	4.12
August	11,930	2,650	a 3, 500	215, 200	4.00	4.61
September			a 5, 930	352, 860	6.74	7.52
October			a 6, 350	390, 450	7. 22	8. 32
November	19, 100		a 7, 590	451, 640	8. 62	9.62
December	28, 950	3,880	a 6, 040	371, 390	6.86	7. 91
The year	28, 950	600	4, 220	3, 062, 960	4. 80	65. 28
1897.	-	0.000		400.050	0.00	0.00
January	5, 370	3, 390	a 2, 050	126, 050	2. 33	2.69
February			a 1, 590	88, 300	1.81	1.88
March	1,380	600	a 710	43, 660	0.81	0.93
April	14, 160	495	a 880	52, 360	1.00	1. 12
May	38, 790	850	a 7, 980	490, 670	9.07	10.46
June	12, 910	3, 460	a 4, 200	249, 920	4. 77	5. 32
July	17,400	2,860	a 5, 120	314, 820	5.82	6.71

^a These means are obtained by averaging the discharge measurements.

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company—Continued.

	Dischar	ge in seco	nd-feet.		Run-off.	
Months.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.
1897.	10 400	0.000	. = .=.	447.010	0.00	0.50
August	18, 460	2,820	a 7, 270	447, 010	8. 26	9. 52
September	21, 110	4, 130	a 6, 880	409, 390	7. 82	8. 72
October	17, 540	3, 390	a 7, 480	459, 930	8. 50	9.80
November	22, 100	3, 810	a 6, 950	413, 550	7. 90	8. 81
December	22, 100	3, 670	a 6, 810	418, 730	7. 74	8. 92
The year	38, 790	495	4, 850	3, 514, 390	5. 51	74. 88
1898.	07.050	0.000	F 050	247 400	0.49	7.40
January	27, 250	2, 260	5,650	347, 400	6. 42	
February	3, 320	1, 230	1,690	93, 860	1.92	2.00
March	2,400	810	1,090	67, 020	1. 24	1. 43
April	24,000	780	2,010	119,600	2. 28	2.54
May	8, 510	1,450	2,680	164, 790	3. 05	3. 52
June	15, 140	1, 760	3, 350	199, 340	3. 81	4. 25
July	23, 860	2,890	6,570	403, 970	7. 47	8.61
August	15, 500	3,000	5, 300	325, 880	6. 02	6. 94
September	8, 540	2, 150	3, 210	191,000	3. 65	4.07
October	23, 370	2,080	5,050	310, 510	5.74	6. 62
November	27, 890	3, 810	7,840	466, 510	8. 91	9.94
December	6,670	1,980	2,860	175, 850	3, 25	3. 75
The year	27, 890	780	3,960	2, 865, 730	4.50	61.07
1899. January	22, 240	1,800	3,848	236, 600	4. 37	5. 04
February	2,540	1, 340	1,730	95, 960	1.98	2.06
March	1, 410	740	988	60, 750	1.12	1. 29
April	3, 280	635	1,090	64, 860	1, 24	1.38
May	17,540	600	2,050	126, 050	2.33	2.69
June	5, 470	1,910	3, 140	186, 840	3.57	3.98
July	17, 750	1,660	3, 950	242, 880	4.49	5. 18
August	25, 870	3,040	5, 720	351, 700	6.50	7.49
September	9,531	2,440	4, 240	252, 300	4.82	5. 38
October	16, 130	2,720	4, 940	303, 750	5. 61	6.47
November	24, 250	2,790	5, 300	315, 370	6.02	6. 75
December	15, 280	940	3,600	221, 360	4. 09	4. 75
				H - 3 - 5 - 5 - 5		52.40
The year	25, 870	600	3, 400	2, 458, 420	3, 86	52.40

^{*} These means are obtained by averaging the discharge measurements.

Estimated monthly discharge of Chagres River at Bohio, from observations of Panama Canal Company—Continued.

[Drainage area, 880 square miles.]

	Dischar	ge in secor	nd-feet.		Rui		
Months.	Months. Maxi- Mini- mum. Mean. Total in acrefeet.		Second- feet per square mile.	Depth in inches.	Rainfall in basin, inches.		
1900.							
January	10, 410	1,480	2,120	130, 350	2.41	2.78	2.44
February	1,380	810	1,060	58, 870	1. 20	1. 25	0. 33
March	920	600	740	45, 500	0.84	0.97	0.32
April	1,765	490	706	42,010	0.80	0.89	3.78
May	9,672	490	1,620	99, 610	1.84	2.12	10.45
June	10,840	1,340	2,860	170, 180	3. 25	3.63	15. 67
July	21, 180	2,010	5, 610	344, 940	6.38	7.36	15. 28
August	19, 240	2,440	5, 260	323, 420	5.98	6.89	12.36
September	18,070	2, 260	4,770	283, 830	5.42	6.05	14. 33
October	23, 860	3, 180	7,000	430, 410	7.95	9.17	15.48
November	20, 300	3,740	6,600	392, 730	7.50	8.37	15.10
December	22, 870	1,800	3,740	229, 960	4. 25	4.90	3. 13
The year.	23, 860	490	3, 520	2, 551, 810	4.00	54.38	108. 67

Estimated monthly discharge of Chagres River at Bohio based on discharge measurements made by the Isthmian Canal Commission.

[Drainage area, 880 square miles.]

134-334	Dischar	ge in secon	nd-feet.		Rur	n-off.	
Month.	Month. Maxi- mum. Mean. Total in acre feet.		Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Colon rainfall, inches.	
1899.							
January	21,830	1,900	4, 150	255, 170	4.72	5.44	6.93
February	2,810	1,300	1,795	99, 690	2.04	2.12	6.49
March	1,420	665	943	57, 980	1.07	1. 23	1.26
April	3,670	570	1,057	62, 900	1.20	1.34	. 43
May	17, 440	540	1,900	116, 830	2.16	2.49	13.90
June	6, 440	2,030	3,500	208, 260	3.98	4.44	6.41
July	17, 730	1,710	4, 372	268, 820	4.97	5.73	27.68
August	24, 520	3, 370	6, 425	395, 060	7.30	8. 42	14.80
September	10, 225	2,680	4,858	289,070	5. 52	6.16	16.55
October	16, 285	2,990	5, 511	338, 860	6. 26	7. 22	15.04
November	23, 320	3,080	5, 732	341, 080	6.51-	7.26	14. 49
December	15, 430	2, 210	3, 950	242, 880	4.49	5.18	9.04
The year	24, 520	540	3, 697	2, 676, 600	4.18	57. 03	133. 02
1900.							
January	10, 155	1,441	2, 203	135, 460	2.50	2.87	2.44
February	1,640	802	1,052	58, 420	1.20	1. 24	0.33
March	877	570	681	41,870	0.77	0.88	0.32
April	1,845	442	652	38, 800	0.74	0.82	3.78
May	9,500	506	1,670	102, 680	1.92	3. 20	10.45
June	12,700	1,640	3, 185	189, 520	3. 62	4.04	15.67
July	20,650	2, 521	5,960	366, 470	6.77	7.80	15. 28
August	18,900	2,859	5,880	361, 550	6.68	7.70	12.36
September	17,800	2,651	5, 190	308, 830	5.90	6.58	14. 33
October	23,000	3, 802	8, 220	505, 430	9.34	10.77	15.48
November	19,800	4, 464	7,540	448, 660	8.57	9.56	15. 10
December	22, 100	1,949	4, 100	252, 100	4.66	5. 37	3, 13
The year	23,000	442	3, 880	2, 809, 790		60.83	108. 67

Ratio of run-off to rainfall =55 per cent.

HYDRAULICS OF CHAGRES RIVER AT ALHAJUELA AND BOHIO

At Alhajuela and Bohio the fluviograph rods and gage rods were read each time a gaging was made. The difference in these simultaneous readings in connection with the distance between the rods, the measured discharge, and the several cross sections of the river furnished the slope, the mean hydraulic radius, and the mean velocity. From these data the value of the coefficient for roughness, "n," in Kutter's formula, was computed, and the results are shown in the table below.

At Alhajuela the distance between the rods is 200 meters. The bed of the river is small gravel, and the banks are steep and free from weeds and bushes. At Bohio the distance between the rods is 1,335 meters. The bed is clay with small gravel and is free from detritus. The banks are high, but are covered with weeds and bushes.

Hydraulic observations on Chagres River.

ALHAJUELA.

Gage height.	Mean area.	Mean dis- charge.	Mean velocity.	Hydraulic radius.	Slope.	"n."
Meters.	Sq.ft.	Sec. ft.	Ft. per sec.			
28. 15	815	580	0.71	3.84	0.000025	0.027
28.28	910	953	1.05	4. 16	0.000050	0.026
28.51	1,075	1,928	1.80	4.74	0.000095	0.023
28.68	1, 200	2,926	2.44	5.17	0.000144	0.022
28.84	1,320	4,040	3.01	5. 58	0.000211	0.023
29.46	1,785	9, 361	5. 20	7. 23	0.000350	0.020
31.01	3,000	25, 872	8.62	11.50	0.000892	0.026
			воніо.			
1.59	1, 340	2,560	1.91	5, 90	0. 000097	0.025
2.50	2,000	6, 100	3.05	8.58	0.000142	0.024
3. 19	2,500	8,930	3.58	10.42	0.000165	0.026
4.42	3, 400	14,600	4.29	13.10	0.000210	0.029
5.50	4,040	21,020	5, 20	14.70	0.000277	0.029

TRINIDAD AND GATUN RIVERS.

Below Bohio the major part of the Chagres flows through the almost completed cut for the canal, its old channel being in many places choked by vegetation; in this stretch it receives the waters of two large tributaries, the Trinidad, and the Gatun. Frequent trips to these were made and current meter measurements were made each time. No gage rods were set on these streams, because if they were set less than 10 miles up, the slope of the rivers being very slight, the fluctuations of the Chagres would materially influence the rod-reading, and the time taken in these trips would be longer than the time taken in making a gaging; the inflow between the mouth and the station would also be omitted.

Discharge of the Gatun and Trinidad rivers. $\label{eq:Gatun} {\rm GATUN}.$

Date.	Dis- charge.	Date.	Dis- charge.	Date.	Dis- charge.
1899.	Secft.	1900.	Secf.	1900.	Secft.
November 17	1,213	March 12	142	June 11	348
December 9		March 15	111	June 14	285
December 29	442	March 19	164	June 18	214
		March 23	133	June 21	225
1900.	1	March 26	178	June 28	616
Tonyowy 11	359	April 5	130	July 5	945
January 11 January 19	218	April 12	88	July 9	1,569
	259	April 17	133	July 12	916
January 25 February 1	209	April 20	98	July 16	962
February 6	216	April 23	117	July 19	729
February 8	198	April 26	237	July 25	925
February 12	160	May 3	71	August 2	922
February 15	151	May 14	65	August 24	1,021
February 22	160	May 18	225	September 5	420
February 26	186	May 21	240	September 11	1, 111
March 1	109	May 30	217	September 18	888
March 6	197	June 7	315		

	feet.
Maximum	1,569
Minimum	
Mean	. 528

TRINIDAD.

Date.	Dis- charge.	Date.	Dis- charge.	Date.	Dis- charge.
1899.	Secft.	1900.	Secft.	1900.	Secft.
November 17	1,687	March 6	368	June 21	1, 358
December 9		March 15	143	June 28	1,537
December 29	896	March 19	242	July 2	1, 337
Docombor 20111111	000	March 23	221	July 5	1,577
1900.		March 26	304	July 9	1,574
		April 12	204	July 12	1,868
January 8	1,210	April 17	226	July 16	1,594
January 11	744	April 20	220	July 19	2, 255
January 15	705	April 23	225	July 25	2, 295
January 19	574	May 1	261	August 2	2, 144
January 22	599	May 3	286	August 7	1, 375
January 25	569	May 10	463	August 24	1, 464
January 29	555	May 14	244	August 30	2, 521
February 1	631	May 18	610	September 5	1, 403
February 6	439	May 21	620	September 8	1, 283
February 8	492	May 24	533	September 11	2, 120
February 12	450	May 30	1,094	September 18	2, 607
February 15	291	June 7	2, 373	September 21	1, 474
February 19	299	June 11	1,379	September 27	2, 256
February 22	264	June 14	993	September 27	2, 200
February 26	358	June 18	931		
March 1	365	June 10	991	THE PARTY OF THE P	

	feet.
Maximum	
Minimum	143
Mean	1, 100

The "mean" is the mean of the monthly means.

FLOODS OF THE CHAGRES RIVER.

The projected canal from Colon to Panama is 47 miles in length and for more than half this distance it follows the valley of the Chagres. Where it leaves this valley to cut through the continental divide the river bed is at an elevation of nearly 50 feet. If the river were taken into a sea-level canal it would form a cataract nearly 50 feet high at this point, which would of course be inadmissible; so that for a sea-level project it would be necessary to construct an enormous channel capable of carrying the flood waters of the Chagres River to the sea independent of the canal and the same would be necessary with all the principal tributaries. It is now generally conceded that for this reason a sea-level canal is impracticable. The magnitude of a flood discharge, however, remains important in its relation to the works necessary for controlling and discharging the surplus waters without injury to the works or obstruction to navigation.

Although nearly the entire country is clothed with vegetation, much of which is very dense, the slopes are so precipitous and rock is so near the surface that the heavy tropical rainfall often produces sudden freshets in the river. A violent rainfall of a few hours converts the banks of the Chagres in the vicinity of Alhajuela and above into a series of small torrents and cascades, causing the river to rise very suddenly and flow with great velocity. It is this feature that lends such importance to the study of the floods of the Chagres in their relation to the proposed canal.

It is stated by the officers of the Panama Railway Company that previous to 1879 no freshet had occurred in the Chagres of magnitude sufficient to cause serious damage to the property of the railway company or to delay its operations. The flood of 1879 caused great damage to the railway and obstructed traffic for a considerable period, and the conclusion follows that it is far greater than any flood that had occurred since the construction of the railway was begun. This conclusion is verified by the testimony of the oldest inhabitants of the region.

Since 1879 sufficient attention has been paid by canal officials to render it certain that no flood equal in magnitude to that of 1879 has since occurred. The flood occurred in November, but we do not know how long it lasted, except that a violent storm raged for six days throughout the Isthmus, the precipitation amounting to 320 millimeters at Panama. De Lesseps and his associates made no mention whatever in their journals or other records of this matter, so vital to their project of a sea-level canal, but, on the contrary, their efforts seem to have been to prevent public knowledge of its magnitude.

The only actual information existing other than that of a general character from the officials of the Panama Railway, above referred to, is the testimony of Mr. Sosa, a young Colombian engineer, who by

inquiry from the inhabitants, or otherwise, decided upon certain points as high water of this flood in the neighborhood of Bohio. Mr. Sosa was unfortunately drowned in the sinking of La Bourgogne, and it is not known how accurate his information was, excepting that he expressed his entire reliance upon it. By his testimony the river reached an elevation of 12 meters above sea level at Bohio at its maximum stage. From the measurements made of the floods of less magnitude, and from the large number of measurements of the river at its lower stage a curve has been plotted expressing the relation of discharge and gage height at Bohio. The existing observations are in satisfactory accordance, and by extrapolating this curve upward to include the flood of 1879 we obtain a discharge for the river at Bohio for gage height 12 meters of 3,860 cubic meters, or about 136,000 cubic feet per second, and is submitted as being the best conclusion permitted. The observations are those given by General Abbot in his note "Sur le régime du Chagres," pages 24 to 27. The results obtained by the company at Bohio being in practical accordance with those observed by the commission are accepted without change.

In this connection three points should be remembered: First, the discharge for "cote" 12 may be greater than here indicated; second, the flood of 1879 may have reached a higher elevation than "cote" 12; third, it is possible that a larger flood than that of 1879 may occur in the future.

Under these circumstances it seems safe to consider the maximum flood wave to be expected on the Chagres at about 140,000 cubic feet per second.

Four great floods occurred since 1879, of which the discharge at Gamboa has been measured or estimated by the Panama Canal Company as follows:

Discharge of floods at Gamboa.

Date.	Gage height.	Discharge (maximum).	Mean for 48 hours.	Percent-
	Meters.	Cu. meters.	Cu. meters.	1
November 25, 1885	23, 60	1,638	1,077	66
December 12, 1888	23, 56	1,628	1,270	78
December 1, 1890	23.70	1,663	833	50
December 17, 1893	21.72	1, 207	759	63

The flood of 1879 seems to have been longer sustained than any of the others, and it seems likely that the ratio of the mean discharge to the maximum should be somewhat greater than the others. General Abbot has assumed the mean discharge for this flood at 80 per cent of the maximum, and this appears to be approximately correct. Eighty per cent of 140,000 cubic feet per second is 112,000 cubic feet per second.

The area of Lake Bohio, according to the plans adopted by the Commission, is as follows:

Area of Lake Bohio.

Elevation.	Acres.	Square miles.
20 meters (65.6 feet)	14, 771	23, 08
25 meters (82 feet)	23,542	36. 78
26 meters (85.3 feet)	24, 627	38.48

The waste weir provided is to be at an elevation of 85 feet above sea level, or slightly less than 26 meters, and is to have a length of 2,000 feet.

This flow continued for 48 hours would result in a total discharge of 444,300 acre-feet, or about 9,300 acre-feet per hour. A sustained discharge of this amount would raise the lake to a head of about 6.6 feet over the sill of the weir. This, however, may be taken as the extreme condition which will never be exceeded.

LOW WATER OF THE CHAGRES RIVER.

The Chagres River being the one feeder to the summit level of the proposed canal, its mean and minimum flow is very important as indicating the amount of storage that must be provided for the operation of the canal during the dry season. The mean flow for the various months of the year, as determined by averaging all the monthly records in our possession since 1892, is as follows:

Mean	flow	of	the	Chagres	River.
------	------	----	-----	---------	--------

		Secft.
January	 	2, 948
March	 	958
April	 	1,555
May	 	3, 252
June	 	3,063
July	 	4,006
August	 	4, 404
September	 	3, 628
October	 	4, 237
November	 	4, 785
December	 	4, 408

Averaging these quantities we find the mean annual discharge is about 3,200 cubic feet per second. As the maximum consumption and loss by leakage and evaporation is estimated at 1,000 cubic feet per second, we find that the month of March is the only month having a shortage in average years; and as this is the record for Gamboa, and the discharge at Bohio, where the dam is to be constructed, is somewhat greater, we may say that the requirements of the canal are less than the average discharge for any month in the year, and if one-third

of the mean annual flow can be saved there will be ample for canal purposes.

But some years furnish less water than others, and to correctly solve the problem of the water supply for the canal we must consider the yield in the minimum year.

In all the observations at Bohio the lowest monthly means are for the months of March and April, 1891, as shown by the mean of eight measurements made in each of those months. More records, however, are at hand for Gamboa than for Bohio, and the lowest reading at the Gamboa fluviograph occurred in the spring of 1900, when, for a period of about two months, the fluviograph at Gamboa indicated a stage of less than 14 meters almost continuously, the lowest point reached being 13.82. This corresponds to a discharge of from 15 to 20 cubic meters per second.

In the examination of the records in Paris an elevation at Gamboa was found for the last three days of March, 1896, giving the stage as 13.1 meters. The rest of the month of March and the first half of April are entirely blank, no record having been kept. It is impossible that this could have been a fluviograph record, since the river would be dry before reaching so low an elevation at the location of the fluviograph, and the only plausible explanation is that given by the officers of the company, that this record was on a rod a considerable distance below the fluviograph; and this statement is confirmed by the reports of discharge on these dates, which are 16.8, 16.8, and 16.9 cubic meters, respectively, leaving no doubt that at this time the river was above the stage reached in 1900. No other record gives a stage of river as low as that reached in 1900.

The year 1891, however, seems to have had a still lower dry-season flow. No fluviograph records were obtainable except such as were given with the measurements of discharge, and these do not show any stage as low as that of 1900; but in so long a time the bed of the river would be likely to change, and the measurements show that it has done so. Of actual gagings we have (page 604) eight for February, eight for March, and eight for April. The measurement on the 1st of May shows low water, while that of May 4 exhibits a freshet.

The indications of the gagings are that up to February 14 the discharge of the river was above the requirements of the canal, while from February 15 to May 3 they were below. This is the same period for which eight measurements per month were made at Bohio. The means are 39 cubic meters per second for February, 17 for March, and 17 for April. This is the lowest discharge at Bohio of which we have record. It is, of course, not certain that a drier year has not occurred, or will not occur, and in making the estimates it will be assumed that the mean of 17 cubic meters, or 600 cubic feet, per second is continuous for ninety days, from February 1 to May 1.

The requirements and losses of the canal in operation, as estimated by this Commission, are as follows:

Water required by Panama Canal.			
	Cubi	ic ft.	per sec.
Lockage			
Power			
Leakage			257
Evaporation	• • • •	• • • • •	207
Total			1,070

Applying this quantity, we have for the 90 days from February 1 to May 1—

	Acre-feet.
Total leakage, lockage, and evaporation, 1,070 cubic feet per second Less inflow	
Deficit	84 000

Taking 24,000 acres as the area of the lake, this will lower the lake about 3.5 feet. An allowance of this amount is therefore ample for the most extreme case.

This brings the elevation of the lake to 81.5 feet, which may be regarded as the elevation reached in the minimum year of a long series, and would occur perhaps only once in a generation. If the consumption and loss should be less than 1,070 cubic feet per second, the deficit would, of course, be diminished.

The dry season of 1900 would have brought the lake level to an elevation of about 82.5.

The possibility always remains of constructing a large reservoir at Alhajuela, which will not only guard against annoying currents in Lake Bohio, but will store sufficient water for use in the dry season, so that the lake need never decline below the sill of the wastewier.

It is indeed true, as stated by General Abbot, that the Chagres is a river well adapted to the service of the proposed Panama canal.

SEDIMENT OBSERVATIONS.

Observations to determine the amount of sediment carried by the Chagres River were made at Alhajuela and Bohio by means of water samples representing the mean condition of the river.

٠	Month.	Alha	Alhajuela.		Bohio.	
		Mud.	Solid matter.	Mud.	Solid matter.	
May	1900.	Cubic yards.			Cubic yards.	
June		. 75, 900	15, 180	152, 720 763, 800	30, 540 152, 760	
August		. 406, 100	81, 230	580,000	116,000	
September		. 208, 300	41,660	396, 800	79, 360	
October		. 485, 040	97,000			

PACIFIC SLOPE.

In a minor degree it is required to know something of the volume and regimen of the Grande River, which is followed by the canal line from Paraiso to the Pacific, and which is the only stream near the canal on that slope.

GRANDE RIVER.

From Culebra to the Pacific Ocean the line of the canal follows the valley of the Grande River, therefore an idea of the floods and the general characteristics of this stream becomes valuable; accordingly, on October 25, 1899, two gage rods were set at Pedro Miguel, the first being 250 yards above and the second 30 yards below the mouth of the Pedro Miguel River. The lower rod could not be set farther downstream on account of the high tides of the Pacific Ocean, the tidal effect at Miraflores being at least 5 feet.

These rods were read at 6 a. m. and 6 p. m., and additional readings were taken during floods.

Estimated monthly discharge of Grande River at 250 yards above the mouth of the Pedro Miguel.

[Drainage area, 10 square miles.]

	Dischar	ge in secon	id-feet.		Rur	n-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1899.							
November	410	10.0	35.0	2,082	3.50	3.90	8. 67
December	- 65	3.0	13.0	800	1.30	1.50	2.34
1900.							
January	37	1.0	3.0	184	0.30	0.35	0.56
February	1	0.5	0.7	39	0.07	0.07	0.09
March	2	0.0	0.2	12	0.02	0.02	0.00
April	1	0.0	0.3	18	0.03	0.03	2.73
May	210	0.6	11.0	676	1.10	1.27	10.66
June	650	3.0	44.0	2,618	4.40	4.91	10.30
July	550	5.0	114.0	7,010	11, 40	13.14	25.04
August	283	2.0	50.0	3,074	5.00	5.76	6. 52
September	660	11.0	38.0	2, 261	3.80	4.24	6.75
October	370	30.0	60.0	3, 690	6.00	6.92	8.68
November							
December							
The year	660	0.0	31.0	22, 464		42.11	82. 34

Ratio of run-off to rainfall = 0.51 per cent.

Estimated monthly discharge of Grande River at 30 yards below the mouth of Pedro Miguel River.

[Drainage area, 19 square miles.]

	Dischar	ge in secon	nd-feet.		Run	-off.	
Month.	Maxi- mum.	Mini- mum.	Mean.	Total in acrefeet.	Second- feet per square mile.	Depth in inches.	Rainfall, inches.
1899.							
November	790	27.0	81.0	4, 820	4. 26	4.75	8. 67
December	100	12.0	26.0	1,600	1. 37	1.58	2. 34
January	50	3.0	7.0	430	0.37	0.43	0.56
February	3	0.0	1.0	56	0.05	0.05	0.09
March	3	0.0	0.2	12	0.01	0.01	0.00
April	2	0.0	0.5	31	0.03	0.03	2, 73
May	310	1.0	24.0	1,476	1.26	1.45	10.66
June	1,550	10.0	105.0	6, 250	5. 53	6. 17	10.30
July	1,850	21.0	295.0	18, 140	15.53	17.90	25. 04
August	1,550	12.0	142.0	8,730	7.47	8, 61	6. 52
September	1,550	18.0	80.0	4, 760	4. 21	4.70	6.75
October	800	34.0	112.0	6, 885	5. 90	6. 80	8. 68
The year	1,550	0.0	74.0	53, 190		52.48	82. 34

Ratio of run-off to rainfall = 0.637 per cent.

RAINFALL.

Notwithstanding the fact that the Isthmus is narrow and the cordillera low in the vicinity of Panama there is a striking difference of rainfall between the Caribbean or northern, and the Pacific or southern coast of the Isthmus in this region. The contrast is similar to that between the east and west coasts of Nicaragua, though not so striking. The mean rainfall at Colon, as shown by a record of nearly thirty years, is 130 inches, while that at Panama, though not so well determined, is only 66.8. The precipitation at Panama and vicinity is confined almost entirely to the months from May to November, inclusive. The rest of the year is the dry season. At Colon, though the rainfall is less during the dry season, there is still considerable precipitation, the mean for April being 4.54, and for January 3.73, while these two months are dry on the Panama side. February and March are less likely to yield any considerable precipitation, but no month is exempt from rainfall on the coast of the Caribbean. The upper portion of the Chagres drainage basin represents the mean between these extremes.

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The longest record of rainfall in the vicinity is that of Colon, which has been kept continuously from March, 1881, to date, with the exception of a period of twenty-one months in 1888–1889. This station, however, is not on the Chagres drainage, and the records kept in that basin do not cover so long a period. They are mainly at Gamboa and Obispo, with very short records at Bohio, Gorgona, and Alhajuela. Short records also exist at Panama, at La Boca, the south end of the canal, and at Naos, an island in the bay of Panama.

The long records of stream flow at Gamboa and Bohio, together with an approximate knowledge of the area of the drainage basin and the observations of rainfall, constitute a valuable contribution to the knowledge of the ratio of rainfall to run-off in the Tropics, the weakest point being the information on rainfall, the only records in the basin being confined to the lower valley, and being, moreover, very short. definite relation could be established between the long Colon record and the mean of the Chagres Basin, it would increase the value of these data to an important extent. For this purpose five stations above Alhajuela were established in 1899, two at different points on Rio Pequeni at Salamanca and Las Minas, one on the Upper Chagres at Santa Barbara, and two at high elevations above the river valley. Of the latter, one is on a hill between the Chagres and Pequeni, 700 feet above the nearest point of the Chagres, and the other is between the Chagres and Puento, about 500 feet above the river. Salamanca and Las Minas were discontinued at the end of 1900. The others were discontinued October 30, 1900. Their relative location is shown on the map, page 530. These stations, considered with those lower in the basin, are taken as the mean for the basin and compared with observations at Colon, as follows:

Rainfall on Isthmus of Panama, 1900, in inches.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Colon	6.06	0.33	1.06	0.75	12. 25	11.65	16.81	17.04	9.37	16.33	20.28	4.13	116.06
Bohio	7.06	0.48	1.04	2,89	7.42	18.40	17.79	14.02	15.40	18.43	24.98	4.02	131.93
Gorgona	2.63	0.13	0.20	3.15	7.07	12.48	19.72	11.04	11.25	11.93			
Gamboa	1.01	0.16	0.13	3.21	6.76	12.15	13.45	8.92	9.24	12.11	10.67	0.79	78.60
Pedro Miguel	0.56	0.09	0.00	2.73	10.66	10.30	25.04	6.52	6.75	8.68	a 8. 67	a 2.34	82.34
Alhajuela	1.82	0.04	0.03	4.10	10.16	17.79	19.73	10,56	17.20	13.26	13.36	1.14	109.19
Campanas	1.54	0.05	0.11	2.66	8.57	22.12	12.78	12.49	13.55	15.34			
Santa Barbara	1.41	0.16	0.09	5.43	13.67	22.54	13.65	12.65	15.66	11.80	ь13.50	a 2.62	113.18
Rio Fea	1.26	0.26	0.11	5.60	12.64	20.48	13.41	9.79	16.51	21.98		a 2.06	
Rio Puente	1.02	0.12	0.08	1.61	10.11	19.35	18.14	20.09	15.50	15.15		a 1.81	
Salamanca	3.20	0.50	0.38	3.22	12.15	8.37	10.46	9.97	18.81	16.20	14.77	2.92	100.95
Las Minas	4.90	1.17	1.21	4.39	12,53	10.91	12.43	15.01	9.90	19.91	16.63	7.23	116. 22

a For 1899.

Rainfall at Colon, in inches, compared with mean rainfall in basin of Chagres River.

*		Colo	n.		Chagres Basin.
Month.	Maximum, 1872.	Minimum, 1884.	1900.	Mean for thirty years.	1900.
January	3.57	3. 39	6.06	3. 56	2. 44
February	0.75	0.39	0.33	1.52	0. 33
March	0.83	0.39	1.06	1.55	0.32
April	1.30	4. 33	0.75	4.42	3.78
May	21.43	10.16	12.25	12. 27	10.45
June	22.00	10.32	11.65	13.46	15.67
July	19.90	15. 59	16.81	16.92	15. 28
August	19.97	13. 27	17.04	15.53	12.36
September	16.20	9.37	9.37	12.77	14. 33
October	30. 32	8.66	16.33	14. 20	15.48
November	19.11	7.05	20.28	20.56	15, 10
December	13. 12	3.62	a 9.04	12.49	a 3. 59
Total	168.50	86.54	120.97	129. 25	109, 13

^a To obtain a comparison for a complete year the rainfall for December, 1899, is included, because during December, 1900, many stations in the basin were discontinued.

Monthly rainfall at Colon, in inches.

[1862-1874 by Drs. White and Kluge, surgeons Panama Railway Company; 1881-1898 by Panama Canal Company; 1898-1900 by Panama Railroad Company.]

Year.	Jan,	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1862										13.10	43.01	16.83	
1863	1.75	2.94	0.85	4.70	13.09	15.32	25.76	10.34	15.54	11.22	17.59	15.21	134. 31
1864	1.90	0.77	0.78	0.44	15.87	8.78	16.54	13.37	17.85	12.83	17.90	16.40	123.43
1865	1.10	1.08	0.02	3.89	9.22	16.85	9.61	18.39	8.55	9.69	22.16	5.58	106.14
1866	3.99	1.07	0.21	4.07	14.76	12.17	16.72	12.72	18.82	15.04	21.72	8.42	129.71
1867	1.56	0.80	0.48	1.20	11.88	8,85	16.03	19.82	5.35	20.50			
1868	1.17	2.77	2.18	0.87	7.24	18.11	20.60	12.50	16.16	13.13	21.58	3.72	120.03
1869	0.83	0.77	0.49	5.04	6.72	10.66	18.22	14.02	8.98	14.82	24.13	10.10	114.78
1870	4.30	3.33	4.95	6.46	20.95	12.48	15.60	16.35	6.74	11.21	32.42	14.85	149.64
1871	15.42	0.53	0.05	1.52	1.63	7.70	23.27	11.56	8.00	12.58	12.38	4.94	99.58
1872	3.57	0.75	0.83	1.30	21.43	22.00	19.90	19.97	16.20	30.32	19.11	13.12	168.50
1873	6.33	0.25	0.13	2.18	3.92	13.20	12.50	10.69	10.91	14.30	11.77	0.94	87.12
1874	5.33	1.34	3.94	18.02	8.92	15.87	13.62	17.28	8.22	16.65	20.62	7.89	137.70
1881			1.08	2, 52	10.04	15. 28	12.24	6.46	6.30	12, 91	22.13	10.35	
1882	1.65	1.10	1.69	1.73	13.23	18.90	19.10	13.94	10.63	14.96	22.09	5.08	124.10
1883	1.85	0.47	0.55	1.77	11.85	10.08	13.39	25.43	11.14	16.77	11.10	10.94	115.34
1884	3.39	0.39	0.39	4.33	10.16	10.32	15.59	13. 27	9.37	8.66	7.05	3.62	86.54
1885	0.87	0.59	0.55	1.34	7.91	16.61	22.99	20.32	17.44	7.99	24.17	25.51	146, 29
1886	2.13	5.00	9.17	1.58	13.15	16.38	11.10	12.20	7.52	14.33	21.89	22.72	137.17
1887	2.01	0.67	0.47	10.63	10.28	16.50	17.05	16.89	15.63	19.61	31.81	13.33	154.88
1888	0.63	1,58	1.26										
1889													
1890	7.24	1.02	2.01	2.99	9.76	17.24	10.24	20.51	22.99	21.77	19.49	19.06	154. 32
1891	2.52	0.51	1.50	0.51	23,00	7.99	14.02	15.98	17.48	17.48	19.49	4.25	124.73
1892	0.98	2.01	3.98	5.00	18.03	16.97	21.77	15.98	16.26	6, 69	26.30	11.30	145. 27
1893	1.73	3, 82	1.81	8.07	The state of the s	12.32	11.50	15.12	9.92	12, 28	17.80	30.94	131.89

Mean rainfall on basin, 129.25, 109.13, 120.97, or 116.60 inches.

Monthly rainfall at Colon-Continued.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1894	5, 35	1.65	0.35	2.16	9.85	12.24	19.10	23.03	18.78	12.40	23.66	25.12	153.69
1895	3.86	1.89	2.09	21.73	16.77	9. 25	17.09	14.13	12.09	16.46	20.47	15, 71	151.54
1896	4.02	1.30	2.01	9.02	16.46	8.50	13.58	15.51	12.84	13.98	15.63	18.66	131.51
1897	3.42	0.04	0.28	3.74	16.34	18.82	14.06	17.24	17.20	5.83	22.16	18.90	138.08
1898	5.04	0.35	1.58	4.72	12.83	16.38	21.89	10.91	10.24	11.38	12.28	7.95	115.55
1899	6.93	6.49	1.26	0.43	13.90	6.41	27.68	14.80	16.55	15.04	14.49	9.04	133. 02
1900	6.06	0.33	1.06	0.75	12. 25	11.65	16.81	17.04	9.37	16.33	20.28	4.13	116.06
Mean	3.56	1.52	1.55	4, 42	12.27	13, 46	16.92	15.53	12.77	14.20	20,56	12.49	129. 25

Monthly rainfall at Bohio, in inches.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
				15.63	8.54	5.55		25. 51	13.35	17.05		
		3.07	8.11	18.54	14.10	15.83	25.20	17.48	26.02	19.57	22.05	
12.36	1.26	3.03	10.59	14.61	19.76	34.96	38.31	13.31	28.23	21.81	6.38	204. 61
9.37	4.49	3.28	1.10	10.35	14.80	17.76	12.99	8.90	19.33	10.43	6.18	118.98
7.06	0.48	1.04	2.89	7.42	18.40	17.79	14.02	15.40	18.43	24.98	4.02	131.93
9.60	2.08	2.60	5. 67	13.31	15.12	18.38	22.63	16.12	21.07	18.77	9.66	155, 01
	12.36 9.37 7.06	12.36 1.26 9.37 4.49 7.06 0.48	3.07 12.36 1.26 3.03 9.37 4.49 3.28 7.06 0.48 1.04									

Monthly rainfall at Gorgona, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896					9.02	6.81	5.16	8.98	13.35	10.94	14. 37		
1897		0.08		2.60	25.12	13.54	9.65	16.93	15.98	14.41	7.16	7.91	
1898	3.42	0.20	0.00	1.38	5.04	4.37	18.50	19.88		7.72	9.61	3.94	
1899	3.78	2.01	3.31									4.58	
1900	2.63	0.13	0.20	3.15	7.07	12.48	19.72	11.04	11.25	11.93			
Mean	3.28	0.60	1.17	2.38	11.56	9.30	13. 26	14.21	13.53	11.25	10.38	5.48	96.40

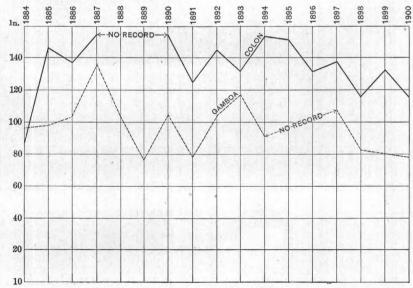


Fig. 235.—Comparative rainfall at Colon and Gamboa.

Monthly rainfall at Gamboa, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1881						10.63	12,40	9.17	10.39	11.06	12.95	4.76	
1882			0.51	1.50	15.47	6.26	10.12	9.88	11.81	8.15	11.81	1.38	
1883				2.60	9.68	11.02	6.54	15.94	4.13	10.04	7.01	6.30	
1884		0.71	0.28	6.46	6.18	13.35	9.62	16.50	10.55	22.36	6.18	2.20	
1885	0.20	0.20	0.00	1.38	11.06	10.35	9.06	15.51	16.10	9.33	13.23	11.06	97.48
1886	0.55	1.06	0.71	2.76	15.71	10.55	11.69	16.38	9.13	13.62	16.10	4.61	102.87
1887	2.20	0.08	0.28	6.85	11.02	19.45	14.02	19.17	11.50	14.88	24.06	16.28	136. 19
1888	0.12	0.63	0.35	1.26	20.47	11.93	3.27	10.24	12.28	9,57	16.18	16.34	102.64
1889	1.97	4.53	1.42	0.00	4.37	- 9.10	7.28	10.51	11.42	13.07	8.70	3.35	75.72
1890	4.06	0.35	2.36	3.03	13.27	11.65	10.43	15.35	8.90	21.41	9.92	4.29	105.03
1891	0.63	0.00	0.35	2.13	7.48	9.29	6.06	8.50	10.47	15.71	10.67	6.38	77.67
1892	1.10	0.67	2.56	4.72	16.81	8.54	13.98	14.33	13.74	11.10	10.24	6.58	104.37
1893	0.67	1.06	0.71	7.44	11,89	10.71	15.87	7.95	10.24	16.50	13.90	20.87	117.81
1894	1.46	0.16	0.04	1.34	10.94	8.78	10.08	8,42	15.16	15.28	10.67	8.27	90.60
1895													
1896					3.35	3.31	5.79						
1897		0.20	0.28	3.23	17.44	12.64	9.10	17.20	18.82	12.80	5. 91	8.62	
1898	2.76	0.12	0.00	1.42	5.32	4.65	18.43	20.16	4.10	8.70	14.57	2.40	82.60
1899	5.00	1.73	1,34	1.42	8.54	8.78	9.45	10.95	13.46	7.95	8.70	2.68	80.00
1900	1.01	0.16	0.13	3.21	6.76	12.15	13.45	8.92	9.24	12.11	10.67	0.79	78.60
Mean	1.67	0.78	0.71	2.99	10.88	10.17	10.35	13, 06	11. 19	12.98	11.74	7.06	93.58

Monthly rainfall at Bas Obispo, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1884	1.10	0.35	0.35	2.16	3.86	11.97	8.46	10.51	13.98	12.40	6.93	2.64	74. 71
1885	0.24	0.12	0.00	1.14	7.36	8.74	6.34	12.84	12.87	8.94	11.10	11.50	81.23
1886	0.83	0.87	0.87	1.69	17.44	12.91	9.02	8.27	10.20	9.37	15.63	3.90	91.00
1887	2.28	0.00	0.12	3.19	10.16	15.43	10.87	8.03	10.98	7.36	14.06	15.79	98. 27
1888	0.16	0.51	0.32	0.91	11.58	11.93	1.93	7.76	7.13	3.82	10.59	10.08	66. 72
1889	0.79	0.32	1.10	6.50	4.57	9.84	6.42	8.98	13.46	13.23	8.54	3.78	77.58
1890	4.53	0.12	2.56	2.56	13.07	14.96	9.88	12.16	13.03	4.80	6.54	7.95	92.16
1891	6.10	0.00	0.35	2.16	5.83	11.54	6, 10	7.76	12, 32	14.49	8.35	8.72	83.82
1892	0.79	0.63	2.56	4.76	15.16	10.51	13.10	11.93	17.36	10.28	11.02	6.97	105.07
1893	0.55	1.34	0.71	3.19	19.57	10.75	14.37	9.57	10.63	19.84	13.35	19.13	123,00
1894	1.97	0.32	0.20	1.38	11.89	10.00	10.59						
Mean	1.76	0.42	0.83	2.69	10.95	11.69	8, 83	9.78	12, 20	10.45	10.61	9.05	89. 26

Monthly rainfall at Culebra, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1883a				1.26	11.50	10.32		10.71	5.47			5.04	
1884	0.20	0.04	0.67	3.78			10.24	13, 62	8.70	10.12	11.18	1.46	
1885	0.28	0.00	0.00	1.61	15.39		4.'29	5.35	11.38	10.63	7.20		
1886	0.43	0.55	0.16	1.18	13.78	12.64	14.33	8.19	7.36	20.63	14.29	5.43	98.97
1887	3.15	0.00	0.04	3.50	7.91	9.96	6.10	8.74	7.64	9.65	12.13	7.95	76.77
1888	0.24	0.04	0.51	0.35	11.42	7.99	2.91	6.54	11.26	5.75	9.53	7.72	64. 25
1894									12.13	13.50	13.23		
1895		0.75											
Меап	0.86	0.23	0.28	1.95	12.00	10.23	7.57	8.86	9.13	11.71	11.26	5.52	79.60

^a Observations at Emperador.

Monthly rainfall at Panama, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1879	0.04	2.52	5.71	5.55	10.28	6.46	7. 91	7.24	9.02	9.80	19.21	0.98	84.78
1880	1.89	0.12	0.16	1.61	4.45	5.00	9.88	11.46	7.91	11.81	6.46	5.51	66.26
1881	0.16	0.16	0.35	3.23	10.35	13.78	7.20	4.49	8.94	9.68	9.72	2.48	70.55
1882	0.00	0.12	0.00	0.98	5.24	6.18	5.35	4.05	4.05	6.69	10.91	2.01	45.60
1894a						7.48	12.72	6.42	7.32	10.51	6.73	8.27	
1895a	1.38	0.08											
1899a									6.14	11.98	8.92	4.35	
1900a	0.76	0.00	0.00	2.24	11.21	8.91	15.81	5.99					
Mean	0.70	0,60	1.24	2.72	8.31	7.97	9.81	6.61	7.23	10.08	10.32	3. 93	69. 52

a Observations at La Boca.

Monthly rainfall at Naos, in inches.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1881											7.48	2.87	
1882	0.00	0.04	0.04	.94	4.53	5.08	1.61	1.14	1.14	2.72	5.04	2.84	25. 12
1883	0.59	0.00	0.00	1.93	4.45	2.56	5.47	5.51	4.64	4.25	7.24	3.11	39.76
1884	2.01	0.04	0.00	.94	4.84	4.17	4.65	2.99	5.71	8.31	8.62	1.34	43.62
1885	0.55	0.20	0.00	. 91	2.56	5.63	2.64	5.51	4.17	9.96	4.37	4.92	41.42
1886	0.00	0.28	1.81	1.92	5. 20	6.26	9.61	5.91	20.75	6.10	4.49	3.74	66.06
1887	0.79	0.04	0.04	2.36	5.24	9.88	4.06	6.69	6.97	7.05	8.82	5.59	57.52
1888	0.08	0.00	0.04	. 28	5.55	4.88	2.01	5.71	8.58	8.11	4.02	1.30	40.55
1889	0.00	0.00	0.91	4.41	5.79	5. 43							
Mean	0.50	0.08	0.35	1.71	4.77	5.49	4.29	4.78	7.42	6.64	6.26	3.21	45.50

THE HIGH PLAINS AND THEIR UTILIZATION

BY

WILLARD D. JOHNSON

(Conclusion of paper in Twenty-first Annual Report, Part IV)

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ERRATA.

Corrections of plate numbers should be made as follows:

For Pl. LV, opposite p. 638, read Pl. LI.

For Pl. LVII, opposite p. 640, read Pl. LII. For Pl. LVIII, opposite p. 644, read Pl. LIV.

For Pl. LIX, opposite p. 646, read Pl. LV.

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THE HIGH PLAINS AND THEIR UTILIZATION.*

By WILLARD D. JOHNSON.

RÉSUMÉ OF PRECEDING PAPER.

POSITION, CHARACTER, AND ORIGIN OF THE HIGH PLAINS.

The High Plains constitute a natural subdivision of the Great Plains area, forming a belt extending north and south midway of its slope. The belt is cut across by streams from the distant mountains on the west, in parallel system, wide apart. Its distinctive character is lost, to the northward, in south-central Nebraska. At the southern end, the Staked Plains of Texas constitute the largest individual plateau fragment.

Except for this cross dissection, the belt preserves, untouched by erosion, an original smooth surface once characteristic of the Great Plains as a whole. In a parallel belt or zone to the east, despite the universal sod covering there, the heavy precipitation of a humid climate has lowered the old surface by degradation, and left it, in the main, irregularly undulated. Here are the Prairies. Again, in a zone to the west, in the absence of sod covering (grass growing only in isolated tufts), even the light precipitation of an arid climate has been effective in lowering the old surface, leaving it, however, not undulated, but sharply and minutely cut up. This is the desert zone. The semiarid or subhumid belt of the High Plains lies between.

Thus, by reason of degradation on either side, the High Plains are in relief. Relatively to the horizontal extent of the individual tables the relief is inconsiderable, but is nevertheless emphasized by the striking contrast of these flat surfaces with contiguous uneven surfaces of degradation on the east and west. The High Plains are conspicuously uplands of survival. Yet their mass, to depths often of several hundred feet, is of unconsolidated silt, sand, and gravel. They are plateaus by virtue of their resistance to erosion; yet they are soft plateaus. Their survival has been due to the protective influence of a universal close-knit sod, to which a subhumid precipitation especially has given origin, and yet against which it is unequal, on a grade of 10 feet to a

^aBeing the conclusion of an unfinished paper on the High Plains and their utilization, by Willard D. Johnson, published in Twenty-first Ann. Rept. U. S. Geol. Survey, Part IV, 1899-1900.

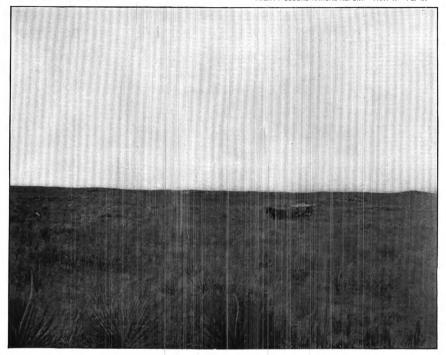
mile, to accomplish the first faint beginnings of erosion and the initiation of drainage. There is no run-off. Even heavy local downpours, which in the arid belt, by rapid concentration, would result in local floods and sharp channeling, are here rendered practically inert by the grass mat until disposed of through ground absorption and evaporation. The High Plains, in short, are held by their sod.

The original smooth plain, of which only this transverse belt remains unscarred, was alluvial—i. e., stream-built. It was spread, in substantially its present position as to elevation and inclination, by widely shifting, heavily loaded, and depositing streams from the mountains. Shifting deposition, burial, and plain building constitute the normal habit of desert streams. There is independent evidence that the climate then was more widely arid than now. Virtually the same mountain streams are at present cutting away and degrading where formerly they made broad fan-form deposits and built up. They are running in fixed courses and have excavated valleys.

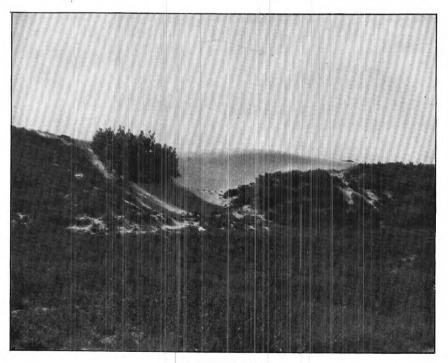
But relatively humid conditions, with valley cutting, not only followed, they preceded, the period of desert accumulation. An earlier topography of wide, shallow troughs and broad intervening ridges, cut in hard rock, was buried. In consequence, the alluvial covering, spread to a smooth surface, has varying depth to bed rock. Over considerable areas above the old valleys this depth exceeds 300 feet.

The geologic date of its building was late Tertiary. In consequence, the sandy and gravelly mass is sometimes referred to as the "Tertiary gravels." It is believed by many to be lacustrine in origin, the assumption being made of deformation of the Great Plains area, first, lowering it from an inclined position, which it must have had during the early erosion, to a level one, and, finally, after the assumed accumulation of broad lake deposits, restoring it to the present inclination. But the writer regards as unmistakable the evidences of graded construction, by desert-stream deposition, upon substantially the same slope as at present.

Among these evidences are the patchy character, the overlapping and the rapid thinning and thickening of the beds of the finer materials, and the prevailing coarseness and channel-form occurrence of the gravel at all levels. With lake deposits, gravel of any size is a phenomenon only of the shore line, and its distribution there will be in symmetrical lines. In the case of the Plains the sources of derivation having been wholly or at least mainly from the one side—that of the Rocky Mountains—gravel should be disposed in long curving bands, parallel in general to that side. Instead, it occurs unmistakably in irregular west-east courses, and at all depths within the mass. This fact is brought out by comparison, on the one hand, of well sections, where wells are closely grouped, and, on the other, of natural sections, where, at the canyon junctions of spring-stream tributaries with the



A. SAND-HILL TRACT.



B. A SAND HILL.

traversing mountain streams, such sections are presented at right angles. As to the coarseness of the gravel, while individual specimens as large as cobbles are to be found at all depths, even so far out from original sources of supply as the central High Plains region, irregular channel-form beds, often traceable for miles on eastward courses, are made up in large part of egg-size material.

The present valleys as a rule are not cut down to bed rock, though the Canadian Valley is, full length. In some cases unconsolidated material is still deep beneath them. This is the condition in the Arkansas Valley at Garden, Kans. Here and for considerable stretches along the floors of several other streams there remains a notable depth of such material, varying in texture from clay to coarse gravel.

NONIRRIGABLE UPLANDS; IRRIGABLE VALLEYS.

The subhumid precipitation is insufficient for agriculture without irrigation and the only possible agricultural lands of the High Plains belt lie within the valleys, where small patches here and there are irrigable. The most evenly tillable area of the Great Plains lies within the High Plains, yet it is as a body nonagricultural, because a supply of water for irrigation is not obtainable. Upon the uplands proper irrigation on a large scale is impossible, and even where it is possible on a small scale it is economically impracticable. All apparent sources of supply considered, there is not water enough for appreciable effect in general and permanent reclamation, and what small supply there is in fact is not economically available.

The seemingly possible sources of supply are (1) the run-off from the region to the west, either as perennial streams or as flood flow, stored; (2) artesian waters of mountain origin, and (3) the ground water underlying the High Plains themselves.

The streams from the relatively small area in the mountains which has eastward drainage are not great rivers, like those, for example, from the Himalayas, which irrigate the arid plains of India, but their volume is insufficient for the needs even of the desert zone which they have first to cross. Already the Arkansas, which some years ago was extensively diverted for irrigation in the valley bottom at Garden, has become dry there in the crop-growing season, because of large increase of the irrigated area to the westward, in Colorado. To prevent losses incident to long transportation, even with the fullest practicable storage, there will inevitably be further contraction and concentration upon more compact areas nearer to the sources of supply, where available lands are abundant.

As to artesian waters, there is no instance, among many experimental deep borings upon the High Plains, of rise to the upland surface. Furthermore, the total volume of the possible artesian supply, at its source, is relatively insignificant.

THE GROUND WATER.

Ground water at greater or less depth is a universal pnenomenon. All the materials of the earth's crust—the hard rocks in great variety and their loose covering of disintegration products alike—are permeable to water; and virtually the whole is saturated with water. There is even an excess over saturation, as indicated by the oceans.

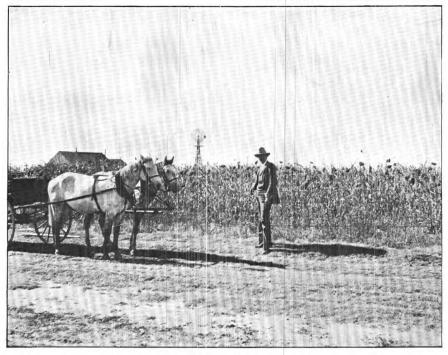
Except for crustal unevenness, which leaves it ponded in confluent basins, this excess would form a continuous ocean envelope. Wherever it does extend, however, the ocean surface conforms very nearly to the ideal spheroidal figure of the earth; and that figure would in effect be completed by continuation of the ocean level as a level of saturation, or universal water plane, beneath all continental and island masses, if it were not for the endless round of evaporation and precipitation by which water is continually lifted from ocean surfaces to be showered upon land surfaces. This water of precipitation in large part runs off again to the sea; a part also is evaporated, either directly or out of the soil; yet some portion penetrates downward to form ground water.

But ground water is not permanently stored. From a definite water plane, or upper level of saturation, it extends indefinitely downward, through practically all of the earth's crust, continually sinking toward sea level—or toward the plane of the sea extended beneath land masses—and continually renewed by ground absorption of some portion of the surface precipitation. Its rate of sinking annually is measured by the depth merely of this fractional part of the annual precipitation. Obviously the downward movement is very slow, much slower than the mean rate of replenishment from precipitation, and at rates varying as greatly as the permeability of the various rock materials and their loose covering varies. But the possibilities of motion are not so great as to admit of appreciable yield to wells under the low heads produced by ordinary pumping. As a rule it is only from loose or unconsolidated material covering "bed rock" that ground water yields appreciably to pumping. To the well maker, therefore, it is only in this cover that ground water occurs at all.

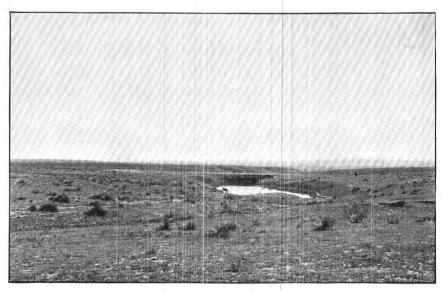
WATER IN HARD AND IN SOFT ROCKS.

A bed of open-textured sandstone may have an actual water content equal, per unit of mass, to that of a gravel bed. Though its interstices are very much smaller, they are correspondingly more numerous. But because they are so much smaller the rate of delivery from the sandstone is so slow as to be imperceptible at ordinary pumping heads,

^aThe first part of this paper, in the Twenty-first Annual Report of the United States Geological Survey, pp. 601-741, closed with an uncompleted discussion of the water resources of the High Plains, Surface waters (the mountain streams) and artesian waters had been considered. The consideration of the third possible source of water supply, the ground water, is now undertaken.



A. "DRY FARMING."



B. A "TANK."

since the frictional resistance to flow increases very rapidly with diminution in the size of openings.

To secure a delivery from the sandstone equal to that from gravel an enormously increased head pressure would be necessary. Such pressures are encountered naturally under so-called artesian conditions, where the influence of a distant very high head is felt in an exceptionally porous rock sheet, extended beneath a relatively impervious sheet. A deep boring, then, opening a way of escape, develops the fact that water may nevertheless be present in hard rock in large volume. Yet the same rock under the pressure of only a few feet created by pumping in the ordinary well would have virtually no delivery and would appear not to be water bearing at all.

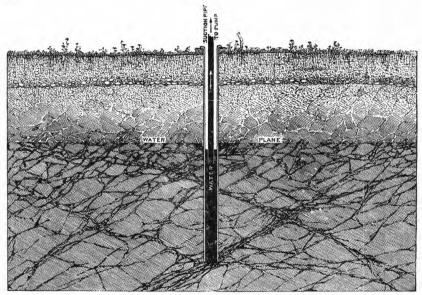


Fig. 236,-Ground water in closely fractured rock.

Water of free delivery is to be encountered in hard rock, however, in fissures as well as where artesian conditions are present, but wells thus supplied are less frequently of value where the fissures are large and encountered singly than where they are small and numerous, and in closely fractured rock the condition approximates to that in loose ground. Indeed, loose ground often grades into underlying sound rock through a disintegration zone of this sort.

That the presence of water in bed rock below loose ground is ever apparent at all, though saturation continues through all rocks to indefinite depths, is due to the fact that the many different varieties of rocks show occasional great differences as to permeability, and that occasionally also they are penetrated by fissure openings. Since among these scattered occurrences within the apparently barren zone there

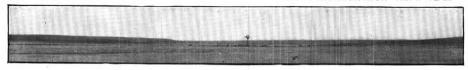
are different rates of movement, or different head pressures manifested, they are generally regarded as disconnected and independent in origin. It is not recognized that they constitute erratic drainage currents merely, along lines of relatively slight resistance, within a universally pervading water body, itself continually sinking at an exceedingly slow rate toward sea level. Hence the generally accepted term "underground waters."

In loose ground, however, the presence of water is everywhere strikingly manifest, though its volume there, per unit of ground mass, may be but little greater than in bed rock. It is obviously a continuous water body, from its definitely marked surface—the water plane—down to the bed-rock "floor." Hence, in this case, the term "ground water."

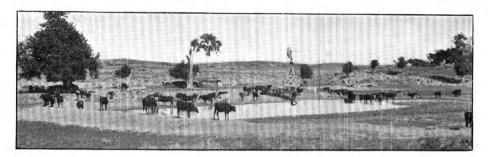
GROUND WATER IN ARID LANDS.

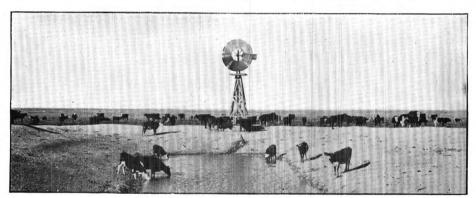
It is only in arid lands, as a rule, that ground water—to use the term in this restricted sense—has volume and unbroken extension sufficient to make of it an impressive phenomenon. In humid lands, coastal plains and valley bottoms excepted, it has light depth and is discontinuous, for humid lands are regions of degradation. The tendency of stream work there is to cut away and remove, not to cover. Bed rock is laid bare, except as, in its progress, the very uneven work of erosion admits, here and there, of shallow accumulations of erosion products, resulting in some depth of loose ground. Arid lands, on the other hand, are normally regions of aggradation. Their tracts of exceptional elevation aside, they are regions of universal burial. burial, accomplished by shifting streams striving always for graded profiles, results in plains. The water plane intersects the ground surface only where the latter has marked topographic irregularity. Hence, characteristically, in arid lands, it has broad and uninterrupted extension, closely paralleling the surface. At the same time, since the loose covering upon bed rock is deep, the ground water has notable volume.

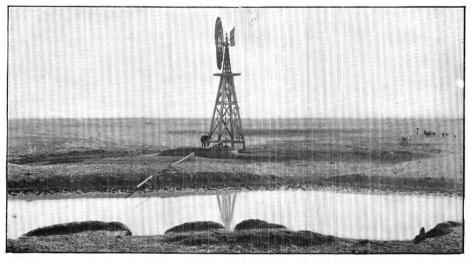
The depth from the ground surface to the water plane in these regions of light precipitation is not necessarily great. It will be slight in proportion as the gently graded surface is extensive and shows no interruption, by channeling, of its cycle of aggradation or smooth building. With indefinite extension the depth to water would be only such as would result from capillary drying. The water plane is always a mounded surface dipping toward topographic depressions which drain off. The mounding will be gentle in proportion as these depressions are far apart. Where, on a desert plain, they are widely separated, the rate of loss by lateral movement, except in limited areas of extreme dryness, will be slower than the rate of resupply from the local precipitation together with the downward-soaking contribution from the silt-burdened streams which build the plain.











DEEP-WELL STOCK-WATERING PLANTS ON UPLANDS.

WATER LEVEL BENEATH THE GREAT PLAINS.

As already noted, it is rarely the case that plain building in arid lands continues long uninterrupted either by deformation or by change of climate. The broad aggradation surface is the characteristic, if not the dominant, feature of desert topography; it is seldom, however, without record, at least faintly made, of vertical shifting of the level of equilibrium between its antagonistic aggrading and degrading forces—a record essentially of transecting valleys, commonly, however, so widened and shallow that the more conspicuous forms are the intervalley plateaus. Usually the relief is so faint that valleys and plateaus alike lie above ground-water level. In such case the water plane is not domed beneath the plateau areas, but, on the contrary, is broadly ridged beneath the valleys, since from the intermittent flow along their axes it is built up.

As noted also, the alluvial covering of the Great Plains as it existed in Tertiary time has, in the comparatively recent past, suffered a reversal of its shaping forces from construction to degradation. vast aggraded surface has been sharply and, in the most part, deeply trenched across by the mountain streams which formerly had spread and deposited uniformly, maintaining it against the erosive tendency of its local precipitation. Suffering now, however, from local attack, unopposed, in both an arid zone bordering the mountains and a humid zone on the east, but protected over the intervening subhumid zone by a covering of sod, the original smooth surface, as we have seen, has been almost completely destroyed, except within this intervening zone of the High Plains. Within the two eroded zones, the water plane presents a surface of complex grades. Beneath the High Plains it has virtually horizontal extension for great distances. Even here, however, it does not have uninterrupted extension throughout the length of the belt; each of the several larger streams from the mountains, which have cut deep transecting valleys, have locally drained it down. Though the mountain run-off does not always reach so far as the High Plains, its valleys nevertheless have feebly perennial flow across this region, because of constant feeding from the ground water. Beneath the intervalley plateaus the water plane lies higher than the valley Within comparatively narrow marginal zones, however, it dips toward them. It dips also as it approaches the limiting escarp-Except that, as a rule, there is no westward dip, the ment on the east. ground-water surface in each instance may be said to be faintly domed. In the case of the Staked Plains Plateau—the most extensive of these great remnantal tables, where the Pecos River turns at a right angle from the usual eastward course and follows the mountain foot in a deep valley—there is a limiting escarpment on the west also, and the water plane, completely domed, lies above running streams on every side, depleted by them rather than supplied.

237.—West-east section of Staked Plains plateau, showing ground-water level above that of limiting river valleys.

It is thus because the old aggradation surface is dissected and its natural ground water drawn down, and not primarily because the precipitation is light, that the water level beneath the High Plains lies comparatively deep. For these plateaus of alluvial material its depth is fixed on the one hand by that of valley dissection and on the other by the rate of supply from precipitation. If the old Tertiary plain had not suffered a downward shifting of its stream grades, the depth to water would be comparatively slight despite the semidesert precipitation.

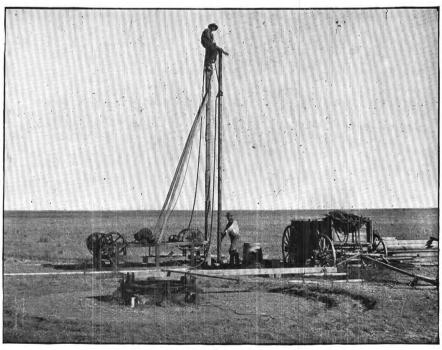
For example, the great wash plain of the Sonora River, in northwestern Mexico, extending fanshape for 75 miles from its canvon opening at the foot of the Sierra Madre to the Gulf of California, has a very arid climate. The river is intermittent from a point a short distance out upon the plain. Beyond this point the intervals of no flow continue through the greater part of the year. During its period of flood the stream, immediately after leaving the mountains, takes long, swinging, and subdividing courses, but probably not once in a decade does one of these reach through to the arc-form shore of the sandy waste at the gulf. Yet the whole area of perhaps 2,000 square miles, with uniform and gentle inclination seaward, is underlain by water at easy pumping depth. well within a short distance of the coast reaches water at a depth of 8 feet-still a little above sea level and fresh. The flat expanses of the Mississippi Valley have little advantage over this desert tract as regards accessibility to water in the ground.

But in this case, unlike that of the High Plains, the surface is at grade; there are no dissecting valleys. Should uplift, however, cause the Sonora River to deeply trench the plain, the ground-water level would sink-not correspondingly, but to a considerable depth-and would acquire a stronger inclination from either side toward the river than at present it has seaward. Under this changed condition of valley dissection and drainage the desert precipitation alone, unlike that of a humid region, would not be able to hold the water level

close to the ground surface. The river, then confined to a single



A.



B

DEEP-WELL MAKING ON UPLANDS.

channel and sunk into the plain, would no longer add to the ground-water supply, but, on the contrary, while losing nothing except by evaporation, would be augmented from the ground water and made perennial.

In like manner it is because of the relatively deep erosion by traversing streams from the mountains, which have blocked out the subhumid belt into plateaus, that the ground-water level of the High Plains lies below economical pumping reach—that is, economical for operations, such as irrigation, calling for water in large volume. If the limit from this point of view be taken to be 15 feet, the average depth to water, even the minimum depth, is greatly in excess of it. The water plane upon the uplands is seldom to be reached within a depth of 50 feet, and upon the Staked Plains, beneath considerable areas, it may lie as deep even as 200 feet.

But while the depth through dry ground to water is considerable, it is notably less as a rule than the depth through saturated ground to bed rock. The ground water of the High Plains, therefore, has large volume, as well as unbroken and nearly level extension of its upper surface for great distances. It is in consequence an impressive phenomenon.

Its volume is less in marked degree, however, than if the climate were humid; beneath plateau areas of such dimensions its level in that event would lie close to the ground surface. By transecting valleys, relatively shallow and far apart, it would not be materially drawn down. It would be an even more impressive phenomenon than the ground water of the High Plains presents. But humid lands above base level do not afford opportunity for such broadly extended and deep accumulations of water in the ground, since they are regions of degradation, not of burial. Primarily, in fact, the phenomenal feature here is the mantle of "Tertiary gravels." Though the quantity of contained water is large absolutely, it is small in comparison with the possible content.

ORIGIN OF THE GROUND WATER OF THE HIGH PLAINS.

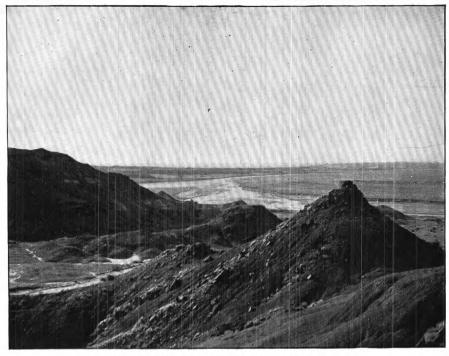
There is a prevalent belief that means will be devised by which, acre for acre, this great accumulation of water within the ground may be put to irrigation use upon the surface. At the same time a notion, finding expression in the generally accepted term "underflow" and involving serious error so far as contemplated results are concerned, prevails, also, to the effect that the ground water has lateral motion fairly comparable to that of surface waters—i. e., that it is continually renewed at such rate that it would be inexhaustible as a supply for irrigation.

The term "flow," used in this connection, is as inappropriate as the term "velocity" would be if applied to the motion of the hands of a

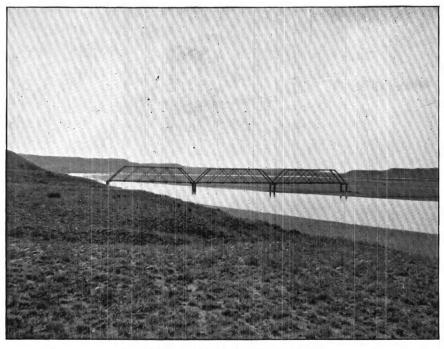
watch. That in some degree there is drainage off must be admitted, since water saturating porous material, however close textured, can not be conceived as remaining permanently at rest, with its surface at a grade. And since the sloping surface is maintained—i. e., the water plane holds virtually a stable position—there must be resupply at a rate equal to that of the loss by drainage.

The serious error here involved rests upon the assumption, which is necessitated, of a rate of resupply beyond the possibilities of even the most humid climate. Even though artesian sources be appealed to (and all rising subterranean waters are essentially artesian), ground water everywhere must be conceded to have its ultimate origin in precipitation. The water of saturation in the land masses is an outcome of the endless process by which free water, lifted from the sea and transported in the atmosphere, is showered again upon the land. The volume of water in loose ground everywhere is immeasurably greater than that of the surface run-off. The latter is virtually but the surplus over saturation. On the assumption of symmetrically domed land masses, there would be no feeding from the ground water into topographic depressions in the effort to attain uniformity of water-plane grade. There would be no spring-fed streams. In such case, run-off would be strictly a surplus; saturation would extend and be maintained close to the surface.

The volume of all the streams of a continental area is insignificant as compared with the volume of the water held in loose ground beneath. Yet the direct contribution from precipitation to streams is much larger as a rule than to the ground water. Obviously, therefore, the great volume of the latter is not to be regarded as other than the storage outcome of slow accumulation. Porous saturated ground is in effect a reservoir—filled to the brim, indeed—but receiving and discharging only a diminutive stream. Its contained water, as compared with that of streams upon the surface, is imprisoned and virtually at Such movement as it has, against the enormous frictional resistance of the ground particles, either bodily or in what may be termed its currents, following gravel courses, must be very slow. The volume of the loss which the whole body of the ground water sustains annually can be no greater than that of the contribution to it annually from precipitation. And since the absorbed portion of the precipitation is such an insignificant quantity comparatively, the rate of groundwater drainage movement must be proportionately slow. This absorbed portion, under average climatic conditions, can be a matter of but a few inches. Over the Staked Plains the mean annual fall is about 15 inches. There is reason to believe that, for that area as a whole, not more than 3 or 4 inches, first and last, escapes evaporation and makes contribution to the ground water. Measured as ground water-filling the ground pores only-its depth would not exceed a foot.



A. CANADIAN RIVER IN NORMAL FLOW.



 ${\it B.}$ CANADIAN VALLEY AFTER HEAVY FLOOD.

Thus, acre for acre, to withdraw even so little as 3 or 4 inches for application in surface irrigation would leave the ground water unreplenished and result in increase of the pumping lift by a foot in a single year. Even on the assumption that lifting from the present depths would be economically practicable, the withdrawal of an amount sufficient for irrigation would rapidly result in exhaustion of the stored supply.

It might be objected that generalizations as to continental areas do not necessarily apply to limited areas, such as that of the great débris plain of the Sonora River. There the ground water, lying close to the surface, in a desert climate, obviously, in large part, is supplied from the stream to which the plain owes its origin. It is not an accumulation from local precipitation. One of the misconceptions involved in the popular notion as to the origin of the Plains ground water is that it, in like manner, comes from the mountains. But, as we have seen, the thick mass of the Tertiary gravels, though spread originally as a unit, by a parallel system of fan-building rivers, is now above grade and much eroded—with large fragmentary areas in a central zone, however, left undisturbed. Here the mountain streams, sunk in transecting valleys, no longer serve, like the Sonora River, to build the ground water to a relatively high level; on the contrary, they drain it down, even below the level at which precipitation alone would sustain it. The ground water of these fragmentary tables of the old plain has its origin in the precipitation upon their extensive surfaces alone.

There is a single local exception to this rule of stream depletion. The Arkansas Valley near Garden is shallow, though wide. The direction of slope of the ground water here is southeastward, toward the "breaks" and deeper valleys in that direction; and, for a few miles, the river, on a more nearly eastward course, runs on a level with the ground-water surface, though at an angle across its slope, so that the dip of the water plane is toward it on the north and away from it on the south. From the mountains to this point, however, the dip on each side of the valley is streamward; to the east, for a considerable distance, it is on each side away; that is, to the westward the river runs below the upland level of the ground water. The ground water there contributes to its flow. To the eastward it runs above, and is depleted in turn. In the neighborhood of Garden the river receives contribution on the one side, and on the other loses.

The Arkansas, along most of its course across the High Plains, has changed its habit, from degradation back again to building. There are topographic evidences to this effect for 50 miles eastward from Dodge. There is strong suggestion that by fan construction in the High Plains region it has lifted itself out of a former deep valley and shifted to another course, the deep valley thus abandoned being that now occupied by the feeble Cimarron. In other transecting valleys terracing

is suggestive of vertical shiftings of the level of stream equilibrium; but there is no other instance, so far as the writer is aware, of valley abandonment by this process.

Since the plateau areas north of the Staked Plains are not separated from the arid zone on the west by an escarpment facing in that direction, it necessarily follows that their ground water is to some extent replenished from both surface and underground drainage passing eastward. On the other hand, those valleys extended from that zone which, within the High Plains belt, are sunk below the level of its

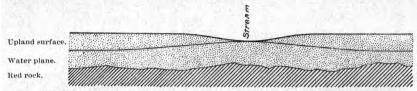


Fig. 238.-Mountain stream of perennial flow contributing to Plains ground water.

ground water, have doubtless, by their drainage effects, more than offset this small gain.

A stream from a mountainous area may have perennial extension for some distance out upon a desert, though lying above the general ground-water level there. Immediately beneath, however, the ground water will be ridged, or, in cross section, mounded, to meet it, as shown in fig. 238.

As before stated, the perennial stream normally lies below the general level of the ground water, and is persistent during intervals between storms for the reason that it then receives ground-water contribution. With many streams no exception is to be made to this

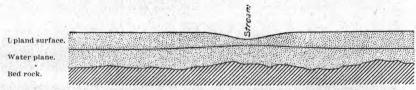
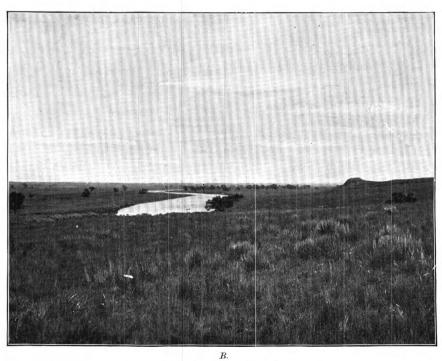


Fig. 239.—Mountain stream of intermittent flow contributing to Plains ground water.

rule; they are spring-fed throughout, without flood flow of importance. The Cimarron, in southwestern Kansas, is an illustration in point; flood flow in the upper branchings of its canyon, which has origin wholly upon the Plains in the arid zone, rarely reaches so far; and no flood flow of consequence, as we have seen, originates within the zone of the High Plains. But partial exception at least is to be made, in arid lands, of those streams which, spring-fed in relatively large headwater regions, have perennial extension into regions of ground absorption. While such streams are not thus locally perennial because of local contribution from the ground water, they neverthe-



A.



BEAVER RIVER IN FLOOD.

less invariably lie in contact with it, though above its general level, and because, locally, they build it up. Smaller mountain streams, which become intermittent tributaries to the larger before reaching the High Plains, make contribution to the ground water without lifting it into contact, though mounding it, as in fig. 239. This mound, or ridge, following the stream course, rises and subsides again after each

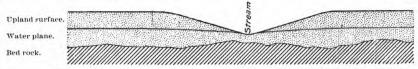


Fig. 240.-Mountain stream of perennial flow draining Plains ground water.

period of flow, and in subsiding some small increment of height is made to the general ground-water level.

But none of these valleys lying above the ground water have extension eastward so far as the High Plains. The Arkansas for a short distance near Garden, as we have seen, contributes to the ground water on the one side, but receives drainage from it on the other. There is,

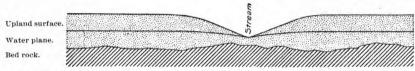


Fig. 241.—Mountain stream of intermittent flow made perennial by contribution from Plains ground water.

however, no other instance on the High Plains of a feeding supply from streams, either perennial or otherwise, which have origin in the mountains. These streams all run below the general ground-water level, drawing it down. Either they have perennial flow throughout, as in fig. 240, or, having intermittent flow originally, they become perennial by ground-water contribution, as in figs. 241 and 242. Of the latter class a special case, illustrated in fig. 324, is presented by

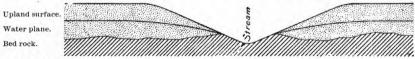


Fig. 242.—Mountain stream, either perennial or intermittent, sunk into Plains bed rock, spring-fed along base of Tertiary.

those streams (either perennial or intermittent originally, but become perennial at last by reason of ground-water feeding) which receive contribution along "spring lines," above their valley bottoms on either hand, marking the contact of the Tertiary with its bed-rock floor.

A stream like the Arkansas in the neighborhood of Garden, which goes dry only during short periods annually, will show water during these periods within a few inches beneath its sandy bed. In the hol-

lows of this bed pools may form, and these pools may, here and there, have feeble rivulet connections. They continue to hold water despite evaporation, obviously because they are continually resupplied from beneath, maintaining the water-plane level. In a mountain canyon, where the gravel bed not only is shallow but has no greater width than the stream at its flood stage, if the periods of no flow be very brief, there will be presented the same phenomenon of water just beneath the surface. It is owing to this fact that the term "underflow" has come into use. In such connection the expression is not misleading, though involving an exaggeration. On much steeper grades, and in coarse material, there is in fact down-grade movement at a measurable rate. The term at first was borrowed to apply to the water found in comparative abundance beneath the broad "sand-wash" floors of the Arkansas and the Platte during their dry periods. wells sunk upon the gently rising valley slopes at increasing distances back from the stream, and finally upon the uplands, disclose the presence of water universally extended at apparently the same elevation as in the valleys. It was sometime later that careful leveling brought out the fact that this elevation increased, at first somewhat rapidly and then gradually, toward the plateau interiors. As wells at the outset were not tubular and deep, but of the dug variety, penetrating only 3 or 4 feet into wet ground, the term "sheet water," or "sheet flow," rather than "underflow," was first employed. The ground water was assumed to be the product of widely extended seepage from When in the sinking of deep tubular wells in search of artesian waters it was found to continue downward, with the same freedom of yield to pumping, through a great thickness of loose material, it was assumed to have origin at points remote and indefinite. This view naturally resulted from the widely prevalent belief that the whole mass had motion at a rate comparable to that of surface waters on similar grades. Among the indications appealed to in support of it there are none which bear examination. While it is true that there is motion of the whole in some degree, it is accomplished mainly through the gravel courses, and, since the gravel courses make up but a small part of the Tertiary mass, this current motion through them must be relatively rapid. As may be experimentally shown, however, it is in fact inappreciably slow. The indications referred to consist in visible motion in dug wells during the course of excavation after the water level has been reached. In the writer's experience these are due invariably to unequal rates of response to the local head induced by pumping, where the excavation, at a single point, has cut into a bed of coarse gravel.

That the source of the ground water is the local precipitation is obviously true in the case at least of the plateau mass of the Staked Plains, where, as we have seen, the ground-water level lies high above

WILD-HAY BOTTOM IN A SPRING-STREAM VALLEY.

limiting valleys on all sides. And since the Staked Plains plateau constitutes much the largest unit among the uneroded upland areas it is reasonably clear that this must be essentially true of the whole. not the volume of the ground water which is the difficulty, but the assumption of an appreciable rate of motion. The volume contained within the Staked Plains table is equivalent to a depth of 25 feet of free water covering the whole. Regarded as a stream, and this idea is involved in the term "underflow," having uniformly this unusual depth, it would be 300 miles in breadth, and, assuming the barely perceptible rate of motion of a foot a minute, it would advance the average width of the Staked Plains in a year so that over 25,000 square miles a depth of 25 feet of water would be renewed annually. It is clear that the ground water is virtually imprisoned, and that upon the High Plains its mean annual depth of renewal (which gives a comparative measure of such motion as it has) is no more than a fractional part of the semidesert precipitation.

It is not to be assumed that contribution of even this small amount is made uniformly over the whole. In proportion as fine material makes up the body of any alluvial mass it will have the larger area of exposure at the surface. Concentration of standing water in the numerous basins, by diminishing evaporation, increases absorption; but the sand and gravel exposures constitute probably the principal areas of intake. These would be relatively small in their sum, especially since the old plain, abandoned by its continually resurfacing streams, has acquired, as a result of decay in place, a nearly universal "adobe" covering; but their area is increased by drifting sand, which here and there occupies considerable tracts. Perhaps one-tenth of the total surface of the High Plains is thus covered. The actual drifting that is, the rate of travel in the direction taken by the prevailing wind—probably is very slow as compared with that in truly arid lands, for grass forms a protecting cover here also; but these tracts have the characteristic ridge-and-hollow topography, nevertheless. textured character of the material (the carpet of grass of the tall varieties peculiar to sandy ground affording both shade and wind protection), together with the pitted character of its surface, must so reduce evaporation that nearly the whole, rather than only a small fractional part, of the annual fall becomes absorbed. There is hard ground beneath (the drifting sand merely rests upon the adobe surface, as deep wind work occasionally reveals), but the superficially absorbed water is held long in contact with it.

As a result of such broad areal irregularity in the depth of the annual increment to the ground water, the water plane should be irregularly, though broadly and faintly, undulated. The upland flats, so called, are not strictly level, even across the direction of their normal slope. Long lines of instrumental leveling, far exceeding the

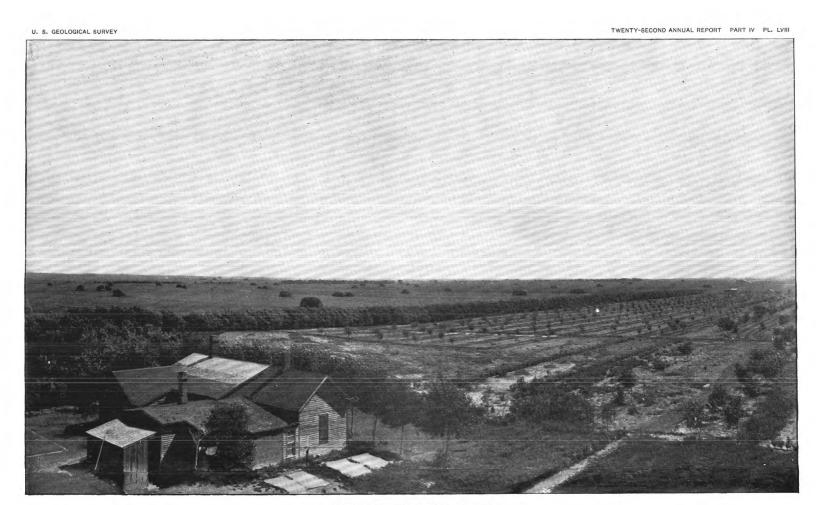
reach of vision, often show considerable variation in elevation. This apparent warping may be in part original. Much of it, however, as we have seen, is probably due to uneven settlement. Variation in the depth to water upon the uplands, even on the assumption of a smoothly sloping water plane, is therefore to be expected, but the water plane itself, independent of the surface undulations, is out of level also. There is actual range of variation amounting sometimes to as much as 150 feet, and this at distances apart not greater than 50 miles.

Summing up, then, for the ground water, it lies much too deep to be economically available for irrigation. This fact should be obvious, in view of the experience in irrigation from wells on the low bottomland benches of the valleys, especially the valley of the Arkansas, at Garden, in western Kansas. From such experience it has been made plain that, even upon bottom lands, it is only upon areas which are exceptionally "shallow to water" where such irrigation pays. Moreover, it has been amply and repeatedly demonstrated, by actual trial, that irrigation upon the uplands is impracticable. Though the ground water has large volume, since the depth of loose ground in which it has been accumulated is great, it has origin solely in the local precipitation of but 15 inches annually. A fraction only of the precipitation is contributed to the ground water, in replenishment of its gradual drainage Only a fraction, again, of this insignificant depth of annual increment would be available for general irrigation. Thus, aside from the insuperable difficulty, from a practical point of view, presented by the high pumping lift, the annual application at the surface, acre for acre, of a foot or more of water, in irrigation, would result in lowering the level of the ground water at the rate of 3 feet or more annually, and in early exhaustion of the stored supply.

SUMMARY OF WATER RESOURCES.

The seemingly possible sources of supply for irrigation of the High Plains are three, namely, the mountain streams, artesian waters, and the ground water.

For the best economic result upon the arid plains as a whole, lands nearest the mountains should first be served. With complete storage of the surface run-off from that area in the mountains which has drainage eastward, the supply would still be insufficient to reclaim the total of fertile, tillable, and readily accessible lands lying between the mountains and the High Plains. Disregarding the claims of this intervening zone, and not taking into account the heavy loss, amounting to the larger part of the whole, which must result from such long transportation, this supply would be sufficient for only a small fraction of the High Plains themselves. The streams which extend from the mountains eastward are not large rivers; the area in



IRRIGATION IN CIMARRON VALLEY.



the mountains which they drain—their catchment area—is small, and the precipitation there is heavy only within the relatively insignificant tracts occupied by the mountain crests.

The intake areas of the possible artesian waters beneath the High Plains are merely scattered patches within the catchment areas of the mountain streams. Because grades there are steep and bed rock is but lightly covered with loose material, much the larger portion of the precipitation is contributed to run-off. Of the small portion absorbed, but a fractional part, in turn, finds its way into artesian beds. An artesian bed can not be made to yield to the full, at the surface, the comparatively feeble volume of what may be termed its stream. The possible artesian supply for the High Plains, therefore, must be inconsiderable as compared with the volume of the mountain run-off; and this run-off, it appears, even if available, would be notably insufficient.

The ground water of the central plateau masses lies much below the present economical pumping limit in irrigation. It has large volume, but it is a stored accumulation from the local precipitation, which does not exceed a mean, for the High Plains as a whole, of 15 inches annually. Its annual increment from this source, which compensates its loss by drainage seaward, thus maintaining a stable water plane, can be at best but a few inches. The draft for general irrigation would need to be at a rate considerably less than this small rate of replenishment, to avoid serious lowering of the water plane, and such a very limited supply, even if obtained at no expense for lifting, would be of no material benefit in irrigation.

Against the High Plains, then, the absolute verdict must be that they are nonirrigable. Compared with the volume of water required, the amounts available from all sources are insignificant. There are, therefore, no means by which this central upland region may have its insufficient precipitation pieced out and be reclaimed for general agriculture.

UTILIZATION OF UPLANDS.

In showing thus in detail that for reclamation of the High Plains to agriculture general irrigation would be necessary, but that this is not possible and that they are therefore to be rated as hopelessly nonagricultural, the negative side of the question of utilization has been fully developed and emphasized.

In view of the awakened interest in the arid region it is important that it should be emphasized, for the possibilities of irrigation are not unlimited. The arid West can not thus be reclaimed entire. Even in the humid East a relatively small area only is agricultural. Though the whole is sufficiently watered, the cultivable area is limited by what is tillable, and in a region of degradation the tillable area necessarily

is small. Similarly, in an arid region, though tillable lands there make up a large part of the whole, the cultivable area is limited, in this case by the water supply. It is the theory of irrigation reclamation in an arid country that the relatively slight precipitation over the whole, so far as possible, is concentrated, in the necessary abundance, upon a fractional part. It follows that large areas well adapted to agriculture except for the lack of water must inevitably be excluded. To this class belong the High Plains.

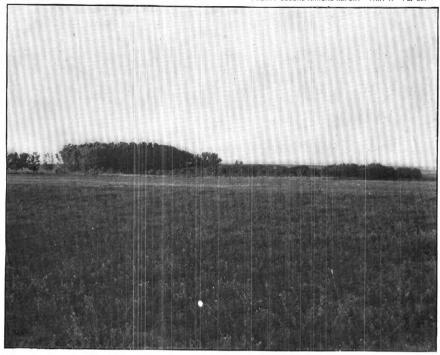
But it does not follow that such lands may not profitably be turned to other use. In large part they support a growth of grass highly nutritious. They may therefore be utilized for the growing of stock, but to somewhat limited extent only. The natural grass crop, as a rule, is scanty, or grows in separated tufts, and value for grazing rapidly diminishes as scantiness of growth and the area required to be covered by the feeding animal increases. Furthermore, watering places are too far apart for utilization of the whole or even a considerable part; zones near to water are overfed, and stock become lean, though the interior areas remain untouched.

STOCK FARMING.

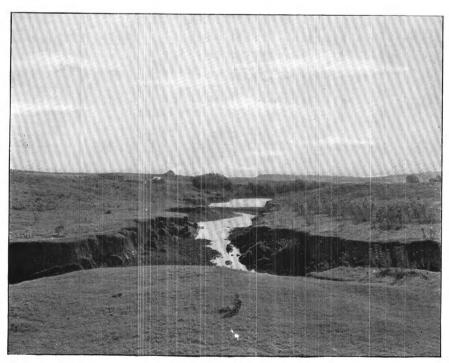
While nonirrigable, and therefore nonagricultural, the subhumid High Plains may yet be reclaimed for pastoral uses. Though their grass covering is everywhere abundant and of excellent quality, they meet the requirements of an ideal pastoral region only in part, so that an artificial process of reclamation in some measure will be necessary.

The broad intervalley plateaus are practically waterless. Their numerous faint depressions sometimes becomes lightly ponded, and continue so for brief periods. Ponding is the only natural reliance for upland watering, but it is at best an uncertain one Ordinarily, these grassy plains may safely be grazed only in narrow zones following their borders, from natural stock-watering points in the valleys and along the foot of the eastward-facing "breaks." In consequence, while the marginal belts as a rule are overgrazed, the interior areas remain virtually untouched. Reclamation will be by means of wells. Full utilization as pastoral lands, and uniform grazing, are to be secured only through the artificial creation of stock-watering points, in comparatively close and even distribution over the interior areas. A supply ample for such very limited use may everywhere be had by windmill pumping from the ground water.

Experiment with windmill watering, especially on the part of the large cattle companies of the Staked Plains, has not only demonstrated the feasibility of such a scheme, but points unmistakably to the disappearance eventually of these occasional large holdings, and to the establishment of a checkerboard subdivision of the whole into unit areas of about $2\frac{1}{2}$ miles on a side, each with a deep well and pumping



A. HEADQUARTERS CATTLE RANCH ON A SPRING CREEK.



B. A "WATER HOLE."

plant centrally located, fenced, and in individual resident ownership. Pioneers in this work of transformation, known as "stock farmers," are already being recruited from the scattered representatives of the considerable population of a decade and a half ago, which for several years was engaged in an elaborate but disastrous experiment in general agriculture. The windmill has made the "dry claim" tenantable. The turning wheel upon the horizon is always the first evidence and the sure sign of habitation.

These individual owners are able to grow only fodder cane of the drought-resisting varieties, such as Kaffir corn, for emergency use in winter. Of more succulent feed for young or especially valuable high-bred stock, and of vegetables and fruit for his own use, the stock farmer can produce nothing. The occasional small irrigable areas within the valleys, because close at hand, will best be able to supply his needs in these respects. Little exploited now, since surrounding tracts are virtually uninhabited, as is conspicuously the case in the regions traversed by the Cimarron and the Beaver, they will ultimately come to have high value.

ARTIFICIAL PROVISION NECESSARY FOR STOCK-WATERING.

The subhumid High Plains, though they must be rated by the agriculturist as within the arid region, present a marked contrast to it by reason of the thick-set character of their grass covering. On the other hand, they share with it the disadvantage of a lack of water. In fact, the wholly waterless areas of the High Plains are of considerable extent.

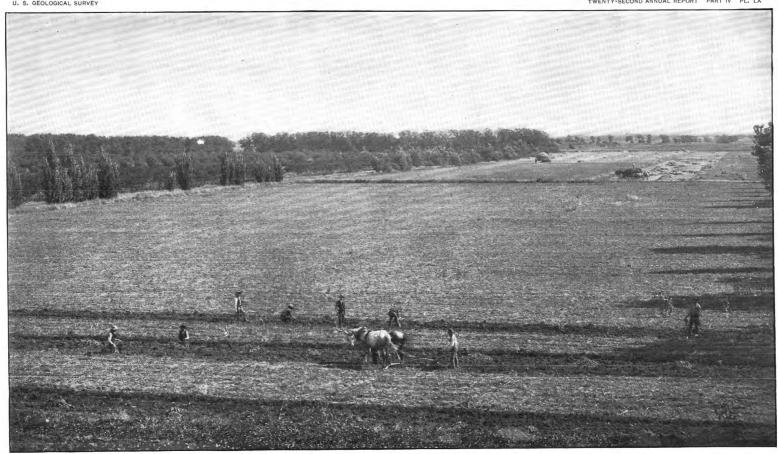
Previous to the agricultural invasion the High Plains, to about the same extent as the arid region generally, were made use of as a public range for cattle. Lying far removed from mountains, their broad surfaces everywhere above water sources—above springs and streams, the ground water, and the maximum rise of all artesian waters—they could safely be grazed only within narrow marginal zones. Despite their superior carpeting of grass, therefore, they are only in small part a pastoral country. In a measure, a process of artificial conversion will be necessary. Even to the stockman, these extensive interior areas of grass land are in effect desert. Artificial watering, providing a drinking supply for stock at points in systematic and close distribution will reclaim them entire. The ground water, by means of wells and windmills, will be the source of supply. Because of the higher value of the smaller quantity required to this end, it will be easily within economical pumping reach. And the supply, even regarded as no more than the inch or so of annual increment to the ground water from local precipitation, will be safely in excess of requirements.

Formerly, under most favorable conditions, only valleys of tran-

secting mountain streams and the zone of springs at the foot of the eastward-facing escarpment could be utilized as breeding grounds; the upland flats were feeding grounds merely. As the difficulty with the High Plains generally is simply their lack of stock-watering places, to provide these in great number, evenly distributed at the necessary short distances apart, will result in transformation of the whole into breeding grounds; in fenced subdivision into private holdings—at first, as a rule, of great size and multiple ownership, but eventually and inevitably of individual ownership and comparatively small size; and in a light resident population correspondingly distributed. The number of cattle which may be grazed to the best advantage (sheep being debarred apparently by the extent to which conditions favor drifting snow in winter) will be very greatly increased. The necessity for long-distance driving and rough usage in general will be almost wholly done away with. The hard-riding cowboy of the earlier period will disappear with the development of the inclosed rectangular "pasture." The amount of "handling" of stock required, and therefore the number of men and horses necessary for that purpose, will be largely reduced. In other words, artificial watering will not only greatly expand the area especially adapted to stock-raising, and to nothing else, it will occasion a radical change and make possible a notable improvement in the methods of stock-raising generally. Accomplishing a large reclamation at small cost, it will eventually result, through elimination of the range feature, in greater economy of production and increased value of the product. Opportunity will be afforded also, through fenced subdivision into pastures, for maintaining a higher standard of quality.

Such opportunity the common or public range can not afford. The beginnings of a change in this direction already are noticeable. Except in northwestern Texas, however, it has hardly as yet been deliberately made. With the few who remain of the great body of settlers of some years ago stock raising is regarded as a makeshift. The lingering "farmer," in deluded waiting still for a radical change of climate, is pasturing a few cattle outside his plowed fields, growing annually a small crop of cane "fodder," of drought-resisting varieties, for tiding the young and the weak of his herd over the more severe periods of the winter season; but chiefly his efforts are devoted each year to continued experiment in wheat raising. As we have seen, he has found the deep well and the windmill necessary to his survival. He does not recognize that it might be made the means as well of his comfortable support.

a The majority were deterred from experiments in this direction by the great depth to water. On that account a few among those who were located near the plateau margins even resorted to the laborious alternative of hauling at short intervals from the valleys and storing in cisterns. Near the abandoned town of Springfield, southwestern Kansas, the writer, in 1897, chanced upon one of these isolated claim holders, who for eight years had persisted in hauling his water by hand from the Cimarron River, 5 miles away, and who, in reply to a suggestion that water might readily be had by boring, of jected that it was "about as far down as it was across."



FORMER IRRIGATION FROM ARKANSAS RIVER AT GARDEN, KANS.

These would-be agriculturists, out of place in a grazing country, are nevertheless, though unwittingly, putting it to its only profitable use. They are becoming "stock farmers."

Neither shade nor fruit trees, nor kitchen-garden produce, except in small quantities as laboriously secured luxuries, can be grown by irrigation at the average high lift; but by multiplication of well and windmill plants over the immense waterless areas in even distribution stock may be supplied with the small quantity of water they need, in numbers limited only by the feed supply, and at relatively small cost. The natural feed supply needs to be supplemented by a small emergency crop of cane fodder, for which irrigation is not necessary. In many cases the annual experiment with wheat has been abandoned for the necessary cultivation of this fodder crop. It is the occasional remaining farmer immigrant of some years ago, with his deep well and windmill, his small but growing herd, and his field of sorghum or of kaffir corn, who is known as the stock farmer, and who in fact has unconsciously worked out, or at least is indicating the solution of, the problem of the most profitable and fullest possible utilization of the High Plains.

THE NATURAL UNIT OF LAND SUBDIVISION.

The area of grass land required for the support of a single head of stock is reduced to the minimum when evenness of feeding is secured. And evenness of feeding is to be secured not alone by providing watering places in proper number, properly spaced apart, for cattle will not distribute themselves in equally divided bunches among the watering places. They quickly develop preferences, which chance seems to determine, but which are difficult to break up; and this leads to very unequal grouping, to overgrazing, and to an underfed condition of the greater number. The remedy is to be sought, after the proper spacing of watering places has been secured, in subdivision on the checkerboard plan, leaving each well at the center of a rectangular fenced inclosure.

In the arid region generally the area of grazing land required for the support of cattle, per head, under the public range method of feeding, is estimated at from 15 to 20 acres. Upon the High Plains, with their thicker carpeting of grass, and under methods of partitioning insuring even feeding, the best experience indicates that it will not exceed 10 acres. Furthermore, a considerable body of experience here also, especially upon the Staked Plains within recent years, goes to show that cattle can not be maintained in the best condition if compelled to range, in their feeding, to distances from water greater than a mile or a mile and a half. In other words, the number of cattle watering at a single well should not be so great that, allowing 10 acres to a head, the outer limits of their feeding ground will be more than

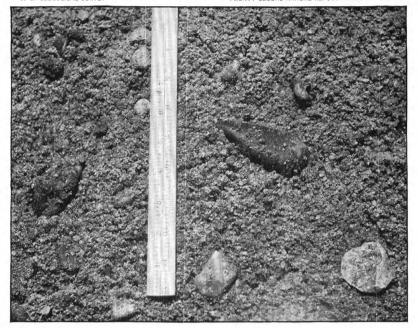
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a mile and a half distant from water; and overstocking is to be avoided only by spacing wells at something less than twice that distance apart. We have here, then, for the unit area, or fenced rectangular pasture of a size determined by natural conditions as economically the best, dimensions of about $2\frac{1}{2}$ miles on a side. Thus this unit area would include $6\frac{1}{4}$ sections of the land survey subdivision system, or 4,000 acres. With water to be had at a central point, approximately, it would afford pasturage for 400 head of cattle.

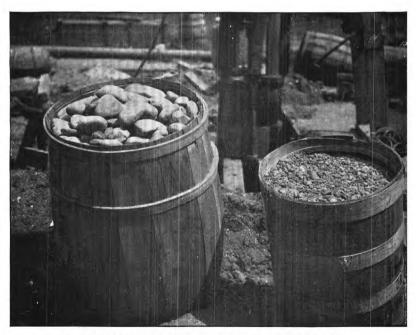
Increase in the number of wells, unless accompanied by corresponding further subdivision, would merely lead again to uneven feeding. Any such elaborate parceling out of the public domain implies its transfer to private owership. Hence, for the individual owner, as a rule, the unite area at the outset would need be smaller. It will appear upon consideration, however, that the minimum size of his holding could hardly be less than 1,000 acres—considerably more than a square mile or full section. A square mile, on the assumption of 10 acres to a head, will afford sustenance for but 64 head, and it is generally accepted in the Plains region that whenever reliance must be had solely upon stock farming, in which cattle are the only salable product, 100 head is the least number from which the individual farmer and his family can secure profit sufficient for more than their bare sup-This is assuming uniformly favorable conditions. One hundred head will be much too small a number for reasonable security against the accidents of the seasons. Thus, the individual stock farmer, in order to be fairly prosperous, will require an area of pasture land at least equal to that which the great corporation finds to be the economic minimum of its necessary checkerboard subdivision into single-well squares. The important fact should here be recognized that the unit area of 4,000 acres, in a region reclaimable by means of drinking wells to pastoral uses only, is fairly comparable in value to no more than the "homestead" unit of 160 acres in an irrigable region reclaimable to general agriculture. The index of the value of this large area is the 400 head of cattle which it will continuously support. The relative value per acre-stating the case liberally, probably—is the ratio of the annual profit from these 400 cattle, upon 64 sections, to that from the agricultural yield of a single quarter section; and the stock farming population will be in the same ratio.

But the High Plains will have been reclaimed and utilized. At present, except so far as stock farming in a very small way has made a beginning, they are without value; and their scientific conversion into pasture lands, aside from quieting a vexing problem which periodically has caused fruitless and demoralizing movements of population, and heavy loss financially, will add materially to the wealth of the several States of which they constitute large unoccupied portions.

 $^{^{}a}$ The writer was informed by the general manager of the largest cattle company operating on the Staked Plains that it was his intention in the future to space his wells $2\frac{1}{4}$ to 3 miles apart.



A CONFUSED MINGLING OF GROUND MATERIAL IN DUG-WELL MAKING.



B. SAMPLES OF THE SECTION IN TUBULAR-WELL MAKING.

Title to these lands, especially in western Kansas, though transferred from Federal ownership almost entire, has in large part either fallen into the hands of loan companies or passed to county ownership through inability of individual claim holders even to pay county taxes. In large part, also, it is burdened with county bonded indebtedness for public improvements, dating from the boom period, and now either in ruins or otherwise valueless. In some cases the counties themselves are virtually nonexistent, so far as population and resident control are concerned. Here the stock farmer is becoming evolved from the homesteader, with his bunch of cattle, his well and windmill, and his patch of fodder cane.

The homesteader dispossessed the early cattleman of a field into which it had been the practice of the latter merely to make wandering incursions; and the few of these newcomers who have retained a hold upon their "dry claims" have been able to do so by becoming stock growers themselves. Eventually, as resident stock growers, they will cover the field; for, through the agency of windmills, pumping almost continuously from the deep-lying ground water, and requiring but little supervision, they have the marked advantage over early practice of being able both to breed and rear their stock, until ready for market, upon compact areas of excellent pasture, fenced and in individual ownership, where formerly stock could not have existed at all. The size of the individual holding, however, will need to be greatly expanded and land values correspondingly readjusted.

Upon the Staked Plains of Texas the early cattlemen have not been completely dispossessed. Not all of that great plateau was public range, and the agricultural invasion did not extend, as in western Kansas, to virtually the whole. Here, from the first, immense tracts—in one case nearly 5,000 square miles—have been held in private ownership, either individual or corporate; and it is in this region, adopting, or adapting, to his needs the results of expensive experimental efforts toward full utilization of their grazing lands by large owners, that the homesteader has become a stock farmer.

The first large holdings on the Staked Plains bordered along the Canadian Valley. The upland was used as "range," to the small extent practicable. The light incision of storm-water drainage, beginning some distance back from its margin, afforded opportunity for storage in small reservoirs or "tanks" (Pl. LII, B), and the marginal feeding ground by this means was in time appreciably extended; but there was no permanent occupation until resort to the deep well and the windmill began to render it possible. Private holdings upon the uplands in large blocks were then at once greatly increased.

So far subdivision of these large holdings into "pastures" has not been brought down to rectangles smaller than 8 or 10 miles on a side;

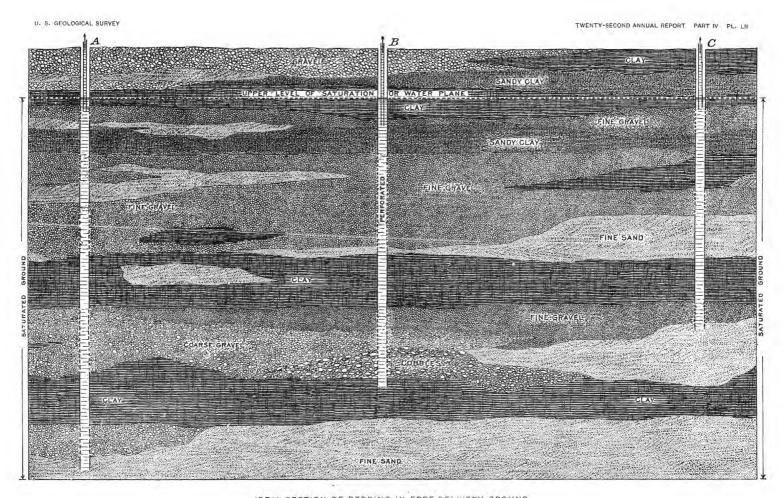
^{*}In Texas public lands are the property of the State.

nor is there anywhere the systematic and close spacing of wells which experience indicates would be the most advantageous; nevertheless, the practice of artificial watering and subdivision has brought about the permanent occupation in some measure of the whole interior area.

The large owner has worked out the local problems of deep-well making. About these there was nothing essentially new, but it needed the successive trial of methods well known elsewhere in order to determine what would best meet local requirements. For there are considerable areas beneath which the depth to water exceeds even 150 feet, though the mean depth is much less. To the eye the upland surface as a rule does not sensibly depart from the horizontal; vet its extent is so great that imperceptible differences of grade, either original or occasioned by broad differential settlement, give to it undulations across the direction of general slope amounting to 100 or 200 feet at points wide apart. Furthermore, the numerous clay sheets are sometimes thick, as well as broadly extended, and have only thin beds of sand, without coarse gravel, intervening, so that it is frequently necessarv. after penetrating deeply through dry ground, to go deeply into wet ground also; and the penetration of wet clay for considerable distances calls for special methods and devices. It has been only after much costly experimentation that right methods, reasonably inexpensive, have come to be adopted.

Mistakes, which experience only has corrected, have been made also as to the types of windmills employed. That which is best adapted to low lifts, for irrigation, where a large volume of water is the prime requisite, and to which can be given close and constant inspection because the area which it serves is several acres only, is not necessarily the best for stock-watering purposes. In such use the wheel must largely be left to itself; the unit area which it serves is measured in square miles, not acres; and it will best answer its purpose if, in uncommon degree, it is self-regulating and strong, requiring little inspection, since it is not a large supply that is needed but a sure one. Again, the best form of storage has been a matter of development. The dug reservoir alone falls short of requirements, though at first this fact was not sufficiently recognized. In summer cattle stand in the water after drinking from it, and keep it thick with stirred-up mud; in winter it freezes over. Pure water is needed; and for the best results it should be cool in summer and in winter not too cold. The ground water as it issues from the pump perfectly meets these requirements. It is essentially spring water, and it has a temperature, winter and summer, of 59° or 60°. A drinking tub, not too large, is provided to first receive it. The reservoir then serves a useful supplementary purpose.

The individual owner of small means has benefited by this experimental work and experience of the cattle companies. At the same



IDEAL SECTION OF BEDDING IN FREE-DELIVERY GROUND.

time, with more unerring instinct for the essential, he has gone a step further on his own account, in adding the feature of supplementary feed provision for the young and weak of his herd during the severe peri-To some extent he has gone further also in providing ods of winter. shelter against the more severe storms in winter and the midday heat in summer. Making his beginning with several head only, to which, therefore, he had been able to give individual care, he has had more forcibly impressed upon him than the large owner the advantage, at critical times, of such additional feed supply and protection. pioneer farmer, unsuccessful as a wheat grower, was more successful in raising drought-resisting crops for feed for cattle, and took more naturally to the idea, carrying it further than did the cattle company, operating through many employees. He will continue to be more successful in all the details of this transformed industry, because of his more direct personal interest. Upon the Staked Plains it is the prevailing impression, and it is the opinion also of the writer, that the "stock farmer," with his one-well rectangle of a half-dozen square miles, will come eventually to possess the field. He will do so because there will here be little or nothing of that advantage from large operations resulting from concentrated effort, which in manufacturing, for example, is so marked, and he will possess a field which heretofore has been, virtually, and in large part still is, a solitude—a desert of waving grass-visited by cattle at all only in brief seasons of basin ponding, as previously it had been by buffalo. The solitude will not be greatly enlivened by a population of one family to a square mile but it will be a resident population, producing abundantly for export a staple product. Upon the Staked Plains, at least, the stock farmer has already given material evidence of success.

UTILIZATION OF VALLEYS.

The valleys, though wide apart and relatively small as to their total area, will yet, by reason of their possibilities for irrigation, contribute in important degree to the full development of this pastoral region. Fodder cane will be the only farm crop which the stock farmer can produce. He will be able to supply himself with meat, and with butter and eggs; the immediate surroundings of his well, shutting out the desert, will present much of the traditional barnyard aspect; but he must supply himself with garden produce by purchase. The irrigable valley areas, because of their comparative nearness, will meet such requirements at a not excessive cost.

But the fullest possible irrigation development will be necessary. The greater portions of the wide valley slopes are merely stock range also. The areas available for irrigation on a scale larger than required for headquarter ranches located there as well, are not numerous. Only bottom lands, level and "shallow to water," will be thus avail-

able; and, in arid lands the "flood plain" of a stream is submerged and modified much more frequently and seriously than in humid lands. The illustrations of Pl. LV show the Canadian River in normal flow; the lower one, however, in the complete removal of several sections of an iron bridge, and in valley widening, which it displays, calls attention also to the overwhelming effects of bottom-land flooding.

There are exceptions, however, where, from special causes, the bottom lands are terraced, presenting two or more levels. Such a condition prevails at Garden, on the Arkansas. Again, the flooding is less serious in those valleys which head, not in the mountains, but in the western arid belt of the Plains. Such a valley is that of the Beaver, shown in Pl. LVI. It is only the tail of a flood which reaches to that section of its length where it trenches the High Plains. Here, and during most of the year, the Beaver is spring-fed. To a larger extent

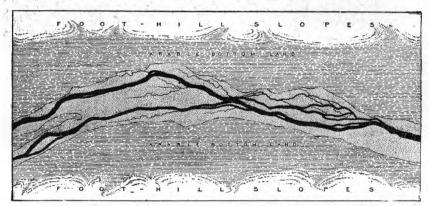


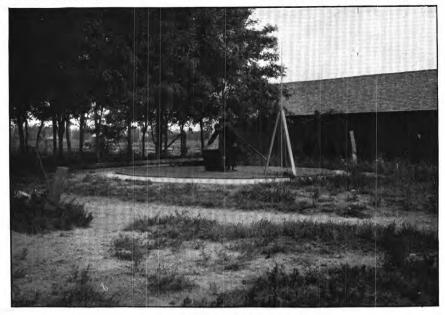
Fig. 243.—Map of valley floor subject to floods, showing sand-wash belt and subdividing stream.

than upon the Canadian, therefore, it has bottom lands available for irrigation.

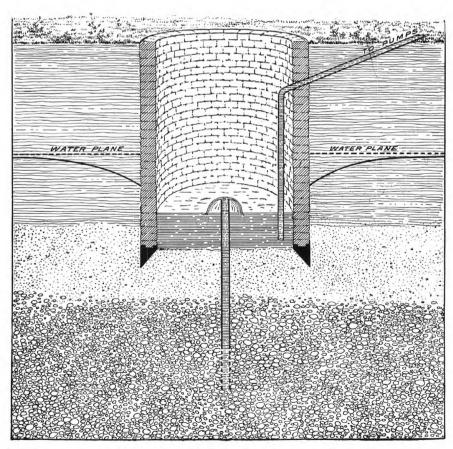
There is marked difference in the character of the bottom-land belts of these two types of valley. The desert stream of constant flow, widely variable in volume and always heavily loaded, not only overruns in some degree and sensibly modifies its flood plain at more frequent intervals than the stream of humid lands, but it subtracts from the arable area of the flood plain at low stages by maintaining a sand-wash belt within it, marking the width of its lateral shiftings.

Of this type are the valleys of the Canadian, the Arkansas, and the Platte. Their shaping streams do not meander in loops, leaving cutoff ox-bows. They dodge or subdivide upon the obstructions created by their temporary deposits, shifting laterally in considerable sections.

The High Plains, as we have seen, do not give origin to such streams, characterized on the one hand by annually recurrent flood-flow and on the other by a heavy burden at all times of erosion products. They do not feed their drainage channels by surface run-off, but from the



arALL. CITY WELL AT GARDEN, KANS.



B. SECTION OF CITY WELL AT GARDEN, KANS.



ground water. Those valleys which head within the arid belt, carrying merely the desert-plain run-off and receiving nothing from the mountains, send tail-floods into and across the High Plains belt only at long intervals. The valleys themselves are the work of these floods of exceptional extension; but, sunk thus below the ground-water level, their normal flow is spring-fed locally, and without the heavy load which leads to spreading by subdivision. It follows single channels. There is no appreciable subtraction from the bottom-land width, since the spring stream is without the sand-wash belt, which is virtually the bed of the silt-burdened stream—diminutive, but of multiple shifting channels. Upon a flat floor of gentle grade the spring-stream intricately meanders. The floor is thus inconveniently cut up; but it is almost entirely arable land and rarely suffers damage by flood.

In striking illustration of these radical differences of stream behavior, under the conditions of full load and relatively light load, respectively,

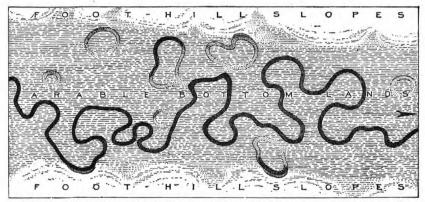


Fig. 244.—Map of valley floor not subject to floods, showing intricately meandering stream.

are the Platte and the Missouri, in the region of their junction, excepting a canyoned length of the former just previous to junction. The Platte subdivides and reunites in many shifting currents. In its upper course the Missouri has this habit also, but here it normally follows a single looping channel. During its frequent periods of flood and of broad submergence it is notably a fully loaded stream, not moving all of its load in suspension, but dragging a portion in shifting deposits. As a rule, however, it has essentially the character of the desert spring creek upon the floor of a long-interval intermittent stream, holding a sinuous course of uniform width, adding to one side what it cuts away from the other.

A notable example of such a valley floor, almost unvisited by run-off floods, yet with a perennial stream of constant volume looping intricately upon it, is that of the Cimarron along much of its course across the High Plains. The spring stream here merely occupies the valley; it has no part itself in valley making. It does not run full length.

Though in some of its live sections it is a strong stream, unvarying in volume, there are other sections in which the bed is permanently dry to depths of 20 or 30 feet. Pl. LVII presents a scene in such a dry section, where, however, the ground water lies at a very light depth. As elsewhere, under like circumstances, wild hay is cut here for winter feed. It happens that the Cimarron Valley floor lies approximately at the ground-water level, though not precisely. At one point it may be a little above, at another a little below.

A few miles above Arkalon, in southwestern Kansas, there is a feeble "reappearance," as it may be termed, of the Cimarron, following a long dry section. A few miles below Arkalon the flow is 82 second-feet. At the point of beginning the general water-plane level beneath the uplands on either side is but slightly above the stream; here it is 35 feet above. Downstream the volume of flow again dwindles, the depth below the water plane diminishing also, until within a few miles again flow ceases entirely. Here, as well measurements in upland wells indicate, the relative water-plane position is reversed. It lies slightly below the stream end, which, showing no lessening in the velocity of flow, nevertheless maintains very nearly a fixed posi-The spring stream, passing fan form into the dry ground, builds upon the water plane, as above it had created locally a depression. Just beyond the Kansas border, southeastward, there is reappearance from the dry stream bed again in even greater volume. This alternation of wet and dry lengths is repeated upstream also from Arkalon.

Wherever within the High Plains belt the Cimarron Valley shows a living stream it is always a meandering, looping stream of uniform width, narrow, clear, and deep, in ground plan having the general character represented in fig. 244. The bottom land upon which it wanders supports a coarser and longer-stemmed grass than the uplands, the grass roots reaching to the ground water, which lies at a depth here, as a rule, of only 2 or 3 feet, grading gently inward to the stream level. The whole area is easily irrigable.

From the first, so far as practicable, these spring-stream bottoms have been utilized for stock-ranch headquarters. They have not been utilized to the full, since such ranches can not, in the nature of the case, be located close together. And as irrigation commonly has been practiced merely to supply garden products for individual ranch needs, they have been irrigated only in small part. But eventually they will receive the highest possible irrigation development. They will then contribute largely to the success of upland stock farming.

At a point on the Cimarron where its valley bottom is abnormally broad—the Englewood Basin—a beginning in irrigation has been made which, in a striking manner, illustrates the possibilities (Pl. LVIII). Here, by ditch diversion, 1,200 acres are watered, and yet about a third only of the perennial run of the stream is utilized.



DISCHARGE OF FEEDER IN CITY WELL AT GARDEN, KANS, DURING HEAVY PUMPING.

These spring-stream valleys are especially a field also for irrigation by windmill pumping from the ground water. The phenomenon of interrupted flow-i. e., of disappearing and reappearing streams, so called—is common. That is, erosion, by floods having origin in the arid belt at intervals of groups of years, readily cuts valleys to the ground-water level; it does not so readily, however, cut below that level. It is only the larger mountain streams, of nearly continuous flow and heavier floods, which show high-level spring lines, indicating deep cutting below the water plane. As soon as saturated ground is reached, its inward creep tends to refill the excavation, during the long interval between flood runs. The valley is thus built up to a flat bottom having the meadow aspect. It is because of this tendency of ground water to hold the floor of a valley of such little-used type close to its own level, and because in the nature of the case it can not do so perfectly, that in this region perennial streams of interrupted flowin alternate dry and wet sections—are of frequent occurrence. water plane is never either high above or deep below the valley bottom. Hence, along the dry sections it is commonly within easy pumping reach. But more commonly it lies just below, since refilling by creep, on gentle slopes so close to saturated ground, is readily accomplished. Thus it is principally these sections, having the general aspect presented in Pl. LVII, and often supporting a growth of tall-stemmed "wild hay," the roots of which, unlike the grass of the uplands, are able to reach water, which are destined, as oasis strips, to supply garden produce to the High Plains.

Many self-supporting ranches will be located upon the long slopes of the larger valleys, several of which, like the Canadian, are sunk not only below the general ground-water level, but deep into the relatively impervious rocks underlying the Tertiary. These ranches will have position at points of exposure of gravel beds along the characteristic "spring-line" at the base of the Tertiary, also occasionally along higher spring-lines, of less positive definition, marking the outcrop levels of widely extended mortar beds.

Midway of the north slope of the Canadian Valley, marking the contact of Tertiary and Red Beds here, is a cattle ranch (that of the Reynolds Land and Cattle Company, on Romero Creek) making excellent use of a spring discharging nearly 2 second-feet. This spring has extension as a stream, for about 2 miles, onto a broad terrace flat. Here the ranch is situated. The full available supply from the stream is not utilized, since the out-of-season flow is not stored; but during the growing season the whole stream is applied in irrigation to the best advantage. This point is the center of control for an area grazing 9,000 head of cattle. It is also the distributing point for supplies to a number of minor outlying headquarters. The ranch buildings are heavily shadowed beneath many shade trees—cotton-

wood, locust, willow, ash, and osage orange; an orchard of several acres furnishes a superabundance of apples, peaches, apricots, pears, nectarines, plums, and cherries; there are arbors of grapes of several varieties, and a garden supplies a surprising assortment of vegetables. An artificial pond produces carp and sunfish; it also yields ice in winter for the preservation of meat and dairy products through the very hot summers—an important innovation in stock-ranch life. In addition, 30 acres are grown to alfalfa, for winter feed for cattle. Storage is in contemplation for increase of this feed crop. By devoting the entire annual flow of the stream to stock feed, supplying orchard and garden from windmills, it is estimated that 1,000 acres may be reclaimed for alfalfa.

Few springs afford so large a flow as 2 second-feet and at the same time occur within reach of irrigable lands. But this ranch (Pl. LIX, A), like many others, is the headquarters for an area which, it would seem, must eventually come into the hands of many individual owners, the majority of them upon dry claims. It will in that event find a ready and profitable market for its present oversupply of fruit and vegetables.

Less important, though more numerous, than the springs and perennial streams, are the "water holes" (Pl. LIX, B). These occur where the stream bed lies so close to the water plane that scour troughs, exposing it, are created by occasional run-off floods. They differ from the spring streams in that they have such short length that motion is not perceptible. Arroyo beds which lie above the water plane exhibit pools of standing water in their hollows after flood runs, but only for a short time. Ground absorption and evaporation soon cause them to disappear. The pools of the characteristic water holes, however, are perennial, or if shallow they may for a time fail, through a few inches of lowering of the water plane during exceptionally dry periods.

They afford natural watering places for stock. But what is much more important, they occur in areas shallow to water—windmill areas. Furthermore, by a little simple engineering they are usually convertible into light-flowing spring streams. Water holes as a rule occur in chains, either of disconnected links or of links feebly connected in groups of two or three. They indicate a limit to valley deepening, which the ground-water level has fixed—a limit easily reached, but to be passed only by streams of frequent flood flow. Valleys that are subject to heavy floods only at long intervals commonly exhibit this almost precise agreement in position of the valley floor with the groundwater level. A ditch in dry ground may usually be dug narrow and with upright sides; but after wet ground has been reached, either the width must be increased or excavation must proceed more rapidly and repeated thereafter at short intervals. The tendency is for creep from either side to cause the banks to recede and the ditch to refill to the water level, creating a wide floor. Broad, waterless valleys, with

The elevation above sea here is nearly 5,000 feet.

MAP SHOWING DISTRIBUTION OF WINDMILL PUMPING WELLS ABOUT GARDEN CITY, KANS.

water just below ground, however, or actually appearing in exceptional hollows, are therefore of not unusual occurrence in the subhumid belt where flood runs come from a distance.

The springs and spring streams have all been occupied as ranch locations from the early years of the stock industry. At few of these ranches, however, has more than a beginning as yet been made toward development of the local possibilities for irrigation.

Such full development of the minor valley patches must await the partitioning and settlement of the upland stretches, creating a market for garden produce. Possession of these favored localities, which will acquire relatively high value, will then pass naturally from the stockfarmers, to whom they will not be vitally necessary, into the hands of agriculturists proper. They will be utilized as truck farms, exhibiting, of necessity, the application of water in garden irrigation by methods the most economical and scientific.

In like manner, in the larger valleys, terrace levels of their floors, exempt from damage by the annual floods, will be utilized to the full. The Canadian and the Smoky Hill, cut relatively deep, have only occasional and small areas of this character, though such as they do afford will acquire high value. There is here a deficiency of irrigable lands. Stream flow is in excess of these small needs. The Beaver and the Arkansas, on the other hand, have lands in excess.

VALLEY IRRIGATION MAINLY FROM WELLS.

The valley lands will be irrigable less because they are near stream level than because they lie close to the ground water. Even along valley bottoms irrigation will be mainly from wells. This is especially true of the spring-stream valleys, of which the Cimarron is a good example. Flow in the typical spring-stream valley is perennial, where there is flow at all; but it is characteristically interrupted, sinking and reappearing, the dry lengths being usually much the longer. In these dry lengths the depth to the ground-water level is still comparatively slight, and irrigation is practicable from wells. It is true in large part also of the mountain streams, because they have intermittent flow, the dry period, or at least the period of enfeeblement, coinciding with the crop-growing season. And it becomes true of these streams especially where irrigation to the westward exhausts their flow in that season, as in the case of the Arkansas along its rather broad bottom from the Colorado-Kansas line to Garden.

The valley of the Canadian, measured across between its upland margins, is the broadest—20 miles or more. But because deep also, and therefore sharply eroded, it has an insignificant total of cultivable and irrigable land. The Arkansas valley, on the other hand, is comparatively narrow and shallow; but its proportion of good land is large and lies close to the water plane, with a great depth of unconsoli-

dated sand and gravel beneath. This is the case with nearly all the spring-stream valleys. They are sunk, as a rule, approximately to the ground-water level, and are there broadened. But they have much more of flat bottom land than is irrigable from their streams, and, for its fullest utilization, recourse must be had to the ground water.

Upon the uplands the ground water proves to be a practicable source of supply for the watering of stock, at pumping lifts reaching even to 300 feet; that is, the diminutive stream obtainable by windmill power from such depths nevertheless is sufficient for the purposes of the stockman. The volume of discharge diminishes as the height of lift increases. What the economical limit will be in irrigation will depend upon the value of the product. Valley irrigation on the High Plains will not pay, as a rule, until a pastoral population, scattered over the intervalley areas, shall have created a local market. It would not pay at present, for example, in the valley of the Upper Beaver; yet eventually a considerable acreage of bottom land there will have a strictly agricultural population occupied in supplying garden and orchard products to the upland stockmen.

The town of Garden, situated on a railroad, is thereby afforded opportunity to compete in a distant market. The economical pumping limit at Garden, under present conditions, can hardly be said to reach 20 feet. Under the more favorable conditions of future development and a local market this will probably not be increased by more than 50 per cent. That is, 25 feet appears to be about the limit of height above the water plane at which irrigation farming from wells can profitably be conducted—at least on a commercial basis. early years of irrigation a notable area of bottom land here, though an inconsiderable portion of the whole, was converted from bare grass land into a veritable garden by ditch diversion from the river. It was owing to the nature of this early conspicuous success in reclamation that the town received its name. However, subsequent development of like character to the westward, in Colorado, resulted in such large drafts upon the river there as eventually to leave it dry in Kansas.

After a period of puzzled inaction, discovery of "the underflow" having meantime been made, recourse was had to windmill pumping from the ground water. Pl. LXV shows the number and the distribution of these pumping wells up to 1899. In that year the area under irrigation by this means very nearly equaled that formerly served from the river. The number of wells is increasing, and the town has been restored practically to its former prosperous condition.

A considerable remaining area here, as with similar tracts in other valleys, awaits the stimulus to development of a local market, which will be the outcome of a systematically distributed pastoral population upon the uplands.

IMPORTANCE OF CORRECT WELL CONSTRUCTION.

The assumption is here made that wells are so constructed that the water level is not materially drawn down, and the lift increased, under ordinary pumping. Few wells are in fact so constructed. Yet, under conditions which almost universally obtain upon the High Plains and in many of the valleys, viz, of deep alluvium, deep in water, nearly all might be. Thus there is a problem of the well, no less important than that of the lifting mechanism. Only this mechanism of pump and wind wheel, or other power device, has so far, however, been made the subject of careful study, in the effort to secure the maximum of well delivery.

Both upon the uplands, for stock watering, and in the valleys, for irrigation, the greater number of wells fall short of their possibilities. Many wells, owing to unintelligent construction, absolutely fail—i. e., are quickly drawn down to the bottom, or temporarily "exhausted," by pumping—where, with slightly increased outlay, full delivery might have been secured. In stock watering, so far, the needs have appeared to be within the possibilities of the average well, so appreciative has the stockman been of even a bare drinking supply in the desert spaces. But in time he will come to recognize that an excess over apparent requirements is necessary in order to avoid stagnation and too high a temperature in summer and freezing in winter. In irrigation, on the other hand, the well at its best falls short of the demands that could profitably be made upon it. It is in areas "shallow to water," therefore, that the differences among wells, in respect to their rates of response to pumping, are conspicuous.

The well for irrigation serves a small area. At Garden there are 102 wells within 1 square mile of valley bottom. Upon the uplands a single well is equal to the stock-watering needs of half a dozen square miles of grazing land. The depth to water in the effective wells about Garden, as we have seen, does not exceed 20 feet, while in the upland wells it ranges down to 300 feet. The problem in each case, however, is the same—namely, to secure a rate of response to maximum pumping sufficiently rapid to prevent serious increase of the pumping lift.

Not only must valley irrigation in the future largely depend upon pumping from the ground water, but it will be solely by means of wells also that the great intervalley uplands will be reclaimed, even to pastoral uses; and while the mechanical processes of well making upon these elevated flats must necessarily differ somewhat from those employed in the valleys, because of the great difference in the depth to water, the principles of well construction in each case, so far as they relate to the intake of water, are the same. Thus the determination of principles and the working out of the best type of construction are of importance to uplands and valleys alike.

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