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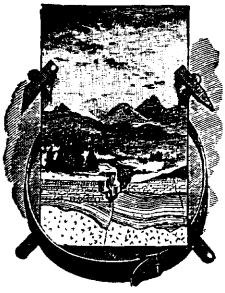
CHARLES D. WALCOTT, DIRECTOR

WATER POWERS OF NORTHERN WISCONSIN

BY

LEONARD S. SMITH



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WATER POWERS OF NORTHERN WISCONSIN.

By L. S. SMITH.

INTRODUCTION.

Significance and extent of water-power resources.—Unlike other great natural resources of the State, such as the forest and mineral wealth, the utilization of which means the final destruction of the source of supply, the water-power resources are as certain and eternal as the sunshine. The importance of water powers to a State so remote from coal mines as is Wisconsin is not likely to be overestimated. Unquestionably these powers are destined to exercise a wide influence on the development of the State. So far as known, not a single important river in the State has as yet been made to fully produce its available power. The lower Fox may be said to come the nearest to this, with a total of 31,898 actual horsepower,[a] all produced in the 35 miles between Lake Winnebago and Green Bay. This large water power has caused the district to take high rank as a paper and pulp manufacturing center. Wisconsin, Chippewa, and St. Croix rivers can each be made to produce power equaling and even exceeding that of the lower Fox. Growth in the development of Wisconsin water powers has been very rapid. During the ten years ending in 1900 the gain was 75 per cent. The following figures show the growth during the last thirty years:

Wisconsin water powers developed.

	Horsepower.
1870	33,700
1880	45,300
1890	56,700
1900	99,000

The annual saving represented by this power over the cost of an equivalent amount of steam power, computed at $20 per horsepower, reaches the sum of nearly $2,000,000.

Sources of information.—Judging from the scant literature descriptive of Wisconsin water powers, but little attention has been directed in the past to this great natural resource of the State. The longest and most accurate description is contained in the Tenth Census of the United States. In Geology of Wisconsin, volume 3, 1880, will be found good detailed descriptions of the Lake Superior rivers from the standpoint of a geologist. Very reliable information regarding the upper headwaters of the larger rivers is given in the reports of the Chief of Engineers, U. S. Army, for the years 1879–1883, inclusive, to which frequent reference is herein made. This work of surveying reservoir sites involved the running of many hundred miles of levels, thus securing numerous water levels on lakes and rivers. The maps of these surveys were never published, but copies of the originals have been obtained, and no pains or expense has been spared to preserve and present these data. A fourth source of information, and a most welcome one, both because of its intrinsic value and because it marks the beginning of a rational and systematic study of Wisconsin water powers, is the detailed survey of part of Chippewa River and the daily discharge records of

[a] Rept. Chief Eng. U. S. Army, 1897, p. 2737.

many important water-power rivers carried on by the United States Geological Survey during the years 1903, 1904, and 1905.[a]

Finally, the data here presented would have lacked much of whatever value and completeness they may have had it not been for the generous support of hydraulic engineers and mill owners.

After exhausting all possible sources of information by correspondence, however, it was found that many points of importance could be cleared up only by a personal visit to the field. In this manner visits were made to St. Croix River at Taylors Falls; to Apple and Willow rivers; to Eau Claire and Chippewa Falls, on Chippewa River; to Black River Falls and Neillsville, on Black River; to Grand Rapids, Stevens Point, Tomahawk, and Rhinelander, on Wisconsin River, and to Oshkosh, Appleton, Menasha, Kaukauna, and Depere, on Fox River.

The importance of these water-power resources to the development of the State would certainly justify it in cooperating financially with the United States Geological Survey by extending the investigation to include hypsometric surveys of the important rivers, especially in the region now undeveloped.

PHYSICAL GEOGRAPHY OF NORTHERN WISCONSIN.

GEOLOGY.[b]

The rock formations of northern Wisconsin readily fall into three classes—the pre-Cambrian crystalline rocks, the Paleozoic rocks, and the Glacial drift. The pre-Cambrian and Paleozoic formations are adjacent to one another, but the loose Glacial drift is distributed irregularly over all the hard-rock formations of the region.

PRE-CAMBRIAN ROCKS.

The pre-Cambrian crystalline rocks consist of various kinds of igneous rocks, such as greenstone or trap rocks, granite, diorite, rhyolite, schists, and gneisses, and varieties of metamorphosed sedimentary rocks, such as quartzite, slate, limestone, conglomerate ferruginous rocks, slate, and schists. The rocks here classed as pre-Cambrian include all those often referred to as the Laurentian (Archean), Huronian, and Keweenawan series. The various kinds of crystalline rocks generally stand on edge, trend in various directions, and form irregular belts and areas throughout the region.

The area of crystalline rocks covers the principal part of northern Wisconsin. Its northern boundary is approximately parallel to and very near the adjacent shore of Lake Superior; on the west it projects irregularly into Minnesota; on the south it extends to the central part of the State, and on the east it reaches within 25 to 40 miles of Green Bay.

The pre-Cambrian region is the highest portion of the State, and in these crystalline highlands the large rivers have their source and flow outward in all directions. The crystalline rocks are generally hard. They do not everywhere have this character, however, and the lack of uniformity causes much irregularity in the surface features. High, rounded knobs of hard granite and quartzite dot the surface of the region, and the abrupt variations in the character of the rock along the river valleys have caused the formation of numerous rapids and waterfalls. The slope of the pre-Cambrian region is relatively steep on the Lake Superior side and comparatively gentle toward the east, south, and west.

PALEOZOIC ROCKS.

The Paleozoic rocks consist of alternating formations of comparatively incoherent, friable sandstone and hard, compact limestone lying unconformably upon the upturned edges of the crystalline rocks and dipping slightly toward the north, east, south, and

[a] The Wisconsin legislature of 1905 appropriated $2,500 for the purpose of surveying the water powers of the State in cooperation with the United States Geological Survey, which has set aside an equal amount for this purpose. In the fall of 1905 Wisconsin, Black, and Flambeau rivers were surveyed. This work is in charge of Leonard S. Smith.

[b] Prepared by S. Weidman, State geologist of Wisconsin.

west—the dip thus being away from the broad central core of the pre-Cambrian region. The Paleozoic rocks of northern Wisconsin include the following formations, named from the base upward: (1) Cambrian ("Potsdam") sandstone, (2) "Lower Magnesian" limestone, (3) St. Peter sandstone, and (4) "Trenton" limestone.

The Cambrian sandstone is by far the most abundant Paleozoic rock of the region. Along the shore of Lake Superior, where it is generally called the Lake Superior sandstone, it forms a strip less than a mile in width at the Michigan boundary, increasing to 15 miles in width at the Minnesota boundary. For variable distances of 15 to 40 miles about the broad central area of the pre-Cambrian to the west, south, and east, the Cambrian is the principal surface rock. It is only adjacent to the shore of Green Bay on the east and in St. Croix and Pierce counties on the west that limestone and sandstone later than the Cambrian occur to any notable extent.

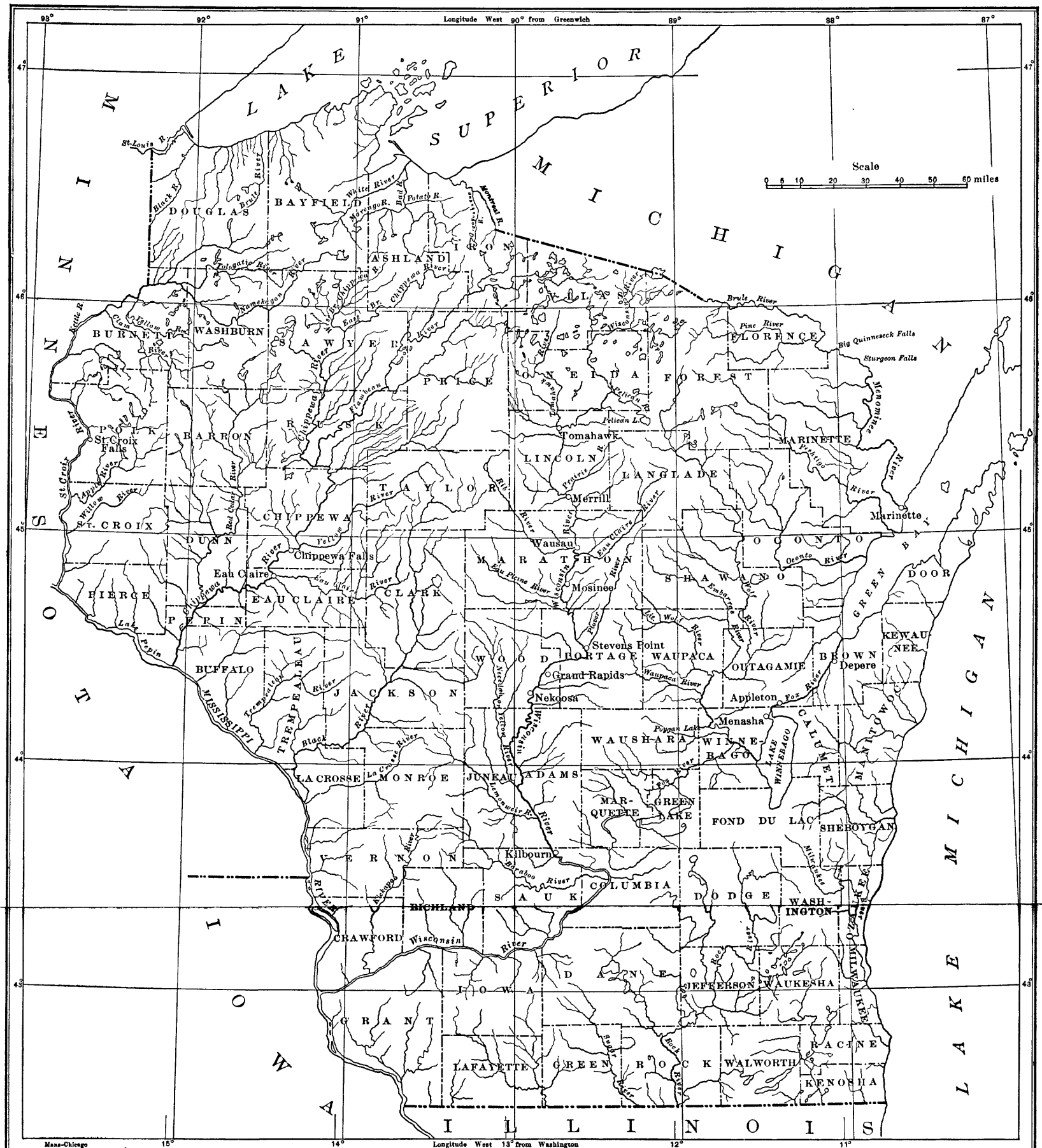
The surface features of the Cambrian sandstone district are mainly broad valley bottoms, dotted here and there with a few pinnacles of hard sand rock. In the region of the limestone, however, the valleys are generally sharp and narrow, and the uplands constitute the main portion of the landscape. The hills and sharp ravines in the limestone district are in sharp contrast with the broad, graded valley bottoms of the sandstone district.

GLACIAL DRIFT.

The Glacial drift consists of a loose, incoherent mass of bowlders, gravel, sand, and clay. In some places the coarse drift is abundant, while in other places clays and sand prevail. The drift has a very irregular thickness throughout the area. It was deposited upon the older crystalline and Paleozoic rocks during the several successive glaciations in Wisconsin and the adjacent region.

Drift in variable quantity occurs throughout northern Wisconsin, being very abundant in the northeastern, northern, and northwestern parts of the region, while in a very irregular but considerable area in the southwestern part the drift is very thin.

The surface of a large part of the drift-covered region is very irregular and uneven, and consists of hills and ridges alternating with basins, swamps, and lakes. In some places the drift covering completely obliterates the topographic features of the crystalline and Paleozoic rocks; in other places it only modifies the older topography. On the whole, however, the glaciation of the region exerted a considerable influence on the distribution of the drainage lines and in shaping the minor inequalities of the land surface. The drift region, from the topographic point of view, may be divided into two general districts—one covered by the older drift series and the other by the later drift. In the district of the older drift, the southwestern part of northern Wisconsin, there are no lakes or ponds, and swamps are very rare. Here the topography is mature and the land has good surface drainage. In the district of the later drift, however, which includes the main portion of northern Wisconsin, the glacial deposits are abundant; ridges and hills of bowldery material occur, and lakes, swamps, and sags are common. In this district, therefore, the surface drainage is often very poor and large amounts of water are held in swamps and ponds. Here, also, there are marked differences in the surface features prevailing over large parts of the district. Along its border is the terminal moraine, often called the "kettle moraine," having a width ranging from 3 or 4 to 20 miles and consisting of numerous drift hills and ridges closely associated with sags, lakes, and ponds. This terminal moraine extends across the entire continent. In crossing this portion of the State it turns north a few miles east of Grand Rapids, thence extends to Antigo, thence in a sinuous belt westward to Barron County, and thence southwest into Minnesota. Back of this terminal moraine—that is, to the east and north—are similar belts known as "recessional moraines," separated one from another by broad areas having the general features of the hard rocks beneath. Between the moraine belts are broad tracts of sandy land, called "barrens," which cover considerable portions of the northwestern part of the State. Along Lake Superior is a broad belt of nearly flat clay land which may be mentioned, though it has no influence on the distribution of the water powers of the region.



DRAINAGE MAP OF WISCONSIN.

TOPOGRAPHY.

The abundant water-power resources of Wisconsin are the result of its unique topography. A wide and comparatively flat highland crosses the northern part of the State. This divide varies in elevation from 1,900 feet in the eastern part to 1,000 feet in the western part, and extends to within 30 miles of Lake Superior. From it the rivers descend radially in all directions except eastward. Owing to the fact that Lakes Superior and Michigan bound the State on the north and east, while Mississippi River forms the southwestern and the larger part of the western boundary, all the rivers must needs find a low trough into which to discharge, and that at a short distance from their source. This condition results in a rapid fall and large water powers.

About 9 per cent of the total area considered belongs to the abrupt Lake Superior watershed and the remainder to the broad southeast, south, and southwest slopes. The divides between the rivers which drain this southern slope are almost imperceptible, in some cases being entirely lost in labyrinths of lakes and swamps.

Hills over 300 feet in height are rare. A few "mounds," or isolated steep hills with extremely narrow bases, rise out of the sandy plains of Jackson and Clark counties, and a few larger, more massive hills, one 1,940 feet above the sea, occur in the valleys of the larger rivers, besides the low, broad hills which form the crests of the Penokee and Copper ranges. These hilly tracts do not cover over 5 per cent of the total area, while about 45 per cent is level upland and about 50 per cent is rolling country, of which a considerable portion is steeply rolling "kettle" or "pot-hole" land.[a]

The surface features are discussed elsewhere, under the head of "Geology," and also in connection with the drainage of each river.

HYDROGRAPHY.

St. Croix, Chippewa, Black, and Wisconsin rivers drain 70 per cent of the northern half of the State, an area nearly equal to that of the State of Maine. The Lake Superior rivers drain only 9.3 per cent and those flowing into Green Bay the remaining 20.7 per cent.

In general, each of the important rivers may be divided into three divisions, differing widely in physical characteristics. First, the headwaters, marked by sluggish streams with low divides, fed by numerous and extensive swamps and lakes, frequently so interlaced that it is impossible to trace out the river divides. Here many of the lakes have dam sites forming natural reservoirs for the river below. Bowlder rapids are here of frequent occurrence. Second, a stretch of maximum descent along the center reach of the river, abounding in numerous falls and long stretches of rapids. This part of the river is always in the region of the pre-Cambrian crystalline rocks, the southern border of which marks the lower limit of the rapids.[b] Third, the lower portion of the course, where for a distance of about 50 miles the river flows through sandstone and limestone, the descent being very slight. This region is, therefore, devoid of water power. In fact, the United States Government has improved the larger rivers along this reach for the purpose of navigation without the use of locks.

As compared with the upper Mississippi basin in Minnesota, the area under discussion may be said to have a steeper grade, the middle portion, containing the main water powers, having an average fall of 3 to 8 feet to the mile. Because of the storage effect of the lakes and swamps, the low-water run-off is as high as from 0.3 to 0.8 second-foot per square mile of drainage area. Probably about a third of the total rainfall finds its way into the streams.

The general use and control of these northern rivers for logging purposes in the past tended to decrease the value of the water powers by withholding the water at times when most needed. All logging on rivers is fast disappearing. Indeed, on many rivers, like the Wisconsin, it has practically given way entirely to railroad transportation. This leaves the rivers free for the permanent development of their water powers. The effect on

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[a] Roth, Filibert, Forestry Conditions of Northern Wisconsin: Bull. Wis. Geol. and Nat. Hist. Survey, No. 1, 1898, pp. 2-3.

[b] The only important exception to this rule is on Wisconsin River at Kilbourn, where the river descends rapidly about 16 feet in the dalles of the Potsdam sandstone.

the stage of water which these dams have had in the past suggests their enlargement, extension, and systematic operation for the sole purpose of increasing the low-water flow.

The United States engineers have surveyed 32 large reservoirs in Wisconsin and have constructed five such reservoirs in Minnesota. The total capacities of the proposed Wisconsin reservoirs are as follows:[a]

Storage capacity of proposed reservoirs in Wisconsin.

River.	Area of overflowed lands.	Storage capacity.
	Acres.	*Cubic feet.*
St. Croix	[b] 102,092	34,334,000,000
Chippewa	Not given.	25,239,000,000
Wisconsin	25,832	19,557,000,000
		79,130,000,000

The intelligent operation of even a part of these reservoirs would have a marked effect in steadying the river discharge. This point will be separately discussed in connection with the several rivers. It may be remarked here that nature, by providing numerous swamps and upward of 1,400 lakes for this region, has accomplished unaided a decided regulation of the water supply.

The availability of these water powers varies greatly on the different rivers, or even on parts of the same river. Those on Wisconsin River, for example, are all reached by the Chicago, Milwaukee and St. Paul Railway, which parallels the river for 100 miles, and by other railroads at certain points. The powers on the lower Chippewa are likewise available; but as yet, because of the small population, the railroads have not built generally into the upper part of the region. The rapid opening up of farms now in progress will soon bring a demand for better transportation.

The present bulletin discusses the water powers of the northern rivers, for the reason that these powers are the least known and least developed.

SOILS.[c]

The soils of northern Wisconsin may be grouped into seven readily recognized classes.

Sandy soils are found in regions known as flood plains, and owe their origin to the sorting action of flowing water as it issued from the melting ice. The two largest areas of this type are found in central Wisconsin east of Black River and in the northwestern part of the State. These soils are so coarse and open that nearly all the rain soaks into the ground, reappearing later at lower levels as springs.

Sandy loams cover a much broader area than the sandy soils, being roughly coincident in distribution with the Potsdam sandstone, from which they have in large part been derived.

Prairie loam is a light, open soil, more closely allied to those described above than to the following ones. It is usually underlain by from 3 to 5 feet of coarse, open gravel. In northern Wisconsin the largest area of this type is found in St. Croix County.

Clayey loam is finer and contains more clay than the soils already described. Such a soil has a great capacity for holding water. "The area of northern Wisconsin covered by this type of soil is larger than that occupied by any other variety."

Loamy clay is still heavier and more clayey than the last, with smaller particles. There are three considerable areas of the soil in this region.

Red clay soil is the most peculiar, the finest grained, and heaviest in the State. It is practically impervious to water. Its areas border Lakes Superior and Michigan.

[a] Rept. Chief. Eng. U. S. Army, 1880.
[b] Including 27,406 acres in Minnesota.
[c] Condensed from F. H. King's description in Northern Wisconsin Handbook.

Swamp soil includes all swamp and marsh land soils. While few very large single areas are covered by these soils, the aggregate amount is probably not less than 1,000,000 to 1,500,000 acres. Some of these lands are now covered by a growth of white cedar, others with tamarack and spruce, the latter being usually found on the borders of both tamarack and cedar swamps, while still others are simply sedge marshes, some of which are yearly cut for hay. In many other swamp areas fires have killed the trees, causing all the small anchoring roots to die and decay, so that the winds have overturned nearly every tree.

Many of the northern swamps are underlain by vast beds of peat, while all have a thick covering of moss and humus. Both these factors play an important part in delaying the water in its journey to the streams.

FOREST CONDITIONS.

"Northern Wisconsin in its primeval state was a vast forest of magnificent timber." This could be said to-day of large areas. The central portion of this region includes mixed forest in which, though the pine has nearly all been cut, there still remain over 5,000 feet of hard wood and hemlock per acre, besides other timber equally valuable. The total area covered by forests of this grade amounts to 8,000 square miles, about the same as that of the State of Massachusetts.

Mr. E. T. Sweet[a] enumerates 34 different kinds of trees which be found on the Lake Superior slope alone. Additional species found on the southern slope would increase this number considerably.

The lumberman's labors were first directed to getting out the pine, both because of its high value and because of the fact that he could float it downstream to market. This industry, including the manufacture into lumber, had an invested capital in 1900 of $100,168,000 and turned out a product valued at $81,983,000.[b] This easily places it as the most important industry of the State. Only two other States exceeded this in 1900. In the same year, according to the United States Census report, Wisconsin was the leading State of the Union in lumber and timber products, their total value being $58,000,000. The amount of pine timber is limited and already its production is waning. Its place is being taken, to a large extent, by hard-wood timber, by cedar posts and poles, and by hemlock lumber and bark. The changes wrought annually by the lumberman's ax and the succeeding forest fires are very considerable. The recent appointment of a State forestry commission promises much for the protection and fostering care of these great interests.

The once popular belief that this northern area was worthless after the loss of its timber has given way in the past ten years to a general confidence in its agricultural possibilities. This is amply evidenced by the rapidity with which these lands are being opened up by farmers and by their rapid appreciation in market value. In 1895 only 7 per cent of the 18,000,000 acres of the northern half of Wisconsin was cultivated. This region has furnished 85,000,000,000 feet B. M. of pine lumber alone in the past sixty years. The gradual clearing of the timber has doubtless had an effect on the run-off of the rivers. Under the changing conditions the rainfall will be less absorbed by the soil and will get to the streams in a shorter period. This is especially true of the swamps, where the fires have burned the thick humus and moss which formerly delayed the passage of the water to the lakes and rivers. It is only fair, however, to call attention to the fact that large areas of the original timber consumed by forest fires have been replaced by a second growth of both hard and soft timber, much of it in the form of dense thickets, which shade and protect the ground more effectually even than the original forest.

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[a] Geol. Wisconsin, vol. 3, 1880, p. 328.

[b] U. S. Census, 1900, pt. 1, p. 293.

CLIMATIC CONDITIONS.

TEMPERATURE.

The climate of this region is characterized by a large amount of sunshine, with high temperatures in summer and extreme cold, deep snows, and clear skies in winter. The summer heat and winter cold are generally tempered by the influence of the bordering lakes. Lakes Superior and Michigan cover an area of over 54,000 square miles and never freeze over in winter. Although the prevailing wind is from some westerly quarter, this is so frequently broken up by the passing of storm centers from the lakes that both the temperature and the humidity of the air are affected by these great bodies of water. Wisconsin rivers are generally frozen over between December 1 and March 30. The following table gives the highest and lowest temperatures for each month of the year for the twelve years ending 1883 at places in or adjacent to this region:

Highest and lowest temperatures for each month of the year for the twelve years ending 1883.[a]

Locality.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec.
Duluth:												
Maximum	51	57	62	75	91	92	99	93	90	78	65	51
Minimum	−38	−34	−26	3	26	36	46	45	30	8	−29	−34
Marquette:												
Maximum	56	69	70	81	92	95	100	96	97	87	66	59
Minimum	−26	−27	−14	3	22	31	40.3	39.7	28	18	− 9	−20
Escanaba:												
Maximum	45	52	57	65	83	88	92	89	84	75	61	48
Minimum	−26	−32	−20	2	20	34	42	38	26	17	9	−23
Alpena:												
Maximum	52	58	66	72	91	97	97	92	92	83	63	56
Minimum	−27	−27	−14	2	22	33.5	45	40	29.3	22	− 4	−15
St. Paul:												
Maximum	49	59	68	82	94	94	100	98	94	87	72	56
Minimum	−31	−32	−22	7	24	39	46	43	30	15	−24	−30
La Crosse:												
Maximum	59	65	72	83	96	98	101	96	92	84	70	60
Minimum	−43	−34	23	10	29	40	52	44	31	18	−21	−37

[a] King, F. H., Northern Wisconsin Handbook, 1896.

In connection with the sudden lowering of the winter temperature, a most interesting phenomenon was observed on St. Croix River by United States engineers in the early winter of 1882:[a]

> This was the apparently close relation between the temperature and the mean velocity and discharge of the stream, the stand of the water being at the same time nearly constant. In the early winter it was found that each cold wave which increased the thickness of the ice about one-tenth of a foot at a time was accompanied by a great falling off of the discharge, to be followed by a partial recovery during the next few days, the same phenomenon recurring with great regularity at each cold wave. The recovery of discharge being in each case only partial, the gradual tendency was downward until the apparent minimum was reached, when there was no appreciable change for several weeks.

PRECIPITATION.

The average rainfall for twenty-five years over the entire State is close to 32.3 inches, distributed by seasons as follows: Winter, 4.7 inches; spring, 7.6 inches; summer, 11.7 inches; autumn, 8.3 inches. If the rainfall of the northern half alone be considered, these figures would probably need to be slightly increased. It is worthy of note that 60 per

[a] Rept. Chief Eng. U. S. Army, 1883, p. 1470.

cent of the rainfall comes in the summer and autumn months, while the least fall is during the winter months. December, January, and February are the months of minimum run-off, both because of smaller precipitation and because of low temperatures and resulting deep frosts.

In general, it may be said that the precipitation in Wisconsin exceeds that of Minnesota and Michigan and about equals that of Iowa.

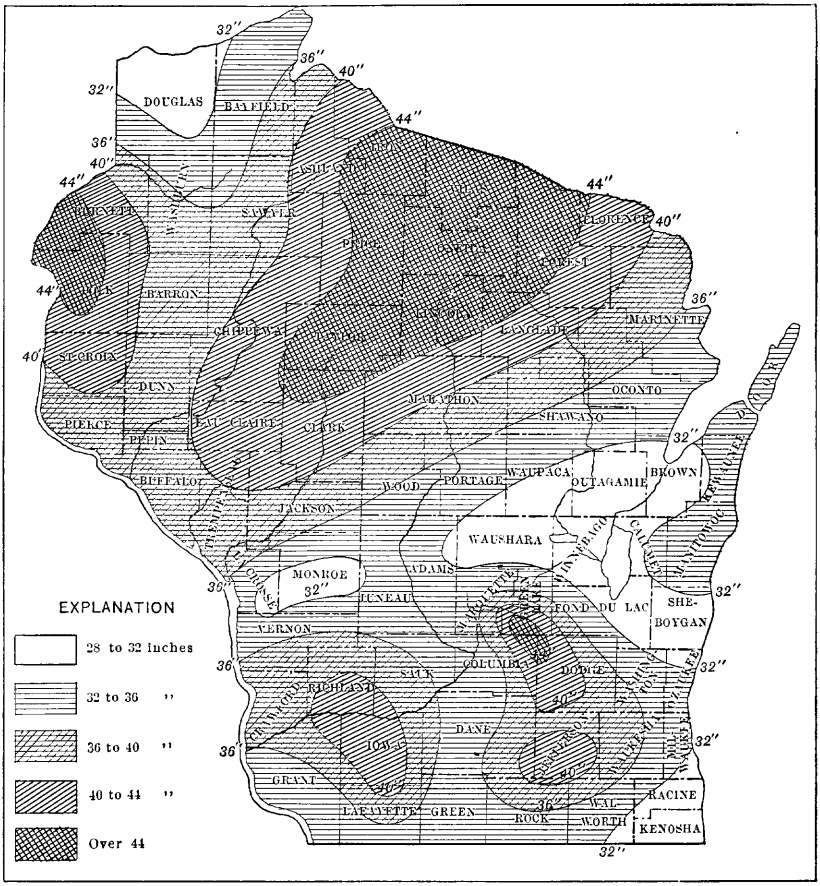

FIG. 1.—Rainfall map of Wisconsin.

Because of its bearing on the run-off of the various river systems, whose discharge measurements for 1903 and 1904 are herein given, the precipitation map shown in fig. 1 has been prepared. It will be noted that the heaviest rainfall occurred in the northern part of the State, averaging about 40 inches.

The following table shows some details of the distribution of rainfall by months:

Average precipitation at five stations in Wisconsin for twenty years.[a]

Detail.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
PERCENTAGES.													
Distribution	100	4.9	4.3	6.1	7.2	10.5	13.8	12.1	11.0	12.0	7.9	5.5	4.9
Classification of days:													
On which rain fell—													
Mean	41.2	43.0	41.9	40.4	40.6	43.7	48.1	41.1	38.2	41.7	36.1	39.3	43.5
Maximum	56.5	77.4	79.2	59.4	59.3	67.5	70.0	66.2	60.6	70.0	60.8	71.0	79.6
Minimum	27.0	18.7	11.3	19.3	21.9	20.7	30.6	17.4	21.3	15.9	12.8	14.9	19.3
Without rain	58.7	57.9	58.1	60.2	59.6	56.3	51.9	58.9	61.8	57.6	63.9	60.7	56.5
Trace to 0.25′	31.4	41.1	36.8	32.4	30.6	30.6	30.9	27.6	25.7	28.4	26.2	32.1	37.7
0.25′ to 0.50′	5.0	3.3	3.4	4.1	5.8	5.3	7.5	5.8	5.3	6.3	4.8	3.9	3.7
0.50′ to 1.00′	3.4	1.4	1.5	2.8	3.0	4.4	5.7	4.9	4.6	4.6	3.6	2.5	1.7
1.00′ to 2.00′	1.4	.3	.3	.4	1.2	1.8	3.2	2.0	1.9	2.6	1.6	.7	.4
2.00′ to 3.00′	.2	.2	.....	.1	.3	.4	.7	.7	.6	.3	.....	.....	.....
3.00′ to 5.00′	.1	.....	.....	.....	.....	.1	.....	.2	.1	.2	.....	.....	.....
Over 5′	.2	.....	.....	.....	.....	.....	.....	.....	.....	.2	.....	.....	.....
NUMBER OF DAYS.													
Greatest consecutive—													
With rain	26	12	16	12	13	13	11	13	15	13	19	14	14
Without rain	14	9	9	8	8	9	13	8	8	8	8	9	13
INCHES OF RAIN.													
Heaviest in 1 day	7.23	2.6	1.8	2.1	2.9	3.1	2.9	4.5	3.9	5.6	7.23	1.8	1.5

[a] Moore, W. L., Rainfall of the United States: Bull. D, U. S. Dept. Agriculture.

The amount of precipitation is fairly constant for the winter and a portion of the fall and spring months, but varies considerably in the summer months.

Exceptionally dry periods occur about once in fifty years, when the average for three consecutive years is 22 inches and the least for one year is 13.5 to 20.5 inches. Dry periods occur once in twenty-five years, when the average for three consecutive years is 24.2 inches and the least for one year is 20.3 inches. Moderately dry periods occur once in ten years. The exceptionally dry periods are preceded by an exceptionally wet period, when the annual precipitation has been as high as 50 inches. This is followed by a period of moderately heavy rainfall, with a maximum of 45 inches. The last exceptionally dry period occurred in 1894 to 1896.[a]

The year 1903 had a moderately heavy rainfall. If the above cycle can be depended on, the next period of maximum rainfall may be expected about the year 1908.

Fig. 2 shows the progressive averages of the precipitation at Milwaukee for the past seventy years, computed by the formula—[b]

$$\frac{a+4b+6c+4d+e}{16}=c'$$

where c represents the rainfall of the year in question and b and a stand for the rainfall in the two years preceding, while d and e represent the rainfall of the following two years.

[a] Kirchoffer, W. G., master's thesis.
[b] After Blandford. See Bull. D, U. S. Weather Bureau.

This curve makes clearer the nature of the rainfall cycle.

In the following table are shown the long-term precipitation records of four typical

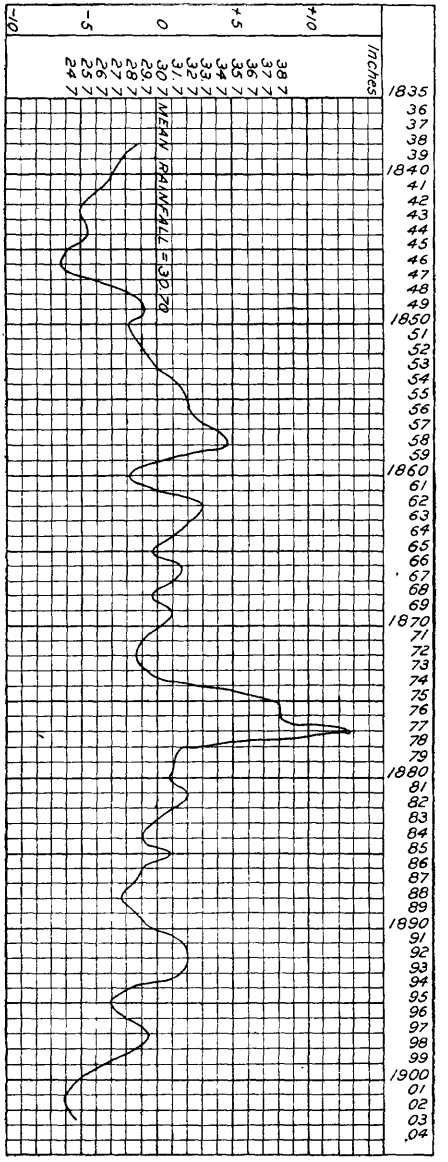

FIG. 2.—Chart showing rainfall at Milwaukee, 1837–1904.

stations in this general region. The rainfall at Milwaukee appears to be considerably less than the average of the State.

Precipitation at Milwaukee and Embarrass, Wis., and Duluth and St. Paul, Minn.

Year.	Milwaukee.	Embarrass.	Duluth.	St. Paul.	Year.	Milwaukee.	Embarrass.	Duluth.	St. Paul.
1845	20.5	.....	.....	.....	1875	35.6	43.9	27.0	30.7
1846	25.3	.....	.....	.....	1876	50.4	48.9	32.3	23.6
1847	22.4	.....	.....	.....	1877	46.2	34.4	34.3	28.7
1848	33.5	.....	.....	.....	1878	38.3	37.6	28.1	22.6
1849	31.1	.....	.....	.....	1879	24.9	41.6	45.3	32.5
1850	26.4	.....	.....	.....	1880	30.0	49.8	38.2	29.8
1851	30.4	.....	.....	.....	1881	39.1	57.4	37.6	39.2
1852	29.3	.....	.....	.....	1882	28.4	49.0	38.0	23.1
1853	30.0	.....	.....	.....	1883	29.5	42.2	23.2	26.5
1854	31.7	.....	.....	.....	1884	30.6	62.1	35.8	26.1
1855	36.0	.....	.....	.....	1885	32.6	42.6	20.0	25.3
1856	29.0	.....	.....	.....	1886	31.5	45.4	33.3	22.9
1857	30.9	.....	.....	.....	1887	30.5	43.6	28.5	25.9
1858	44.9	.....	.....	.....	1888	23.5	43.9	27.3	25.8
1859	28.9	.....	.....	29.1	1889	31.7	33.8	32.0	17.1
1860	24.0	.....	.....	34.2	1890	30.1	44.0	24.1	23.5
1861	31.9	.....	27.7	30.5	1891	29.8	41.2	29.5	21.8
1862	38.3	.....	35.4	34.5	1892	35.0	44.9	28.5	32.6
1863	31.8	.....	22.8	15.7	1893	32.9	23.1	23.3	26.0
1864	27.8	28.9	17.8	14.9	1894	27.8	.....	31.7	25.8
1865	30.1	36.3	20.9	38.1	1895	24.9	16.7	22.3	24.3
1866	34.0	34.5	30.6	27.9	1896	29.0	32.4	27.1	34.7
1867	24.6	29.0	25.7	33.6	1897	31.0	25.3	30.9	30.5
1868	29.4	38.8	.....	30.7	1898	32.4	28.1	19.7	25.3
1869	37.8	39.3	.....	32.2	1899	22.8	27.8	30.5	27.5
1870	26.6	41.9	.....	32.1	1900	30.1	.....	23.1	34.2
1871	32.0	37.7	31.2	30.7	1901	18.1	.....	26.7	25.8
1872	26.2	28.5	30.1	29.6	1902	28.6	.....	26.1	31.8
1873	30.6	35.0	38.8	34.6	1903	23.4	.....	28.0	37.9
1874	30.8	31.0	36.5	35.5	1904	29.9	.....	24.5	34.1

FOX RIVER SYSTEM.

DRAINAGE.

Lake Winnebago, the largest inland lake in Wisconsin, divides Fox River into two radically different sections, the upper and the lower Fox. The upper river approaches from the southeast to within about a mile of Wisconsin River at Portage, then turns to the northeast on its course to Lake Winnebago. It winds, with low banks, through broad savannas having only a gentle slope, passing a total distance of 25 miles through three long lakes before reaching Lake Winnebago.

Mud Lake, Buffalo Lake, and Lake Puckaway have been caused by the deposits of affluents which the main stream has not been able to wash away, plainly indicating that the present upper Fox did not erode its course, for it has not even the power to keep itself free, but instead is filling up. Lake Butte des Morts and Lake Winnebago are depressions which the present tendency is to fill up.[a]

Major Warren's hypotheses for these peculiar conditions have been widely accepted, and are so interesting that they are here given:

We have only to suppose that all the waters of Lake Winnebago basin (including that of the upper Fox) formerly drained to Wisconsin River; that a slow change of level in this region elevated the southwestern part and depressed the northeastern part till a large lake was formed, which finally overflowed, forming the course of the lower Fox. This explains the present doubling back in the course of the

[a] Warren, G. K., Rept. on Wisconsin and Fox rivers, 1876.

upper Fox and tributaries, and it accounts for the close relation and yet opposite courses of Fox and Wisconsin rivers. As the level changed the erosion at the outlet could not keep pace with it and so prevent a lake forming, because a granite ridge lies near the surface between the Wisconsin and Buffalo Lake. When the lower Fox outlet formed the loose material covering the rocks rapidly gave way and lowered the lake level down to the rock, which now (1875) keeps it to its present level. The period of this change was post-Glacial, because this alluvial terrace is free from Glacial drift, which it could not have been if formed before in a region like this, surrounded by Glacial drift deposit.

UPPER FOX.

Fox River descends only 40.4 feet in the 95.5 miles between Portage and Lake Winnebago—an average fall of less than 0.5 foot to the mile.

The following table shows the river profile in detail as given by United States engineers:

Profile of Fox River from Lake Winnebago (Oshkosh) to Portage lock (Fort Winnebago).

Station.	Distance—		Elevation above sea level.	Descent between points.	
	From Lake Winnebago.	Between points.		Total.	Per mile
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Lake Winnebago	0	.....	746.1	.....	
Eureka lock, crest	24.6	24.6	748.8	2.7	
Berlin lock, crest	32.9	8.3	750.6	1.8	
White River lock, crest	33.9	10.0	755.7	5.1	
Princeton lock, crest (Lake Puckawa)	43.3	9.4	760.2	9.4	0.42
Grand River lock, crest	64.0	20.7	763.9	3.7	
Montello lock, crest (Lake Buffalo)	67.3	3.3	768.9	5.0	
Governor Bend lock, crest	91.4	24.1	774.7	5.8	
Fort Winnebago lock (Portage)	95.5	4.1	781.6	6.9	

Fox River has been improved for navigation by the Federal Government along this entire distance by the building of 10 locks, but the slight fall gives few opportunities for water power.

The first dam on the Fox is at Pardeeville, where a head of 14 feet is available. Wisconsin River is about 10 feet above Fox River at Portage, and this fall could be utilized by a dam near the Fort Winnebago lock. A considerable quantity of water could be discharged through the canal with safety.

At Montello, 28 miles below, a turbine is installed under a head of 3 feet, developing power for a gristmill. No developed power is in use on the river below this point.

The three principal tributaries of the upper Fox have a fall of about 250 feet—much greater than that of the main river; they are all found on the north side. These branches, Montello, Mecan, and White rivers, start as clear, steady springs, running from the sand ridges of the drift covering that portion of the basin. They are each about 20 miles long, and would be unimportant except for the fact that their fall, combined with their steadiness of flow, makes them of considerable value.

Montello River joins the upper Fox at Montello. A dam at this point has a head of 11 feet, furnishing power for a flouring mill and a woolen mill. This head could be easily increased to 16 feet.

The following table shows the principal developed powers on the tributaries of the upper Fox.

Developed water powers on tributaries of upper Fox River.

Location and stream.	Owner and use.	Head.	H. P.
Hatton, Little River	C. F. Stollyman, flour and feed	10	33
Lawrence, Duck Creek	C. E. Pierce, flour and feed	11	70
Manchester, Grand River	G. Pfeiffer, flour	12	45
Marblehead, De Nevue Creek	D. I. Williams, flour and feed	30	30
Markesan, Grand River	P. Wieski, flour and feed	11	30
Oxford, Neenah Creek	H. Larmer, flour and feed	9	70
Do	H. E. McNutt, flour and feed	14	190
Pine River, Pine Creek	Skinner & Johnson, flour and feed	14	60
Poysippe, Pine Creek	W. H. Paulsen, flour and feed	9	70
Princeton, ditch from Mecan River	Teske & Zierka, flour, feed, and electric light	19	180
Ripon, Silver Creek	Nohr Milling Co., flour and feed	12	120
Saxeville, Pine Creek	B. W. Heald, flour and feed	10	54
Waumander, Waumander Creek	A. G. Ochsner, flour	15	27
Wautoma, Mecan River	William Henke, flour and feed	8	36
Westfield, Montello River	Cochran & Nettinger, flour and feed	10	85

LOWER FOX.

GEOLOGY AND TOPOGRAPHY.

East of Wolf River Valley is the more prominent though similar valley of Green Bay and Lake Winnebago. In pre-Glacial time it must have been much smaller in size, having been excavated to its present great size by the glacier. Lake Winnebago alone covers about 200 square miles, while the area of the connecting valley below (lower Fox River) is 400 square miles.

The western slope of both valleys is gradual, but the eastern slope is precipitous, being cut out of the soft Cincinnati shales overlain by the hard "Niagara" limestone. The bed is the hard "Galena" limestone of the "Trenton" series. The eastern side of the lower Fox River drainage basin rises abruptly 100 to 200 feet above the water in Green Bay, and continues as a line of cliffs along the eastern shore of the present Lake Winnebago, and thence southward, though largely covered with drift in the southern part of the State. The glacial action sent down an immense ice sheet, cutting out the valley of Lake Michigan, while a branch tongue gouged out Green Bay Valley to its present size. On the peninsula between Green Bay and Lake Michigan was formed the prominent Kettle Range, a medial moraine.

The floor of Green Bay Valley has a rapid rise, Lake Winnebago being 166 feet above Green Bay. The portion of the old valley now occupied by the upper Fox was largely filled with drift, and it seems probable that to the action of the glacier in cutting down the intervening "Lower Magnesian" rampart and in partially filling the upper valley of Fox River is due the change in the flow of upper Fox and Wolf rivers through the newly enlarged Green Bay Valley to the lake. It is also likely that the change in flow is partly due to a depression toward the north, which occurred during or after the recession of the glacier, as suggested by Major Warren. This depression caused an advance of Lake Michigan, which rearranged the drift and deposited the red clays. By means of the latter this ancient shore of the lake can now be traced northward beyond Shawano, on Wolf River, westward up Fox River above Berlin, and southward to a few miles north of Fond du Lac. Lake Winnebago is a comparatively modern reservoir, formed in the valley by the deposition of glacial drift.

PROFILE.

The table below gives in detail the profile of the river to-day, after the extensive navigation improvements by the United States Government:

Profile of Fox River from Lake Winnebago (Menasha) to Green Bay.[a]

Station.	Distance.		Elevation above sea level.	Descent between points.	
	From Menasha.	Between points.		Total.	Per mile.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Menasha dam, crest	0.0		746.1		
Appleton upper lock, crest	5.1	5.1	736.5	9.6	1.9
Appleton locks, foot	6.3	1.2	699.7	36.8	30.6
Cedars lock, crest	9.6	3.3	699.7	.0	.0
Littlechute locks:					
Crest	10.6	1.0	690.0	9.7	9.7
Foot	11.6	1.0	653.8	36.2	36.2
Grand Kaukauna locks:					
Crest	13.3	1.7	653.8	.0	.0
Foot	14.2	.9	603.3	50.5	56.1
Rapide Croche lock:					
Crest	17.9	3.7	603.3	.0	.0
Foot	17.9	.25	593.9	9.4	37.6
Little Kaukauna lock:					
Crest	23.9	6.0	593.9	.0	.0
Foot	23.9	.2	587.7	6.2	31.0
Depere lock:					
Crest	29.8	5.9	587.7	.0	.0
Foot	29.8	.0	580.0	7.7	.....
Green Bay	35.2	5.4	580.0	.0	.....

[a] From United States engineer's profile of the river.

These improvements have changed the river into long stretches of slack water, with perhaps short rapids at the foot of a dam, except at Grand Kaukauna and Grand Chute, the site of the city of Appleton, where the rapids are passed by canals, while the river flows over its original steep bed.

RAINFALL AND RUN-OFF.

The United States engineers have maintained a gaging station at Rapide Croche dam ever since March, 1896. The assistant engineer in charge, L. M. Mann, states that the crest of the dam at this point is well suited for a weir. Care is taken to read the gage three times daily, the mean reading being used to calculate the daily discharge.

According to these records the mean low-water discharge for the past eight years was 1,409 second-feet and the average discharge 3,007 second-feet; 2,660 second-feet may be regarded as the ordinary flow of the river. Because of the steadying effect of Lake Winnebago and the lakes above, formed by the expansion of upper Fox and Wolf rivers, the discharge of the river is remarkably uniform. At Appleton the ordinary variation from low to high water is scarcely more than 2 or 3 feet throughout the year.

The following table gives the maximum, the minimum, and the average flow for each month for nearly nine years, ending December, 1904, as measured at Rapide Croche dam, and also the rainfall and run-off for the same period:

Estimated monthly discharge of lower Fox River at Rapide Croche dam.

[Drainage area, 6,200 square miles.]

Month.	Discharge in second-feet.			Run-off.		Rainfall.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Inches.	Per cent of rainfall.
1895.							
January	4,972	2,262	3,931	0.634	0.731	.....	.....
February	5,201	2,545	4,320	.697	.726	.....	.....
March	5,796	2,062	3,947	.637	.734	.....	.....
April	12,706	3,076	8,510	1.37	1.53	.....	.....
May	6,386	4,233	5,610	.905	1.04	.....	.....
June	15,416	6,628	12,760	2.06	2.30	.....	.....
July	11,982	3,451	7,612	1.23	1.42	.....	.....
August	5,173	3,047	4,424	.714	.823	.....	.....
September	5,072	2,242	3,988	.643	.717	.....	.....
October	4,185	2,071	3,417	.551	.635	.....	.....
1896.							
March	1,739	697	1,284	.207	.239	1.14	21.0
April	1,765	406	940	.152	.170	4.39	3.87
May	4,246	1,563	3,140	.506	.583	5.23	11.1
June	4,605	2,173	3,726	.601	.670	2.75	24.4
July	3,863	880	2,787	.450	.519	3.09	16.8
August	2,607	123	1,470	.237	.273	3.09	8.83
September	390	9	146	.024	.027	3.23	.84
October	1,888	145	1,065	.172	.198	2.55	7.76
November	2,882	985	2,007	.324	.362	3.06	11.8
December	3,558	838	2,367	.382	.440	1.04	42.3
The year	.....	.....	.....	.....	.....	29.57	.....
1897.							
January	3,795	1,512	2,762	.445	.513	1.37	37.5
February	3,522	1,297	2,765	.446	.464	1.17	39.6
March	5,344	1,160	2,711	.437	.504	2.19	23 1
April	8,728	3,296	6,132	.989	1.10	2.00	55.0
May	5,344	2,519	4,016	.648	.747	1.74	42.9
June	4,749	2,032	3,246	.524	.585	5.06	11.6
July	4,071	1,297	3,200	.516	.595	3.51	16.9
August	3,230	116	1,881	.303	.349	2.00	17.4
September	1,588	272	833	.134	.150	2.53	5.9
October	2,608	299	1,424	.230	.265	2.15	12.3
November	2,664	861	1,862	.300	.335	1.50	22.3
December	3,770	806	2,314	.373	.430	.86	50.0
The year	8,728	116	2,762	.445	6.04	26.08	23.2
1898.							
January	3,158	1,425	2,559	.413	.476	.71	67.1
February	3,196	1,494	2,359	.380	.397	1.21	32.8
March	3,872	1,782	2,968	.479	.552	2.18	25.3
April	5,692	2,568	4,079	.658	.734	2.02	36.4
May	6,852	2,204	4,743	.765	.882	2.75	32.1
June	4,969	1,604	3,216	.519	.579	3.84	15.1
July	2,553	438	1,571	.253	.292	3.09	9.45
August	2,805	866	1,817	.293	.338	3.00	11.3
September	1,795	442	1,088	.175	.195	2.36	8.25
October	2,368	383	1,201	.194	.224	3.15	7.10

Estimated monthly discharge of lower Fox River at Rapide Croche dam—Continued.

Month.	Discharge in second-feet.			Run-off.		Rainfall.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Inches.	Per cent of rainfall.
1898.							
November	2,725	1,234	2,213	0.357	0.398	1.49	26.7
December	2,805	994	2,175	.351	.405	.35	116.0
The year	6,852	383	2,499	.403	5.47	26.15	20.9
1899.							
January	2,417	771	1,905	.307	.354	1.12	31.6
February	2,810	1,014	2,075	.335	.349	.90	38.8
March	3,435	995	2,252	.363	.418	2.31	18.2
April	5,707	1,447	3,657	.590	.658	3.00	21.9
May	8,767	3,787	6,209	1.00	1.15	3.08	37.3
June	8,571	4,018	6,298	1.02	1.14	5.40	21.2
July	5,171	1,741	3,786	.611	.704	3.29	21.4
August	3,505	791	1,836	.296	.341	2.73	12.5
September	1,437	707	988	.159	.177	2.68	6.60
October	2,079	398	1,144	.185	.213	3.02	7.05
November	2,648	613	2,119	.342	.382	.74	51.6
December	2,572	105	2,042	.329	.379	1.47	25.4
The year	8,767	105	2,859	.461	6.26	29.74	21.1
1900.							
January	2,684	841	2,174	.351	.405	.74	54.7
February	3,024	1,044	2,247	.362	.377	1.56	24.2
March	3,677	1,110	2,556	.412	.475	1.09	43.6
April	4,355	1,107	3,414	.551	.615	2.82	21.8
May	4,054	1,383	2,976	.480	.553	1.61	34.5
June	2,208	258	873	.141	.157	2.68	5.86
July	2,413	131	958	.154	.178	6.45	2.76
August	2,646	1,057	1,831	.295	.340	4.30	7.91
September	3,518	1,107	2,021	.326	.364	6.17	5.90
October	8,036	1,734	5,230	.844	.973	7.08	13.7
November	9,597	4,948	8,062	1.30	1.45	1.57	92.4
December	8,222	1,668	4,353	.702	.809	.69	117.0
The year	9,597	131	3,058	.493	6.70	36.76	18.2
1901.							
January	4,349	1,939	3,526	.569	.656	.90	72.9
February	4,634	1,825	3,773	.609	.634	.46	138.0
March	6,431	1,742	3,839	.619	.714	3.04	23.5
April	12,033	2,469	8,960	1.45	1.62	.79	205.0
May	6,905	3,453	4,994	.805	.928	2.72	34.1
June	5,087	1,741	3,723	.600	.669	4.62	14.5
July	4,557	2,045	3,501	.565	.651	6.41	10.2
August	3,846	1,130	2,176	.351	.405	2.38	17.2
September	1,687	675	1,221	.197	.220	3.96	5.56
October	3,873	9,910	2,551	.411	.474	2.93	16.2
November	3,873	1,640	3,256	.525	.586	1.25	46.9
December	3,672	1,464	2,768	.446	.514	.81	63.5
The year	12,033	675	3,691	.596	8.07	30.27	26.7

Estimated monthly discharge of lower Fox River at Rapide Croche dam—Continued.

Month.	Discharge in second-feet.			Run-off.		Rainfall.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Inches.	Per cent of rainfall.
1902.							
January	3,136	765	2,263	0.365	0.421	0.69	61.1
February	3,480	696	2,142	.345	.359	1.53	23.5
March	4,019	1,135	2,892	.466	.537	1.50	35.8
April	3,252	947	2,335	.377	.421	2.42	17.4
May	12,317	1,471	4,935	.796	.918	4.02	22.8
June	11,868	3,491	6,930	1.12	1.25	3.89	22.1
July	5,703	1,647	4,304	.694	.800	5.47	14.6
August	4,086	1,311	2,896	.467	.538	1.40	38.4
September	1,865	515	1,266	.204	.228	2.81	8.11
October	3,024	435	1,818	.293	.338	1.94	17.4
November	3,184	756	2,394	.386	.431	2.90	14.9
December	3,100	892	2,274	.367	.423	1.93	21.9
The year	12,317	435	3,037	.490	6.66	30.50	21.8
1903.							
January	3,756	1,206	2,760	.445	.513	.47	109.5
February	3,652	1,675	2,949	.476	.496	.80	62.0
March	8,437	1,780	3,827	.617	.711	3.12	22.8
April	9,297	3,886	6,500	1.05	1.17	3.14	37.3
May	7,378	3,043	5,532	.892	1.03	5.87	17.5
June	6,791	2,656	5,061	.816	.910	2.14	42.5
July	5,571	1,856	4,124	.665	.767	5.47	14.0
August	4,449	1,438	3,446	.556	.641	6.23	10.3
September	5,519	1,829	4,321	.697	.778	5.91	13.2
October	5,826	2,590	4,686	.756	.872	2.75	31.7
November	5,077	1,733	3,686	.595	.664	1.14	58.3
December	3,702	1,319	2,885	.465	.536	.71	75.5
The year	9,297	1,206	4,148	.669	9.09	37.75	24.1
1904.							
January	3,869	1,185	3,074	.496	.571	.38	150.0
February	4,134	1,565	3,128	.505	.545	1.45	37.6
March	7,425	1,724	3,398	.548	.632	1.80	35.1
April	9,637	1,612	6,669	1.08	1.20	1.86	64.5
May	11,682	4,456	8,707	1.40	1.61	5.93	27.1
June	9,793	2,336	6,682	1.08	1.20	3.99	30.1
July	4,111	1,416	3,105	.501	.578	3.98	14.5
August	4,043	1,551	2,985	.481	.554	3.01	18.4
September	2,631	988	1,854	.299	.334	5.75	5.81
October	6,434	1,324	3,457	.558	.643	4.73	13.6
November	6,935	1,667	4,056	.654	.730	.30	243.5
December	4,594	1,812	3,618	.584	.673	2.13	31.6
The year	11,682	988	4,228	.682	9.270	35.31	26.2

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	3,012	4,672	4,697	4,798	4,373	6,628	11,982	4,884	4,698	2,071	.....	.....
2	2,262	4,328	4,438	3,185	5,852	7,339	10,639	4,963	5,072	2,132	.....	.....
3	3,350	4,766	4,285	3,076	5,880	6,935	10,433	4,964	3,387	3,546	.....	.....
4	3,781	5,164	4,260	5,064	5,910	7,225	10,585	4,936	3,048	3,584	.....	.....
5	4,447	3,765	2,846	5,595	5,949	8,277	10,664	5,173	3,788	3,366	.....	.....
6	4,269	2,689	2,611	5,998	6,135	15,416	10,639	3,411	4,102	3,554	.....	.....
7	4,285	4,785	3,982	5,804	4,493	14,244	9,415	3,385	4,487	3,932	.....	.....
8	3 024	4,973	3,998	7,052	4,233	14,178	9,206	4,382	4,395	3,057	.....	.....
9	2,967	5,063	4,021	8,803	5,546	15,132	7,865	4,847	4,430	2,504	.....	.....
10	4,244	5,009	4,419	9,422	6,386	14,286	7,416	4,898	3,969	3,899	.....	.....
11	4,422	5,173	4,214	11,435	6,155	14,122	8,803	4,242	3,106	3,971	.....	.....
12	4,594	4,061	2,704	12,354	6,037	14,060	9,124	4,847	4,372	4,022	.....	.....
13	4,559	2,892	2,264	12,706	6,066	14,559	9,066	3,577	4,144	3,884	.....	.....
14	4,102	4,830	2,062	12,187	4,642	14,585	8,769	3,383	4,327	3,764	.....	.....
15	3,112	5,201	3,892	12,033	4,399	14,219	8,521	4,849	4,447	2,774	.....	.....
16	2,497	4,785	3,685	11,063	6,179	14,365	7,165	4,937	4,243	2,227	.....	.....
17	3,916	4,723	3,876	11,110	6,165	14,588	6,699	4,937	2,856	3,955	.....	.....
18	4,244	4,637	4,313	11,637	6,274	13,981	8,860	5,027	2,826	4,052	.....	.....
19	4,602	3,369	2,529	12,277	5,891	14,277	7,873	4,785	4,236	4,086	.....	.....
20	4,654	2,545	2,098	11,879	6,115	14,279	6,597	3,047	4,405	3,939	.....	.....
21	4,619	4,839	4,228	10,336	4,803	14,191	6,577	3,526	4,447	3,956	.....	.....
22	3,027	4,910	4,490	10,639	4,386	13,419	5,804	4,794	4,294	2,088	.....	.....
23	2,963	4,847	5,796	9,406	5,804	13,674	4,583	4,892	4,337	2,173	.....	.....
24	4,742	4,777	5,757	9,032	6,047	13,513	3,451	5,036	2,974	3,917	.....	.....
25	4,829	4,356	5,626	9,208	5,880	12,524	5,797	5,019	2,242	4,021	.....	.....
26	4,576	3,055	4,508	7,661	5,880	11,892	6,179	4,804	4,030	4,069	.....	.....
27	4,972	2,575	5,546	5,862	5,841	14,021	5,498	3,593	4,421	4,081	.....	.....
28	4,653	4,186	4,353	6,164	4,566	12,265	5,545	3,518	4,162	4,160	.....	.....
29	3,413	.....	4,268	6,144	5,129	12,509	5,192	4,145	4,285	2,710	.....	.....
30	3,137	.....	4,395	3,362	6,597	12,251	3,562	4,086	4,127	2,263	.....	.....
31	4,576	.....	4,185	.....	6,312	.....	3,480	4,26	.....	4,185	.....	.....
Total	121,850	120,975	122,346	255,292	173,925	382,954	235,989	137,156	119,657	105,942	.....	.....
1896.												
1	.....	.....	888	1,272	2,406	2,789	3,694	912	259	145	985	2,821
2	.....	.....	697	1,027	2,088	4,246	3,728	1,048	298	608	1,048	3 135
3	.....	.....	1,386	922	1,563	4,246	3,761	1,512	179	838	1,512	3,230
4	.....	.....	1,226	760	1,639	4,141	2,032	2,314	78	608	1,537	3,558
5	.....	.....	1,395	1,048	3,493	4,282	880	2,461	36	683	1,872	3,135
6	.....	.....	1,338	780	3,166	3,967	1,820	2,578	36	1,440	1,872	1,952
7	.....	.....	1,430	761	3,312	3,897	3,592	2,607	179	880	1,792	2,372
8	.....	.....	1,113	922	2,993	3,135	3,394	2,490	328	1,070	1,563	2,821
9	.....	.....	919	859	3,230	4,461	3,863	1,250	390	880	1,093	2,789
10	.....	.....	1,271	964	2,032	4,282	3,728	1,392	122	1,093	2,201	2 913
11	.....	.....	1,479	859	1,575	4,605	3,761	1,818	192	608	2,229	2,913
12	.....	.....	1,407	406	3,361	4,389	2,201	1,818	136	779	2,638	2,729
13	.....	.....	1,407	644	3,427	4,106	1,952	1,765	48	1,093	2,729	1,647
14	.....	.....	1,271	859	3,476	3,296	3,592	1,723	48	964	2,729	1,672
15	.....	.....	981	922	3,558	2,913	3,525	2,006	205	922	1,115	2,519
16	.....	.....	837	985	3,396	4,037	3,525	985	145	1,093	1,160	2,460
17	.....	.....	1,437	1,048	2,686	3,796	3,694	1,352	192	1,138	2,460	2,607
18	.....	.....	1,248	985	2,460	3,897	3,296	2,006	134	608	2,729	2,578
19	.....	.....	1,486	644	3,591	3,897	1,872	2 032	78	722	2,668	2,578
20	.....	.....	1,366	608	3,897	3,897	1,672	2,061	195	1,362	2,729	1,563

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
21			1,414	943	3,897	2,431	2,913	2,006	17	1,647	2,882	1,613
22			1,024	943	3,897	2,461	2,607	1,899	145	1,440	1,639	2,519
23			1,024	901	4,071	3,967	2,314	2,454	134	1,563	1,440	2,460
24			1,739	985	2,729	4,211	2,607	838	36	1,613	2,608	2,431
25			1,461	1,273	2,387	3,932	2,607	327	112	543	2,789	838
26			1,224	556	3,932	4,141	1,563	123	122	556	2,821	1,160
27			1,179	780	4,246	3,897	1,563	259	27	1,440	2,669	838
28			1,605	1,027	4,071	2,608	2,913	375	9	1,272	1,818	1,792
29			1,337	1,765	4,161	2,173	2,669	406	374	1,845	1,205	2,913
30			1,522	1,765	4,071	3,693	2,490	453	134	1,888	1,672	2,607
31			1,707		2,519		2,578	312		1,672		2,229
Total			39,818	28,213	97,330	111,793	86,406	45,582	4,388	33,013	60,204	73,392
1897.												
1	2,201	1,563	1,472	3,728	5,344	3,263	3,761	2,314	468	1,160	1,160	1,820
2	2,173	3,040	3,263	4,037	4,071	3,659	3,863	1,765	621	1,070	1,983	1,832
3	1,512	3,361	3,263	4,966	4,002	3,727	4,037	3,103	343	702	2,209	2,128
4	2,088	3,103	3,135	3,296	4,886	3,727	2,490	3,103	328	556	2,615	2,226
5	2,789	3,072	3,395	4,037	5,079	3,761	1,297	3,230	328	1,138	2,642	1,638
6	3,104	3,263	2,608	5,624	4,713	2,201	2,173	3,072	390	1,115	2,664	1,196
7	3,394	1,440	1,183	6,329	4,605	2,402	4,002	3,040	272	1,160	1,973	2,401
8	3,008	1,563	1,393	6,329	4,354	3,361	4,071	1,926	539	1,183	1,390	2,474
9	2,759	3,008	2,431	6,533	3,198	3,230	3,932	1,416	702	985	1,861	2,497
10	2,607	3,361	2,490	6,533	2,759	3,329	3,932	2,760	556	741	1,964	2,748
11	2,286	3,040	2,461	5,231	4,354	3,459	2,402	2,608	664	556	1,912	2,568
12	3,072	3,198	2,578	4 789	4,497	3,659	2,402	2,490	390	1,345	1,964	1,905
13	3,198	3,198	2,461	6,614	4,461	2,229	3,459	2,490	390	1,512	2,183	1,102
14	3,072	2,189	1,512	6,410	4,141	2,229	3,558	2,608	819	1,512	1,481	2,512
15	3,040	1,297	1,160	6,533	4,425	3,394	3,694	1,440	1,416	1,897	1,092	3,409
16	2,788	3,103	2,490	6,329	3,329	4,749	3,897	1,345	1,588	1,952	1,833	3,439
17	1,644	3,072	2,314	6,779	2,913	4,037	3,694	3,431	1,440	1,048	1,912	3,770
18	1,872	3,230	2,619	7,072	4,106	3,727	2,229	2,638	1,205	722	1,964	1,880
19	3,230	3,198	3,460	5,419	4,282	3,727	2,006	2,431	761	1,897	2,432	2,213
20	3,795	3,361	5,344	7,114	4,425	2,286	3,394	1,765	702	2,061	2,412	1,559
21	3,459	1,639	2,821	7,582	4,318	2,314	3,558	1,093	943	1,897	1,387	2,424
22	3,198	1,723	2,461	7,326	4,461	3,525	3,761	1,048	1,205	1,897	861	2,665
23	3,394	3,135	3,694	8,728	3,072	3,525	3,694	1,352	1,393	299	2,045	2,642
24	2,759	3,522	3,626	8,549	2,759	3,592	3,525	1,273	1,369	1,115	1,207	2,732
25	1,899	3,378	3,328	6,946	4,141	3,263	1,926	1,273	1,160	1,239	2,476	1,878
26	2,945	3,458	3,394	6,329	4,246	3,528	2,117	901	644	2,117	2,107	806
27	2,945	3,135	3,135	7,539	4,246	2,343	3,008	1,160	838	2,490	2,148	1,657
28	3,103	1,765	1,512	6,329	4,071	2,032	3,198	343	1,138	2,373	1,281	2,900
29	3,361		1,962	5,459	4,071	3,932	3,394	374	1,183	2,608	1,097	2,808
30	3,103		3,394	5,459	2,638	3,727	3,394	116	1,183	2,286	1,002	2,923
31	1,818		3,694		2,519		3,329	403		1,512		2,969
Total	85,616	77,415	84,053	183,948	124,486	97,397	99,197	58,311	24,978	44,145	55,857	71,721
1898.												
1	3,063	2,793	2,676	4,056	3,776	4,969	2,553	876	1,652	602	2,609	2,805
2	2,099	2,762	2,698	4,176	3,799	4,522	2,496	1,546	1,795	554	2,351	2,766
3	1,425	2,931	2,753	2,846	5,508	4,579	1,771	1,649	1,639	517	2,237	2,714
4	2,535	3,196	2,908	2,568	5,016	4,397	438	1,670	1,317	857	2,134	1,789
5	3,000	3,062	2,752	3,890	6,668	3,578	1,868	1,585	726	595	2,187	1,647
6	3,039	2,038	1,699	4,072	6,852	2,388	1,865	1,667	1,454	771	1,457	2,479

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
7	2,946	1,766	1,782	4,159	6,098	4,018	1,769	973	1,532	801	1,234	2,609
8	2,977	2,504	3,064	4,115	4,921	4,408	1,639	1,074	1,629	1,024	2,617	2,699
9	1,873	2,665	3,669	4,150	4,333	4,276	1,466	1,653	1,735	383	2,475	2,572
10	1,396	2,583	3,761	2,925	5,889	4,175	1,096	1,685	1,714	638	2,485	1,379
11	2,953	2,701	3,394	2,837	5,904	4,364	1,042	1,695	1,133	1,056	2,497	2,153
12	2,969	2,679	3,192	4,291	5,683	3,215	1,535	1,660	750	1,092	2,542	1,539
13	2,901	1,723	1,868	4,273	5,487	2,524	1,757	1,835	1,288	1,246	1,543	2,345
14	2,946	1,578	1,902	4,054	5,432	3,690	1,798	1,213	1,115	1,155	1,451	2,637
15	3,079	2,331	3,224	4,189	4,018	3,703	1,842	1,226	1,186	1,156	2,438	2,791
16	1,864	2,549	3,288	4,301	3,457	3,723	1,792	1,765	1,080	745	2,453	2,715
17	1,569	2,490	3,111	2,924	4,551	3,167	1,074	2,273	1,177	755	2,552	2,215
18	2,908	2,468	3,135	3,025	5,088	3,690	1,245	2,460	778	1,300	2,563	1,343
19	2,799	2,497	3,435	4,372	4,758	2,343	1,699	2,805	442	1,178	2,482	1,462
20	3,078	1,528	1,938	4,650	4,647	2,076	1,639	2,752	760	1,304	1,747	2,453
21	2,859	1,587	2,235	4,776	4,739	2,453	1,616	2,024	818	1,892	1,281	2,409
22	2,915	2,403	3,280	5,692	3,577	2,623	1,664	866	959	1,865	2,704	2,398
23	1,925	2,409	3,200	4,894	3,157	2,603	1,685	2,571	906	1,136	2,549	2,241
24	1,741	2,505	3,122	3,176	4,338	2,624	1,088	2,579	933	760	2,499	2,303
25	2,962	2,403	3,643	3,462	4,594	2,488	989	2,482	676	2,043	2,725	994
26	2,985	2,505	3,361	4,656	4,471	1,623	1,557	2,468	491	1,815	2,572	1,017
27	3,077	1,494	2,565	5,089	4,739	1,604	1,641	2,572	681	1,845	1,486	1,544
28	3,158	1,914	3,035	5,136	4,612	1,863	1,618	1,942	693	2,064	1,402	2,412
29	2,964	.....	3,872	4,767	3,857	2,230	1,687	1,195	877	2,233	2,606	2,446
30	1,851	.....	3,728	4,839	2,204	2,567	1,661	1,848	693	1,489	2,519	2,315
31	1,461	.....	3,736	.....	4,872	.....	1,117	1,717	.....	2,368	.....	2,244
Total	79,317	66,064	92,026	122,360	147,045	96,483	48,707	56,326	32,629	37,239	66,397	67,435
1899.												
1	1,533	2,111	1,931	3,279	3,787	5,209	5,042	3,345	1,292	831	2,104	2,205
2	1,488	2,174	2,113	1,837	5,020	5,238	4,031	3,505	1,437	764	2,648	2,455
3	2,366	2,275	2,134	1,447	5,121	5,432	3,133	3,121	842	1,560	2,542	1,667
4	2,417	2,261	2,113	3,756	5,417	4,733	3,678	2,396	1,003	1,037	2,446	952
5	2,187	1,453	1,352	4,249	5,395	4,018	3,361	2,418	1,411	996	1,742	2,549
6	2,393	2,458	1,279	4,641	5,500	5,518	4,923	1,745	1,121	1,193	1,261	2,411
7	2,173	2,175	1,976	4,839	4,446	5,633	5,171	956	991	1,100	2,579	2,475
8	1,466	1,303	1,932	4,425	4,145	5,565	4,726	2,043	953	928	2,622	2,572
9	1,465	2,681	2,027	2,823	5,924	5,062	3,942	2,585	996	774	2,523	2,530
10	2,316	2,572	2,062	2,249	6,192	5,369	3,019	2,394	792	964	2,635	1,775
11	2,329	2,810	2,034	3,741	6,618	4,406	4,592	2,343	578	922	2,619	1,020
12	2,316	2,047	2,355	3,821	7,601	4,334	4,715	2,357	945	1,056	1,890	2,366
13	2,106	1,711	1,336	3,812	8,050	5,878	4,882	1,547	825	1,144	1,143	2,498
14	2,406	2,588	1,913	3,976	7,301	7,091	4,852	1,250	891	982	2,187	2,352
15	1,514	2,646	2,289	3,721	7,763	7,080	4,974	1,852	889	779	2,381	2,395
16	1,604	2,534	2,692	2,199	8,562	7,681	3,773	1,812	831	398	2,351	2,339
17	2,254	2,619	2,612	2,004	8,767	7,408	3,021	1,829	831	969	2,352	1,780
18	2,379	2,453	2,553	3,461	7,838	6,702	4,516	1,946	1,001	1,039	2,261	1,259
19	2,352	1,243	1,353	3,946	8,421	6,853	4,511	1,973	1,166	1,179	1,774	2,576
20	2,347	1,291	995	3,778	8,431	8,123	4,186	1,026	996	1,304	613	2,381
21	2,330	1,902	2,731	3,955	7,046	8,095	3,881	1,163	1,039	1,327	2,301	2,388
22	1,409	2,117	3,001	4,154	6,272	8,571	3,701	1,578	991	885	2,205	2,417
23	1,506	2,152	2,756	2,798	5,263	8,515	2,459	1,609	855	685	2,237	2,497
24	1,729	1,995	2,832	2,813	5,333	8,277	1,741	1,772	707	1,480	2,209	1,752
25	1,562	2,104	2,829	4,336	5,451	7,338	3,193	1,317	719	1,551	2,352	105
26	1,690	1,395	1,910	4,524	5,263	6,594	3,336	1,339	922	1,404	1,873	958

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
27	1,981	1,014	1,243	4,565	5,525	7,372	3,364	944	1,138	1,829	905	2,123
28	771	2,007	3,192	5,707	5,898	6,029	3,395	791	1,099	2,029	2,329	2,185
29	1,506	.....	3,297	4,913	5,160	5,797	3,232	1,307	1,206	1,493	2,159	2,417
30	1,346	.....	3,325	3,947	5,466	5,007	2,051	1,351	1,166	769	2,330	2,241
31	1,803	.....	3,435	.....	5,513	.....	1,982	1,299	.....	°2,079	.....	1,659
Total	59,044	58,091	69,802	109,716	192,489	188,928	117,383	56,913	29,613	35,450	63,573	63,299
1900.												
1	841	2,395	2,432	2,454	3,636	1,482	276	2,646	1,976	1,734	9,535	6,608
2	2,352	2,366	2,468	1,107	3,882	1,574	511	2,106	1,640	4,007	9,397	4,372
3	2,391	2,446	2,490	3,554	4,028	1,375	319	1,946	1,421	5,185	9,597	3,512
4	2,406	1,641	1,707	3,846	4,010	1,102	131	1,966	1,962	5,479	8,225	5,674
5	2,479	1,044	1,110	3,967	4,054	1,929	820	1,638	2,141	4,846	7,650	5,943
6	2,568	2,366	1,342	4,063	2,779	2,208	352	1,287	1,894	4,758	8,989	5,807
7	1,576	2,381	2,576	3,791	1,674	2,085	345	1,956	2,050	3,657	9,039	5,683
8	1,213	3,024	2,639	2,903	2,461	1,467	294	1,912	2,113	2,848	8,418	5,439
9	2,406	2,420	2,614	1,751	2,283	1,302	365	2,075	1,333	4,827	8,658	8,222
10	2,669	2,398	2,636	3,510	2,275	989	473	1,973	1,143	5,165	9,260	3,586
11	2,684	1,675	1,921	3,770	2,240	1,013	353	2,043	1,973	5,117	7,830	5,245
12	2,646	1,071	1,352	4,067	2,285	1,217	333	1,498	2,071	4,813	7,567	5,052
13	2,677	2,316	2,666	4,006	1,784	1,189	394	1,057	2,187	4,668	8,775	5,075
14	1,736	2,654	2,973	4,080	1,753	756	382	1,825	2,075	3,559	8,456	5,301
15	1,236	2,707	3,036	2,560	3,741	353	538	1,905	2,184	3,028	8,076	4,099
16	2,527	2,729	2,961	2,237	3,989	497	979	1,889	1,163	4,461	6,611	2,725
17	2,424	2,662	2,935	3,942	3,799	394	1,176	2,039	1,167	4,885	6,909	2,240
18	2,639	1,895	2,069	4,355	3,885	437	1,067	2,002	1,949	5,285	5,654	4,118
19	2,534	1,314	1,354	4,089	3,791	573	907	1,434	1,899	5,254	4,948	4,292
20	2,657	2,861	2,710	4,137	2,665	523	1,192	1,120	2,062	5,703	7,536	4,314
21	1,719	2,840	2,832	4,072	2,105	569	1,152	2,120	2,020	4,599	7,875	4,378
22	1,043	2,606	2,904	2,932	3,729	585	799	2,007	2,169	4,225	8,249	4,457
23	2,632	2,687	2,954	1,977	3,937	264	1,170	1,875	1,433	6,510	8,189	4,035
24	2,549	2,646	3,296	3,856	3,872	262	1,846	1,966	1,107	6,270	8,792	1,668
25	2,461	1,434	2,259	4,089	3,889	396	2,047	1,924	2,329	7,427	7,100	3,224
26	2,579	1,296	1,300	4,106	3,694	258	1,982	1,440	2,891	7,572	6,917	2,621
27	2,420	2,411	3,159	4,063	2,539	360	1,979	1,115	2,810	7,624	8,415	4,068
28	1,508	2,624	3,644	4,225	1,383	298	1,905	1,912	3,391	6,393	8,632	4,147
29	1,219	.....	3,677	2,862	2,103	386	1,536	1,928	3,518	6,336	8,328	4,111
30	2,166	.....	3,560	2,064	2,149	341	1,672	2,127	2,561	7,855	8,239	3,191
31	2,439	.....	3,652	.....	1,859	.....	2,413	2,023	.....	8,036	.....	1,728
Total	67,396	62,909	79,228	102,435	92,273	26,184	29,708	56,754	60,632	162,126	241,866	134,935
1901.												
1	3,822	3,475	4,362	2,469	6,328	4,803	2,045	3,834	1,197	1,161	3,664	2,586
2	4,000	3,734	4,262	4,664	6,905	3,802	3,496	3,846	1,161	1,782	3,804	1,685
3	4,215	2,659	2,741	5,086	5,990	3,473	3,740	3,787	1,636	1,863	2,674	2,653
4	4,202	1,825	2,109	5,209	6,032	4,913	2,618	2,648	1,682	1,748	1,789	3,520
5	4,253	3,723	4,073	5,385	4,769	5,087	3,194	1,713	1,687	1,713	3,699	3,497
6	3,016	4,096	4,481	6,081	3,799	4,905	4,097	2,553	1,682	1,228	3,728	3,459
7	2,043	4,352	4,262	6,777	5,707	4,647	2,945	2,605	1,649	991	3,711	3,648
8	3,939	4,515	4,262	7,075	5,536	4,846	2,722	2,321	1,105	2,067	3,728	2,329
9	4,279	4,541	4,210	10,675	5,498	2,834	4,185	2,406	893	2,145	3,584	1,598
10	4,349	2,796	2,908	10,986	5,574	2,654	4,557	2,336	1,449	2,265	2,585	3,257
11	4,159	2,045	1,793	11,579	5,428	3,873	4,080	1,503	984	2,468	1,654	3,585
12	4,009	4,164	2,206	12,033	4,183	3,916	4,154	1,607	1,199	2,314	3,447	3,669

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.												
13	3,046	4,181	4,000	11,573	3,754	4,443	4,041	2,579	1,051	1,740	3,766	3,672
14	2,235	4,434	4,121	11,088	5,012	4,273	3,131	2,512	1,194	1,260	3,766	3,139
15	3,914	4,262	4,059	10,728	5,564	3,911	2,809	2,497	706	3,633	3,771	2,524
16	3,929	4,292	4,169	11,869	5,428	2,586	3,996	2,642	1,146	3,357	3,856	1,555
17	2,480	3,068	2,818	11,935	5,371	1,741	4,089	2,575	1,009	3,252	2,697	2,894
18	3,542	2,227	1,742	11,614	5,011	3,475	4,002	1,617	1,039	3,366	1,661	3,349
19	3,981	4,309	3,967	11,467	4,099	4,087	3,898	1,404	1,004	3,136	3,644	3,316
20	2,965	4,470	4,030	11,334	3,715	4,148	4,067	1,737	1,090	2,099	3,873	2,939
21	2,835	4,392	4,554	9,926	5,006	3,948	2,912	1,607	1,056	1,574	3,728	3,312
22	3,521	4,500	4,143	9,302	5,261	3,956	2,230	1,764	675	3,539	3,833	2,645
23	3,885	4,393	4,109	11,103	5,312	3,137	3,623	1,885	1,020	3,728	3,717	1,567
24	3,885	3,085	3,433	9,826	4,686	2,493	3,899	1,795	1,276	3,622	2,485	2,953
25	3,898	2,489	4,615	9,467	4,938	3,336	3,936	1,542	1,449	3,664	1,640	2,095
26	3,813	4,402	6,431	9,240	3,884	3,506	3,833	1,130	1,513	3,749	3,212	1,971
27	2,563	4,634	4,994	8,395	3,759	3,474	3,791	1,849	1,449	2,719	3,585	2,860
28	1,939	4,577	4,084	7,401	4,875	3,554	2,668	1,892	1,437	1,646	3,476	3,088
29	3,286	.....	4,367	7,244	3,453	3,506	2,138	1,932	1,073	3,597	3,432	2,177
30	3,668	.....	4,245	7,271	5,010	2,354	3,724	1,622	1,124	3,873	3,456	1,464
31	3,643	.....	3,469	.....	4,920	.....	3,921	1,725	.....	3,791	.....	2,796
Total	109,314	105,640	119,019	268,802	154,807	111,681	108,541	67,465	36,635	79,090	97,665	85,802
1902.												
1	3,096	2,595	3,368	2,765	2,393	9,573	5,703	3,727	910	1,286	2,962	987
2	3,104	917	1,190	2,964	2,469	10,488	5,601	3,276	1,111	1,499	1,004	2,930
3	2,938	1,488	1,632	3,011	2,423	11,868	5,447	1,544	1,682	1,596	1,314	2,899
4	3,060	2,446	2,497	3,106	1,471	11,462	3,372	2,532	1,690	1,498	2,716	3,060
5	1,058	2,513	2,632	3,252	2,079	11,050	3,453	3,692	1,723	435	2,931	2,907
6	1,676	2,609	2,758	1,603	2,845	10,407	3,010	3,912	1,865	736	2,854	3,022
7	2,776	2,609	2,827	1,706	3,537	9,886	3,349	4,086	704	1,576	2,973	892
8	2,860	2,408	2,754	3,134	4,079	7,311	5,534	3,999	1,244	1,751	3,012	1,662
9	3,136	696	1,135	3,102	3,131	7,886	5,533	3,894	1,709	1,613	914	2,799
10	2,993	1,427	1,575	3,147	4,018	8,343	5,326	1,532	1,759	1,613	1,273	2,845
11	2,915	2,389	3,866	3,102	2,075	8,209	5,280	2,362	1,653	1,526	2,977	3,100
12	765	2,595	3,274	3,119	2,743	6,222	5,136	3,666	1,550	651	3,028	3,045
13	1,285	2,587	3,608	1,459	4,637	6,431	4,639	4,047	1,669	1,042	2,946	2,996
14	2,494	2,477	3,690	1,759	4,917	3,998	3,264	4,031	821	2,116	2,891	1,158
15	2,344	2,455	3,567	2,108	5,056	5,840	5,125	3,853	1,083	2,391	2,891	1,335
16	2,461	1,063	1,603	2,366	4,917	4,169	5,142	3,958	965	2,250	756	2,654
17	2,514	1,421	1,765	2,449	4,615	6,156	5,265	1,500	1,203	2,219	1,308	2,665
18	2,505	2,492	3,707	2,265	2,484	6,282	5,281	2,097	1,208	2,716	2,841	2,619
19	1,139	2,413	3,841	2,376	2,692	5,439	5,163	2,539	1,317	715	2,832	2,609
20	1,099	2,587	3,841	1,086	4,682	5,992	2,896	2,733	1,174	1,455	2,962	2,688
21	2,422	2,366	3,994	2,069	5,085	6,088	3,150	2,913	652	2,120	2,954	1,256
22	2,113	2,486	3,969	2,267	4,862	3,852	4,248	2,927	887	2,646	2,915	1,609
23	2,450	1,085	1,852	2,069	4,725	4,215	4,209	2,869	1,473	2,534	958	2,602
24	2,422	1,377	1,723	2,314	4,949	5,866	4,325	1,311	1,452	2,676	1,349	2,642
25	2,429	2,210	3,777	1,986	5,719	6,089	4,566	1,773	1,174	2,681	2,977	1,494
26	927	2,424	3,925	2,247	7,422	6,001	4,287	2,763	1,369	1,086	3,184	1,579
27	1,389	2,366	4,019	947	9,941	5,707	1,647	2,891	1,336	1,286	2,860	2,654
28	2,425	3,480	3,841	1,571	11,227	5,740	2,265	2,879	515	1,785	2,962	1,142
29	2,558	.....	3,926	2,381	12,317	3,491	3,441	2,789	851	2,963	3,123	1,574
30	2,425	.....	1,769	2,312	9,869	3,852	3,733	2,158	1,222	3,024	1,138	2,468
31	2,373	.....	1,735	.....	9,599	.....	4,024	1,529	.....	2,875	.....	2,587
Total	70,151	59,981	89,660	70,042	152,978	207,913	133,414	89,782	37,971	56,360	71,805	70,479

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
1	2,587	1,675	1,829	6,192	6,009	5,677	5,571	4,393	4,195	5,312	2,664	2,819
2	2,631	2,102	1,780	6,597	6,306	6,791	5,419	2,827	4,281	5,293	2,102	2,385
3	2,587	3,008	3,191	6,806	6,145	6,069	5,278	3,011	4,298	2,805	4,674	1,915
4	1,206	3,053	3,197	7,649	4,275	5,429	3,509	3,845	4,325	2,618	4,772	3,669
5	1,479	3,097	3,453	9,297	6,118	5,386	2,055	4,136	4,324	5,321	4,769	3,628
6	2,662	3,394	3,318	7,729	5,989	5,989	2,721	3,756	1,829	4,993	4,965	1,653
7	2,818	3,387	3,665	7,661	6,237	3,747	3,943	3,707	1,936	5,826	4,929	1,973
8	2,767	1,825	2,301	6,379	6,078	4,089	3,746	3,787	3,935	5,595	1,975	3,507
9	2,832	1,837	2,070	6,342	5,911	5,812	4,093	2,206	4,708	5,339	2,098	3,621
10	2,409	3,390	3,560	6,783	3,629	5,969	3,796	2,875	4,809	5,339	4,230	3,702
11	1,559	3,581	3,981	8,283	3,964	5,564	4,009	3,671	5,077	2,845	4,957	3,595
12	1,522	3,593	4,199	7,807	5,698	6,009	1,856	4,021	5,086	2,577	5,077	3,644
13	2,954	3,652	4,064	7,402	5,467	5,735	3,370	4,134	2,734	5,340	4,731	1,623
14	3,187	3,501	3,962	8,394	5,771	3,501	4,992	4,030	2,731	5,509	4,846	1,827
15	3,610	2,005	2,550	8,517	5,467	3,818	4,684	4,134	5,199	5,482	2,226	2,964
16	3,655	2,042	2,207	6,236	5,841	5,631	5,157	1,438	5,312	5,510	1,859	3,516
17	3,493	3,368	4,178	6,216	3,421	5,668	5,149	2,003	5,293	5,434	4,219	3,694
18	1 295	3,269	4,650	6,339	3,869	5,716	5,139	4,064	5,387	2,760	4,466	3,702
19	1,953	3,285	8,437	4,188	6,088	5,354	2,700	4,099	4,442	2,957	4,888	3,677
20	3,503	3,431	6,454	4,518	6,127	5,232	3 174	4,047	3,751	5,599	4,504	2,000
21	3,476	3,468	3,887	6,429	6,127	3,326	5,047	4,021	2,489	5,134	4,282	1,916
22	3,664	2,379	1,815	6,246	5,933	3,645	4,945	1,874	5,106	5,368	1,733	3,328
23	3,436	1,749	2,340	6,657	6,157	5,429	5,102	3,869	5,369	5,293	2,307	3,424
24	3,543	3,232	5,086	5,784	3,043	5,476	5,176	1,965	5,481	5,283	4,422	1,908
25	1,293	3,107	5,055	4,796	3,824	5,411	4,918	3,794	5,415	2,590	4,484	3,353
26	1,935	3,068	4,838	3,886	6,216	5,335	2,538	4,291	5,519	2,666	3,874	1,584
27	3,289	3,457	4,839	4,376	7,378	5,204	2,189	4,449	3,481	5,133	3,310	1,319
28	3,435	3,627	4,967	6,207	6,421	2,656	4,442	4,244	2,991	5,302	3,378	2,162
29	3,527	.....	3,979	6,011	6,138	3,089	4,555	4,099	5,013	5,264	1,977	3,134
30	3,514	.....	3,337	5,288	6,657	5,084	4,254	1,781	5,059	5,217	1,873	3,619
31	3,756	.....	5,454	.....	5,199	.....	4,321	2,257	.....	5,264	.....	3,587
Total	85,577	82,582	118,643	195,015	171,503	151,841	127,848	106,828	129,635	145,268	110,591	89,448
1904.												
1	3,497	2,371	3,408	4,127	6,742	9,539	3,428	2,745	2,631	2,124	4,245	3,869
2	3,595	3,586	3,457	3,878	7,316	9,411	3,282	3,489	2,399	1,355	4,767	4,405
3	1,898	3,545	3,545	1,612	5,794	9,283	2,682	3,617	2,231	1,324	4,785	4,354
4	2,221	3,538	3,522	4,091	5,477	9,793	2,243	3,636	1,327	2,499	4,750	3,005
5	3,189	3,306	3,505	4,317	5,804	8,253	2,799	3,546	1,622	3,385	4,829	2,527
6	3,507	3,505	1,724	4,507	5,784	8,404	3,578	3,676	1,949	3,480	4,423	4,077
7	3,869	1,664	1,769	4,410	5,813	8,799	1,416	2,575	2,000	3,678	2,611	4,379
8	3,861	2,073	3,392	4,879	4,456	8,248	3,578	2,833	2,013	3,628	4,346	4,413
9	3,752	3,530	3,147	5,334	5,417	6,968	3,483	3,833	1,863	2,412	4,742	4,269
10	1,762	3,595	3,545	2,564	7,548	8,179	2,603	3,754	2,096	3,563	4,794	4,277
11	2,027	3,636	3,668	3,887	10,052	8,483	2,769	3,987	1,312	3,797	4,847	2,881
12	3,719	3,710	3,465	5,737	10,960	8,139	3,459	3,924	1,545	3,354	5,137	2,452
13	3,628	3,663	1,818	6,108	11,682	8,027	3,452	4,043	1,907	3,592	3,280	3,069
14	3,465	1,565	1,988	7,168	11,183	8,527	3,658	2,698	2,103	3,609	2,663	3,638
15	3,572	1,904	3,289	7,495	9,810	8,125	3,475	3,087	2,162	3,717	4,525	3,699
16	3,587	3,504	3,644	8,015	10,168	8,315	3,428	3,226	2,124	2,345	4,637	3,757
17	1,481	3,400	3,424	7,647	11,022	8,281	2,466	3,098	2,091	1,894	4,576	3,721
18	2,018	3,662	3,481	8,233	10,960	7,356	2,832	3,217	1,568	3,453	4,481	2,871
19	3,166	3,628	3,130	9,637	10,604	5,999	3,459	3,197	1,361	3,379	4,499	2,299

Mean daily discharge, in second-feet, of lower Fox River at Rapide Croche dam—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
20	3,352	3,710	1,739	9,434	10,168	5,776	3,344	3,240	1,762	4,488	2,538	3,711
21	3,329	1,689	2,036	9,399	9,574	6,167	3,206	2,214	1,825	4,470	2,286	4,439
22	3,408	2,237	3,913	9,190	8,571	5,241	3,420	1,722	988	4,248	4,102	4,354
23	3,392	3,760	4,335	9,018	9,099	3,758	3,359	2,443	1,988	3,018	4,421	4,111
24	1,185	3,962	5,185	7,436	9,845	3,617	2,345	2,531	1,888	2,915	3,264	4,077
25	2,096	4,082	7,425	7,126	10,168	2,336	2,585	2,396	1,276	4,336	3,379	2,253
26	3,668	4,134	5,429	8,823	10,812	2,336	2,909	1,551	1,381	4,694	4,285	1,812
27	3,727	3,810	2,354	9,075	9,389	2,585	3,146	2,503	1,975	4,542	2,748	3,162
28	3,869	1,843	2,504	9,028	9,527	3,474	3,498	2,595	1,925	4,575	1,667	3,700
29	3,752	2,091	3,359	9,017	8,720	3,538	3,584	2,115	2,267	6,434	3,127	3,677
30	3,848	.....	3,748	8,868	8,471	3,491	4,111	2,389	2,052	3,690	6,935	4,594
31	1,885	.....	4,385	.....	8,989	.....	2,659	2,645	.....	3,158	.....	4,311
Total	95,307	90,703	105,333	20,060	269,925	200,448	96,253	92,525	55,631	107,156	121,689	112,163

Unlike many other northern rivers the lower Fox is rarely troubled with ice gorges, because the ice on Lake Winnebago melts gradually. It is stated that trouble is sometimes experienced from anchor ice forming on the rapids in exceptionally cold weather, but this is largely prevented by the system of slack-water navigation.

The absence of great freshets prevents backwater and allows the construction of the mills out into the stream, as well as connecting sidetracks on short trestles only a few feet above the water, with perfect safety.

The bed of the river in nearly all cases is in hard limestone. Excellent quarries of fine building stone have been opened for use in both the Government and private improvements of the river.

WATER POWERS.

GENERAL STATEMENT.

No other river system in the State has so large a proportion of its total descent concentrated in its lower reaches as has the Fox. Between Lake Winnebago and Green Bay the river descends a total of 166 feet in a series of eight rapids. The total drainage area of the river is 6,449 square miles, of which area 6,046 square miles, or 94 per cent, are included above the outlet of Lake Winnebago. These two facts—the large concentration of fall in the lower river and the location of 94 per cent of its drainage area above this concentration—have the effect of producing extensive and valuable water powers.

Before any improvements had been made the river flowed between wooded clay bluffs from 10 to 70 feet or more in height, in some places rising abruptly from the river's edge on each side. Through this channel ran the clear, dashing river over its limestone bed from 300 to 1,000 feet wide. Great changes have since been made. [a]

[a] Tenth Census.

The following table gives the location and amount of fall at each of these rapids before improvement, according to surveys of Major Suter in 1866:

Rapids on lower Fox River in 1866 (before improvement).[a]

Name.	Descent.	Distance apart.
	Feet.	*Miles.*
Depere	8	.....
Little Kaukauna	8	6.0
Rapide Croche	8	6.0
Grand Kaukauna	50	4.5
Littlechute	38	2.5
Cedar rapids	10	.75
Grand Chute	38	4.0
Winnebago rapids	10	4.25
Green Bay to Lake Winnebago	170	28.0

[a] Warren, G. K., Report, 1876, p. 29.

LEGAL STATUS.

In 1846 Congress passed an act granting a large amount of land to the State of Wisconsin for the purpose of making a navigable route from Lake Michigan along Fox River to Wisconsin River. In 1853 the State, after expending $400,000 upon the improvements, passed the whole matter, including the land, into the hands of the Fox and Wisconsin Improvement Company. This company issued bonds, completed the improvement, and in 1856 the first steamer passed through from Mississippi River to Green Bay. On the advent of railroads soon after the route fell into disuse, and the company was unable to pay interest on its bonds. Suit was brought by the holders of these bonds, and the franchises, property, and land grants of the company were sold to a corporation organized in 1866 as the Green Bay and Mississippi Canal Company. In 1870 the United States appraised the value of the locks and canals at $145,000, took possession of them on the payment of this sum, and has since exercised control in the interests of navigation.

The Green Bay and Mississippi Canal Company still exists and retains its land grants, water-power franchises, and other property. The company claims the right to all surplus water after the needs of navigation are supplied. This claim includes the right to tap the canals at any point and draw off the water, provided navigation is not interfered with, as well as the right to take all the surplus flow of the river at the head of each rapids and use it at that level. This claim has been confirmed by the United States Supreme Court. The company does not claim ownership of power which is developed at a level below the head of a rapids by persons owning the land and using water which has passed the tailraces of the company.

In some cases this company owns the power, while others own the land. These interests have in some instances been mutualized in a joint company; in others protracted lawsuits have resulted in preventing the development and use of the water power up to the present time. The water powers at Rapide Croche and Little Kaukauna dams have not been improved for this reason.

As the low-water flow of the river falls far short of being sufficient for the turbines now installed, frequent controversies and lawsuits concerning the ownership of the water have resulted. Finally a few years ago the Neenah and Menasha Water Power Company, composed of practically all the users of water for power purposes on the river, was formed to regulate the use of the surplus water not required for navigation. Under the rules of the Secretary of War water may not be drawn below the crest of the Menasha dam except by

his special permit. Such permission is frequently given, however, to help out the great manufacturing interests concerned.

Fox River discharges from Lake Winnebago in two nearly parallel channels, distant about three-fourths of a mile from each other. These branches join in less than 2 miles in Lake Butte des Morts, an expansion of the river 3 miles long and extending at right angles to the general direction of the river.

Menasha and Neenah are located at the lower end of the two channels, Menasha on the north side of the northern channel and Neenah on the south side of the southern channel. These cities are about 1 mile apart and have a total population of about 12,000.

The river banks are here only 10 feet or less high. There is a dam in each channel, with an average head of 8 feet, the two maintaining the level of Lake Winnebago. These dams would develop 2,400 theoretical horsepower.[a]

The riparian owners on the Neenah channel improved the water powers before the ship canal was begun, and thus obtained a prior right under a State charter. Most of the manufactories are located on the strip of land, averaging 125 feet wide, between the river and the race.

NEENAH.

The Kimberly Clark Paper Company is the most extensive user of water power at Neenah, having installed 20 turbines under a head of 7½ feet, rated at 1,560 horsepower. In addition, this firm has 550 steam horsepower, all used in the manufacture of sulphite and ground wood pulp. The Neenah Paper Company has installed 11 turbines under a head of 7 feet, rated at 838 horsepower, and reports an additional 750 steam horsepower, all used in the manufacture of paper. The Winnebago Paper Mills have installed turbines under a 9-foot head, rated at 854 horsepower, which is supplemented with 450 steam horsepower.

Other power users in Neenah are included in the following table:

Additional water powers at Neenah.

Owner and use.	Turbines.		Steam H. P.	Remarks.
	Head.	H. P.		
	Feet.			
Kreuger & Lachmann, flour	8.0	469	125	
Neenah Boot and Shoe Manufacturing Co	8.0	39	12	Use steam when water is cut off.
Neenah and Menasha Gas and Electric Light Co.	7.5	199	125	
Robert Jamison, machine shop	8.0	94	10	
Wulff, Clausen & Co., flour	8.0	123	60	Burned.

MENASHA.

The Government canal is located at Menasha. This canal has a total length of about 4,320 feet, its single lock being located at the lower end, near Lake Butte des Morts. This dam develops 2,487 theoretical horsepower at ordinary flow. The Federal Government entered into an agreement with certain persons under which they constructed the navigation improvements and received in return the ownership of the resulting water powers. As a consequence the Green Bay and Mississippi Canal Company has no interest in these water powers.

A dam 475 feet long at the head of the canal develops a head of 8.2 feet, though some of the turbines work under heads of 6 to 8 feet. The strip of land between the canal and river is used for the location of numerous manufacturing plants, all the power, except that of the Howard Paper Mill, being taken from the canal.

[a] This estimate is based on an ordinary discharge of 2,660 second-feet, equal to a run-off of about 0.43 second-feet per square mile.

The largest water-power user at Menasha is the George A. Whiting Company, which owns the right to "first-class water." Its 6 turbines work under an average head of 8 feet and are rated at 503 horsepower. The company, which is engaged in the manufacture of paper, has also installed 265 steam horsepower.

Another large concern is the Menasha Wooden Ware Company, whose turbines work under an average head of 5 feet and are rated at 414 horsepower. This is supplemented by 1,090 steam horsepower.

The other important water-power users in Menasha are included in the following table:

Additional water powers at Menasha.[a]

Owner and use.	Turbines.		Steam H. P.	Remarks.
	Head.	H. P.		
	Feet.			
Gilbert Paper Co.	5	243	800–1,000	
Howard Paper Co.	5	321	200	
John Strange Paper Co.	5	156	250	Leased.
Banner Flouring Mills	5	90	50	
MacKinnon Excelsior Co.	6	124	225	
MacKinnon Pulley Co.	6	25	25	
John Schneider, planing mill	6	124	.....	
Valley Knitting Co., hose, mittens, etc.	4	38	.....	
Menasha Woolen Mills	5	35	Small engines.	When water is low.

[a] Authority, L. M. Mann, United States assistant engineer.

For the entire distance of 5 miles between Menasha and the Appleton upper dam the river affords slack-water navigation; indeed, it has been claimed that later improvements on the Appleton dam have caused the water at Menasha to back up a foot or more above its original level. As Appleton is approached the clay banks rise to a height of 50 or 60 feet.

APPLETON.

Fall.—Because of their intrinsic value, as well as on account of their early development, the Appleton powers are not excelled on the lower Fox. According to the Government profile the river has a total fall of 36.7 feet in a distance of 1.2 miles. This head is developed by three dams, which divide the river into upper, middle, and lower levels, with estimated theoretical horsepower[a] at ordinary flow of 4,238, 2,225, and 2,558, respectively.

At Appleton the river by a gradual bend changes its course from northeast to southeast, again turning to the northeast just above the lower dam. On the left bank the clay bluffs rise steeply 50 to 70 feet, while on the opposite bank is a flat extending for 3,500 feet, and perhaps 1,300 feet wide, beyond which rise high bluffs, as on the left bank. For the purposes of navigation the Government has constructed two dams, dividing the descent into two levels. The second or middle dam was constructed by private enterprise and is used exclusively for water power.

Upper dam.—The upper dam is a substantial stone structure. It extends from the foot of State street on the left bank normal to the shore for 250 feet, thence diagonally downstream for 700 feet to a point 400 feet from the right bank. From this latter point a retaining wall or long pier extends downstream 800 feet to the right bank. The head varies from about 10 feet at the upper end of the dam to 18 feet at the lower end, the average, as given by the Government engineers, being 14 feet. Its available water power is taken from a race along the left bank, from the ship canal on the right bank, and from the adjacent retaining wall.

[a] Estimated by U. S. Asst. Engr. L. M. Mann, on flow of 170,000 minute-feet, at 4,508, 2,367, and 2,721.

The extreme variation of head is stated at 2 feet, but the ordinary variation is only half that amount. It is due to the manner of using water by the Neenah mills, and to the prevalence of strong winds blowing continuously on Lake Winnebago and changing its volume of discharge.

The race on the left bank is 600 feet long, several extensive paper, pulp, and flouring mills occupying the strip of land between it and the river. Here are located the Appleton Paper and Pulp Company, with installed turbines under 11-foot head, rated at 550 horsepower; the Kimberly & Clark Company; the Vulcan and Tioga mills, with about 710 and 770 turbine horsepower, respectively; and the Atlas paper mill, with 766 turbine horsepower. The Appleton Waterworks Company, 1,400 feet below, receives power from this canal through a flume which affords a head of 18 feet. The above powers by long-established usage are recognized as belonging to the respective companies, and not to the Green Bay and Mississippi Canal Company.

Of the power developed on the right bank, nearly all is taken from the long pier. The Green Bay and Mississippi Canal Company owns the land on this side of the river and leases power to users.

The head here varies from 12 feet near the upper end of the pier to 16 feet at the lower end. The water is taken through ten arched openings in the stone pier from the large bay above. This power is fully developed by the Wisconsin Traction, Heat, Light, and Power Company, with turbines under 16-foot head, rated at 2,250 porsepower (besides 2,000 steam horsepower).

Of the few unused power sites on this dam the greater number are located on the ship canal, and, as heretofore stated, are owned by the Green Bay and Mississippi Canal Company. The following table gives the developed powers:

Water powers on the United States canal at Appleton.

Owner and use.	Water power.			Steam H. P.
	Average head.	Rated H. P.	Entitled to—	
	Feet.			
Riverside Paper and Fiber Co	14.0	383	300	.....
Appleton Chair Co., furniture	7.5	26	25	35
Union Toy and Furniture Co	8.0	50	25	30

Middle dam.—The middle dam also is independent of both the Government work and the Green Bay and Mississippi Canal Company. It was built by private capital for water-power purposes only. It is 2,400 feet below the upper dam and is about 450 feet long. The dam was constructed of timber in 1877 and has its foundation in limestone. A canal leads down the north (left) bank. The south end of the dam abuts on Grand Chute Island, West's hydraulic canal being supplied from the adjacent basin.

Previous to 1877 power had been developed by wing dams passing upstream from both banks for several hundred feet. The present dam is reported to have an average head of 7.3 feet, developing at ordinary flow (2,660 second-feet) 2,190 theoretical horsepower. The head at the various factories and mills varies from 7 to 14 feet, depending on their location, the variation being similar to that at the upper dam. The water level is remarkable for uniformity.

The north-shore race is 800 feet long, supplying a head varying from 9 feet at the upper end to 12 feet at the lower.

West's canal starts at the right abutment of the dam and extends down Grand Chute Island for about 1,700 feet, nearly parallel to the river. It has a width of about 130 feet, with earth and stone embankment about 3 feet above the water surface. The head averages 10 feet. Several fine power sites still unoccupied on this canal are especially desirable because of excellent transportation facilities.

The following table gives the important users of water power from the middle dam:

Water powers on the middle dam, Appleton.[a]

Owner and use.	Water power.			Steam H. P.
	Average head.	Rated H. P.	Entitled to—	
Fox River Paper Co.:[b]	*Feet.*			
Ravine mill Lincoln mill Fox River mill	11.0	2,126	$\frac{3}{7}$ flow of Fox River less 25 H. P.	1,050
Patton Paper Co Patton Pulp Co	8.0	814	1,250 H. P	500
Telulah paper mill, pulp	8.5 14.0	465 903	3,000 sq. in	500
Appleton Machine Co	5.0	14	500 sq. in	25
Appleton woolen mill, paper, knitting, etc	5.0	47	90 H. P	50
Fourth Ward planing mill, lumber	8.0	28	30 H. P	
Marston & Beveridge, hubs and spokes	8.0	77	75 H. P	
Valley iron works	7.0	47	40 H. P	

[a] Authority, L. M. Mann, U. S. assistant engineer.
[b] Power used by Fox River Paper Co. (three mills) are located on West's canal; the other powers are on the left bank.

Lower dam.—The lower or Government dam is located about three-fourths of a mile below the middle dam and just below the lower bend of the river, at a point where the river is 485 feet wide. The dam extends downstream from the left bank 417 feet, at an angle of about 45° with the channel, to an embankment which extends 600 feet farther downstream. The lower-level ship canal is back of this embankment. The river runs close to the left bank, which is high and steep, while on the right bank a flat 200 to 300 feet wide intervenes between the shore and the bluffs. There are four methods of utilizing the power—viz, from the abutment of the dam, from the race on the left bank, from the ship canal, and from the Telulah Water Power Company's canal on the right shore. The average head of this dam is stated at 8.5 feet, which at ordinary flow gives 2,550 theoretical horsepower. The report of Capt. L. M. Mann, on whose authority the above statement is made, shows that about 850 horsepower remain to be installed. There is said to be a fall of 3 feet in the 1,500 feet below the dam. This water power is owned by the Green Bay and Mississippi Canal Company.

The left or west-shore race starts at a point 450 feet above the dam and extends nearly parallel to the channel a distance of 1,200 feet below the dam. The bluffs rise steeply from the water, so that mills must extend out over the river. It is claimed that this race is entitled to one-fourth of the stream flow.

The right or east canal, known as the Hyde & Harriman canal, has several good locations for mills. The land adjacent was owned by Mr. W. Hyde and Judge J. E. Harriman, while the power belonged to the Green Bay and Mississippi Canal Company. These interests were united and the canal completed in 1880. It starts at the head of the ship canal and skirts the bluffs for its entire length of 2,250 feet, leaving a wide strip of flat land between it and the river. An earth embankment forms the river side. The cross section of the canal at its upper end is 120 by 7 feet, but it gradually decreases. Its head varies but slightly and is said to average 10 feet. The most important mill on this canal is that of the Telulah Paper Company, with a total of 11 turbines, rated at 1,368 actual horsepower.

CEDARS DAM.

This dam backs up the water for the entire distance of 3.3 miles to the lower Appleton dam, affording slack-water navigation. Fox River in this stretch is hemmed in by

high clay banks and has an average width of 600 feet. At a short distance below the dam however, a small creek enters from the north, causing the bluffs to recede from the river and follow up the creek, leaving a flat area of perhaps 35 acres. The dam is situated about 1,000 feet below the point where the bluffs leave the river. It crosses the river in a normal distance of 810 feet. It has an average head of 9.7 feet, which at an ordinary flow of 2,660 second-feet gives 2,910 theoretical horsepower. This power is owned by the Green Bay and Mississippi Canal Company, but the entire power is leased to the Kimberly & Clark Paper Company for a paper mill. This firm reports an installation of 33 turbines, under a head of 11 feet, rated at 4,217 actual horsepower.

LITTLECHUTE.

The next Government dam is located 4,000 feet below the Cedars dam at a small village called Littlechute. The river has extensive rapids at this point, there being a total descent, according to the Government profile, of 36.2 feet in the 2 miles between the foot of the Cedars lock and the backwater of the Kaukauna dam below. These rapids are passed by a canal 6,500 feet long on the left bank of the river. One lock of 16-foot lift is located about 1,000 feet from the head of the canal, and a composite lock of about 20-foot head is located at the lower end of the canal.

The river is about 840 feet wide at the dam site. On the left bank the bluffs retreat from the river slightly, leaving a narrow flat and some small islands. On the right bank there is a break of perhaps 1,500 feet in the bluffs. This power and the adjacent land belong to the Green Bay and Mississippi Canal Company. The dam has a head of 12 feet, but the total available head, because of the adjacent rapids in the 7,000 feet below the dam, is stated to be 34 feet. This descent, with a flow of 2,660 second-feet, gives 10,200 theoretical horsepower. It is certain that to develop more than half this amount would require a large expenditure of money. At the present time 20 feet of fall have been developed.

The Littlechute Pulp Company has installed 24 (mostly 54-inch) turbines under a head of 12 feet, rated at 3,000 actual horsepower. The power next in importance on this dam, and the only power not leased from the Green Bay and Mississippi Canal Company, is that of a flouring mill owned by Arnold Verstigen, run by 6 turbines rated at 100 horsepower.

COMBINED LOCKS DAM.

About a mile below the Littlechute dam is the Combined Locks dam, owned by the Combined Locks Paper Company. A view of this dam, together with part of the company's plant, is shown in Pl. II, *B*. The company has 49 turbines installed, rated at 4,438 practical horsepower, leased from the Green Bay and Mississippi Canal Company.

GRAND KAUKAUNA DAM.

A descent of 50.3 feet in a distance of less than a mile entitles the Grand Kaukauna rapids to first place in all the water powers of the lower Fox River. Both topographic and transportation conditions are very favorable for improvement. The Kaukauna dam is distant 2.5 miles from the Littlechute dam and produces slack water to the end of the Littlechute canal. The rapids are passed by a ship canal 7,400 feet long, extending from the dam and including 5 locks with an aggregate lift of 50.3 feet, all located on the left bank of the river. At its middle point this canal is distant 1,000 feet from the river. The river is about 700 feet wide at the dam, but a quarter of a mile below broadens out between several islands to a maximum width in the middle of the rapids of over 2,000 feet. The islands are low, but all have the limestone base. These islands, together with the flats on both sides of the river, give fine facilities for water-power development. The distance across the valley from bluff to bluff is about 3,500 feet.

The water powers are made available in three or more ways, viz, from the ship canal, from the Kaukauna Water Power canal, and from the Edwards & Mead canal. There is

A. DAM ON LOWER FOX RIVER AT DEPERE.

Looking east.

B. COMBINED LOCKS DAM ON LOWER FOX RIVER AT LITTLECHUTE.

Private dam; plant cost $1,250,000.

a frontage of 900 feet or more on the upper level of the ship canal suitable for power development and furnishing an average head of about 16 feet. The Kaukauna Water Power canal starts 400 feet above the dam, thence runs 400 feet at an angle from the shore of about 45°. At a point about 200 feet from the river it turns and runs parallel to the south channel of the river for 2,000 feet. Its greatest width, 150 feet, is at the bulkhead. Its minimum width is 86 feet and its depth is 11 feet. There is said to be a descent of 2 feet in the total length of 2,400 feet, and the average head furnished is 18 feet. Along the side and end of the canal there is a total frontage of 2,100 feet available for power sites and mills.

The Kaukauna Water Power Company's claims to one-half the flow of the river were denied by the Green Bay and Mississippi Canal Company at the time of the construction of these improvements, and the matter was taken into the courts for adjudication. After successive trials in the State courts the question was finally settled by the United States Supreme Court October, 1898, in favor of the Green Bay and Mississippi Canal Company, which thereupon purchased the entire plant and canal of the Kaukauna Water Power Company.

In this decision the Supreme Court held broadly that the use of the surplus waters created by the Government dam and canal at Kaukauna belonged to the Green Bay and Mississippi Canal Company, but that "after such waters had passed over the dam and through the sluices and had found their way into the unimproved bed of the stream, the rights and disputes of the riparian owners must be determined by the State court."

The Edwards & Mead canal was built under the direction of Capt. N. M. Edwards, engineer for the Green Bay and Mississippi Canal Company. Advantage was taken of a branch of the main north channel running between two large islands; this was formed into a pocket by damming the ends and sides. This channel starts 600 feet below the bridge, and the dam was placed 1,000 feet below its head. As the water is taken from below the first level of the rapids the Green Bay and Mississippi Canal Company could make no legal claim to it, but subsequent to its development bought the power. The sides of the channel are substantially built of earth on the south side and dry rubble masonry on the north side.

Recently very comprehensive plans have been prepared for the improvement of the lower level at Kaukauna, which will produce 6,500 theoretical horsepower. These plans include the blasting out of the tailrace so as to develop a 21-foot head at the present Government dam, and also the construction of a new masonsy dam below which will develop 27 feet additional. As this dam would render useless some of the present improvements below the Government dam, it will be necessary to purchase such property before the new dam can be constructed. These developments will be made as soon as a suitable tenant is found.

At the present time the Green Bay and Mississippi Canal Company offers for rent 3,000 theoretical horsepower already developed at the headrace of the Kaukauna WaterPower Company's canal, recently purchased. Large store buildings at this point, though partially destroyed by fire, could readily be converted into a large manufacturing plant.

The city of Kaukauna has 5,000 inhabitants and is on the main line of the Chicago and Northwestern Railway, being also reached by the Fox River Valley Electric Railway.

The following table gives a list of the power users at Kaukauna and the installed turbine power:

Water powers on Fox River at Kaukauna. [a]

Owner.	Water power.			Steam H. P.
	Average head.	Rated H. P.	Entitled to—	
	Feet.			
Badger Paper Co	16	1,230	.....	450
Chicago and Northwestern Rwy. shops	7	47	75	110
Kaukauna Fiber Co	14	194	100	200
Kaukauna Machine Co	14	250	75	15
Kaukauna Electric Light Co	14	194	.....	160
Thilmany Pulp and Paper Co	14	389	275	175
Western Paper Bag Co	15	1,400	400	310
Outagamie Paper Co	21	816	1,500	.....
Lindauer Pulp Co	12	.....	.....	.....
Reese Pulp Co	12	440	.....	350
Thilmany Pulp and Paper Co	12	709	.....	567

[a] Nos. 1–4 are owned jointly by the Green Bay and Mississippi Canal Company; Nos. 5–9 are leased from the same company; Nos. 10 and 11 are leased from same company and Edwards.

Below Kaukauna Rapids the river is from 1,200 to 2,200 feet wide for nearly 2 miles, but it gradually contracts to a width of about 500 feet for the lower half of its course between Kaukauna and Rapide Croche. Almost without exception the bluffs rise directly from the river for the entire distance. Navigation is also by slack water from the Grand Kaukauna Canal to the Rapide Croche dam.

RAPIDE CROCHE DAM.

The Rapide Croche dam is located 4.5 miles below the Grand Kaukauna dam and was built by the Government for navigation purposes. It is about 450 feet long and has an average head of 8.5 feet. The bluffs rise on either side close to the river, except on the left bank at the site of the ship canal. This canal starts just above the dam and extends downstream for a distance of 1,760 feet to the lock. This forms a strip of land well suited for power or mill sites, being 900 feet long and varying in width from 20 feet at the ends to 200 feet at the middle. This ground and 120 acres adjacent is owned by the Green Bay and Mississippi Canal Company.

The Rapide Croche dam develops 2,400 theoretical horsepower, which may be leased on extremely favorable terms. At the present time this power is not utilized. Its location, nearly midway between Green Bay and Appleton, is convenient for the development of electric power for railroad or other purposes. The Chicago and Northwestern Railway and the Fox River Valley Electric Railway are close at hand on the left bank.

LITTLE KAUKAUNA DAM.

Six miles below the Rapide Croche dam is located another Government dam which furnishes slack-water navigation in this stretch of the river. This dam is about 550 feet long and furnishes a head of 8 feet. The bluffs rise close to the right bank, but on the left bank recede for several hundred feet. Advantage is taken of this fact to locate the Government canal here. This canal is 950 feet long and has a single lock at its lower end.

The power here, like that at Rapide Croche, is owned by the Green Bay and Mississippi Canal Company, while the riparian rights are owned by other parties. This fact has led to a protracted legal struggle, which has resulted in preventing the utilization of the valuable water powers. It is stated on good authority that these suits have recently been settled and that improvements will soon be made.

A large number of water-power lots would be made available by the construction of a tailrace parallel to the canal about as shown in fig. 3. An 8-foot head with a flow of 2,660 second-feet, gives 2,400 theoretical horsepower.

DEPERE DAM.

This dam at Depere, a city of over 4,000 inhabitants, about 7 miles from the mouth of Fox River, is the last dam and lock on the river. A view of it is shown in Pl. II, A. The dam is of crib construction, about 2,000 feet long, and furnishes an average head of 7 feet, which, at an ordinary flow of 2,660 second-feet, gives 2,100 theoretical horsepower. A modern steel bridge is located just below the dam.

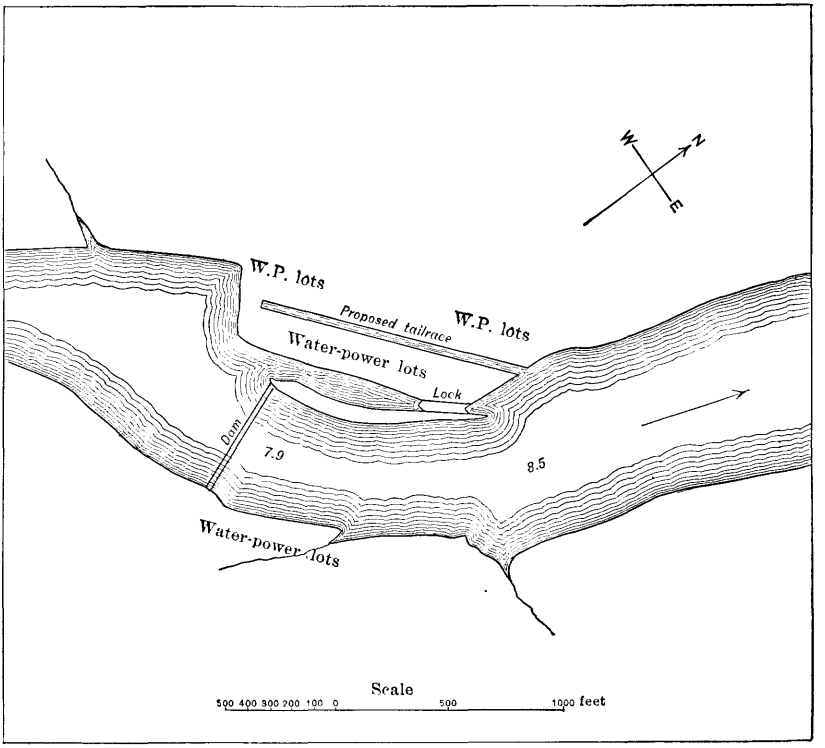

FIG. 3 – Plan of water-power development at Little Kaukauna, Wis.

This power does not belong to the Green Bay and Misssisippi Canal Company, for it was built under a contract whereby the riparian owners were to have the use of the power in return for the maintenance of navigation improvements.

The American Writing Paper Company, which has one of the largest and most modern paper mills on the river, has installed 16 large turbines, with a rating of 1,565 practical horsepower. In addition the company uses 1,300 steam horsepower. It is entitled to the total power of the river less 290 horsepower. The value of its annual product is stated at $600,000.

On the right bank, taking water from the ship canal, are located the J. P. Dousman Company's flouring mill, with 175 actual turbine horsepower, and the Depere Electric Light and Power Company's plant, with 100 actual turbine horsepower. The flouring mill has a capacity of 300 barrels a day. These are the last powers on the river.

RAILROADS.

Attention has elsewhere been called to the fact that the freedom from freshets which lower Fox River enjoys allows the building of railroad side tracks over or across the river so as to reach any mill no matter how situated. The river thus enjoys excellent railroad facilities. The Chicago and Northwestern Railway closely follows the left bank of the river between Neenah and Green Bay, and a branch performs a similar service for all the mills between Menasha and Kaukauna on the right bank. The Chicago, Milwaukee and St. Paul Railway reaches Neenah, Menasha, and Appleton, while another branch parallels the river between Green Bay and Depere. The Wisconsin Central line reaches Neenah and Menasha. Besides the steam lines, the river's entire length is closely followed by an electric interurban railroad, which provides a train every hour at reduced rates.

The navigation improvements maintained by the Federal Government provide for a 6-foot channel between Oshkosh and Green Bay. While this channel is insufficient for the larger freight boats navigating the Great Lakes, the commerce on lower Fox River has been sufficient to reduce the railroad freight rates to an exceedingly reasonable basis. This gives the numerous factories on this river a very marked advantage in shipping both raw materials and finished products. This advantage, together with the extremely low rates at which water power may be rented ($5 to $10 per annum per horsepower), has already made this one of the largest manufacturing districts in the State.

MENOMINEE RIVER SYSTEM.

This river is formed by the junction of Michigamme and Brule rivers, and for its entire length of about 104 miles forms the boundary between Wisconsin and Michigan. It flows in a general southeasterly direction, entering Green Bay at Marinette.

DRAINAGE.

The Menominee drainage basin is narrow in its lower portion, but widens as the stream is ascended, the river receiving important branches near its source. Its total drainage area is about 4,000 square miles, of which 1,430 square miles is in Wisconsin.

Like Chippewa River, it has a main arm to the north, Michigamme River, which is nearly as long as the main river, its source, in fact, being within 12 miles of Lake Superior. This has an important bearing on the discharge of the Menominee, because it secures the large run-off due to the heavy precipitation of that region as well as the steadying effect of the enlarged drainage. The combined drainage area of Brule and Michigamme rivers amounts to 1,769 square miles [a]—nearly one-half that of the entire river system.

PROFILE.

From its head, at the junction of Brule and Michigamme rivers, to its mouth, a distance of about 104 miles, the river descends about 700 feet. In addition to this its Wisconsin tributaries descend about 300 feet, and those in Michigan 470 feet. The opportunities for water power are numerous, because of the frequent concentrations of descent in rapids along the entire course of the river. The following descriptions of the most important water powers are taken from data furnished by Messrs. O'Keef & Orbison, hydraulic engineers, of Appleton, Wis., who also loaned maps and profiles of the river, and from the very full descriptions by James L. Greenleaf, C. E., in the census report.[b]

Quoting from the latter:

> It will be evident from the following account that there is an immense amount of water power on the Menominee awaiting development, the concentrations of the descent in numerous rapids and falls supplying remarkably fine opportunities for improvements. Any works for the utilization of the power would have to be so constructed as not to interfere with the manufacturing company in the driving of logs; but dams, etc., could be built so as to be no hindrance to the passage of logs.

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[a] Tenth Census, vol. 17, p. 57.
[b] Water powers of the Northwest: Tenth Census, vol. 17, pp. 59-60.

In the table that follows will be found a statement in detail of the descent of Menominee River, together with other valuable data:

Profile of Menominee River from its mouth to head of upper rapids, Twin Falls.[a]

No.	Station.	Distance— From mouth.	Distance— Between points.	Elevation above sea level.	Descent between points. Total.	Descent between points. Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river	.....	.....	580.0	.....	.....
2	Dam No. 1, foot	2.0	2.0	580.0	.....	.....
3	Dam No. 2, foot	2.5	.5	587.0	7.0	14.0
4	Dam No. 3, foot	2.75	.25	594.0	7.0	28.0
5	Schappies rapids, foot	7.7	5.0	612.0	18.0	3.6
6	Schappies rapids, head	8.7	1.0	622.0±	10.0	10.0±
7	Grand rapids, foot (mouth of Little Cedar River)	22.0	13.3	649.0±	27.0	2.0±
8	Grand rapids, head (NW. ¼ sec. 32, T. 34 N., R. 23 E.)	24.5	2.5	669.0±	20.0	8.0
9	Railroad crossing, Ross	26.5	2.0	671.8	2.8	1.4
10	White rapids, foot (lot 1, sec. 30, T. 35 N., R. 21 E.)	50.7	24.2	683.4	11.6	48.0
11	White rapids, head (south line sec. 7, T. 35 N., R. 22. E.)	53.7	3.0	714.4	31.0	103.0
12	Pemena rapids, foot (mouth Pemena Creek)	61.5	7.8	748.3	30.3	3.9
13	Pemena rapids, head (south line sec. 5, T. 36 N., R. 22 E.)	63.0	1.5	767.1	18.8	12.5
14	Pemena dam, foot	67.0	4.0	773.1	6.0	15.0
15	Pemena dam, crest	67.5	.5	786.2	13.1	26.2
16	Sturgeon Falls, foot	77.0	9.5	803.9	17.7	1.9
17	Sturgeon Falls, head	77.5	.5	816.8	12.9	25.8
18	Sturgeon River, mouth	78.1	.6	818.0	1.2	2.0
19	Norway, Mich. (where public road joins river)	80.1	2.0	824.0	6.0	3.0
20	Iron Mountain, Mich. (500 feet above old ferry)	84.1	4.0	851.0	27.0	6.7
21	Little Quinnesec Falls, foot	85.4	1.3	878.0	27.0	20.7
22	Little Quinnesec Falls, head	85.65	.25	942.0	64.0	256.0
23	Big Quinnesec Falls, foot	89.9	4.25	966.0	24.0	5.6
24	Railroad bridge south of Iron Mountain	91.15	1.25	1,020.0	54.0	43.3
25	Highway bridge south of Iron Mountain	92.4	1.25	1,045.0	25.0	20.0
26	Railroad bridge, river siding	100.4	8.0	1,065.3	20.3	2.5
27	Twin Falls (500 feet below lower rapids)	101.4	1.0	1,072.5	7.2	7.2
28	Twin Falls (head of upper rapids)	102.1	.7	1,099.8	27.3	3.9

[a] Authority: No. 1, U. S. Lake Survey; Nos. 2–6, Menominee River Boom Company; Nos. 7, 8, and 10–18, T. W. Orbison; No. 9, Wisconsin and Michigan Railway; Nos. 19–27, U. S. Geol. Survey; No. 28, Chicago and Northwestern Railway.

GEOLOGY.

While the surface is largely covered, generally deeply, by glacial drift, the Menominee and all its tributaries flow over hard, pre-Cambrian crystalline rocks as far south as the mouth of Pike River, or fully two-thirds its length. In this region important iron mines are found. Below the mouth of Pike River the Menominee flows 10 miles across the Cambrian sandstone, then for 18 miles across the next higher layer, the "Lower Magnesian" limestone, and for the last 8 miles to its mouth across the "Trenton" group of limestones.[a]

The crossing of the Cambrian sandstone results in no rapids of importance, but two rapids occur in passing the "Lower Magnesian" and the "Trenton" limestones. Most of the rapids, of course, are in the harder crystalline rocks above the mouth of Pike River.

The topography of the country through which Menominee River flows can not be described as mountainous, but many high ridges give diversity to the surface. The Wisconsin branches, Pine and Brule rivers, rise side by side with the Flambeau and the Wisconsin in

[a] Geol. Wisconsin, p. —.

a high, flat plateau, abounding in lakes and swamps. In many cases the rivers head in lakes but a few rods apart, or even in the same swamp. These lakes and swamps have an elevation of nearly 1,600 feet above sea level, or 1,000 feet above Lake Michigan. The Michigan branches flow from a similar though even higher region, and it is certain that these swamps and lake reservoirs exert a marked influence in steadying the discharge of the river.

RAINFALL AND RUN-OFF.

Because of the paucity of data concerning the discharge of rivers in this region, it is exceedingly difficult to estimate the ordinary discharge. The discharge measurements in this district have been made since 1901, and most of them since 1903.

The rivers mentioned below are similarly situated with respect to Lake Superior, which is perhaps the governing factor in determining the rainfall. In 1903 Escanaba River yielded a minimum of 700 second-feet from 891 square miles. Measurements made by the I. Stevenson Company indicate a minimum flow of this river, in a dry year, of 400 second-feet. Measurements of Iron River, continuing from November, 1901, to April, 1904, show a minimum flow of 0.8 second-foot per square mile for two months in 1902, and the same for February, 1903. It seems reasonably certain that except in unusually dry years the ordinary low-water discharge of these rivers is not far from 0.6 second-foot per square mile. In 1904, a year of average rainfall, the minimum run-off occurred in the month of December, when it averaged 0.77 second-foot per square mile.

In the following tables will be found the maximum, minimum, and mean discharge in second-feet of Menominee River at Little Quinnesec Falls during twelve months of 1898 and 1899:

Estimated monthly discharge of Menominee River at Little Quinnesec Falls, Wis.[a], May, 1898, to August, 1899.

[Drainage area, 2,432 square miles.]

Date.	Discharge.			Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.
1898.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*
May	3,802	2,443	3,086	1.26	1.45
June	3,616	1,447	2,459	1.01	1.13
July	2,740	655	1,439	.59	.68
August	4,968	498	2,282	.94	1.08
September	3,544	797	2,566	1.05	1.17
October	5,735	1,947	3,248	1.34	1.54
November	3,601	1,484	2,766	1.14	1.27
1899.					
April	4,642	3,083	4,011	1.65	1.84
May	4,485	3,744	4,112	1.69	1.95
June	4,624	2,017	3,476	1.43	1.60
July	2,521	804	1,819	.75	.86
August	1,789	1,408	1,573	.65	.75

[a] For the daily discharge for this time see Water-Supply Paper No. 83, pp. 256–257. Measurements were made by J. H. Wallace, C. E., and furnished by Kimberly & Clark, of Niagara, Wis.

It will be seen that the smallest monthly average during this time was 0.59 second-foot per square mile of drainage. Lumbering operations on Menominee River, though declining since 1892, are still active. The operation of the many logging dams must have a great effect on the regimen of the river. In a few years the lumber will be so nearly removed that it will be cheaper to carry logs by railroad. Then the dams can be used to augment the low-water flow. This will greatly enhance the value of the water powers.

The average annual rainfall of this region is estimated by the Tenth Census at 35 inches, or 10 per cent in excess of the average of the State.

The following table gives the annual precipitation in the valleys of Wolf, Oconto, Peshtigo, and Menominee rivers for the eleven years ending in 1904:

Annual precipitation, with averages, at seven stations in Wisconsin covering eleven years.

Station.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	Average.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Inches.*
Amherst	.....	.....	35.1	30.2	28.7	30.2	37.6	.....	32.1	.....	30.2	34.7
Koepenick	23.8	24.9	32.2	25.5	28.1	31.3	46.6	33.0	27.7	42.9	43.0	32.6
Florence	27.6	27.2	29.2	25.7	27.5	34.3	37.9	32.7	.....	43.3	.....	31.7
Oconto	29.8	29.9	36.0	28.1	29.7	26.4	38.0	28.1	29.3	34.1	34.7	31.3
New London	.....	.....	.....	27.4	29.0	.....	35.6	28.1	34.3	28.8	31.1	30.8
Shawano	27.9	.....	32.8	25.3	25.3	27.9	39.3	.....	.....	.....	.....	29.8
Waupaca	.....	.....	33.6	26.5	24.3	32.4	.....	26.0	30.8	32.0	32.0	29.7
Average	27.3	27.3	36.3	27.0	27.5	30.8	39.1	29.6	30.8	36.2	34.2	31.5

The summary given above, embodying observations of the yearly rainfall from 1894 to 1904, inclusive, at seven near-by stations, shows the average rainfall of this section for the above period to be 31.5 inches. This is very conservative, for earlier observations for longer periods show larger averages, as will be seen from the following:

Record of precipitation at two stations in Wisconsin prior to 1894.

[From the Smithsonian tables.]

Station.	Period covered.	Precipitation.
	Years.	*Inches.*
Embarrass	35	38.3
Weyauwega	12	44.1

There is reason to believe that the rainfall at the headwaters of these rivers is in excess of that on the lower part of the drainage area, where most of the observation stations are located.

The following table compiled from Bulletin C, United States Weather Bureau, shows

the result of observations of precipitation and temperature in the basins of Fox, Oconto, Menominee, and Wolf rivers for the years stated prior to 1876:

Record of precipitation and temperature at nine stations in Wisconsin prior to 1876.

Station.	Period of observation.	Precipitation.					Temperature.	
		Spring.	Summer.	Autumn.	Winter.	Year.	Summer.	Winter.
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*
Wautoma	1871–1874	5.50	6.25	1.98	3.16	25.92	.....	.....
Portage	1836–1845	5.58	11.46	7.63	2.83	27.50	68.22	19.81
Weyauwega	1861–1873	6.74	17.85	14.23	5.31	44.13	68.20	19.32
Waupaca	1867–1874	5.50	14.50	6.92	3.93	25.92	70.17	20.48
Menasha	1857–1858	6.83	10.73	7.06	5.14	29.76	65.30	23.11
Appleton	1856–1871	7.65	10.24	6.92	3.70	28.51	67.48	20.15
Green Bay	1858–1865	6.18	9.35	10.43	4.46	32.42	68.10	18.62
Embarrass	1864–1874	8.14	12.49	8.21	5.73	34.57	66.82	18.25
Escanaba	1872–1876	8.52	13.72	10.57	3.28	36.09	.....	.....

It will be noted that the upper portion of this drainage area is scarcely represented in the above tables, the stations where rainfall observations were made being grouped in the lower portion of the river valleys. There is reason to believe that the average rainfall would be found to be sensibly larger for a series of stations more evenly distributed so as to include the northern portion.

The following discharge measurements, gage heights, and rating table are the result of observations by hydrographers of the United States Geological Survey on Menominee River, near Iron Mountain, Mich.:

Discharge measurements of Menominee River at Homestead bridge, near Iron Mountain, Mich., 1902 to 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
1902.		*Feet.*	*Sq. feet.*	*Ft. pr. sec.*	*Feet.*	*Sec-feet.*
September 4	Horton and Gregory	.....	.....	.....	1.90	1,322
November 4	W. V. Savicki	.....	.....	.....	2.67	1,584
1903.						
April 9[a]	L. R. Stockman	202	1,532	2.22	5.40	3,409
April 19	....do	.....	2,000	2.78	7.32	5,570
July 22	....do	208	1,455	2.17	4.20	3,161
August 25	....do	208	1,342	1.76	3.60	2,357
September 16	....do	212	2,875	[b]3.41	10.38	9,490
October 27	....do	205	1,477	1.93	3.99	2,856
1904.						
May 18	E. Johnson, jr	210	2,312	2.68	7.95	6,193
June 1	....do	210	2,522	3.01	8.97	7,591
August 10	....do	205	1,101	1.42	2.06	1,558
September 5	....do	210	1,571	2.02	4.34	3,176
October 11	F. W. Hanna	225	2,408	3.20	8.25	7,714
November 18	E. Johnson, jr	210	1,511	1.94	4.02	2,925
1905.						
April 12	S. K. Clapp	220	2,271	2.90	7.43	6,588
May 22	....do	215	2,035	2.32	6.85	4,718
June 15	M. S. Brennon	208	1,421	1.78	3.67	2,524
July 13	....do	225	2,100	2.50	6.58	5,230
August 13	....do	207	1,346	1.83	3.24	2,469

[a] Stream full of logs; probably log jam.

[b] Mean velocity=85 per cent of surface velocity.

Mean daily gage height, in feet, of Menominee River near Iron Mountain, Mich., September 4, 1902, to December 31, 1905.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1902.					1902.				
1		1.67	2.52	1.60	17	1.40	1.65	6.45	2.55
2		1.53	2.80	2.22	18	1.45	1.92	5.65	2.70
3		1.55	2.95	2.80	19	1.35	1.60	5.35	2.63
4	1.90	1.45	2.72	2.25	20	1.35	1.65	5.00	2.75
5	1.60	1.55	2.85	1.85	21	1.20	1.57	4.47	2.75
6	2.00	1.58	2.95	1.95	22	1.45	1.65	4.45	2.57
7	2.25	1.60	2.50	2.25	23	1.52	1.67	3.90	2.40
8	2.35	1.67	2.60	2.70	24	1.48	2.42	3.92	2.32
9	2.05	1.77	2.50	3.45	25	1.47	2.80	3.45	2.35
10	1.92	1.30	2.40	3.35	26	1.40	3.22	3.30	2.20
11	1.87	1.50	2.45	3.60	27	1.40	2.95	3.00	2.10
12	1.95	1.55	3.27	3.35	28	1.35	3.57	2.62	2.00
13	1.65	2.85	4.85	3.05	29	1.38	3.07	2.55	2.15
14	1.53	2.95	6.07	2.90	30	1.55	2.83	2.62	2.20
15	1.45	2.47	6.88	2.85	31	.....	2.75	.....	2.10
16	1.40	1.82	6.57	2.90					

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
1	2.55	2.35	2.38	4.68	7.95	9.30	3.70	6.25	4.45	4.30	3.80	3.60
2	2.52	2.30	2.38	5.15	7.85	8.05	4.80	6.20	4.05	4.40	3.80	3.65
3	2.42	2.20	2.42	5.65	9.55	6.30	6.50	4.55	3.70	5.20	3.75	3.55
4	2.48	2.15	2.40	6.35	8.80	7.60	3.85	5.60	3.50	6.60	4.10	3.55
5	2.50	2.15	2.35	2.25	9.45	7.05	3.50	6.60	3.65	7.70	4.00	3.70
6	2.30	2.28	2.48	4.75	9.48	6.50	7.40	8.00	4.00	7.50	3.80	3.60
7	2.25	2.25	2.55	8.30	9.72	3.40	6.30	9.00	4.65	7.65	3.50	3.40
8	2.40	2.22	2.68	5.50	9.60	4.85	5.95	8.90	5.70	7.55	3.65	3.35
9	2.35	2.20	2.72	5.50	9.32	4.85	5.45	7.20	6.65	7.10	3.50	3.35
10	2.30	2.28	2.72	6.05	7.90	4.45	5.25	6.70	6.90	6.85	3.40	3.05
11	2.35	2.40	2.75	6.25	8.98	3.90	5.20	6.75	5.80	6.70	4.10	2.90
12	2.30	2.28	3.00	7.25	8.10	3.50	6.00	6.60	5.50	6.50	4.95	2.60
13	2.20	2.22	3.32	7.15	9.90	4.40	4.65	6.50	7.60	6.25	3.50	2.50
14	2.10	2.25	3.55	6.70	9.45	6.75	4.60	5.40	8.10	5.75	3.20	2.40
15	2.18	2.20	3.50	7.45	9.18	4.50	4.00	5.60	9.00	5.50	3.25	2.45
16	2.22	2.25	3.48	7.52	8.65	4.45	3.40	5.60	10.50	5.40	3.55	2.40
17	2.25	2.22	3.55	7.55	7.60	4.55	3.05	3.70	11.20	4.85	3.25	2.40
18	2.25	2.18	4.25	7.80	6.22	4.80	2.75	4.05	10.40	4.90	2.85	2.35
19	2.32	2.20	6.25	8.30	7.55	3.75	2.85	4.25	9.45	4.90	2.65	2.65
20	2.25	2.18	8.38	7.45	8.72	4.80	2.40	4.05	8.70	4.90	2.85	2.35
21	2.10	2.10	8.85	7.58	9.05	2.30	3.10	3.75	8.00	5.20	2.50	2.30
22	2.20	2.00	7.50	7.05	7.40	3.10	4.20	3.70	6.85	5.30	3.25	2.25
23	2.22	1.95	6.20	6.90	9.40	2.70	3.15	5.75	6.95	4.35	3.00	2.35
24	2.15	2.20	5.95	7.65	6.80	3.10	5.10	3.75	6.35	4.20	3.10	2.30
25	2.12	2.25	5.80	7.50	7.80	2.80	3.25	3.35	5.90	4.05	2.90	2.35
26	2.25	2.32	6.15	7.75	7.15	2.00	4.80	4.05	4.45	3.80	3.00	2.65
27	2.35	2.45	5.42	7.00	8.45	3.80	5.30	4.65	5.50	3.90	2.85	3.15
28	2.25	2.38	5.50	6.45	10.40	2.70	5.70	3.85	4.80	3.85	3.00	3.25
29	2.35	.....	5.15	6.82	11.85	2.45	6.85	3.90	4.40	3.80	3.10	3.10
30	2.35	.....	4.65	7.45	10.10	2.00	8.20	4.00	4.00	3.75	3.60	3.05
31	2.20	.....	4.30	.....	10.75	.....	7.10	4.55	.....	3.70	.....	3.15

Mean daily gage height, in feet, of Menominee River near Iron Mountain, Mich., September 4, 1902, to December 31, 1905—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
1	.....	4.30	4.75	4.65	7.90	8.45	4.60	2.35	1.80	3.05	3.10	2.42
2	.....	4.25	4.70	4.55	7.95	6.95	2.35	3.30	3.15	2.75	3.65	2.20
3	3.20	4.30	4.55	4.35	8.70	5.65	2.20	2.90	3.70	2.65	4.10	2.22
4	2.90	4.50	4.10	4.60	9.70	6.30	2.90	3.00	4.95	2.45	3.75	2.25
5	2.70	4.30	3.90	5.10	8.15	9.60	2.80	1.30	4.30	2.75	3.25	2.55
6	2.75	4.25	4.50	4.85	9.70	7.30	3.70	2.70	4.00	2.85	3.50	2.50
7	2.75	4.20	4.90	4.70	8.50	8.80	3.60	1.30	4.10	2.55	3.80	2.30
8	3.20	4.20	4.80	4.65	10.40	7.50	3.60	1.20	4.10	2.90	4.85	2.92
9	3.60	4.25	4.70	6.05	11.95	8.55	4.20	1.45	3.70	3.80	4.10	2.95
10	3.50	4.00	3.95	6.20	(a)	8.50	5.30	3.20	3.15	6.70	3.10	2.97
11	3.45	3.90	3.50	4.10	11.80	7.50	4.10	3.80	2.90	7.60	3.20	2.75
12	3.20	3.95	3.00	3.80	11.10	6.70	4.20	4.40	3.10	8.25	3.20	2.50
13	3.10	3.90	3.15	3.65	10.70	6.70	1.80	4.00	2.55	7.80	3.25	2.32
14	3.40	3.85	3.30	3.70	10.55	5.90	4.30	1.90	2.85	7.35	3.05	2.27
15	4.25	3.95	3.25	3.75	9.65	5.40	3.75	2.05	3.50	6.40	2.95	2.32
16	4.30	3.80	3.00	4.10	9.05	4.95	4.30	3.70	3.40	5.90	3.05	2.32
17	4.30	3.75	3.05	3.95	8.10	4.60	1.65	3.60	2.80	5.55	2.80	2.47
18	4.35	3.75	3.35	4.25	8.15	4.50	3.25	4.00	3.15	5.30	3.85	2.50
19	4.35	3.70	3.45	4.40	8.15	3.70	3.05	3.10	2.60	5.20	3.15	2.47
20	4.40	3.90	3.15	4.30	6.25	3.50	2.50	3.15	2.70	5.00	2.92	2.27
21	4.15	3.75	3.15	4.35	4.90	3.50	4.30	2.40	2.95	5.00	2.90	2.22
22	4.10	3.60	3.40	4.40	6.15	4.40	2.70	3.65	2.30	5.05	2.67	2.42
23	4.25	3.60	3.45	5.45	6.10	3.70	2.30	3.45	2.55	5.05	2.77	2.37
24	4.25	3.55	3.75	6.05	7.05	3.70	1.30	3.90	3.80	5.15	2.85	2.40
25	4.20	3.65	4.55	7.35	8.25	5.45	2.75	3.30	3.90	5.05	2.75	.....
26	4.20	3.55	4.60	7.25	9.60	7.20	1.40	3.40	3.95	5.15	2.42	2.47
27	4.25	3.75	4.35	7.45	(a)	6.75	2.70	2.70	4.15	5.05	1.92	2.32
28	4.20	4.55	4.40	8.35	10.90	5.60	1.50	2.30	4.00	4.85	1.75	2.20
29	4.50	4.90	4.30	7.75	10.00	6.70	3.10	1.90	3.50	4.35	2.00	(b)
30	4.45	.....	4.55	7.40	8.70	6.70	1.45	2.05	3.37	4.30	2.07	.....
31	4.35	.....	4.60	.....	8.00	.....	1.30	1.95	.....	3.90	.....	2.60
1905.												
1	2.60	.....	2.35	7.40	8.60	3.60	5.50	4.20	2.80	2.82	3.30	1.80
2	2.58	.....	2.38	6.80	8.40	5.60	8.60	3.70	3.90	2.80	3.30	1.75
3	.....	.....	2.45	6.70	8.50	2.40	6.40	3.40	7.20	2.50	3.20	2.25
4	.....	.....	.....	7.00	9.10	2.40	7.10	3.50	8.00	2.42	3.00	2.30
5	2.35	.....	.....	7.90	9.20	3.50	8.00	3.40	7.80	2.42	3.00	2.25
6	2.60	2.70	.....	8.00	9.20	6.30	8.00	3.45	7.00	2.35	3.00	2.65
7	2.60	.....	.....	7.45	9.30	6.90	7.60	3.30	6.30	2.40	2.95	3.30
8	2.80	.....	2.60	6.80	9.20	7.30	7.60	3.25	5.30	2.42	2.88	3.15
9	2.82	.....	2.62	6.80	9.80	6.30	5.80	3.40	4.60	2.40	2.92	3.20
10	.....	.....	2.60	6.60	9.60	7.10	4.20	3.30	4.40	2.35	3.00	3.20
11	.....	.....	.....	7.00	9.10	5.20	5.20	3.40	4.10	2.40	3.00	3.30
12	.....	.....	.....	7.30	9.00	5.80	4.90	3.20	3.70	2.45	3.00	3.20
13	.....	2.40	.....	7.40	9.10	5.70	5.40	3.20	3.35	2.50	2.90	3.45
14	.....	.....	.....	7.40	8.30	5.70	5.20	3.30	3.00	2.55	2.98	3.30
15	.....	.....	2.38	6.70	7.40	5.80	5.60	3.30	2.95	2.80	3.10	3.25
16	3.20	.....	2.30	6.40	8.60	6.40	4.30	2.80	3.60	2.90	3.15	3.40
17	.....	.....	2.22	6.10	9.70	7.30	4.40	2.50	4.30	2.82	3.05	3.30
18	2.90	2.55	2.25	6.20	10.10	7.20	6.10	2.65	4.40	2.98	2.90	3.25
19	2.92	.....	2.35	5.80	10.20	10.20	3.90	2.50	4.80	3.10	2.88	3.00

a Gage under water.

b River frozen.

Mean daily gage height, in feet, of Menominee River near Iron Mountain, Mich., September 4, 1903, to December 31, 1905—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905												
20	2.95	.....	2.50	5.80	9.30	9.30	3.40	2.70	4.90	3.30	2.90	2.95
21	2.78	2.35	2.40	5.70	10.20	6.70	2.20	2.72	4.80	3.50	3.05	2.85
22	2.75	.....	2.45	6.00	7.40	8.40	2.05	2.25	4.40	3.50	3.05	2.70
23	2.50	.....	2.50	6.20	7.40	6.50	2.95	2.00	3.80	3.50	3.10	2.60
	.....	.....	2.65	6.00	7.40	6.50	3.90	2.22	3.50	3.50	3.05	2.60
	.....	2.35	2.98	5.80	6.00	5.80	3.70	2.28	3.45	3.55	3.15	2.62
	.....	2.40	3.40	6.40	5.20	5.60	3.70	2.20	3.15	3.50	3.20	2.65
	.....	2.40	3.80	6.80	7.60	7.80	3.40	2.28	2.95	3.40	3.05	2.70
	.....	2.45	4.60	7.60	5.60	7.60	3.95	2.10	3.05	3.20	2.90	2.55
	3.00	.....	6.00	8.00	4.80	8.00	4.60	2.12	2.85	3.20	2.50	2.40
	.....	.....	7.60	8.60	5.80	8.90	4.70	2.07	2.80	3.20	1.80	2.40
	.....	.....	7.40	.....	3.40	.....	4.60	2.00	.....	3.30	.....	2.48

Rating table for Menominee River near Iron Mountain, Mich., September 4, 1902, to December 31, 1905.

Gage height.	Discharge	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.2	1,032	2.8	2,080	4.4	3,242	6.8	5,230
1.3	1,094	2.9	2,150	4.5	3,319	7.0	5,420
1.4	1,156	3.0	2,220	4.6	3,396	7.2	5,615
1.5	1,219	3.1	2,290	4.7	3,474	7.4	5,815
1.6	1,282	3.2	2,361	4.8	3,552	7.6	6,025
1.7	1,346	3.3	2,432	4.9	3,630	7.8	6,235
1.8	1,410	3.4	2,503	5.0	3,708	8.0	6,450
1.9	1,475	3.5	2,575	5.2	3,865	8.5	7,020
2.0	1,540	3.6	2,647	5.4	4,023	9.0	7,630
2.1	1,606	3.7	2,719	5.6	4,183	9.5	8,280
2.2	1,672	3.8	2,792	5.8	4,345	10.0	8,970
2.3	1,739	3.9	2,866	6.0	4,510	10.5	9,670
2.4	1,806	4.0	2,940	6.2	4,680	11.0	10,370
2.5	1,874	4.1	3,015	6.4	4,860	11.5	11,070
2.6	1,942	4.2	3,090	6.6	5,040	12.0	11,770
2.7	2,011	4.3	3,166				

Estimated monthly discharge of Menominee River near Iron Mountain, Mich., September, 1902, to December 31, 1905.

[Drainage area, 2,415 square miles.]

Date.	Discharge.			Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.
190 .	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*
September (4–30)	1,772	1,032	1,295	0.536	0.538
October	2,625	1,094	1,596	.661	.762
November	5,306	1,806	2,829	1.17	1.30
December	2,647	1,282	1,909	.790	.911
1903.					
April	6,780	1,705	5,175	2.39	2.14
May	11,560	4,698	7,496	3.57	3.10
June	8,020	1,540	3,417	1.57	1.41
July	6,670	1,806	3,553	1.70	1.47
August	7,630	2,467	4,049	1.94	1.68
September	10,650	2,575	5,091	2.35	2.11
October	6,130	2,719	4,057	1.94	1.68
November	3,669	1,874	2,505	1.16	1.04
December	2,719	1,705	2,150	1.03	.890
1904.[a]					
April	8,150	2,683	3,995	1.84	1.65
May	11,770	3,630	7,879	3.76	3.26
June	8,410	2,575	4,791	3.21	1.98
July	3,396	1,094	2,196	1.05	.909
August	3,242	1,032	2,125	1.01	.880
September	3,669	1,410	2,488	1.15	1.03
October	6,725	1,840	3,650	1.74	1.51
November	3,591	1,378	2,293	1.06	.949
December	2,199	1,672	1,838	.877	.761
1905.[a]					
April	7,140	4,265	5,282	2.19	2.44
May	9,250	2,503	6,810	2.82	3.25
June	9,250	1,806	5,011	2.07	2.31
July	7,140	1,573	3,850	1.59	1.83
August	3,090	1,540	2,130	.882	1.02
September	6,450	2,080	3,284	1.36	1.52
October	2,611	1,772	2,163	.896	1.03
November	2,432	1,410	2,204	.913	1.02
December	2,539	1,378	2,085	.863	.995

[a] Ice conditions January, February, and March. No estimate made.

The following table of drainage areas of Menominee River at various points is compiled from Water-Supply and Irrigation Paper No. 83:

Menominee River drainage areas.

	Square miles.
Brule River above Iron River	170.0
Iron River above mouth	94.7
Brule River, including Iron River	264.7
Brule River above Paint River	305.0
Paint River at mouth	738.5
Brule River at junction with Michigamme River	1,044.0

	Square miles.
Michigamme River at mouth	723.7
Menominee River at junction of Brule and Michigamme rivers	1,767.7
Menominee River above junction with Pine River	1,833.0
Pine River	586.0
Menominee River, including Pine River	2,419.0
Menominee River above Sturgeon River	2,538.0
Sturgeon River at mouth	396.0
Menominee River, including Sturgeon River	2,934.0
Menominee River above junction with Pemebonwon River	2,993.0
Peme Bon Won River	163.0
Menominee River, including Pemebonwon River	3,156.0
Menominee River above junction with Pike River	3,274.0
Pike River	292.0
Menominee River, including Pike River	3,566.0
Menominee River above Little Cedar River	3,792.0
Little Cedar River	149.0
Menominee River, including Little Cedar River	3,941.0
Menominee River at mouth	4,113.0

WATER POWERS.

GENERAL CONDITIONS.

Principally because of the opening up of the many rich and valuable iron mines of this region, and the resulting extensive railroad building, the valley of Menominee River has had a rapid development. The following railroads at present have extensions in this territory: Chicago, Milwaukee and St. Paul; Chicago and Northwestern; Minneapolis, St. Paul and Sault Ste. Marie; and Wisconsin and Michigan. All of them cross the Menominee one or more times, and several are near enough to run short spurs to the important water-power sites. The developed water power is at present used for the most part in mining and for the operation of lumber, paper, and pulp mills.

Menominee River varies in width from 200 to 600 or 700 feet far up toward the headwaters. For the first 7 miles from the junction of the Brule and Michigamme there are no heavy rapids, but, in the language of the lumberman, there is "strong water" all the way and probably many good water-power sites.

BAD WATER RAPIDS.

The first notable rapids, known as the Bad Water rapids, occur 7 miles below the head of the river, in sec. 27, T. 40 N., R. 19 E., at a point where the river, 100 feet wide, descends 5 feet over a ledge of rock. While definite information is lacking, it is likely that a dam could be built here, giving a head of 10 feet.

TWIN FALLS.

About 3½ miles below Bad Water rapids, in sec. 2, T. 39 N., R. 19 E., are the Twin Falls, about one-half mile apart. The vertical fall in each case is 12 feet, but the adjacent rapids are sufficient to increase the total descent to 28 feet.

PINE RIVER RAPIDS.

For 6 miles below the foot of Twin Falls the total descent of the river is but 20 feet, and the only rapids worthy of note are those extending for about five-eighths of a mile on both sides of the mouth of Pine River. Here an island divides the river into two channels with rocky bed. The descent of the rapids at this point is said to be 6 feet, but as the banks are high a dam could develop more than this. Pine River increases the drainage area by 586 square miles.

HORSE RACE RAPIDS.

The most important rapids between Twin Falls and Big Quinnesec Falls, called the Horse Race, are found in sec. 7, T. 38 N., R. 20 E., both above and below the Chicago, Milwaukee and St. Paul Railroad bridge. These rapids consist of two pitches, the upper of about 20 and the lower of 8 feet descent, separated by about 2,000 feet of less swift water. As the banks are high and the river narrow, it seems likely that a dam could be economically constructed here to develop about 40 feet of head. This site is only 3 miles from Iron Mountain, Mich.

BIG QUINNESEC FALLS.

A little over 7 miles below the mouth of Pine River, and 4 miles from Quinnesec, are the Big (Upper) Quinnesec Falls. These are located in sec. 6, T. 38 N., R. 20 E.

At Upper Quinnesec Falls the river narrows to hardly more than 50 feet wide (map measurement) between rocky banks of igneous origin. Immediately at the foot of the falls the river widens out, and about 800 feet below is 700 feet across. On the Wisconsin side the banks are 80 to 100 feet high and on the Michigan side 30 to 40 feet.[a]

Below the falls the river descends only 2 feet to the mile for a distance of about 3 miles. At present only 54 feet of the total head is improved, one-half of the power being used to compress air for the supply of the Chapin Iron Mines at Iron Mountain, 3½ miles distant. The remaining portion is to be harnessed in 1905 and used for operating mines at Norway, 9 miles away. On account of the local conditions it is unlikely that much more than the present head can be economically developed.

LITTLE QUINNESEC FALLS.

Four miles below in sec. 10, T. 38 N., R. 20 E., are the Little (lower) Quinnesec Falls, which, together with the upper falls, described above, form the most important powers on the river. For the greater portion of the distance between the upper and lower Quinnesec Falls there is comparatively quiet water. The greater part of the descent of 24 feet in this distance occurs in the lower 2 miles. Above the upper and below the lower falls the banks are generally high near the river, but between these falls the hills recede from the river an average distance of about one-half mile and are separated from it by a flat and in some places swampy area.

Maj. T. B. Brooks, who reported on the geology of this district, considered that the shore deposits indicated the presence of a lake at a comparatively recent date.

Above Little Quinnesec Falls the river runs southwest, but at the foot of the falls it suddenly turns at right angles and runs southeast, the water surging down an incline of about 45° and then plunging into the comparatively still water of the basin below. The total fall is 62 feet. A short distance above the falls the river is 250 feet wide, but narrows down at the pitch to about 50 feet. The falls are hemmed in by great masses of greenstone and schist rock. Along the Michigan side a steep cliff of greenstone at least 140 feet high forms the bank for a distance of a mile or more. A smaller, but similar, rib of rock forms the Wisconsin bank for about 700 feet.

Formerly Little Quinnesec Falls were partially developed under 25 feet head for wood-pulp grinding; but in 1898 they were redeveloped by the Kimberly & Clark Company for wood-pulp and paper manufacturing. A ledge of rock, which is used for a bridge pier, divides the falls into two channels. The present development gives a net head of 62 feet, equivalent to 8,370 theoretical horsepower. An actual installation of turbines, generating 5,800 horsepower, consumes all the available power.

SAND PORTAGE RAPIDS.

These rapids lie between Little Quinnesec Falls and the mouth of Sturgeon River. They receive this name because the Indians, in making their "carry" around part of them,

[a] Tenth Census, vol. 17.

passed over a large amount of sand. The rapids are scattered along a distance of 6 miles, in which space there is a descent of 60 feet. About half of this amount is concentrated in the 1½ miles between the falls and the old cable bridge or ferry below. As the topographic map shows very high banks, fairly close together, a head of 25 feet or more may some day be developed here. The Chicago and Northwestern Railway is distant only 1.5 miles.

Between the above-described dam site and a point 2.5 miles below, the river descends 27 feet. A point due south of Norway, Mich., and on the road leading from that city is probably the best location for the dam to develop this fall, but even here a dam not less than 700 feet long would probably be required.

Menominee River descends but 6 feet between this point and the mouth of Sturgeon River. This may be considered a part of the Sturgeon Falls power.

STURGEON FALLS.

From below the mouth of Sturgeon River to a point just above Pemebonwon River, a distance of 10 miles, the drainage area increases from 2,934 square miles to 2,993 square miles. In this stretch are Sturgeon Falls, one-half mile below the mouth of Sturgeon River, in sec. 22, T. 38 N., R. 21 E., Wisconsin. These falls have high rock-ledge banks, with two pitches aggregating 13 feet. By backing the water a distance of about 3 miles this head could be increased to 15 feet. At the head of the falls the river narrows to about 200 feet, but at the foot it spreads out into a broad basin. In order to use the power it will probably be necessary to blast out a race in the rocks or build a flume and locate the mill at or near the foot of the rapids.

In the next 10 miles the river descends only 17 feet, with a fairly even grade, except for two or three small rapids. The largest of these, Nose Peak rapids, is about 1,000 feet long and descends about 4 feet.

PEMENA DAM AND RAPIDS.

A logging dam which, together with the adjacent rapids, gives a fall of 14 feet in a distance of a quarter of a mile is located in sec. 24, T. 37 N., R. 21 E. The Minneapolis, St. Paul and Sault Ste. Marie Railway crosses the river 2½ miles above the dam and passes within a fraction of a mile from it. The operation of a dam at this point for lumbering purposes greatly lessens the amount of available power. At the present rate of progress, however, this dam will be needed for logging only a few more years. It has been found elsewhere in the State that river logging, except for pine, can not compete with railroad transportation.

From below Pemebonwon River to a point just below Pike River, a distance of 18 miles, the drainage area increases from 3,156 square miles to 3,566 square miles. Pemena, Chalk Hill, and White rapids occur in this distance.

About a mile above the mouth of Pemebonwon River, in sec. 8, T. 36 N., R. 21 E., the Pemena rapids begin. They extend for a distance of about 2 miles, with a total descent of 20.2 feet.[a] The river bed here is a metamorphic slaty schist, and the location is said to be favorable for a dam site. The Wisconsin and Michigan Railway runs parallel to the river at this point and is only 2 miles distant, and the Minneapolis, St. Paul and Sault Ste. Marie Railway crosses the river a few miles above.

CHALK HILL RAPIDS.

In the 11 miles between the foot of Pemena rapids and the head of White rapids the river descends 38 feet, the grade being even except for three small rapids of from 3 to 6 feet each. Chalk Hill rapids, the most important of these three, are located in sec. 6, T. 35 N., R. 21 E. They run over a slaty rock at a point said to be suitable for a dam, and if developed in connection with other falls about half a mile above would give a total head of 8 feet or more.

[a] This statement is based on an accurate profile of the river, prepared by Mr. T. W. Orbison, C. E., from his actual surveys. The statement made in the Tenth Census, vol. 17, p. 61, that the total fall is 70 feet, is evidently an error.

WHITE RAPIDS.

Four miles above the mouth of Pike River, in sec. 19, T. 35 N., R. 21 E., are the White rapids. The bed of the river is said to be gravel and bowlders, and the banks are high enough to give a head of 30 feet, thus developing the fall for 3 miles. Even above this limit the river descends 10 feet in 1¼ miles, as will be seen from the profile (p. 51). A head of 30 feet at ordinary low water would develop 5,350 theoretical horsepower.

From below Pike River to a point just above Little Cedar River, a distance of 25 miles, the drainage area increases from 3,566 to 3,792 square miles.

All the rapids thus far described have been over the pre-Cambrian crystalline rocks. In the next 28 miles the river crosses the Cambrian sandstone and "Lower Magnesian" limestone. No falls or rapids worthy of note occur until Grand rapids are reached, immediately above the mouth of Little Cedar River, in sec. 5, T. 33 N., R. 22 E. These rapids are caused by a descent over hard "Trenton" limestone, underlain by softer strata. They have a fall stated at 25 feet in a length of 3 miles, but of this fall only that in the lower 2 miles, amounting to 18 feet, can be cheaply developed. Both the Wisconsin and Michigan and the Chicago, Milwaukee and St. Paul railways pass within 2 or 3 miles of this site.

From below the mouth of Little Cedar River to the mouth of the Menominee, 23 miles, the drainage increases from 3,941 to 4,113 square miles.

TWIN ISLAND RAPIDS.

These rapids are situated about 7 miles below the Grand rapids and 16 miles from the mouth of the river. They extend for three-fourths of a mile and are said to descend 10 feet. The two islands lie one below the other, dividing the river into east and west channels. The bed of the river is limestone, the banks are steep, and a dam could be built across each channel to the islands. The total length of such dams is estimated at about 700 feet. A sawmill with a 6-foot head once occupied the east channel.

SCHAPPIES RAPIDS.

Located about 5 miles from the mouth of Menominee River, in T. 31 N. and between Rs. 22 and 23 E., Schappies rapids extend for a distance of about a mile. During the winter of 1897 a survey was made of these rapids by a competent engineer, Mr. C. B. Pride, at a time of extreme low water. He found a discharge of 2,370 second-feet and determined that a head of 18 feet could be economically obtained. This power belongs to the Menominee River Boom Company. The Chicago, Milwaukee and St. Paul Railway is located about 3 miles distant.

MARINETTE DAMS.

The last series of rapids is found at Marinette, Wis., near the mouth of the Menominee. The natural channel probably had about 12 feet descent here, but the Menominee River Boom Company built three dams, one above another, the upper one backing the water to the foot of Schappies rapids. The first of these dams, 850 feet long, located about 3 miles from the mouth of the river, in T. 30 N. and near the line between Rs. 23 and 24 E., develops a head of 7 feet.[a] Power is applied to two paper and pulp mills owned by the Marinette and Menominee Paper Company and also to a flouring mill. No statement of the turbine installation at the paper mills is made, but that at the flouring mill is 95 horsepower.

The third dam from the mouth is located on the west line of sec. 1, T. 30 N., R. 23 E. This dam is 940 feet long and has a head of 18 feet. The middle or second dam is located about a quarter of a mile below the third dam and is 700 feet long, with a head of 7 feet. It is used for boom purposes only. The Marinette and Menominee Paper Company mill

[a] Data regarding the Marinette dams furnished by the owners.

is located just below this dam, but it takes power through a canal from the third dam. Its turbines therefore work under a total head of about 24 feet.

The owners of these three dams state that each could be raised from 5 to 10 feet higher than at present.

TRIBUTARIES OF MENOMINEE RIVER.

The notable Wisconsin tributaries of Menominee River are Brule, Pine, Pemebonwon, and Pike rivers.

Brule River courses in a bed composed mostly of gravel and bowlders of the drift, and for this reason has few vertical falls, one of 10 feet being said to exist at its mouth. It is described as having a series of rapids or "strong water" for its entire length of 42 miles. Its total drainage area, including that of Paint River, is 1,044 square miles.

The following table gives a fairly complete profile of Brule River:

Profile of Brule River, Wisconsin, from its mouth to sec. 23, T. 41 N., R. 14 E.[a]

No.	Station.	Distance— From mouth.	Distance— Between points.	Elevation above sea level.	Descent between points. Total.	Descent between points. Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Brule, Wis. (C. & N. W. bridge)	7.0	.....	1,260	.....	.....
2	½ mile below section line 22-23, T. 41 N., R. 15 E	24.0	±17.0	1,411	151	8.8
3	Center of bend E. ¼ stake, sec. 31, T. 41 N., R. 15 E	29.5	5.4	1,431	20	3.7
4	¼ mile west of east line, sec. 24, T. 41 N., R. 14 E	31.6	2.1	1,468	37	18.0
5	0.4 mile below dam. Noted below	33.1	1.5	1,490	22	14.6
6	Above dam 800 feet east of ¼ post, sec. 22-23, T. 41 N., R. 14 E	33.5	.4	1,507	17	42.5
7	¼ mile last of section line 22-23, T. 41 N., R. 14 E	35.5	2.0	1,520	13	6.5

[a] Authority: No. 1, Chicago and Northwestern Railway; Nos. 2–7, U. S. Geol. Survey.

Pine River, the largest tributary lying wholly in Wisconsin, has a total length of 53 miles and drains an area of 586 square miles.

In the first half mile from its mouth the current is very rapid[b]; in the next 12 or 13 miles the fall is comparatively slight, and in the next 3 miles there are two falls of 8 feet each 1,000 feet apart, half a mile of strong water, succeeded by another fall of 12 feet, then, half a mile above, a fall of 40 feet. Sixty feet above this is a logging dam belonging to the Menominee River Improvement Company.[b]

The length of Pike River is 48 miles.

[b] Tenth Census.

DAMS ON MENOMINEE RIVER AND TRIBUTARIES.

The location and height of dams on Menominee River and tributaries in Wisconsin are shown in the following table:

Dams on Menominee River and tributaries in Wisconsin.

Dam.	Section.	Township.	Range.	Height of dam.
Menominee River:				*Feet.*
1	6	30	24	7
2	1	30	23	7
3	32	31	22	14
Pemena dam	24	37	21	12
Pike River:				
1	8	35	21	9
2	16	35	20	13
North Branch of North Branch Pike River	28	37	18	13
North Branch Pike River:				
1	32	36	20	9
2	20	36	20	13
South Branch Pike River:				
1	19	35	20	13
2	31	36	19	9
3	35	36	18	11
4	29	36	18	10
5	17	36	18	6
Pine River:				
1	30	39	18	9
2	11	39	15	10
3	10	39	14	10
4	36	40	13	9
Brule River:				
1	5	40	17	7
2	19	41	16	8
3	15	42	13	8
Wheeler dam	23	41	14	10

PESHTIGO RIVER.

In length, grade, shape, and size of drainage area Peshtigo River closely resembles its neighbor, the Oconto. It descends an average of nearly 10 feet to the mile, but few of its powers have as yet been developed, because this region is very thinly populated. The only powers reported are two at Peshtigo. A dam with a 10-foot head, owned by the Peshtigo Lumber Company, supplies the power for a sawmill, which has turbines of 1,390 horsepower installed. A flouring mill of 50 horsepower is also located at Peshtigo.

The next important development is a power known as "High Falls" in sec. 1, T. 32 N., R. 18 E. In a distance of 165 feet the river descends 46 feet. A dam 1,000 feet long would increase this to 55 feet. In a recent report on this power by a competent engineer, it is stated that a dam 200 feet long 1½ miles above this point would create an immense reservoir. Both dam sites are on the pre-Cambrian rock, and the banks are of clay and sand.

A few miles below, in sec. 9, T. 32 N., R. 19 E., are the Grindstone Rapids, with a fall of 25 feet. The banks at this point are said to be high and steep. The Wisconsin Geological Survey map shows a descent of 35 feet in sec. 10, T. 33 N., R. 18 E. A dam at Ellis Junction creates a large pond and furnishes a head of 12 feet, which was formerly used to run a sawmill. It is now proposed to increase this head to 24 feet and to use the power for a new pulp mill.

Between Ellis Junction and the mouth the Chicago, Milwaukee and St. Paul and the Chicago and Northwestern railways are adjacent to the river, which is still being used for lumbering purposes. Besides the above-described dams, logging dams are located in sec. 10, T. 33 N., R. 18 E., and in sec. 22, T. 34 N., R. 18 E., with heads of 10 and 8 feet, respectively. The following table shows the profile of the river:

Profile of Peshtigo River from its mouth to near North Crandon.

Station.	Distance from mouth.	Elevation above sea level.	Authority.
	Miles.	*Feet.*	
Mouth of river		581.3	United States engineers.
Peshtigo	18	594.7	Wisconsin and Michigan Rwy.
Do	+18	619.7	Chicago and Northwestern Rwy.
West of Ellis Junction	48	658.0	Do.
Near North Crandon	140	1,620.0	Minneapolis, St. Paul and Sault Ste. Marie Rwy.

OCONTO RIVER.

GENERAL CONDITIONS.

Oconto River rises in a number of small lakes and swamps in the plateau region, at an elevation of about 1,530 feet above the sea. In its length of 87 miles it descends 945 feet. In the upper 35 miles of its course the river flows over the crystalline rocks, and here is found about two-thirds of its total fall. Upon leaving the crystalline rocks the river flows nearly due south for 20 miles over the Cambrian sandstones. At Underhill it turns abruptly and flows nearly due east, crossing the "Lower Magnesian" and "Trenton" limestones and joining Lake Michigan near Oconto. The profile of the river is shown in the following table:

Profile of Oconto River, Wisconsin, from its mouth to Wabena.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Chicago and Northwestern Railway bridge, Oconto	2	.....	581	.....	.....
2	Chicago, Milwaukee and St. Paul Railway bridge, Oconto	7	5	590	9	1.8
3	Stiles	13	6	614	24	4.0
4	Underhill	33	20	770	156	7.8
5	Surings	44	11	791	21	1.9
6	One mile south of mountain	60	16	916	125	7.8
7	Two miles north of mountain	63	3	941	25	8.3
8	Wabena	87	24	1,526	585	24.3

The most important powers are found in the last 33 miles of its course, in which distance the river descends 190 feet.

WATER POWERS.

STILES.

The first dam above the mouth of the Oconto River is located at Stiles, in sec. 34, T. 28 N. R. 20 E., where a dam 400 feet long, with 11-foot head, furnishes power for saw and pulp mills owned by the Anson Eldred Company. This company has installed turbines of 500

[a] Authority: Nos. 1 and 4–8, Chicago and Northwestern Railway; Nos. 2 and 3, Chicago, Milwaukee and St. Paul Railway.

horsepower. It is reported that by constructing a dike about 450 feet long the head could be increased to 18 feet.

OCONTO FALLS.

The most important concentration of fall on the river, about 100 feet, occurs in the "Lower Magnesian" limestone at Oconto Falls, in sec. 25, T. 28 N., R. 19 E. A dam owned by the Falls Manufacturing Company has a head of 37 feet and supplies power for a large paper and pulp mill. The company has installed turbines rated at 1,370 horsepower, besides 400 steam horsepower. About a quarter of a mile farther up is located a dam of 19-foot head, which furnishes power for a large pulp mill, belonging to the Union Manufacturing Company. Seven turbines rated at 940 horsepower are installed. These run twenty-four hours every day except Sunday. Only half a mile below the Falls Manufacturing Company's dam are some important rapids, where an excellent power is available. It is estimated that a dam 250 feet long would develop a head of nearly 40 feet. This power is owned by E. A. Edmonds, who has a charter for a dam at this point with a head of 27.5 feet. The Chicago and Northwestern railway furnishes excellent shipping facilities at all the Oconto Falls powers described above.

PULCIFER DAM.

The last dam used for power purposes is located in sec. 6, T. 27 N., R. 18 E., and furnishes power for a gristmill. It is also used for logging purposes.

MISCELLANEOUS POWERS

The following table gives the location and extent of the most important developed and undeveloped water powers on the Oconto River:

Water powers on Oconto River.

No.	Location.	Estimated head.[a]	H. P. installed.	Use.
	DEVELOPED POWERS.	*Feet.*		
1	Stiles, sec. 34, T. 28 N., R. 20 E.	11	500	Saw and pulp mill.
2	Oconto Falls, sec. 25, T. 28 N., R. 19 E.	37	1,370	Paper and pulp mill.
3	Oconto Falls, sec. 26, T. 28 N., R. 19 E.	19	940	Pulp mill.
4	Pulcifer, sec. 6, T. 27 N., R. 18 E.	12	45	Flouring mill and driving.
5	Sec. 25, T. 31 N., R. 16 E.	12	.....	Driving only.
6	Sec. 4, T. 31 N., R. 16 E.	10	.....	Do.
7	Sec. 23, T. 32 N., R. 16 E.	10	.....	Do.
8	Sec. 30, T. 33 N., R. 17 E.	12	.....	Do.
9	Sec. 5, T. 33 N., R. 16 E.	10	.....	Do.
10	Sec. 1, T. 33 N., R. 15 E.	10	.....	Do.
11	Sec. 11, T. 32 N., R. 16 E.	10	.....	Do.
12	Sec. 34, T. 33 N., R. 16 E.	10	.....	Do.
13	Sec. 30, T. 33 N., R. 16 E.	10	.....	Do.
14	Sec. 27, T. 33 N., R. 15 E.	12	.....	Do.
15	Sec. 18, T. 31 N., R. 17 E.	10	.....	Do.
16	Sec. 33, T. 32 N., R. 17 E.	10	.....	Do.
17	Sec. 21, T. 32 N., R. 17 E.	10	.....	Do.
18	Sec. 23, T. 30 N., R. 16 E.	10	.....	Do.
19	Sec. 16, T. 30 N., R. 16 E.	6	.....	Do.
	UNDEVELOPED POWERS.			
20	Oconto, sec. 23, T. 28 N., R. 21 E.	12	.....	
21	Oconto Falls, sec. 31, T. 28 N., R. 20 E.	40	.....	
22	Sec. 34, T. 28 N., R. 18 E.	15	.....	
23	Sec. 23, T. 31 N., R. 16 E.	20	.....	

[a] The first four heads are reported by owners; the remainder are estimated by Mr. W. A. Holt, of the Holt Lumber Co., Oconto.

WOLF RIVER SYSTEM.

GENERAL CONDITIONS.

Wolf River rises in a number of lakes about 25 miles south of the Michigan boundary and flows in a general southerly direction, entering upper Fox River at a point about 10 miles west of Lake Winnebago. Though nominally a branch of Fox River, it is in reality the master stream, having over three times the discharge. Wolf River receives all its important tributaries from the west and at points relatively near its mouth. It has been elsewhere noted (p. 64) that there is much evidence that the river formerly ran west and joined Mississippi River through the present Wisconsin River Valley between Portage and Prairie du Chien.

In the upper half of its course Wolf River has formed its bed in the pre-Cambrian crystalline rocks, and in this distance the descent of the river is very rapid. At the Chicago and Northwestern railway crossing, 2 miles west of Lenox, the river has an elevation of 1,562 feet above the sea. In the 80 miles between this point and Shawano the river descends 774 feet, or 9.7 feet per mile. This steep gradient causes many rapids and falls. Lumbering dams have been maintained on the upper river at the following points:[a] Sec. 9, T. 33 N., R. 12 E.; Lilly dam, sec. 34, T. 33 N., R. 13 E.; sec. 10, T. 31 N., R. 14 E.; sec. 25, T. 31 N., R. 14 E., and at several other places lower down. In the 40 miles above Shawano small undeveloped powers of 10 to 15 feet head are of frequent occurrence.

Shawano, the head of navigation on the river, and county seat of Shawano County, has a population of 2,000. A dam is located at this point, with a head of 12 feet. It is used to grind wood pulp. Shawano also marks the point of transition from the pre-Cambrian to the Cambrian sandstone. It is at this point that the river crosses the old coast line of Lake Michigan and enters the region of red clay. Below Shawano the stream is sluggish, its descent being only about 42 feet to Lake Winnebago, a distance of about 80 miles. The banks are low, and in high water the surrounding flats are all covered, the river sometimes expanding at time of heavy freshets to several miles in width. For obvious reasons there can be no water powers in this lower region.

The profile of Wolf River for 160 miles of its course is shown in the following table:

Profile of Wolf River, Wisconsin, from mouth to near Lenox.

Station.	Distance from mouth.	Elevation above sea level.	Authority.
	Miles.	*Feet.*	
Winneconne	.....	746.4	United States Engineers.
New London	33	749.5	Chicago and Northwestern Railway.
Shawano	80	788.0	Do.
Lenox	160	1,562.5	Do.

[a] Wisconsin Geological Survey maps.

RUN-OFF.

The following tables showing gage-height observations and discharge measurements at Winneconne and near Northport, on Wolf River, are from data published by the United States Geological Survey:

Discharge measurements of Wolf River at Winneconne, Wis., in 1903.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
January 5[a]	L. R. Stockman	5.50	904
January 24[a]	do	5.30	1,436
February 20	do	5.00	1,285
March 24	do	6.60	9,998
April 15	do	6.90	3,808
May 11	do	6.70	3,537
June 20	do	6.40	3,194

[a] River frozen.

Mean daily gage height, in feet, of Wolf River at Winneconne, Wis., January 1 to July 25, 1903.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1	5.50	5.30	4.80	7.10	6.60	7.00	6.10
2	5.50	5.30	4.80	7.20	6.65	7.00	6.10
3	5.50	5.30	4.80	7.20	6.70	7.00	6.10
4	5.50	5.20	4.80	7.10	6.65	6.90	6.10
5	5.50	5.20	4.80	7.10	6.60	6.80	6.10
6	5.50	5.20	4.90	7.10	6.65	6.80	6.10
7	5.50	5.20	4.90	7.05	6.70	6.85	6.20
8	5.50	5.20	4.90	6.90	6.70	6.80	6.20
9	5.50	5.20	4.90	6.80	6.70	6.80	6.20
10	5.50	5.10	5.00	6.95	6.70	6.80	6.30
11	5.50	5.10	5.00	7.10	6.80	6.70	6.30
12	5.50	5.10	5.10	7.00	6.80	6.70	6.30
13	5.50	5.10	5.25	7.00	6.80	6.60	6.30
14	5.50	5.10	5.30	6.90	6.80	6.60	6.30
15	5.50	5.00	5.60	6.80	6.80	6.60	6.30
16	5.50	5.00	5.70	6.85	6.80	6.50	6.30
17	5.50	5.00	5.80	6.90	6.80	6.50	6.30
18	5.40	5.00	5.90	6.80	6.80	6.45	6.40
19	5.40	5.00	6.00	6.80	6.80	6.45	6.40
20	5.40	5.00	6.20	6.75	6.80	6.40	6.40
21	5.40	4.90	6.30	6.70	6.80	6.40	6.30
22	5.40	4.90	6.40	6.80	6.80	6.40	6.30
23	5.40	4.90	6.50	6.80	6.80	6.30	6.20
24	5.40	4.90	6.60	6.80	6.85	6.30	6.20
25	5.40	4.90	6.70	6.80	6.90	6.20	6.10
26	5.40	4.80	6.80	6.80	6.90	6.20	.....
27	5.30	4.80	6.90	6.70	7.05	6.10	.....
28	5.30	4.80	6.90	6.70	6.90	6.10	.....
29	5.30	.....	6.90	6.65	7.00	6.10	.....
30	5.30	.....	7.00	6.60	7.00	6.10	.....
31	5.30	.....	7.10	.....	7.00	.....	.....

Discharge measurements of Wolf River near Northport, Wis., in 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
April 5	F. W. Hanna	182	2,642	2.64	7.03	6,965
May 27	S. K. Clapp	171	2,198	1.8	4.65	3,964
June 17	M. S. Brennan	151	2,553	1.97	6.42	5,032
July 15	do	176	2,300	1.69	5.06	3,885
August 16	do	176	2,053	1.26	3.01	2,594
September 22	F. W. Hanna	172	1,978	1.41	3.6	2,781

Mean daily gage height, in feet, of Wolf River near Northport, Wis., April 6 to December 30, 1905.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		3.40	6.00	3.30	2.00	1.60	1.55	1.30	1.70
2		3.60	5.00	3.00	2.30	2.40	1.40	1.40	1.60
3		3.80	5.00	3.40	2.20	2.60	1.35	1.50	1.40
4		4.00	4.90	3.60	2.10	2.20	1.30	1.60	1.50
5		4.20	4.60	3.80	2.30	3.10	1.15	1.70	1.60
6	6.90	4.40	5.60	3.30	2.20	3.40	1.10	1.95	1.75
7	6.80	4.60	5.40	4.30	2.40	3.60	.90	2.10	1.80
8	6.70	4.80	5.30	4.60	2.90	3.30	.85	2.30	1.90
9	6.60	4.80	5.80	4.60	3.30	3.40	.70	2.50	2.10
10	6.50	5.00	5.80	4.90	4.00	3.60	.65	2.70	2.00
11	6.40	5.00	5.80	5.00	3.50	3.80	.60	2.60	1.90
12	6.30	5.20	5.90	5.20	3.60	3.50	.50	2.40	1.95
13	6.10	5.60	6.10	5.10	3.60	2.80	.35	2.30	1.80
14	6.00	5.80	6.40	5.10	3.00	2.50	.10	2.20	1.60
15	5.80	5.60	6.40	4.90	3.00	2.70	.25	2.10	1.40
16	5.60	5.50	6.60	4.20	3.50	2.90	.40	1.80	1.20
17	5.50	5.30	6.50	4.60	3.50	2.80	.75	1.50	1.20
18	5.20	5.30	6.40	4.30	3.30	3.00	.90	1.40	1.10
19	5.20	5.20	6.40	4.80	3.20	3.40	1.15	1.30	1.00
20	4.90	5.00	6.20	4.60	3.00	.....	1.50	1.20	1.00
21	4.80	4.80	6.00	4.45	2.80	2.90	2.20	1.10	1.00
22	4.80	4.60	5.80	4.20	2.40	2.80	2.60	1.00	1.00
23	4.30	4.60	5.60	4.10	2.50	3.70	2.90	.90	.90
24	4.10	4.80	5.30	4.00	2.30	3.60	3.20	.80	.90
25	4.00	5.00	5.10	3.30	2.00	3.40	3.40	.60	.75
26	3.80	5.00	4.70	3.60	1.80	3.25	3.30	.40	.60
27	3.60	4.60	4.40	2.80	1.60	3.10	3.20	.20	.50
28	3.50	4.30	4.00	2.50	1.40	2.90	3.00	.60	.50
29	3.50	5.40	3.80	2.30	1.20	2.75	2.10	.80	.40
30	3.40	5.60	3.50	2.20	1.10	2.35	2.30	1.90	.40
31	.....	5.80	.....	2.00	1.00	.....	2.00	.....	.....

TRIBUTARIES OF WOLF RIVER.

The lower part of the Wolf River drainage area is more thickly settled than the upper, and as a result the tributaries which occupy this lower portion are rather fully developed. This is especially true of Embarrass, Little Wolf, and Waupaca rivers.

WATER POWERS.

The following table shows the water powers on Wolf River and its tributaries:

Water powers on Wolf River and its tributaries.

Location and stream.	Owner and use.	Head.	H. P.
		Feet.	
Manowa, sec. 15, T. 23 N., R. 13 E., Little Wolf River.	Little Wolf River Lumber Co., grist, lumber, electric light.	10	390
Littlewolf, sec. 34, T. 23 N., R. 13 E., Little Wolf River.	Booth & Smith, grist, lumber, electric light.	9	60
Scandinavia, south branch Little Wolf River	Henry Peterson, feed mill	8	23
Sec. 22, T. 23 N., R. 11 E., south branch of Little Wolf River.	J. I. Wralstatt, feed mill	9	50
Phlox, sec. 26, T. 30 N., R. 12 E., Red River	J. Kaufman, saw and planing mill	14	75
Mount Morris, sec. 16, T. 19 N., R. 11 E., Rattlesnake Creek.	Wm. Kemp, grist mill	12	44
Wittenberg, sec. 10, T. 27 N., R. 11 E., Embarrass River.	Viking Lumber Co., sawmill	12	75
North branch of Embarrass River	N. M. Edwards, sawmill	13	50
Sec. 7, T. 26 N., R. 13 E., Embarrass River	N. M. Edwards, undeveloped	20	.....
Embarrass, sec. 5, T. 25 N., R. 15 E., Embarrass River.	Decker & Beedle, lumber and planing mill.	8	115
Sec. 23, T. 26 N., R. 13 E., middle branch of Embarrass River.	Theo. Boettner, flouring mill	9	200
Sec. 15, T. 27 N., R. 15 E., north branch of Embarrass River.	Seiber & Dumke, sawmill	13	192
Sec. 23, T. 28 N., R. 12 E., north branch of Embarrass River.	L. A. Weikel, saw, planing, and feed mill.	16	116
Pilla, sec. 9, T. 26 N., R. 14 E., Embarrass River.	Grosskopt, saw and planing mill	13	60
Sec. 9, T. 27 N., R. 12 E., middle branch of Embarrass River.	Buckstaff Lumber Co.; power house burned.	10	.....
Waupaca, sec. 32, T. 22 N., R. 12 E., Crystal River.	Waupaca woolen mills	8	35
Waupaca, sec. 20, T. 22 N., R. 12 E., Waupaca River.	A. G. Nelson, planing and grist mill	6½	65
City of Waupaca, Waupaca River	Electric Light Co	18	200
Do	Undeveloped	15	.....
Sherman, sec. 18, T. 22 N., R. 11 E., Waupaca River.	Brooks & Root, flouring mill	7	100
Weyauwega, sec. 4, T. 21 N., R. 13 E., Waupaca River.	Weed Gunnard, flour, planing, and electric light.	10	480
Waupaca, Waupaca River	C. Gurines, brick manufacture	8	50
Amherst, Spring Creek	N. Howard, feed mill	10	20
Rural, sec. 10, T. 21 N., R. 11 E., Arbor Creek	J. Ashmun, flouring and saw mill	9	96
Gresham, sec. 3, T. 27 N., R. 14 E., Red River	A. G. Schmidt, sawmill	11	100
Sec. 6, T. 27 N., R. 15 E, Red River	Undeveloped	.....	.....
Sec. 19, T. 27 N., R. 14 E., Red River	.....do	.....	.....
Sec. 18, T. 28 N., R. 14 E., Red River	.....do	.....	.....
Sec. 15, T. 26 N., R. 10 E., Little Wolf River	Little Wolf River Lumber Co., logging	7	0
Sec. 7, T. 25 N., R. 11 E., Little Wolf River	.....do	7	0
Sec. 5, T. 24 N., R. 13 E., Little Wolf River	.....do	7	0
Sec. 9, T. 33 N., R. 12 E., Wolf River	Used for logging	.....	.....
Sec. 34, T. 33 N., R. 13 E., Wolf River	.....do	.....	.....
Sec. 10, T. 31 N., R. 14 E., Wolf River	.....do	.....	.....
Sec. 25, T. 31 N., R. 14 E., Wolf River	.....do	.....	.....

WISCONSIN RIVER SYSTEM.

TOPOGRAPHY AND DRAINAGE.

Because of its length, its great drainage area, and its central location Wisconsin River is preeminently the main river of the State.

Like the Flambeau, the headwaters of Wisconsin River are found in an intricate network of lakes and swamps occupying the flat plateau region near the northern boundary. Its extreme source is found in Lake Vieux Desert, a body of water about 10 square miles on the line separating the northern peninsula of Michigan from Wisconsin, at about 1,650 feet above sea level. The general course of the river for the first 300 miles is south. At a point near Portage it turns abruptly westward, and in the next 100 miles flows nearly west, joining Mississippi River at Prairie du Chien, only 40 miles from the southern boundary of the State.

The drainage basin includes 12,280 square miles, with an average width of 50 miles and a length of about 225 miles. The apportionment of this drainage area among the several tributaries of Wisconsin River is shown in the following table:

Distances and drainage areas of Wisconsin River.

River.[a]	Distance.		Drainage area above station.
	From source.	Between stations.	
	Miles.	*Miles.*	*Sq. miles.*
Pelican, above mouth		60	940
Pelican, mouth	60	0	1,202
Tomahawk	85	25	2,111
Prairie	113	28	2,697
Rib, above mouth		23	3,192
Rib, mouth	136	0	3,690
Eau Claire	138	2	4,114
Eau Pleine, above mouth		20	4,268
Eau Pleine, mouth	158	0	4,645
Little Eau Pleine	166	8	5,005
Plover	184	18	5,300
Yellow, above mouth		64	6,448
Yellow, mouth	248	0	7,394
Lemonweir	259	11	8,172
Baraboo	292	33	9,095
Wisconsin	407	115	12,280

[a] Station is at mouth of river unless otherwise stated.

Because of its long traverse from the extreme northern to the extreme southwestern part of Wisconsin the topography of the basin includes nearly every form found in the State. Like the upper Chippewa Valley, the northern half is a densely wooded region of hard and soft timber except where cleared for farming. The woods gradually give way to a semi-prairie region with a gently undulating surface, but with occasional decided ridges both of rock and glacial origin. A very striking surface feature toward the southern part is found in the "Baraboo quartzite" ranges, which have an elevation of from 400 to 700 feet above the surrounding country. These ranges comprise two main ridges from 4 to 6 miles apart, extending nearly east and west in the section of country west of Portage for about 25 miles, but uniting and ending abruptly on the west side of the valley, near Portage. The angle of the river at this point seems due to its effort to secure a passage around this rock barrier.

Through a portion of the city of Portage and southward, the river can hardly be said to have an eastern divide. Fox River approaches within 1½ miles of the Wisconsin at this point, only a low marsh intervening. Even this marsh has a slope of about 3 feet toward Fox River. At the present time levees at this and other points prevent the Wisconsin at times of high water from overflowing into Fox River. These levees for a distance of several miles compel the river to flow along the contour instead of in the direction of maximum slope.

The reasons for this and other peculiarities of its valley are interestingly discussed in Geology of Wisconsin, (vol. 3):

> It is evident that such an uncertain divide as this can not have formed one of the original permanent features of the drainage of the region, but as the disposition of the surface soil is due to glacial action, modified by subsequent erosion and transportation, this may be fairly attributed to such a cause. The rampart of limestone which compels the lower Wisconsin to flow west does not stop south of Portage, but continues east and north, although less prominent, forming an eastern barrier to the flow of the Wolf River. The course of the upper Fox to Lake Winnebago is sluggish, consisting largely of marshes and lake-like expansions. On account of the depression of the divide at Portage, the continuation of the southern barrier northeast, the small slope of the upper Fox, the large trough of the Wisconsin below Portage, which it is unable to occupy, while above the river is more nearly in proportion to its channel of drainage, and finally the evidently modern outlet for the Wolf and the upper Fox through the lower Fox—the conclusion is reasonable, if not inevitable, that at one time the Lake Winnebago system drained southwest into the Mississippi and the Wolf was the true continuation of the Wisconsin above Portage, while the present upper Wisconsin was merely a tributary of the main stream.

LAKE ELEVATIONS AND RESERVOIR SITES.

Attention has elsewhere been called (p. 15) to the opportunity of increasing the low-water flow of the northern rivers by the construction of dams near the headwaters for use as reservoirs. The opportunity for such a system on Wisconsin River is especially good, because the ownership of the lands to be flooded is in the hands of a comparatively few corporations and a beginning has already been made. For example, a well-built dam at the foot of the Tomahawk chain of lakes, which impounds water covering many square miles of reservoir, has been used for several years to regulate the stage of the river for the mills below the mouth of the Tomahawk. In scores of cases the dams are already constructed for logging purposes and need only to be kept in repair to be of service for power regulation when they are no longer needed for their original purpose, as will soon be the case.

It has been proposed to build or maintain dams at the following points: Lake Vieux Desert, sec. 17, T. 42 N., R. 11 E.; Twin Lakes, sec. 19, T. 41 N., R. 11 E.; Eagle Lakes, sec. 31, T. 40 N., R. 10 E.; Sugarcamp Lakes, sec. 17, T. 39 N., R. 9 E.; Buckataban Lakes, sec. 24, T. 41 N., R. 9 E.; Little St. Germain Lake, sec. 2, T. 39 N., R. 8 E.; Big St. Germain Lake, sec. 18, T. 39 N., R. 8 E.

At many if not most of the larger lakes near the headwaters, logging companies have long maintained dams, which some day will serve the double purpose of reservoirs and sources of power. A list of some of these lakes, together with their elevation above the sea, as determined by United States engineers, is given in the following table:

Lakes at headwaters tributary to Wisconsin River.

Name of lake.	At headwaters of—	Elevation above sea level.
		Feet.
Eagle	Eagle River	1,582.0
Catfish	do	1,583.0
Cranberry	do	1,583.5
Long	do	1,592.2
Planting Ground	do	1,592.2
Fish	do	1,592.2
Medicine	do	1,592.2
Stone	do	1,592.2
Dog	do	1,592.2
Big	do	1,592.2
Pelican	Pelican River	1,590.0
Tomahawk	Tomahawk River	1,562.2
Island	do	1,560.4
Keawasogan	do	1,560.4
Mud	do	1,553.4
Squirrel	do	1,542.9

The following table *a* gives dimensions and other data of eight reservoir sites surveyed by United States engineers as an aid to navigation on Mississippi River:

Proposed United States Government reservoirs on Wisconsin River.

Name.	Location.			Elevation of low water at dam site.	Maximum dimensions.				Reservoir.		Area of watershed.
					Dam.		Dike.				
	Section.	Township.	Range.		Length.	Height.	Length.	Height.	Area.	Capacity.	
				Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. mi.*	*Cubic feet.*	*Sq. mi.*
Pelican	6	36 N.	9 E.	1,520.83	800	28	3,625	15	13.45	5,153,180,527	301.0
Sugarcamp	17	39 N.	9 E.	1,562.00	235	12.5	260	4	5.00	1,356,284,160	60.0
Otter rapids	36	40 N.	9 E.	1,578.07	1,300	22	700	5	30.74	7,389,727,488	447.0
Tomahawk	7	39 N.	6 E.	1,554.67	190	12			13.46	2,226,113,036	101.5
Squirrel	1	38 N.	5 E.	1,521.78	315	17			5.30	1,338,163,200	56.0
Rice	9	35 N.	6 E.		1,100	14			6.00	1,043,516,880	396.0
Vieux Desert	17	42 N.	11 E.						7.00	400,000,000	19.0
Twin Lakes	19	41 N.	11 E.						6.50	650,000,000	30.0
									87.45	19,556,985,291	1,410.5

Subsequent to this report two of these dams, at Rhinelander (Pelican) and Tomahawk, have been constructed by private enterprise for power purposes; several others have been constructed with reduced heads. It will be noted that the proposed Government reservoirs have a total area of 87.45 square miles and a drainage area of 1,410½ square miles. It was proposed to fill the reservoirs during the spring freshets and then allow the water to escape at times of low water. The United States engineers estimated that these reservoirs would maintain a flow of 3,000 second-feet for three months of the year. Such a flow would nearly double the present low-water flow of the river and its resulting water power. Incidentally the use of such reservoirs would to a large extent serve to reduce the dangers of high floods, both to dams and to overflowed lands. It would, in fact, tend to restore the regimen of the river to that which it possessed before deforesting and cultivation began to transform a great primeval forest region into cleared and well-cultivated fields.

PROFILE.

According to the United States engineers, the elevation of Lake Vieux Desert is about 1,650 feet, while the elevation of the mouth of Wisconsin River at Prairie du Chien is 604 feet at low water or 625 feet at high water. This gives a total descent of about 1,046 feet in an estimated length of 429 miles, or about 2½ feet per mile. About 634 feet of this fall occur in the 150 miles between Rhinelander and Nekoosa, an average of 4.23 feet per mile. This descent is concentrated at many places, producing a large number of valuable water powers, many of which have been improved and used by important industries.

The fall in the main tributaries is even greater in many cases than that in the parent stream, and owing to this fact, and also to the absence of lakes and swamps, it is likely that their discharge is subject to great extremes.

a Rept. Chief Eng. U. S. Army, 1880, p. 1655.

A statement in detail of the profile of Wisconsin River is given in the following table:

Profile of Wisconsin River from its mouth to Lake Vieux Desert.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river			604.0		
2	Sauk City	90.0	90.0	746.0	142.0	1.5
3	Merrimac	102.0	12.0	764.0	18.0	1.5
4	Portage	118.0	16.0	790.0	26.0	1.63
5	Kilbourn, railroad bridge	138.0	20.0	814.0	24.0	1.2
6	Sec. 36, T. 15 N., R. 5 E., north line	147.0	9.0	833.0	19.0	2.1
7	Peterwell bridge, opposite Necedah	174.0	27.0	875.3	42.3	1.57
	Nekoosa dam:					
8	Below	208.0	34.0	918.9	43.6	1.28
9	Above			936.6	17.7	
	Port Edwards dam:					
10	Below	212.5	4.5	938.5	1.9	.4
11	Above			955.5	17.0	
	South Centralia dam:					
12	Below	214.0	1.5	957.3	1.8	1.2
13	Above			969.3	12.0	
	Grand Rapids dam:					
14	Below	216.5	2.5	979.8	10.5	4.2
15	Above			1,002.0	22.2	
	Biron dam:					
16	Below	220.5	4.0	1,005.5	3.5	.9
17	Above			1,016.3	10.8	
	Lower paper mill south of Stevens Point:					
18	Below	233.0	12.5	1,032.4	16.1	1.3
19	Above			1,044.0	11.6	
	Upper paper mill south of Stevens Point:					
20	Below	233.5	.5	1,045.5	1.5	3.0
21	Above			1,058.8	13.3	
22	Stevens Point, Wisconsin Central bridge	236.0	2.5	1,063.8	4.0	1.6
23	Sec. 23, T. 24 N., R. 7 E	240.0	4.0	1,075.8	13.0	3.2
24	Knowlton bridge, Chicago, Milwaukee and St. Paul Rwy	257.0	17.0	1,092.2	16.4	.97
25	Sec. 8, T. 26 N., R. 7 E	260.5	3.5	1,097.4	5.2	1.5
26	Sec. 31, T. 27 N., R. 7 E., south line	264.5	4.0	1,104.0	6.6	1.65
27	Mosinee rapids, foot, sec. 29, T. 27 N., R. 7 E., south line	266.0	2.0	1,105.8	1.8	.9
28	Mosinee dam, above	266.5	.5	1,124.6	18.8	37.6
29	Black Creek, mouth of	270.5	4.0	1,125.9	1.3	.3
30	Cedar Creek, mouth of	274.0	3.5	1,130.6	4.7	1.34
31	Eau Claire River, mouth of	279.0	5.0	1,138.6	8.0	1.6
32	Rib River, mouth of	280.5	1.5	1,142.8	4.2	2.8
33	Lower Wausau bridge	283.0	2.5	1,151.0	8.2	3.3
	Wausau dam:					
34	Below	283.5	.5	1,171.0	20.0	40.0
35	Above			1,177.7	6.7	
	Brokaw dam:					
36	Foot	289.0	5.5	1,182.7	5.0	.9
37	Crest			1,194.7	12.0	

[a] Authority: Nos. 1 (low-water elevation) and 53–57, United States engineers; 2 and 3, Major Warren; 4–35, Wisconsin water-power survey by the U. S. G. S. and State authorities; 36–52, levels run by C. B. Pride in 1900 for the Wisconsin River Valley Advancement Association; 56, Chicago and Northwestern Ry.

Profile of Wisconsin River from its mouth to Lake Vieux Desert—Continued.

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
38	Pine River, mouth	298.0	9.0	1,212.7	18.0	2.0
	Merrill:					
39	Lindore dam, foot	304.0	6.0	1,214.7	2.0	.33
40	Lindore dam, crest			1,227.7	13.0	
41	Upper dam, crest	305.0	1.0	1,233.7	6.0	6.0
42	Bill Cross rapids, foot	314.0	9.0	1,245.7	12.0	1.3
43	Grandfather rapids, foot	318.0	4.0	1,272.2	26.5	6.6
44	1.5 miles above, head	319.5	1.5	1,361.7	89.5	6.0
45	Grandmother rapids, foot	321.2	1.7	1,370.7	9.0	5.3
46	Gilbert Station	326.7	5.5	1,409.7	39.0	7.1
	Tomahawk dam:					
47	Foot	328.7	2.0	1,412.7	3.0	1.5
48	Crest			1,425.7	13.0	
49	Nigger Island	344.7	16.0	1,449.4	23.7	1.48
50	Whirlpool rapids, head	346.7	2.0	1,464.8	15.4	7.7
51	Hat rapids, foot	351.7	5.0	1,477.4	12.6	2.5
	Rhinelander dam:					
52	Foot	357.7	6.0	1,523.2	45.8	7.6
53	Crest			1,553.2	30.0	
54	Otter rapids, head	392.7	35.0	1,570.7	17.5	.5
55	Sec. 30, T. 41 N., R. 10 E	402.7	10.0	1,592.7	22.0	2.2
56	Sec. 6, T. 41 N., R. 10 E	416.7	14.0	1,644.0	51.3	3.66
57	Lake Vieux Desert	429.0	12.3	1,650.0	± 6.0	.5

GEOLOGY.

All that part of the Wisconsin River basin above Nekoosa, including over half the entire drainage, is underlain by pre-Cambrian rocks. North of Merrill this region has been covered so deeply by drift that the rock rarely outcrops except in the river bed. These rocks, by presenting a barrier to further erosion, cause numerous rapids; in fact, all the water powers, with but a single exception,[a] are found in the pre-Cambrian area. Below Nekoosa the pre-Cambrian rocks give way to the softer Cambrian sandstone, the disintegration of which has made the bed of the river one succession of shifting sandbars, almost without interruption, to its mouth. North of Nekoosa this sandy belt rapidly narrows and, at Merrill, 90 miles above, almost entirely disappears, being replaced by the clayey loams and loamy clays. North of Tomahawk the clays are replaced again by sandy soils containing gravel and by bowlders and glacial drift.[b] In the 60 miles below the city of Tomahawk the tributaries of Wisconsin River flow mainly through a clayey-loam soil, except for a narrow strip adjacent to the main stream, where, as before stated, the sandy soil predominates.

RAINFALL AND RUN-OFF.

The United States Geological Survey has maintained regular gaging stations at Necedah and Merrill since November, 1902. As the rainfall during 1904 was very close to the average rainfall for the past thirty years, the run-off data for this year are especially valuable.

[a] Kilbourn, in the Cambrian sandstone.
[b] Weidman, Samuel, Wis. Geol. Nat. Hist. Survey, Bull. 11, pl. 1.

Rainfall records for this drainage area are given elsewhere in this report. The following tables give the run-off data:

Discharge measurements of Wisconsin River near Necedah, Wis., in 1902, 1903, 1904, and 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
1902.		*Feet.*	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
December 2	L. R. Stockman				4.90	3,875
December 23	do				5.40	3,534
1903.						
January 13[a]	do	280	2,617	1.18	5.65	2,840
February 5[a]	do	284	2,360	1.26	5.80	2,585
March 5[a]	do	284	2,411	1.09	5.80	2,422
March 26	Johnson and Stockman		5,405	3.94	11.05	21,280
April 2	L. R. Stockman	220	4,206	2.42	7.55	10,190
April 28	do	309	3,860	1.84	6.50	7,123
June 12	do	281	3,282	1.79	6.00	5,888
July 7	do	316	4,708	4.43	10.50	20,860
August 19	do	302	2,832	2.46	6.20	6,962
September 4	do	276	2,463	2.05	5.30	5,047
October 12	do	314	3,871	3.23	9.43	12,500
1904.						
January 12[a]	E. Johnson, jr	286	2,031	1.33	4.60	3,000
May 11	do	317	4,685	3.65	9.60	17,110
May 23	Johnson and Hanna	314	3,717	2.67	7.05	9,921
July 16	E. Johnson, jr	294	3,525	1.66	5.80	5,845
September 21	do	294	1,823	2.08	4.92	3,800
October 14	F. W. Hanna	449	6,216	5.71	13.35	[b] 34,420
1905.						
April 4	S. K. Clapp		5,777	5.07	12.33	29,290
May 25	do	317	4,437	3.23	7.65	13,350
June 12	M. L. Brennon	437	6,017	4.99	12.9	30,050
August 9	do	314	3,846	2.4	6.85	9,268

NOTE.—Width is the actual width of water surface, not including piers. Area of section is the total area of the measured section, including both moving and still water.

[a] Frozen. [b] Add to this discharge 3,000 second-feet overflow.

Mean daily gage height, in feet, of Wisconsin River near Necedah, Wis., December 2, 1902, to December 31, 1905.

Day.	1902.	1903.										
	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		5.90	5.75	5.75	7.70	6.65	10.55	4.70	4.80	5.20	7.10	5.70	5.60
2	4.90	5.90	5.70	5.60	7.55	8.30	9.85	4.60	4.95	5.50	6.60	5.55	6.20
3	4.95	5.80	5.90	5.85	7.35	9.35	8.85	7.70	4.75	5.40	6.80	5.70	6.90
4	5.10	5.75	5.80	5.80	7.50	9.75	8.15	8.90	4.80	5.30	6.80	5.75	7.10
5	4.85	5.60	5.75	5.75	7.40	9.95	7.60	10.10	4.85	5.30	7.05	5.55	6.80
6	4.75	5.70	5.90	5.80	7.25	10.15	7.40	10.00	5.65	5.40	8.30	5.45	6.80
7	4.70	5.65	5.80	5.90	7.15	10.05	7.15	10.60	6.65	5.60	9.05	5.30	6.60
8	4.30	5.45	5.70	5.50	7.20	9.70	6.85	10.60	7.75	6.10	8.95	5.50	6.70
9	4.85	5.60	5.60	5.50	7.10	9.30	6.65	9.70	8.00	6.10	9.15	5.35	6.50
10	5.25	5.50	5.80	6.25	7.25	8.80	6.55	8.40	7.70	6.80	9.80	5.30	6.40
11	5.20	5.45	5.75	6.40	7.05	8.25	6.20	7.80	7.50	7.30	9.80	5.25	6.30
12	5.40	5.50	5.65	7.05	6.90	8.15	6.00	7.50	7.20	7.30	9.35	5.30	6.00
13	5.25	5.65	5.90	7.65	6.80	8.45	6.15	7.10	6.90	7.20	8.90	5.30	[a] 4.10
14	5.30	5.75	5.80	6.75	6.75	9.05	5.85	6.70	6.70	8.60	8.30	5.30	4.40

[a] River frozen December 13 to 31.

Mean daily gage height, in feet, of Wisconsin River near Necedah, Wis., December 2, 1902, to December 31, 1905—Continued.

Day.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
15	5.35	5.45	5.75	7.30	6.80	9.80	5.70	6.55	6.70	10.90	7.90	5.35	4.50
16	5.65	5.80	5.65	7.75	6.95	10.10	5.45	6.25	6.40	12.50	7.65	5.25	4.40
17	5.65	5.65	5.65	8.35	7.10	9.90	5.35	6.00	6.20	13.40	7.55	5.35	4.00
18	5.30	5.55	5.55	8.70	7.25	9.35	5.60	6.10	6.40	14.60	7.25	4.90	4.40
19	5.50	5.45	5.75	8.85	7.10	8.70	5.45	5.90	6.10	14.60	6.95	4.90	4.30
20	5.45	5.75	5.70	10.00	6.90	8.30	5.25	6.00	5.70	14.60	7.00	5.00	5.00
21	5.30	5.65	5.70	11.40	6.50	7.95	5.15	5.90	5.90	13.80	6.95	5.10	4.80
22	5.30	5.55	5.65	12.70	6.55	7.90	4.90	5.60	5.40	12.70	6.55	5.05	4.90
23	5.40	5.85	5.55	13.55	6.30	7.75	5.20	5.40	5.10	11.40	6.40	4.95	4.90
24	5.60	5.80	5.70	12.85	6.20	7.45	4.95	5.20	5.10	10.60	6.40	5.20	4.80
25	6.40	5.80	5.65	11.80	6.05	7.35	4.70	5.30	5.40	9.90	6.30	5.20	4.70
26	6.30	5.65	5.65	10.90	6.10	7.60	4.80	5.30	5.20	8.70	6.10	5.05	4.70
27	6.60	5.85	5.70	10.05	6.35	8.00	4.75	5.00	5.30	8.15	6.05	5.00	4.90
28	6.15	5.80	5.85	9.35	6.50	8.70	4.80	5.10	5.30	7.95	5.95	5.15	4.80
29	6.05	5.70	.....	8.95	6.85	9.55	4.70	5.00	5.20	7.65	6.00	5.00	4.90
30	6.20	5.80	.....	8.50	6.60	10.55	4.85	4.90	5.00	7.55	5.80	5.40	4.90
31	6.00	5.80	.....	8.00	.....	11.00	.....	4.80	5.00	.....	5.70	.....	4.90

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
1	[a] 6.00	5.10	5.30	[b] 6.60	9.80	11.20	6.30	4.50	4.80	6.60	7.10	4.80
2	5.70	5.20	5.30	6.30	9.20	10.00	6.50	4.70	4.80	6.45	6.90	4.80
3	5.90	5.10	5.30	6.50	8.90	9.10	6.50	4.90	4.80	6.20	6.60	4.80
4	5.60	5.00	5.30	6.90	8.40	8.60	6.30	4.80	4.80	6.10	6.70	[c]
5	6.00	5.20	5.30	6.60	8.00	8.40	6.20	4.70	4.30	7.00	6.50	.....
6	6.00	5.20	5.30	6.80	7.80	9.00	6.30	4.70	5.80	6.00	6.40	.....
7	5.90	5.20	5.30	7.00	7.40	9.90	6.00	4.30	6.30	5.90	6.10	.....
8	6.10	5.00	5.40	7.20	.....	10.50	5.90	4.40	5.90	6.30	6.10	.....
9	6.10	5.20	5.40	7.50	7.40	10.50	6.10	4.80	5.70	6.42	6.60	.....
10	6.00	4.90	5.30	7.90	7.90	9.80	6.30	4.90	5.70	6.70	6.10	5.10
11	5.90	5.10	5.30	8.80	9.50	9.00	6.40	5.30	5.30	8.40	5.90	.....
12	5.10	5.20	5.30	9.80	10.50	8.30	6.80	5.30	5.70	10.10	5.20	.....
13	5.10	5.10	5.30	9.80	10.50	7.80	7.10	5.40	5.30	12.00	5.50	.....
14	5.20	5.20	5.20	9.40	9.90	7.50	7.00	5.30	5.50	13.20	5.50	.....
15	5.20	5.10	5.30	8.70	9.40	7.20	6.50	5.30	5.60	13.00	5.60	.....
16	5.30	5.20	5.20	8.30	9.20	6.80	5.90	5.70	4.90	11.90	5.80	.....
17	5.20	5.20	5.20	7.70	9.00	6.90	5.80	5.00	5.20	10.30	5.50	5.50
18	5.10	5.10	5.20	7.30	8.50	6.70	5.50	5.10	5.30	9.40	5.30	.....
19	5.30	5.10	5.10	7.50	8.00	6.50	5.80	5.00	5.90	9.00	4.80	.....
20	5.00	5.00	5.00	7.50	7.70	6.20	5.50	5.00	5.70	8.40	5.00	.....
21	5.20	5.10	4.90	7.70	7.40	5.90	5.60	5.00	4.80	7.90	5.00	.....
22	5.20	5.10	5.00	7.70	7.20	5.80	5.30	4.70	4.90	8.00	5.30	.....
23	5.20	5.10	5.00	7.50	7.10	6.20	5.00	5.10	4.80	8.50	5.40	.....
24	5.10	5.10	4.80	7.60	7.00	5.70	4.80	4.80	4.70	8.50	5.30	6.00
25	5.00	5.20	5.00	8.00	7.50	6.00	4.50	4.90	4.85	8.30	4.90	.....
26	5.10	5.30	5.00	9.30	8.10	5.70	4.80	4.90	4.80	8.30	5.50	.....
27	5.00	5.40	5.20	10.30	9.40	6.10	4.90	5.00	6.70	7.90	5.10	.....
28	5.10	5.20	5.20	10.90	10.60	5.80	4.80	5.90	7.40	7.60	4.80	.....
29	5.20	5.10	5.20	10.70	11.90	6.10	4.70	4.60	7.40	7.50	5.00	.....
30	5.20	.....	5.50	10.50	12.60	6.00	4.80	5.00	7.00	7.40	5.00	.....
31	5.10	.....	5.80	.....	12.30	.....	4.70	4.70	.....	7.00	.....	6.00

[a] River frozen January 1 to March 31. Ice, average thickness, 10 inches.
[b] Ice conditions April 1 to 12.
[c] River frozen December 4 to 31. Ice 1 foot to 2 feet thick.

Mean daily gage height, in feet, of Wisconsin River near Necedah, Wis., December 2, 1902, to December 31, 1905—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	(a)	(a)	(a)	13.30	5.95	6.50	7.30	5.50	5.90	6.00	5.80	b 5.40
2				13.30	6.10	6.40	7.30	5.30	6.00	5.70	5.50	5.10
3				12.80	6.10	6.40	7.50	5.20	6.20	5.60	5.30	5.10
4		6.00	5.70	12.40	6.00	6.30	7.50	5.20	6.00	5.50	5.40	5.30
5				11.90	6.00	7.70	7.50	5.60	6.10	5.40	5.50	5.60
6				11.60	6.50	8.30	8.10	5.30	6.10	5.40	5.40	5.80
7	6.00			11.80	6.60	11.00	8.60	5.40	6.55	5.40	5.40	6.80
8				11.90	6.70	12.50	9.10	6.60	6.20	5.40	5.40	6.05
9				11.40	6.90	15.00	8.70	6.90	5.70	5.20	5.50	6.20
10				10.60	7.00	17.00	8.30	7.10	5.60	5.30	5.50	8.60
11			6.15	9.90	7.00	16.00	7.60	6.70	5.50	5.00	5.60	8.80
12				9.30	7.50	13.00	7.40	6.50	5.30	4.90	5.50	8.40
13		6.00		9.00	8.30	11.90	7.00	6.70	5.40	4.70	5.50	7.70
14	6.00			8.60	8.50	11.50	6.60	6.40	5.50	4.70	5.50	7.70
15				8.40	8.30	11.20	6.70	6.20	5.50	5.10	5.30	7.60
16				8.00	8.60	10.40	6.50	5.90	5.30	5.10	5.30	7.60
17				7.80	9.30	9.70	6.30	6.00	5.40	5.30	5.10	7.80
18				7.50	9.80	9.50	6.50	5.90	5.50	5.30	5.20	7.30
19				7.10	9.80	9.60	6.30	5.80	6.90	5.60	5.20	7.30
20		6.00		6.70	9.70	11.20	6.30	5.60	7.40	5.60	5.30	7.30
21	6.10		5.00	6.60	9.30	12.40	6.30	5.50	8.20	5.80	5.20	7.20
22			5.00	6.60	8.80	12.30	6.10	5.70	8.40	6.30	4.90	7.10
23			5.00	6.50	8.30	11.00	5.90	5.70	8.40	6.70	4.90	7.10
24			5.30	6.40	8.00	9.80	5.70	5.50	7.80	7.00	4.90	6.80
25		6.00	5.60	6.30	7.70	8.80	5.75	5.70	7.20	6.80	4.80	6.30
26			6.80	6.00	7.20	8.30	6.00	5.90	6.80	6.70	5.10	6.30
27			7.10	6.15	7.10	8.00	5.50	5.30	6.50	6.60	5.10	7.10
28	6.00		8.30	6.00	7.00	7.80	5.10	5.00	6.00	6.40	5.50	6.50
29			9.30	5.95	6.70	7.40	5.30	5.80	5.90	6.20	5.30	6.40
30			10.70	5.90	6.80	7.00	5.10	5.70	6.00	6.20	5.40	6.30
31					6.60		5.30	5.70		6.00		6.10

a River frozen over January 1 to March 20. Gage heights are to water surface in a hole in the ice. Thickness of ice, 2 to 2.5 feet.

b No ice record for December.

Rating table for Wisconsin River near Necedah, Wis., from March 10 to July 5, 1903.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.6	3,400	5.9	5,680	7.2	9,160	8.8	14,160
4.7	3,540	6.0	5,900	7.3	9,460	9.0	14,800
4.8	3,690	6.1	6,130	7.4	9,760	9.2	15,440
4.9	3,840	6.2	6,370	7.5	10,060	9.4	16,080
5.0	4,000	6.3	6,620	7.6	10,360	9.6	16,720
5.1	4,160	6.4	6,880	7.7	10,670	9.8	17,360
5.2	4,320	6.5	7,150	7.8	10,980	10.0	18,000
5.3	4,490	6.6	7,430	7.9	11,290	10.5	19,600
5.4	4,670	6.7	7,710	8.0	11,600	11.0	21,200
5.5	4,860	6.8	8,000	8.2	12,240	11.5	22,920
5.6	5,060	6.9	8,290	8.4	12,880	12.0	24,670
5.7	5,260	7.0	8,580	8.6	13,520	13.0	28,360
5.8	5,470	7.1	8,870				

[a] Flood in July changed channel.

Rating table for Wisconsin River near Necedah, Wis., from July 6 to December 12, 1903.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet*	*Second-feet.*
4.8	4,200	6.1	6,730	7.4	10,440	9.2	16,480
4.9	4,350	6.2	6,970	7.5	10,760	9.4	17,160
5.0	4,510	6.3	7,220	7.6	11,080	9.6	17,840
5.1	4,680	6.4	7,480	7.7	11,410	9.8	18,520
5.2	4,860	6.5	7,750	7.8	11,740	10.0	19,200
5.3	5,040	6.6	8,030	7.9	12,070	10.5	20,900
5.4	5,230	6.7	8,320	8.0	12,400	11.0	22,600
5.5	5,430	6.8	8,620	8.2	13,080	11 5	24,300
5.6	5,630	6.9	8,920	8.4	13,760	12.0	26,000
5.7	5,840	7.0	9,220	8.6	14,440	12.5	27,700
5.8	6,050	7.1	9,520	8.8	15,120	13.0	29,400
5.9	6,270	7.2	9,820	9.0	15,800	14.0	32,800
6.0	6,500	7.3	10,130				

Rating table for Wisconsin River near Necedah, Wis., from January 1 to December 31, 1904.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet*
4.0	1,800	5.4	4,880	6.7	8,500	9.0	15,400
4.1	2,000	5.5	5,130	6.8	8,800	9.2	16,000
4.2	2,200	5.6	5,380	6.9	9,100	9.4	16,600
4.3	2,400	5.7	5,640	7.0	9,400	9.6	17,200
4.4	2,600	5.8	5,900	7.2	10,000	9.8	17,800
4.5	2,810	5.9	6,170	7.4	10,600	10.0	18,400
4.6	3,020	6.0	6,440	7.6	11,200	10.5	19,900
4.7	3,240	6.1	6,720	7.8	11,800	11.0	21,400
4.8	3,400	6.2	7,010	8.0	12,400	11.5	23,610
4.9	3,690	6.3	7,300	8.2	13,000	12.0	25,860
5.0	3,930	6.4	7,600	8.4	13,600	12.5	28,230
5.1	4,150	6.5	7,900	8.6	14,200	13.0	30,750
5.2	4,390	6.6	8,200	8.8	14,800	13.5	38,450
5.3	4,630						

Rating table for Wisconsin River near Necedah, Wis., from January 1 to December 31, 1905.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.00	1,800	5.50	5,130	7.00	9,400	9.80	17,800
4.10	2,000	5.60	5,380	7.20	10,000	10.00	18,400
4.20	2,200	5.70	5,640	7.40	10,600	10.50	19,900
4.30	2,400	5.80	5,900	7.60	11,200	11.00	21,400
4.40	2,600	5.90	6,170	7.80	11,800	11.50	23,610
4.50	2,810	6.00	6,440	8.00	12,400	12.00	25,860
4.60	3,020	6.10	6,720	8.20	13,000	12.50	28,230
4.70	3,240	6.20	7,010	8.40	13,600	13.00	30,750
4.80	3,460	6.30	7,300	8.60	14,200	13.50	38,450
4.90	3,690	6.40	7,600	8.80	14,800	14.00	46,200
5.00	3,920	6.50	7,900	9.00	15,400	15.00	61,800
5.10	4,150	6.60	8,200	9.20	16,000	16.00	77,500
5.20	4,390	6.70	8,500	9.40	16,600	17.00	93,300
5.30	4,630	6.80	8,800	9.60	17,200	18.00	109,200
5.40	4,880	6.90	9,100				

The last table is applicable only for open-channel conditions. It is based on 23 discharge measurements made during 1902–1905. It is well defined between gage heights 4.5 feet and 10.5 feet. The table has been extended beyond these limits. From gage height 6.3 feet to 11 feet the rating curve is a tangent, the difference being 300 per tenth. Above 11 feet the bank overflows, which causes the discharge to increase at a greater rate per foot.

Estimated monthly discharge of Wisconsin River near Necedah, Wis., 1903 to 1905.

[Drainage area, 5,800 square miles.]

Date.	Discharge.			Run-off.		Rainfall.[a]
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1903.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
January			[b]2,600	0.45	0.52	0.36
February			[b]2,550	.44	.46	.91
March [c]	30,450		11,859	2.04	2.35	2.33
April	10,670	6,015	8,322	1.43	1.60	4.06
May	21,200	7,570	14,492	2.50	2.88	6.23
June	19,760	3,540	6,897	1.19	1.33	1.26
July	21,240	3,400	9,022	1.56	1.80	6.11
August	12,400	4,125	6,648	1.15	1.33	6.26
September	34,840	4,860	15,832	2.73	3.05	5.86
October	18,520	5,840	10,586	1.83	2.11	2.11
November	5,945	4,350	5,007	.86	.96	1.09
December 1–12 [d]	9,520	[e]5,630	[e]7,798	[e]1.34	[e].60	.88
1904.						
January						.33
February						1.20
March						1.49
April	21,100	7,300	12,830	2.21	2.47	2.01
May	28,720	9,400	15,250	2.63	3.03	6.20
June	22,280	5,640	11,350	1.96	2.19	4.81
July	9,700	2,810	5,926	1.02	1.18	3.28
August	6,170	2,400	3,845	.663	.764	3.21

[a] Rainfall for 1903 is the average of the recorded precipitation at the following stations: Antigo, Koepenick, Stevens Point, Wausau, Amherst, Grand Rapids, and Medford. That for 1904 includes the same stations, except Medford and adding Minocqua and Prentice.
[b] Estimated.
[c] March 1 to 9, inclusive, estimated.
[d] River frozen December 13 to 31.
[e] Twelve-day period.

Estimated monthly discharge of Wisconsin River near Necedah, Wis., for 1903 to 1905—Continued.

Date.	Discharge.			Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1904.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
September	10,600	2,400	5,227	.901	1.01	4.53
October	33,830	6,170	13,590	2.34	2.70	5.70
November	9,700	3,460	5,698	.982	1.10	.25
December						1.86
1905.[a]						
March 21–30		20,500	3,920	9,037	1.56	0.58
April		35,370	6,170	15,790	2.72	3.04
May		17,800	6,305	11,060	1.91	2.20
June		93,300	7,300	23,320	4.02	4.48
July		15,700	4,150	8,711	1.50	1.73
August		9,700	3,920	6,099	1.05	1.21
September		13,600	4,630	7,419	1.28	1.43
October		9,400	3,240	5,748	.991	1.14
November		5,900	3,460	4,667	.805	.898
December		14,800	4,150	8,888	1.53	1.76
The year						34.87

[a] No estimate for ice period.

Discharge measurements of Wisconsin River at Merrill, Wis., in 1902, 1903, 1904, and 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
1902.		*Feet.*	*Square feet.*	*Feet per second.*	*Feet.*	*Second feet.*
November 17	L. R. Stockman				7.6	9,015
December 10	do				3.8	1,394
1903.						
January 20[a]	do	310	718	1.91	4.05	1,376
February 16[a]	do	310	669	1.86	3.70	1,250
March 20	do	344	2,639	3.78	8.90	9,995
May 7[b]	do	332	2,232	3.54	6.85	7,893
June 17[b]	do	308	1,269	1.78	4.72	2,258
July 13	do	305	1,424	2.10	5.70	2,993
August 22[b]	do	283	1,115	2.36	5.00	2,638
September 11	E. C. Murphy	343	1,759	3.19	6.66	5,614
October 24	L. R. Stockman	334	1,594	2.61	6.08	4,159
1904.						
May 12[b]	E. Johnson, jr	334	2,220	3.71	7.85	8,242
June 5	do	334	2,286	4.19	8.25	9,587
July 15[b]	do	334	1,366	1.98	5.30	3,107
September 21	do	312	1,210	1.91	5.01	2,312
October 14	F. W. Hanna	327	2,333	4.42	8.25	10,323
November 30[a]	E. Johnson, jr	306	1,237	1.85	4.97	2,294
1905.						
April 10	S. K. Clapp	334	2,189	3.84	7.8	8,396
May 26	do	324	1,679	2.69	6.25	4,519
June 10	M. S. Brennan	334	2,334	4.06	8.17	9,478
July 10	do	332	1,596	2.73	6.48	4,357

[a] Partly frozen. [b] Affected by log jam.

Mean daily gage height, in feet, of Wisconsin River at Merrill, Wis., November 16, 1902, to December 31, 1905.

Day.	1902.		1903.										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	3.65	3.80	3.70	6.75	6.65	.....	7.05	4.30	.....	6.50	5.85	5.10
2	.....	.....	3.70	3.80	3.70	6.70	8.30	.....	7.65	4.30	5.50	5.90	5.60	5.10
3	.....	.....	3.85	3.85	3.80	6.55	.....	.....	7.65	4.90	5.70	6.90	5.30	5.25
4	.....	.....	3.80	3.80	3.75	6.65	.....	.....	8.70	5.60	5.80	7.85	5.30	5.10
5	.....	.....	3.75	3.85	3.80	6.75	.....	.....	8.80	6.55	6.00	8.00	5.30	5.25
6	.....	.....	3.70	3.85	3.70	6.70	.....	.....	8.70	7.45	6.10	7.80	5.75	5.15
7	.....	.....	3.75	3.90	3.80	6.80	.....	.....	8.30	7.35	6.10	8.85	5.30	5.20
8	.....	.....	3.70	3.80	3.75	6.90	.....	.....	8.10	7.25	6.50	8.55	5.10	5.20
9	.....	.....	3.65	3.90	3.75	6.75	.....	.....	7.70	(a)	6.60	8.35	5.20	5.15
10	.....	4.00	3.65	3.85	3.90	6.70	.....	.....	7.60	.....	6.80	8.20	5.10	5.05
11	.....	3.95	3.70	3.55	4.05	6.75	.....	.....	7.50	.....	6.90	7.70	5.30	4.95
12	.....	4.00	3.70	3.85	4.20	6.55	.....	.....	7.30	.....	9.10	7.25	5.25	4.70
13	.....	4.00	3.80	3.75	4.75	6.05	.....	.....	6.30	.....	9.40	7.35	5.25	4.90
14	.....	3.85	3.75	3.70	5.00	6.70	.....	.....	5.50	.....	10.00	7.10	5.25	4.80
15	.....	3.65	3.65	3.75	5.05	6.75	.....	.....	6.00	.....	11.10	7.10	5.05	5.30
16	3.60	3.85	3.50	3.80	5.05	6.80	.....	.....	5.40	.....	11.50	6.75	5.50	4.55
17	3.80	3.85	3.70	3.90	5.50	6.85	.....	.....	5.50	.....	10.80	6.60	5.35	5.00
18	2.50	3.90	3.70	3.75	5.55	6.75	.....	.....	5.40	.....	10.10	6.60	4.65	5.10
19	2.05	3.85	4.20	3.55	7.90	7.10	.....	5.15	5.15	.....	9.40	6.60	4.75	5.10
20	1.90	4.05	4.00	3.70	8.35	7.20	.....	5.20	5.55	.....	8.90	6.35	4.85	5.20
21	1.90	3.80	3.85	3.65	8.30	7.10	.....	5.55	4.65	.....	8.50	6.35	4.75	5.20
22	1.55	3.80	4.00	3.85	8.00	6.80	.....	5.60	4.90	.....	8.10	6.35	4.55	4.80
23	1.05	3.75	4.00	3.45	8.25	6.75	.....	6.00	5.40	.....	7.90	6.40	4.60	4.80
24	.90	3.85	4.00	3.65	7.50	6.80	.....	6.45	5.10	.....	7.70	6.15	4.70	5.10
25	1.05	4.05	4.10	3.70	7.35	7.05	.....	6.40	4.65	.....	7.10	6.05	4.90	5.00
26	.55	3.95	4.05	3.70	7.00	6.10	.....	5.85	5.10	.....	7.20	6.00	5.35	5.20
27	.15	3.90	4.00	3.60	6.65	6.35	.....	5.35	4.10	.....	7.20	5.85	5.25	5.50
28	.05	3.80	3.85	3.65	6.05	6.50	.....	5.35	4.50	.....	7.05	5.75	4.85	5.60
29	.10	3.70	3.95	.....	6.80	6.85	.....	6.30	5.60	.....	5.40	5.85	4.85	5.50
30	.....	3.70	3.90	.....	6.45	6.60	.....	6.75	4.50	.....	6.05	5.95	5.05	5.80
31	.....	3.70	3.85	.....	6.70	.....	.....	.....	4.30	.....	.....	5.60	.....	5.60

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
1	5.90	5.65	5.90	5.90	7.55	7.55	6.75	5.15	5.05	6.15	6.70	4.85
2	6.00	5.65	5.95	5.85	7.10	7.25	6.80	5.20	4.90	6.25	6.60	5.20
3	6.05	5.60	5.90	5.90	6.80	7.30	6.60	5.10	5.95	6.70	6.25	4.85
4	6.10	5.55	5.90	5.85	7.05	7.70	6.20	5.00	7.80	5.85	5.90	4.85
5	6.10	5.70	5.90	5.90	7.30	8.05	6.25	5.05	6.90	6.40	5.75	4.75
6	6.00	5.70	5.85	6.40	6.75	8.30	6.20	5.25	6.25	5.90	5.70	4.95
7	5.75	5.60	5.95	6.35	6.75	7.80	6.20	5.20	7.05	5.60	5.55	4.80
8	5.80	5.80	5.85	6.65	7.05	7.85	6.35	6.65	7.00	6.70	5.15	5.15
9	5.50	5.80	5.90	7.20	8.40	7.55	6.70	5.10	6.75	7.75	4.70	5.00
10	5.85	5.75	5.90	7.15	8.20	7.35	6.95	5.20	5.90	10.10	4.55	5.00
11	5.55	5.85	5.90	7.15	7.90	7.00	7.20	5.30	6.15	10.40	4.40	4.65
12	5.70	5.75	5.90	6.75	7.95	7.55	6.55	6.20	6.60	10.15	4.75	4.45
13	5.75	6.10	5.80	6.80	7.70	7.25	5.45	7.15	6.15	9.05	5.90	4.80
14	5.70	5.55	5.80	6.65	7.95	6.50	6.00	5.50	5.95	8.30	6.00	5.05
15	5.55	5.60	5.90	6.35	7.70	6.20	5.75	5.30	5.95	7.55	4.60	5.20

(a) Chain gage stolen.

Mean daily gage height, in feet, of Winconsin River at Merrill, Wis., November 16, 1902, to December 31, 1905—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
16	5.60	5.65	5.85	5.85	7.90	6.10	5.60	5.70	5.90	7.15	4.50	5.30
17	5.60	5.95	5.90	6.45	7.40	6.05	5.80	6.65	5.90	6.90	4.55	5.20
18	5.55	5.90	5.75	6.30	6.55	6.10	6.05	5.90	5.95	6.90	4.55	5.20
19	5.65	5.90	5.65	6.35	6.75	6.50	4.50	5.75	5.90	6.95	4.75	5.10
20	5.60	6.15	5.70	6.15	6.75	6.20	4.60	6.40	5.20	6.25	5.05	5.05
21	5.70	5.85	5.75	6.05	6.85	6.05	5.10	6.10	5.35	6.35	5.10	5.20
22	5.65	5.95	5.80	6.05	7.05	6.10	5.20	6.20	5.05	6.80	5.25	5.70
23	5.60	5.90	5.35	6.10	7.05	6.05	5.30	6.15	5.50	6.65	5.10	5.25
24	5.50	5.90	5.75	7.00	7.05	7.25	4.90	5.85	6.80	6.55	4.95	5.20
25	5.85	5.90	6.00	8.10	8.10	5.60	4.50	5.80	7.10	7.10	4.75	5.45
26	5.55	5.90	5.85	8.35	10.10	6.00	4.60	5.70	7.75	7.20	4.95	5.05
27	5.55	5.90	5.55	8.45	10.60	6.25	5.40	6.00	7.15	6.90	5.45	5.60
28	5.55	5.90	5.70	8.50	9.80	7.25	5.10	5.50	7.20	6.75	5.15	5.95
29	5.55	5.95	5.80	8.20	9.05	6.80	5.50	5.90	6.40	6.85	5.15	5.60
30	5.55	.....	5.70	7.75	8.60	6.30	5.70	6.35	6.10	6.65	4.85	5.50
31	5.50	.....	5.80	.....	7.95	.....	5.50	5.05	.....	6.25	.....	5.15
1905.												
1	5.20	5.25	5.35	8.90	5.15	5.80	7.40	5.05	6.10	6.20	6.20	5.20
2	4.95	5.00	5.35	8.80	5.70	5.70	7.30	5.45	6.20	6.00	6.30	5.70
3	5.20	4.90	5.20	9.20	6.20	5.90	7.50	5.35	6.15	6.20	5.60	5.60
4	5.70	5.15	5.40	8.90	6.10	5.50	7.60	5.35	6.70	6.00	5.25	5.80
5	5.35	5.50	5.25	8.80	6.25	7.60	8.00	5.95	6.70	6.05	5.80	5.40
6	5.40	5.35	5.35	8.80	6.40	10.40	8.20	6.10	6.25	6.00	5.35	5.25
7	5.20	5.15	5.55	8.80	6.45	10.00	7.70	6.85	6.00	5.30	5.10	5.55
8	5.45	5.25	5.15	8.20	7.20	9.00	7.80	6.00	6.25	5.30	5.55	5.55
9	5.15	5.10	5.20	8.60	6.70	9.00	8.00	6.25	6.10	4.30	5.45	5.35
10	5.05	5.40	5.65	7.80	6.45	8.40	7.20	6.40	6.30	4.90	5.90	5.75
11	5.35	5.20	5.45	7.40	6.95	8.50	6.85	6.05	6.15	6.15	5.80	5.70
12	5.50	4.95	5.05	7.20	7.20	8.40	7.05	5.75	6.30	6.80	5.15	5.55
13	5.50	5.20	5.45	7.40	6.90	7.80	6.20	6.00	6.65	6.45	5.30	5.60
14	5.90	5.25	4.70	7.00	7.40	7.80	6.30	6.15	6.40	6.55	5.00	5.60
15	6.00	5.15	4.70	6.90	7.60	7.60	6.80	5.90	6.05	5.90	5.20	5.35
16	5.95	5.50	4.95	7.20	7.60	8.10	6.50	6.05	6.40	6.15	5.65	5.70
17	5.75	5.70	5.05	7.40	7.80	10.40	6.30	5.90	6.60	5.85	5.70	6.15
18	5.85	5.65	5.25	7.00	7.80	10.60	6.55	6.40	6.45	6.25	5.75	5.50
19	5.65	5.55	5.25	6.45	7.50	10.60	5.05	6.25	6.90	6.65	5.85	5.60
20	5.15	5.35	5.25	6.45	7.30	9.60	5.65	6.20	7.35	6.85	5.45	5.65
21	5.15	4.30	5.50	6.45	7.00	9.20	6.45	5.90	6.70	6.70	5.75	5.75
22	5.60	5.20	4.95	6.05	6.75	8.60	6.00	6.80	7.30	6.70	5.75	5.75
23	5.80	5.75	4.95	5.95	6.80	8.50	5.50	6.50	6.90	6.80	5.75	5.45
24	6.05	5.80	5.35	5.60	6.40	8.00	5.40	4.80	6.80	6.15	5.60	5.55
25	6.15	5.60	4.55	5.75	6.45	7.60	5.20	5.55	6.50	6.30	5.70	5.90
26	5.85	5.15	5.75	6.20	6.30	6.90	5.10	6.35	6.25	6.70	5.20	6.25
27	5.85	5.65	6.05	5.90	6.35	7.60	5.65	6.40	6.55	6.55	4.80	5.90
28	5.25	5.35	7.40	5.65	6.35	7.50	5.80	6.25	6.15	6.90	5.15	5.60
29	5.10	.....	8.00	5.95	6.25	6.75	5.60	5.75	5.95	6.50	5.65	5.85
30	5.05	.....	8.60	5.45	6.25	7.05	5.75	6.00	6.45	5.70	5.50	5.70
31	5.15	.....	8.50	.....	6.00	.....	4.30	6.80	.....	5.80	.....	5.40

NOTE.—No ice record at this station.

Rating table for Wisconsin River at highway bridge near Merrill, Wis., from June 17, 1903, to December 31, 1904.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-ft.*	*Feet.*	*Second-ft.*	*Feet.*	*Second-ft.*	*Feet.*	*Second-ft.*
4.5	1,485	5.5	3,225	6.5	5,485	8.0	9,565
4.6	1,645	5.6	3,425	6.6	5,725	8.2	10,225
4.7	1,805	5.7	3,635	6.7	5,975	8.4	10,885
4.8	1,970	5.8	3,855	6.8	6,225	8.6	11,545
4.9	2,140	5.9	4,075	6.9	6,475	8.8	12,205
5.0	2,310	6.0	4,305	7.0	6,725	9.0	12,865
5.1	2,485	6.1	4,535	7.2	7,245	9.5	14,515
5.2	2,665	6.2	4,765	7.4	7,785	10.0	16,165
5.3	2,845	6.3	5,005	7.6	8,345	10.5	17,815
5.4	3,035	6.4	5,245	7.8	8,935	11.0	19,465

Estimated monthly discharge of Wisconsin River at Merrill, Wis., for 1904.

[Drainage area, 2,630 square miles.]

Date.	Discharge.			Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1904.	*Sec. ft.*	*Sec. ft.*	*Sec. ft*	*Sec. ft.*	*Inches.*	*Inches.*
January	4,535	3,225	3,664	1.39	1.60	0.33
February	4,655	3,330	3,749	1.43	1.54	1.20
March	4,305	2,945	3,889	1.48	1.71	1.49
April	11,220	3,970	6,242	2.37	2.64	2.01
May	18,140	5,610	8,935	3.40	3.92	6.20
June	10,560	3,425	6,472	2.46	2.74	4.81
July	7,245	1,485	3,957	1.51	1.74	3.28
August	7,110	2,310	3,766	1.43	1.65	3.21
September	8,935	2,140	5,000	1.90	2.12	4.53
October	17,480	3,425	7,343	2.79	3.22	5.70
November	5,975	1,410	2,800	1.06	1.18	.25
December	4,195	1,490	2,566	.976	1.12	1.86
The year	18,140	1,410	4,865	1.85	25.18	34.87

RAILROADS.

The railway facilities will be discussed in connection with each power, but in general it may be said that they are excellent. The willingness of the railroads to go where there is an assured traffic is seen at Nekoosa. Since the construction of the paper and pulp mill at this point three different railroads have extended their lines to the mill.

The land is being rapidly cleared and made into farms, especially during the past five years. This fact insures the certain and steady extension of the railroads in this region.

WATER POWERS.

In the first 138 miles above its mouth Wisconsin River occupies a wide, sandy valley, entirely devoid of any falls or rapids, and showing a very uniform descent of only 1½ feet per mile.

KILBOURN.

The first water power is found at Kilbourn, where the river flows across the Cambrian sandstone in a narrow, deep gorge known as "The Dell," 100 to 600 feet wide and 40 to 70 feet deep. The drainage area of Wisconsin River at Kilbourn is about 8,200 square miles. According to discharge measurements made by United States engineers, the low-water discharge is 3,000 second-feet. A dam with a crest 3 feet above low water was for many years operated here, under an old charter, the power being used for a flouring mill. This was burned down over thirty years ago and since that time no use has been made of the power.

The Madison Traction Company, of Madison, Wis., has a charter for a 15-foot dam above the ordinary low-water level, with the privilege of 2 feet of flashboards, giving a head of 17 feet or more. It has been proposed to build an electric railroad from Madison northward via Kilbourn, as an extension of the present Madison street railway system, and the plans contemplate using this water power to drive the dynamos.

The river continues to flow in the Cambrian sandstone for the next 70 miles, until Nekoosa is reached. Although the river descends over 105 feet in this distance the fall is so evenly distributed that good water-power sites are lacking. At Nekoosa, however, for the first time, we find the river flowing in the hard pre-Cambrian crystalline rock. In the next 8½ miles above, the river has a descent of 83 feet, nearly all of which is improved by 5 dams. These dams furnish power for 5 large modern paper and pulp mills and will be described in order, beginning below.

NEKOOSA.

A rock crib dam at Nekoosa develops a head of nearly 20 feet. This power is used to operate a modern paper and sulphite mill, one of the largest on the river, owned by the Nekoosa Paper Company. An installation of 37 turbines is reported, developing a total of 4,560 actual horsepower for twenty-four hours per day. The drainage area of the river at this point is about 5,700 square miles.

PORT EDWARDS.

About 4½ miles farther upstream is another fully developed power owned by the John Edwards Manufacturing Company. A head of 18 feet is here available. Turbine wheels, to the number of 28, develop 3,860 actual horsepower, which is used to run a large paper and pulp mill. Two miles farther upstream is the Centralia Pulp and Water Power Company's dam, with an average head of 13 feet. Turbines of 1,460 horsepower are here installed, according to the company's report, all used in the manufacture of paper and pulp.

GRAND RAPIDS.

One of the largest and most complete paper and pulp mills in the entire State, owned by the Consolidated Paper and Power Company, is located on the west side of the river, within the city limits of Grand Rapids. This mill was erected in 1902 and its installation of paper-making machinery has all the recent important improvements. Before this mill was constructed there was a total descent of 30.8 feet between the foot of Biron dam, 4 miles above, and the Grand Rapids bridge. Of this amount the new masonry and concrete dam of the Consolidated Paper and Power Company develops a head of about 25 feet. Turbines of 6,500 horsepower are already installed, flume space being also provided for the development of an additional 1,000 horsepower for future expansion. Prior rights to 500 horsepower developed by this dam are owned by the Grand Rapids Milling Company, which uses it in the manufacture of flour.

The Pioneer Wood and Pulp Company has certain rights to about 600 or 800 horsepower "when the stage of the river will permit," which has meant about ten months each year. This power is used by the company for grinding wood pulp. The Grand Rapids foundry also has rights to about 40 horsepower from the same dam. The milling company

and the foundry both receive their power from the Consolidated Company in consideration for power previously owned by them and displaced by the present dam.

The above-described four paper mills have the advantage of competition in freight rates incident to being served by each of the following railways: The Chicago and Northwestern; Chicago, Milwaukee and St. Paul; Green Bay and Western; and Wisconsin Central.

About 4 miles above Grand Rapids is located the dam of the Grand Rapids Paper and Pulp Company. A head of from 10 to 12 feet, depending on the stage of the water, is reported with turbines already installed of 3,063 horsepower. This company is served by the Green Bay and Western Railroad. In the 13 miles between the crest of the Biron dam and the foot of the next one above, near Stevens Point, Wisconsin River descends 16 feet. The only rapids in this distance is one of 3½ feet called "Crooked Rift," about 4 miles above the Biron dam. The greater part of this fall properly belongs to the Biron power and is largely developed by the splash boards of that dam.

STEVENS POINT.

Owing to the peculiar topography of the river valley between Nekoosa and Stevens Point, whereby the adjacent tributaries flow for long distances parallel to the main river, and to the decided narrowing of the river valley between these points, the discharge of Wisconsin River at Stevens Point does not differ greatly from that at Nekoosa. The drainage area at Stevens Point is about 5,600 square miles.

In the city of Stevens Point and immediately south of it are found three developed powers and one undeveloped. Of the former, the lower two are owned and operated by the Wisconsin River Paper and Pulp Company. One of its dams is located in the NE. ¼ sec. 17, T. 23 N., R. 8 E., just below the mouth of Plover River, and supplies a head of 9 feet. At this point a large island occupies the middle of the river and is made use of in the construction of the dam. The company has installed turbines rated at 1,370 horsepower. One-half mile above this dam, at a point where the river is much narrower, is located the second dam belonging to this company, giving an average head of 16 feet. Here are installed 18 turbines rated at 4,660 horsepower. This power, as well as that derived from the dam below, is used in the manufacture of pulp and paper. Both mills are located on the east or right bank and have good shipping facilities. Above the last-described power and about a mile below the dam next above is an undeveloped power of about 7-foot head belonging to the same company. As the river is wide at this point, a very long dam would be required to develop this power, but its location in the city would make it very valuable.

The third dam is located within the limits of the city of Stevens Point and is owned by the Jackson Milling Company. This dam develops an average head of 7 feet. The owners have installed only 3 turbines, rated at 140 horsepower, which is used to run a flour and feed mill. By building a new dam 1,000 feet below the present one, with a crest of 10 feet, a 12-foot head could easily be obtained without flooding. On account of its location in a growing city of 10,000 people, it would seem that all this power could easily find takers at remunerative rates.

BATTLE ISLAND.

In the 19 miles between the head of the upper dam at Stevens Point and the bridge of the Chicago, Milwaukee and St. Paul Railway near Knowlton, according to railroad levels, the river descends 30 feet. In this distance there is only one opportunity for the development of water power, namely, at Battle Island, in sec. 28, T. 26 N., R. 7 E. From the foot of the rapids at Mosinee to Battle Island, according to a survey, there is a fall of 20 feet. The banks at this point are said to be high, so that a dam could be economically built with a head of 20 feet. The Wisconsin Valley division of the Chicago, Milwaukee

and St. Paul Railway is distant less than a mile from this site, and rock and timber are very abundant and near at hand; in fact, the bed and banks of the river are in rock.

MOSINEE.

An easily developed power, one of the best on the river, is found at Mosinee, in sec. 31, T. 27 N., R. 7 E. It is owned by the Joseph Dessert Lumber Company. About forty years ago a flooding dam with a head of 5 or 6 feet was built here, and it has since been rebuilt several times. The dam was located near the head of the rapids, probably because of the ease of construction due to a large island in the river at this point. Later a sawmill was built on the right bank, thereby securing a head of about 12 feet. At the present time this mill is run by steam power, and no use is made of the water power. An effort is now being made to interest capital to develop this power to its maximum amount for a proposed paper and pulp mill. This will require a new dam. Such a dam could be made to develop a head of 20.7 feet by flooding a small marsh above. The high banks and the bed of the river are in the hard crystalline rock.

ROTHCHILDS.

In the 18 miles between the east quarter stake of sec. 35, T. 29 N., R. 7 E., below the mills at Wausau, and the crest of the Mosinee dam, Wisconsin River descends 28 feet.[a] A considerable portion of this fall is concentrated in rapids in sec. 24, T. 28 N., R. 7 E. at a place called Rothchilds. The right bank is steep, but the left bank is much less so. A dam could be built here which would develop a head of nearly 20 feet, but it would need to be long. Rib and Eau Claire rivers, with drainage areas of 500 and 423 square miles, respectively, enter Wisconsin River from opposite sides but a short distance above Rothchilds. This place is 7 miles from Wausau and is reached by the Chicago, Milwaukee and St. Paul Railway. During the year 1903 Wausau capitalists made earnest efforts to acquire the necessary flowage rights for the improvement of this power, but the owners of the land were unwilling to sell at the rates offered and the project was dropped.

WAUSAU.

Only a portion of the valuable water power located in the city of Wausau has been developed. A high granite island, nearly a quarter of a mile long, occupies the middle third of the river at this place, the main dam being built from the head of this island to the right bank, a distance of about 350 feet. The guard lock is located on the opposite channel, at the site of the Scott Street Bridge, and is about 300 feet long.

Near the head of the island is located the McEchroy roller mill. Three turbines, installed under an average head of only 7½ feet, develop 296 actual horsepower, which is ample for this mill as at present equipped.

About 1,000 feet below the guard lock are situated the Alexander Stewart Lumber Company's planing and saw mills, working under heads of 9 and 11 feet, respectively. Four turbines, rated at 200 horsepower, are installed. The planing mill runs ten and the sawmill twenty hours a day. The company also has 350 steam horsepower.

About 1,300 feet below the guard lock is located the plant of the Wausau Paper Mills Company, which takes its power from the old dam, but because of the location so far below has the advantage of the additional fall in the river. This gives an average head of 14 feet. The company has installed 12 turbines, rated at about 3,600 actual horsepower, and in addition has 500 steam horsepower. This mill runs twenty-four hours a day.

During the past year the Wausau Electric Company has acquired rights to two-ninths of the total flow of the stream, and has blasted a new tailrace out of the solid rock for a distance of 300 or 400 feet, thereby increasing the head to 22½ feet. This company has as yet installed only one pair of turbines, rated at 700 horsepower, but intends to double

[a] U. S. Geol. Survey topographic map.

this in two years. The Stewart Lumber Company owns three-ninths and D. L. Plumer four-ninths of the total flow of the river.

Wausau is a city of about 13,000 inhabitants and is the county seat of Marathon County. The Marshfield branch of the Chicago and Northwestern Railway crosses Wisconsin River at this point, and the city is served also by the Chicago, Milwaukee and St. Paul Railway.

BROKAW.

In the 20 miles (by river) between the foot of the lower dam at Merrill and the head of the Wausau dam Wisconsin River descends about 55 feet, 35 feet of this being between Wausau and the mouth of Pine River.[a] The only portion of this fall at present developed is at Brokaw, where a dam with a head of 12 feet furnishes power for a large paper and pulp mill. Twelve turbines, rated at 3,964 horsepower, are installed. Brokaw is about 6 miles above Wausau, in sec. 3, T. 29 N., R. 6 E., and is reached by the Chicago, Milwaukee and St. Paul Railway.

TRAPP RAPIDS.

About 4 miles above Brokaw, near the mouth of Trapp River, are the Trapp rapids.[b] The bed of the river is in the hard crystalline rocks, and, according to the topographic map, both banks are about 30 or 35 feet high and the river 600 feet wide. A head of 18 or 20 feet could probably be developed here by a dam. The nearest city is Merrill, a place of over 9,000 inhabitants, distant only 8 miles by the Chicago, Milwaukee and St. Paul Railway.

MERRILL.

In the city of Merrill are two dams. The lower one, which has recently been repaired and partially rebuilt, is located between lots 1 and 3, sec. 12, T. 31 N., R. 6 E., and gives an average head of 14 feet. This power is owned by the Merrill Electric Light Company, which has installed and uses 600 horsepower. The remainder of the power is leased to the Lindore Paper Company, which in 1904 blasted out a new tailrace about 600 feet below the dam and has here installed 23 turbines under a 14-foot head, rated at 2,220 horsepower.

The second dam within the city limits of Merrill is located in sec. 10, T. 31 N., R. 6 E., about 2¼ miles above the paper mill, and is used for boom purposes only. It has a length of about 475 feet and develops an average head of 8 feet. A similar dam with an 8-foot head is located about 2 miles above, between secs. 8 and 9, T. 31 N., R. 6 E., and is also used only for boom purposes. Both dams are owned by the Wisconsin River Driving Association. As these dams are of little use at present, owing to the decline of the lumber interests, a company is now being formed to greatly improve the two powers by the construction of a new dam, to be located between secs. 9 and 16, T. 31 N., R. 6 E. It is stated that a head of 24 feet can be obtained here to run a new paper mill.

Wisconsin River is joined at Merrill by Prairie River. Between Merrill and Rhinelander Tomahawk and Pelican rivers add their waters from an aggregate drainage area of 3,300 square miles.

BILL CROSS RAPIDS.

The next power in order above Merrill is found at Bill Cross Rapids, in sec. 13, T. 32 N., R. 5 E., not far from the east quarter stake. Between this point and the foot of Grandfather Rapids the river descends 26½ feet. As the banks are reported high at this point it is probable that a head of 20 to 24 feet could be obtained. This dam site is distant 5 miles from the Chicago, Milwaukee and St. Paul Railway.

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[a] U. S. Geol. Survey topographic map.

[b] The power and riparian rights at these rapids are owned by G. D. Jones, Neal Brown, and Carl Mathie, of Wausau, Wis.

A. GRANDFATHER RAPIDS, WISCONSIN RIVER.

Ninety feet fall in 1½ miles.

B. BRUNETT FALLS, CHIPPEWA RIVER.

GRANDFATHER RAPIDS.

In the 53 miles between the foot of the upper dam at Merrill and the foot of the Rhinelander dam the river has a natural descent of 277 feet, an average of 5.2 feet per mile. In this stretch, besides several other fine powers, are included Grandfather Rapids, the largest water power on the river, developed or undeveloped. These rapids begin in the NE. ¼ sec. 30, T. 33 N., R. 6 E., and extend to the SW. ¼ sec. 31, a distance of 1½ miles, and are the most noted rapids on the river. A view of them is shown in Pl. III, *A*. The descent in this distance is 89½ feet. The high bank and the bed of the river are in the hard pre-Cambrian rock. For nearly thirty years the Wisconsin River Logging Association has maintained three logging dams on these rapids. It is probable that the cheapest method of developing this power would be to construct three dams of 30 feet head each, and that the power could be best employed by paper mills. The site is about midway in the 20 mile stretch from Merrill to Tomahawk.

About 1.5 miles above Grandfather Rapids are some small rapids where a 8.9-foot dam would back the water to the foot of Grandmother Rapids.

GRANDMOTHER RAPIDS.

From the foot of the present Tomahawk dam to the foot of Grandmother Rapids, Wisconsin River descends 41 feet, 6½ feet of which are concentrated at these rapids in a distance of 40 rods. According to a survey, 39 feet can be developed here. One dam site should be near the south line of sec. 10, T. 33 N., R. 6 E., which is distant only 2½ miles from the Chicago, Milwaukee and St. Paul Railway at Irma.

TOMAHAWK DAM.

This dam, which has a head of 13.2 feet, is located in the SW. ¼ sec. 10, T. 34, N., R. 6 E. It has a total pondage of over 4 square miles, the largest on the river, backing up the water in the main river for about 6 miles, as well as in the tributaries. The steadying effect which this dam exerts, together with that of several dams on adjoining lakes, must be very beneficial. This power has been used for several years for running a large paper mill located on the left bank and reached by spur tracks of the Chicago, Milwaukee and St. Paul Railway. The installation is 650 horsepower. During the summer of 1904 another paper mill was erected on the opposite bank, taking its power from the same dam.

PINE CREEK RAPIDS.

From the foot of Whirlpool Rapids to the backwater of the Tomahawk dam, a distance of 10 miles, the river has a nearly even descent of 23½ feet, 20 feet of which could be developed by one or possibly two dams. A 20-foot dam located about a mile east of the city of Tomahawk, in the SE. ¼ sec. 25, T. 35 N., R. 6 E., would back the water up into Pine River. Most of the land thus to be overflowed belongs to lumbering companies or to the Bradley Company, of Tomahawk, Wis. This dam site is less than half a mile from the Marinette, Tomahawk and Western Railway.

WHIRLPOOL RAPIDS.

These rapids extend from the west line of sec. 12, T. 35 N., R. 7 E., to the north line of Lincoln County, a distance of about 2 miles, in which the river descends 15.4 feet. Between the head of Whirlpool Rapids and the foot of Hat Rapids there is a descent of 12.63 feet. A suitable dam at the foot of Nigger Island, in sec. 12, T. 35 N., R. 7 E., would develop a head of 28 feet. The banks are said to be high, with an abundance of rock and timber adjacent to the dam site. The drainage area at this point is 1,300 square miles. Three different railroad lines are located within 3 or 4 miles of this site, and Tomahawk, a city of 2,500 population, is 7 miles west.

HAT RAPIDS.

Between the mouth of Pelican River and the foot of Hat rapids, in sec. 27, T. 36 N., R. 8 E., the Wisconsin descends about 22 feet. As the banks are high, a dam in sec. 27 between lots 4 and 5 could be made to develop about 20 feet of head. The drainage area at this point is 1,220 square miles. The Rhinelander Power Company has been formed to develop this power, and from Mr. A. W. Sheldon, Rhinelander, Wis., its attorney, the following facts were learned. A recent survey shows that the concrete dam should be located 13 rods north of the south line of sec. 27, T. 36 N., R. 8 E. It will be 264 feet long, with earthen dikes, in addition, of 80 and 250 feet. Such a dam would create a head of 20.3 feet. The site is only 5 miles from Rhinelander, a city of over 5,000 inhabitants, reached by both the Chicago and Northwestern and the Minneapolis, St. Paul and Sault Ste. Marie railways. The power could be either used at the site for a paper mill or electrically transmitted to Rhinelander for lighting and power purposes. The latter is stated as the present intention of the owners. An officer of the company states that all the contracts for construction and machinery have been let, and that the plant is expected to be in operation by September, 1905.

RHINELANDER DAM.

Between the foot of the present dam of the Rhinelander Paper and Pulp Company, in the city of Rhinelander, and the foot of Otter rapids, in sec. 36, T. 40 N., R. 9 E., a distance of about 35 miles, the river descends 79.2 feet. The dam develops 30 feet of this descent, and the power is used to run one of the largest paper and pulp mills on the river. The company has installed turbines rated at a total of 3,000 actual horsepower and has also 1,200 steam horsepower. The daily capacity of this mill is 45 tons of finished paper, 40 tons of pulp, and 40 tons of sulphite pulp.

The river above this point has a drainage area of about 940 square miles. Above Rhinelander the river banks are lower and the opportunities for developing large powers few. In the 35 miles between Rhinelander and the source there are two rapids, called Rainbow rapids and Otter rapids. In this distance, according to the United States engineers,[a] between the head of Otter rapids and a point about a mile above the mouth of Pelican River, the descent of Wisconsin River is only 57 feet, or about 1.62 feet per mile.

RAINBOW RAPIDS.

These rapids are of small extent. They are located in sec. 6, T. 38 N., R. 8 E., and a head of 6 to 10 feet could be secured.

OTTER RAPIDS.

The most important power above Rhinelander is at Otter rapids, where a logging dam with a head of about 10 feet was early constructed. The rapids proper descend 16 feet,[a] so that a head of this amount or more could be developed. The dam site is between lots 6 and 8, sec. 36, T. 40 N., R. 9 E. The drainage area above this point is about 500 square miles.

According to the Chicago and Northwestern Railway, the Wisconsin River at Conover, in sec. 9, T. 41 N., R. 10 E., has an elevation of 1,644 feet above the sea. This would give a fall of 66 feet in the 24 miles between Conover and the head of Otter rapids.

TRIBUTARIES OF WISCONSIN RIVER.

GENERAL STATEMENT.

The watershed line on each side of the Wisconsin Valley is between 300 and 400 feet above the main river, and as the tributaries have to descend this distance in a length of 50 or 60 miles they have many rapids and available powers. In the upper portion of

[a] Rept. Chief Eng., U. S. Army, 1881, p. 1824.

their courses the tributaries flow over the hard pre-Cambrian rock, giving many rapids. The lower valleys, however, are filled by continued erosion, so that with few exceptions, no powers are found here.

The length and drainage area of certain streams tributary to Wisconsin River are shown in the following table:

Principal tributaries of Wisconsin River.

River.	Length.	Drainage area.
	Miles.	*Sq. miles.*
Pelican	25	262
Tomahawk	50	714
Rib	50	498
Eau Claire	50	423
Eau Pleine	50	377
Yellow	70	946
Lemonweir	50	588
Baraboo	70	655
Kickapoo	75	760

Only Kickapoo, Baraboo, and Lemonweir rivers and their branches have been as yet fully or even largely developed, but the present rapid settlement of this northern region is fast bringing a demand for the utilization of these valuable water-power resources. While these powers are small as compared with those on the main river, in the aggregate they are large, and their wide distribution makes them of still greater value. In some cases, because of the ease with which they can be developed and controlled, manufacturers seem to prefer them to the larger but more expensive powers on the parent river. An example of this is seen in the present power developments on Prairie River.

ST. GERMAIN RIVER.

Although but 20 miles long, St. Germain River has at least three good dam sites located as follows: (1) SW. ¼ sec. 31, T. 41 N., R. 8 E.; (2) near the outlet of Big St. Germain Lake, sec. 32, T. 40 N., R. 8 E.; and (3) near the northeast corner of sec. 18, T. 39 N., R. 8 E. At the second dam site a head of 20 feet and at the third site a head of 26 feet are reported as feasible.

TOMAHAWK RIVER.

This river rises in about 40 lakes with elevations of from 1,540 to 1,575 feet above the sea, the largest of which is Tomahawk Lake, with an area of 7 square miles. The river joins the Wisconsin at Tomahawk after a course of about 50 miles.

The dam in Wisconsin River at Tomahawk backs the water in Tomahawk River to an elevation of 1,442 feet, so that the remaining descent is about 120 feet, or 2.4 feet per mile, nearly half of which is concentrated in four rapids. Only one of these has been developed for power purposes, the dam being located about 2 miles above the mouth of the river, where a head of about 18 feet is obtained. At present only 300 horsepower are here utilized, in a tannery belonging to the United States Leather Company.

Eight miles above this dam, in lots 5 and 6, sec. 21, T. 36 N., R. 6 E., are the Prairie rapids, with a descent of 20 feet; 10 miles above, in lots 1 and 4, sec. 17, T. 37 N., R. 6 E., are the Halfbreed rapids, with descent of 8 feet; and 12 miles still farther upstream, in sec. 27, T. 38 N., R. 5 E., are the Cedar rapids, with descent of 12 feet.

PELICAN RIVER.

This river rises in a series of lakes, the largest being known by the same name, at an elevation of 1,590 feet above the sea. The river flows west and joins the Wisconsin near

Rhinelander, after descending about 50 feet in its length of 25 miles. The following table shows the location of promising dam sites, none of which are as yet developed:

Dam-site locations on Pelican River.

	Possible head (feet).
Between lots 4 and 6, sec. 4, T. 36 N., R. 10 E.	6 to 8
SW. ¼ sec. 17, T. 36 N., R. 10 E.	6
Between lots 3 and 4, sec. 26, T. 36 N., R. 9 E.	10
Between lot 1, sec. 21, and lot 1, sec. 22, T. 36 N., R. 9 E.	12

PRAIRIE RIVER.

Although Prairie River has a drainage area of only 214 square miles and is without lakes at its upper headwaters, its water powers are of sufficient importance to have already attracted capital for their development. At the eastern limits of the city of Merrill a dam 200 feet long is being rebuilt so as to give a head of 21 feet. This dam is owned by the Prairie River Power and Boom Company. Nine miles northeast, in sec. 13, T. 32 N., R. 7 E., at a point where the river has worn a deep channel in the rocks, forming dalles, a masonry dam to furnish a head of 72 feet is now being built by the same company. This power will be transmitted electrically to the lower dam for use in a paper mill now under construction.

In sec. 14, T. 33 N., R. 8 E., are smaller dalles, where a head of 20 feet may be obtained.

RIB RIVER.

Rib River rises in two small lakes, the larger of which, Rib Lake, has an elevation of about 1,556 feet. After a course of about 50 miles, the Rib joins Wisconsin River a mile below the city of Wausau. Its total descent is 400 feet, an average of 8 feet to the mile. A considerable part of this descent is concentrated in the middle third of its length.

The first power is found at Marathon, 10 miles from its mouth, where a dam about 80 feet long develops a head of 18 feet. About 5 miles above, in the city of Rib Falls, a dam 100 feet long develops a head of 20 feet. In sec. 24, T. 30 N., R. 4 E., there is an undeveloped power with a head of 18 feet.

EAU CLAIRE RIVER.

The Eau Claire enters Wisconsin River 2 miles below the mouth of Rib River, and from the opposite (eastern) side. It has a smaller drainage area than that of the Rib, and a much larger proportion of its descent is distributed in its lower part.

A total of 148 feet is concentrated at the following points, given in order from the mouth of the river.[a]

Dam-site locations on Eau Claire River.

Location.	Head.	Remarks.
	Feet.	
Schofield, sec. 12, T. 28 N., R. 7 E.	12	Developed (old mill abandoned).
Manser's, sec. 10, T. 28 N., R. 8 E.	25	Developed, but only part used.
Old Kelley, sec. 13, T. 28 N., R. 8 E.	25	Developed for logging.
Barnards rapids, sec. 23, T. 29 N., R. 9 E.	22	Undeveloped.
The Dalles, sec. 7, T. 29 N., R. 10 E.	40	Do.
Three Rolls, sec. 34, T. 30 N., R. 10 E.	12	Do.
Little rapids, sec. 22, T. 30 N., R. 10 E.	12	Do.

The first three powers are adjacent to the Chicago and Northwestern Railway, and are used chiefly for boom purposes.

[a] Authority: D. L. Plummer, C. E.

EAU PLEINE RIVER.

This river has a narrower and smaller drainage area than either the Rib or the Eau Claire and is entirely devoid of lakes. Like the latter, it has considerable descent concentrated in its lower reaches, one power with a 15-foot head being located within 2 miles of its mouth. Following is a summary of its powers:

Dam-site locations on Eau Pleine River.

Location.	Head.	Remarks.
	Feet.	
Sec. 18, T. 26 N., R. 6 E.	15	Undeveloped.
Sec. 24, T. 26 N., R. 6 E.	15	Do.
Sec. 13, T. 27 N., R. 3 E.	15	Do.
Sec. 4, T. 27 N., R. 3 E.	10±	Developed.
Sec. 24, T. 28 N., R. 2 E.	10±	.....

BLACK RIVER.

TOPOGRAPHY AND DRAINAGE.

Black River, hemmed in by the Chippewa on the west and the Wisconsin on the east, is restricted to a long and narrow watershed of about 2,270 square miles,[a] with an average width of only 20 miles. At one point the branches of Chippewa River extend to within a quarter of a mile of Black River. Unlike that of the Chippewa, about a third of the Black River drainage area is in the comparatively level sandstone region, so that the maximum watershed available for water powers, namely, at Black River Falls, is only 1,570 square miles.[a] The watershed narrows rapidly as the river is ascended, and at Neillsville, 22 miles in an air line from Black River Falls, the drainage area is reduced to only 729 square miles.[a] Were it not for this small watershed, the steep gradient of the river and its high, rocky banks would insure large water powers. Black River rises at an elevation of about 1,400 feet above sea level, and after a sinuous course of over 140 miles joins Mississippi River at La Crosse. The total descent in this distance is 772 feet, with details as shown in the following table:

Profile of Black River from its mouth near La Crosse to near Withee.[b]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	La Crosse (near)	.....	.....	628	.....	.....
2	Black River Falls: Below dam	55.0	55.0	749	121	2.2
3	Above dam	55.0	.0	763	14	.....
4	Chicago, St. Paul, Minneapolis and Omaha Railroad bridge	58.0	3.0	766	3	1.0
5	Halls Creek, mouth of	61.6	3.6	776	10	2.8
6	Halcyon	67.0	5.4	793	17	3.1
7	Hatfield railroad bridge	71.2	4 2	838	45	10.4
8	East Forks, mouth of	74.2	3.0	846	8	2.7
9	Dells dam, below	77.5	3.3	874	28	8.5

[a] Census report, vol. 17, 1880, p. 87.
[b] Authority: No. 1 (low-water elevation), Mississippi River Commission; 2 to 22, Joint Survey of Wis. Geol. and Nat. Hist. Survey and United States Geological Survey.

Profile of Black River from its mouth near La Crosse to near Withee—Continued.

No.	Station.	Distance.		Elevation above sea level.	Desent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
10	Wedges Creek, mouth of	78.5	1.0	993	19	19.0
11	Cunningham Creek, mouth of	84.8	6.3	909	16	2.5
12	Center sec. 22, T. 24 N., R. 2 W.	86.8	2.0	929	20	10.0
13	O'Neill Creek, Neillsville	0.8	4.0	989	60	15.0
14	Bridge, secs. 9 and 16, T. 25 N., R. 2 W	98.8	8.0	1,034	45	5.6
15	Bridge, secs. 21 and 28, T. 27 N., R. 2 W	103.5	4.7	1,070	36	7.9
16	Bridge, Fairchild and Northeastern Rwy	107.8	4.3	1,094	24	5.6
17	Site New Greenwood dam	109.3	1.5	1,105	11	7.3
18	Between secs. 27 and 28, T. 27 N., R. 2 W	110.3	1.0	1,107	2	2.0
19	Hemlock dam, 600 feet below	113.5	3.2	1,132	25	8.0
20	Hemlock dam, above	113.6	.1	1,151	19	.....
21	Bridge, secs. 20 and 29, T. 29 N., R. 2 W	119.6	6.0	1,167	16	2.7
22	Bridge, Wisconsin Central Rwy., west of Withee	125.1	5.5	1,187	20	3.6

In the 55 miles below the city of Black River Falls the river flows through the sandstone country in a wide valley with low banks, making dam construction very expensive, if not entirely impracticable. In the 40 miles next above Black River Falls the river has worn its bed into the hard, crystalline rocks, which rise from 10 to 60 feet or more from the water, frequently in nearly vertical walls. The descent in this distance is 337 feet, nearly 9 feet to the mile. It is only in this stretch that important water powers occur. In the upper third of the valley the crystalline rocks frequently outcrop, but the resulting rapids are of less importance. The United States Geological Survey maintained a gaging station on Black River at Melrose for nine months in 1903, but as the station proved unsatisfactory it was abandoned August 1, 1903. Such measurements and observations as were taken are given below:

Discharge measurements of Black River near Melrose, Wis., in 1903.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
January 15	L. R. Stockman	4.30	*a* 598
February 7	do	4.30	*a* 508
April 4	do	5.90	2,982
May 1	do	11.00	10,931
June 13	do	3.90	842

a Frozen.

Mean daily gage height, in feet, of Black River near Melrose, Wis., December 4, 1902, to August 1, 1903.

Day.	1902.	1903.							
	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	.....	5.05	4.10	4.30	5.10	11.00	7.60	3.60	3.75
2	.....	5.00	4.10	4.35	4.85	10.00	.....	6.70	.....
3	.....	4.90	4.10	4.40	5.30	10.25	.....	11.20	.....
4	3.75	4.75	4.10	4.45	5.65	10.50	.....	10.90	.....
5	3.95	4.60	4.10	4.60	5.90	9.65	6.00	13.00	.....
6	4.00	4.60	4.20	4.75	6.50	9.05	4.70	12.30	.....
7	3.80	4.50	4.20	(a)	6.65	8.15	4.40	10.20	.....
8	4.35	4.50	4.20	6.25	6.50	7.00	4.30	7.90	.....
9	4.35	(a)	4.20	8.20	6.20	6.95	4.25	6.90	.....
10	4.30	4.40	4.20	9.30	5.50	6.55	4.00	7.40	.....
11	4.35	4.40	4.30	9.70	5.60	6.10	4.00	8.70	.....
12	4.20	4.40	4.25	10.75	.....	6.65	3.95	7.20	.....
13	4.20	4.40	4.20	12.05	5.45	10.60	3.95	6.70	.....
14	4.10	4.40	4.20	12.55	5.60	12.00	3.80	6.20	.....
15	4.15	(a)	4.20	11.55	5.95	10.90	3.80	5.80	.....
16	4.10	4.30	4.10	9.85	5.85	9.15	3.80	5.30	.....
17	4.00	4.30	4.15	9.40	6.05	7.80	3.70	4.50	.....
18	4.00	4.30	4.00	10.35	5.60	6.55	3.70	4.20	.....
19	4.05	4.30	3.95	11.95	5.00	6.50	3.70	4.10	.....
20	4.25	4.20	3.90	13.40	5.15	6.40	3.70	4.00	.....
21	4.60	4.20	3.90	12.90	4.50	6.30	3.70	4.00	.....
22	4.95	4.20	4.00	11.40	4.65	5.90	3.70	4.00	.....
23	5.80	4.20	4.00	9.65	4.30	6.50	3.70	3.90	.....
24	6.05	4.20	4.00	8.05	4.30	5.70	3.60	3.90	.....
25	5.85	4.20	4.05	7.65	4.35	5.80	3.60	3.90	.....
26	5.80	4.20	4.10	6.65	4.65	5.95	3.50	3.75	.....
27	5.65	4.20	4.20	6.02	.85	8.40	3.50	3.90	.....
28	5.50	4.20	4.35	6.55	5.00	11.85	3.50	4.20	.....
29	5.35	4.20	.....	5.70	5.65	12.60	3.50	4.00	.....
30	5.20	4.20	.....	6.55	6.80	10.95	3.50	3.80	.....
31	.....	4.10	.....	5.30	.....	9.50	.....	3.75	.....

a Observer absent.

A gaging station was established by the United States Geological Survey at Neillsville April 7, 1905, and the following data have been collected:

Discharge measurements of Black River at Neillsville, Wis., in 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
April 7	Hanna and Clapp	192	1,021	3. 5	7.7	3,279
May 24	S. K. Clapp	165	471	2.18	4.95	1,024
June 13	M. S. Brennon	192	945	3.15	7.26	2,978
July 11	.....do	161	392	1.56	4.25	612
August 11	.....do	151	242	.93	3.3	225
September 25	F. W. Hanna	163	419	1.86	4.35	780

NOTE.— *Width* is the actual width of water surface, not including piers. *Area of section* is the total area of the measured section, including both moving and still water.

Mean daily gage height, in feet, of Black River at Neillsville, Wis., for 1905.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.4	3.7	4.4	2.7	3.3	3.5	3.7	4.0
2	.....	3.4	3.3	4.4	2.6	3.2	3.5	3.5	4.2
3	.....	4.1	3.2	4.9	2.6	3.5	3.4	3.5	3.8
4	.....	5.3	7.7	6.5	2.6	3.4	3.4	3.5	3.7
5	.....	5.2	14.2	8.4	2.9	3.6	3.0	3.5	3.8
6	8.2	4.9	19.8	8.0	2.7	3.2	3.0	3.7	3.5
7	7.7	5.0	16.5	6.8	4.2	3.1	3.1	4.1	3.5
8	6.9	4.6	11.5	5.9	4.0	3.0	2.7	4.1	3.4
9	6.2	4.6	8.8	5.3	4.0	2.9	2.4	3.9	3.3
10	6.0	5.9	7.6	4.7	3.5	2.8	3.1	3.8	3.4
11	5.7	6.6	8.6	4.2	3.3	2.7	3.0	3.7	3.4
12	5.5	6.7	8.0	3.8	3.3	2.8	3.0	3.7	3.5
13	5.1	6.2	7.1	3.9	3.3	2.7	3.0	3.6	3.4
14	4.8	10.7	6.2	4.0	3.3	2.7	3.0	3.5	3.4
15	4.6	10.1	5.5	4.8	3.2	4.3	4.0	3.4	3.5
16	4.3	9.2	5.8	4.5	3.0	6.0	4.9	3.4	3.4
17	3.9	8.7	11.2	4.0	2.9	6.0	5.4	3.4	3.3
18	3.8	8.2	10.7	3.8	3.0	6.1	5.5	3.4	3.0
19	4.2	6.6	8.6	4.2	3.0	8.6	5.6	3.4	3.0
20	3.9	6.0	7.0	4.3	3.0	8.3	6.6	3.3	3.2
21	3.2	5.3	6.0	4.0	3.2	7.5	6.9	3.2	3.1
22	3.1	5.1	5.2	3.8	3.5	6.3	6.5	3.2	3.1
23	3.1	4.9	4.5	3.3	3.4	5.8	5.9	3.2	3.3
24	3.5	4.7	4.1	3.1	3.6	4.7	5.5	3.5	3.5
25	3.4	4.3	3.9	3.1	3.4	4.2	5.0	4.2	3.5
26	3.4	4.2	3.7	3.0	3.3	3.9	4.6	4.6	3.5
27	3.4	4.1	3.5	2.9	3.2	3.8	4.4	4.5	3.4
28	3.4	3.9	3.3	2.9	3.0	3.7	4.1	4.3	3.4
29	3.4	3.9	3.3	2.8	3.4	3.6	3.9	3.9	3.4
30	3.4	3.8	3.5	2.8	3.5	3.8	3.7	3.7	3.5
31	.....	3.8	.....	2.7	3.3	.....	3.6	.....	3.5

NOTE.—No ice record at this station.

Rating table for Black River at Neillsville, Wis., from April 6 to December 31, 1905.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.00	150	4.80	990	6.60	2,310	8.40	4,120
3.10	177	4.90	1,055	6.70	2,395	8.50	4,230
3.20	205	5.00	1,120	6.80	2,480	8.60	4,340
3.30	235	5.10	1,185	6.90	2,570	8.70	4,460
3.40	267	5.20	1,250	7.00	2,660	8.80	4,580
3.50	301	5.30	1,315	7.10	2,750	8.90	4,700
3.60	338	5.40	1,385	7.20	2,850	9.00	4,820
3.70	379	5.50	1,455	7.30	2,950	9.10	4,940
3.80	424	5.60	1,525	7.40	3,050	9.20	5,060
3.90	473	5.70	1,600	7.50	3,150	9.30	5,180
4.00	525	5.80	1,675	7.60	3,250	9.40	5,300
4.10	579	5.90	1,750	7.70	3,350	9.50	5,420
4.20	635	6.00	1,825	7.80	3,460	9.60	5,540
4.30	692	6.10	1,905	7.90	3,570	9.70	5,660
4.40	750	6.20	1,985	8.00	3,680	9.80	5,780
4.50	810	6.30	2,065	8.10	3,790	9.90	5,900
4.60	870	6.40	2,145	8.20	3,900	10.00	6,020
4.70	930	6.50	2,225	8.30	4,010		

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1905. It is well defined between gage heights 3.3 feet and 7.7 feet. Beyond the limits of the table the discharge is only approximate.

Estimated monthly discharge of Black River at Neillsville, Wis., for 1905.

Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
April (6-30)	3,900	177	1,036
May	6,910	267	1,768
June	23,060	205	3,840
July	4,120	80	884
August	635	60	229
September	4,340	80	918
October	2,570	20	750
November	870	205	392
December	635	150	292

WATER POWERS.

It is many years since Black River was used for lumbering, and as the surrounding country is well settled, it seems likely that the near future will see a demand for the available water powers. These powers, while not of the largest, are so situated as to be cheaply developed. The river has no large tributaries, but nearly all its numerous small feeders are now developed and used to run grist and saw mills. At the present time several projects are being exploited which look to the employment of these powers by interurban electric railroads and other enterprises in near-by cities.

BLACK RIVER FALLS.

The first dam in the river is at Black River Falls and is of timber construction. The power developed is owned by the city of Black River Falls, with turbines working under a head of 13 feet, and by J. J. McGillivray, with turbines under a head of 16 feet. The present tailrace could be lowered 3 or 4 feet, and the crest of the dam could be raised the same amount without flooding. This improvement would give a total head of 20 feet. The turbines now installed develop about 345 horsepower, which is used to run an electric-light plant, a sash and door mill, a wagon shop, and a gristmill.

About 1½ miles below the above-described dam is the site of an old sawmill dam, 300 feet long, which at one time was made to develop a head of 7 feet.

BLACK RIVER FALLS TO NEILLSVILLE.

Because of the high, rocky banks and high gradient of this river, dams of 15 to 20 feet head could be installed nearly every 2 or 3 miles between Black River Falls and Neillsville, but only a few of the largest undeveloped powers will be described.

The first dam site above Black River Falls is located near the east line of sec. 2, T. 21 N., R. 4 W., just below the Chicago, St. Paul, Minneapolis and Omaha Railway bridge. At this point the rocky banks form a narrow gorge and are high enough to furnish a head of 30 feet or more. By the use of a short canal this head could probably be increased. This site belongs to the Black River Improvement Company, of La Crosse, Wis. Another undeveloped power, similar in all respects, for which a charter has been granted, is at Halcyon, in sec. 16, T. 22 N., R. 3 W. A 30-foot dam here would back the water nearly to Hatfield, 3 miles above. A still more important dam site is located at Hatfield, just above the bridge of the Green Bay and Western Railroad. According to surveys made recently it is possible to obtain here a head of 50 feet, which could be increased to about 85 feet by means of a long canal. Such a dam would create a large pondage by backing up the water for 7 miles. This would cover up dam sites in sec. 35, T. 23 N., R. 3 W., and also the "Dells dam" in sec. 18, T. 23 N., R. 2 W., near the mouth of Wedges Creek. At the latter site a head of 25 feet could be easily secured.

In the 6 miles below Neillsville, between the mouths of O'Neill and Cunningham creeks, the river descends 80 feet, 42 feet of which can be easily developed at Ross Eddy rapids, where a large part of this gradient is concentrated. It has been proposed to build a crib dam 250 feet long, with a crest of 18 feet, at the head of these rapids, and then conduct the water through a canal 95 rods long (in earth), thereby cutting off a long bend of the river and giving a total fall of 42 feet.[a] The outlet of such a canal would provide a favorable power site, free from any injury from ice jams.

NEILLSVILLE.

The last important undeveloped water power, known as Westons Rapids and owned by V. Huntzicker, of Neillsville, Wis., is located in sec. 2, T. 24 N., R. 2 W., about 1½ miles above Neillsville. From the head of these rapids near the north line of the NW. ¼ sec. 2, to the south line of same section, a distance of about a mile, the river descends 21.2 feet.[a] The owner proposes to locate a crib dam 250 feet long, with a crest of 18 feet, near the center of the section, and by making use of a canal in earth 600 feet long to obtain a head of 24 feet. A franchise has recently been obtained from the city of Neillsville for the employment of this power in lighting the city and for other purposes.

HEMLOCK DAM.

The most important developed power on the upper river is in sec. 15, T. 27 N., R. 2 W. This dam, called the Hemlock dam, has a head which averages 12 feet. Four turbines are installed here, with a total of 175 horsepower, used to run a roller flouring mill. The dam was originally erected for lumbering purposes.

Because of the unusually steep gradient in the branches of Black River a water power of from 10 to 20 feet can be located at frequent intervals on these streams. Several of the many mills in such locations report an available head of from 35 to 40 feet. In nearly every case timber and rock are found near the dam sites.

RAILROADS.

That portion of Black River containing the important powers is fairly well served by railroads. The river is crossed by the Chicago, St. Paul, Minneapolis and Omaha Railway four times, and once each by the Wisconsin Central Railway and the Green Bay and Western Railroad.

CHIPPEWA RIVER SYSTEM.

TOPOGRAPHY AND DRAINAGE.

The Chippewa drainage system has its source in over a hundred lakes, large and small, with many connecting swamps, near the Michigan boundary and only 20 miles from Lake Superior. The drainage area has a length of 180 miles, a maximum width of 90 miles, and an average width of nearly 60 miles. The general direction of the drainage, except in the extreme western part, is toward the southwest. Chippewa River unites with the Mississippi at the foot of Lake Pepin, after a course of 267 miles. The total area drained by the river is 9,573 square miles, of which about 6,000 include the most unsettled region of northern Wisconsin. This area includes the richest forests of the State, of both soft and hard timber. Although lumbering operations have been very active here for many years, considerable pine timber still remains, chiefly at the upper headwaters, but it is fast disappearing. Most of the large tracts of pine lands are owned by large corporations, and many of them are reached by long lines of logging railroads, which in many cases have been purchased by the trunk-line railroads and made a part of their systems. The extensive use of such railroads has greatly relieved the rivers of the burden of transporting logs, and correspondingly added to the value of the rivers for water-power purposes.

The main line of drainage runs very nearly along the central line of the basin, but the name of Chippewa River is not given to this continuation of the principal stream. The

[a] Authority: C. Stockwell, county surveyor.

river divides 112 miles from the mouth; one branch, the prolongation of the line of drainage, called the Flambeau, rises in the lakes near the Michigan line, at an elevation of a little over 1,600 feet above the sea; the other branch, rising farther west and flowing more directly south, receives the name Chippewa. The Flambeau drains 1,983 square miles, while Chippewa River, above their junction, drains only 1,777 square miles. About 56 miles above this junction the Chippewa again divides into East and West branches, the one flowing from the northeast, the other from the north, draining, respectively, 278 and 480 square miles.

The lakes of this region are situated in two widely separated groups, one in the extreme northeastern part, at the headwaters of Flambeau River, and the other in the northwestern part, at the headwaters of what is known as the main stream and of Red Cedar River. The remainder of the area is almost devoid of lakes. The wooded regions, however, include very large areas of cedar and tamarack swamps.

GEOLOGY.

The pre-Cambrian crystalline rocks form the underlying strata in the area above Chippewa Falls, while below that point they are replaced by the Cambrian sandstone. The entire area above Chippewa Falls is covered with glacial drift, so that the rock appears only in the river bed. The country is level or rolling. In the southern part of the area the rivers have eroded deeply into the drift and rock, but in the northern portion they have not cut much below the surface.

With only a few exceptions (the most notable one at Eau Claire) all the many and important water powers on Chippewa River are found in the region of the pre-Cambrian crystalline rocks, but because of the deep drift the powers on the upper streams occur as bowlder rapids.

PROPOSED RESERVOIR SITES.

According to detailed surveys made by United States engineers, this drainage area is favored with an unusual number of excellent sites for reservoirs. A list of these sites, with valuable data concerning them, is given in the following table:

Proposed United States Government dams on Chippewa River. [a]

Location and name.	Length.		Maximum height.		Drainage area above reservoir.
	Dam.	Dike.	Dam above low water.	Dike.	
East Branch Chippewa River:	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. miles.*
Bear Lake	1,015	200	19.5	8.5	244.5
Little Chief Lake	710	.....	24.0	.....	57.6
West Branch Chippewa River:					
Moose Lake	1,235	160	25.7	1.5	214.3
Pakwawang Lake	900	.....	25.5	.....	257.2
Court Oreilles	260	100	6.5	5.0	114.0
Chippewa River, Paint Creek	620	.....	22.0	.....	3,943.1
Total	4,740	460	.....	.....	4,830.7
Butternut Creek, Butternut Lake	336	.....	10.0	.....	40.0
Manitouish River, Rest Lake	250	75	15.0	2.5	211.6
North Fork Flambeau, Bear Creek	2,500	2,000	15.0	10.5	154.5
Dore Flambeau:					
Round Lake	170	250	10.0	10.0	63.0
Squaw Lake	250	.....	9.0	.....	39.0
Turtle River, Park Lake	297	.....	15.0	.....	174.0
Grand total	8,543	2,785	.....	.....	5,512.8

[a] Rept. Chief Eng. U. S. Army, 1880, p. 1648.

Proposed United States Government dams on Chippewa River—Continued.

Location and name.	Supply (one-third of 30 inches rainfall).	Capacity of reservoir.	Surplus over reservoir capacity.	Supply from reservoir for 90 days.	Cost of dam and dike.
East Branch Chippewa River:	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Sec.-feet.*	
Bear Lake	5,677,951,910	1,113,148,856	4,564,803,054	143.1	$25,925
Little Chief Lake	1,337,627,935	771,332,009	566,295,926	99.2	40,702
West Branch Chippewa River:					
Moose Lake	4,976,626,153	2,-01,783,402	1,234,725,814	260.0	45,090
Pakwawang Lake	5,972,880,292	7,692,997,229		989.3	66,449
Court Oreilles	2,647,388,621	2,647,388,621		340.4	2,492
Chippewa River, Paint Creek	91,569,456,760	505,336,720	91,064,120,040	65.0	60,000
Total	112,181,931,671	14,751,986,837	97,429,944,834	1,897.0	240,658
Butternut Creek, Butternut Lake	928,908,288	585,446,400	343,461,888	75.3	5,216
Manitouish River, Rest Lake	4,897,100,264	1,840,000,000	757,813,112	236.6	7,665
North Fork Flambeau, Bear Creek	3,107,280,000	5,406,567,152		695.3	47,500
Dore Flambeau:					
Round Lake	1,382,304,000	1,303,036,416	79,267,584	167.6	10,550
Squaw Lake	864,230,400	731,808,000	132,422,400	94.1	4,000
Turtle River, Park Lake	4,026,198,428	620,782,720	3,405,415,708	79.8	9,941
Grand total	127,387,953,051	25,239,627,525	102,148,325,526	3,245.7	325,530

It will be seen from the above table that the systematic operation of these proposed reservoirs for this purpose would increase the ordinary low-water flow of the river by 3,245 second-feet for ninety days a year, thus about doubling the present available water power of the river. Estimated upon a run-off of one-fourth of the annual rainfall, assumed at 30 inches, this increase would be 2,800 second-feet for ninety days.

Experiments now being carried on by the Government in Minnesota on five similarly constructed dams will doubtless determine whether the reservoir system at the headwaters of the Mississippi will be extended to include any of the above proposed dams. Probably the main obstacle to building such reservoirs at the present time by the Government is the fact that, owing to the settling up of this region, the land has now become very valuable. The total cost would seem to be prohibitive. That the owners of water powers are in favor of such Governmental control is certain. Besides adding to the amount of power, such a system would prevent, in large measure, the danger to dams by floods. The building of even a part of these dams would have marked economic value. Already private enterprise has developed some of the smaller of these reservoirs.

RAILROADS.

The logging interests of the river are controlled by the Chippewa Falls Lumber and Boom Company, with headquarters at Chippewa Falls, a thriving city of about 10,000 population. The largest city of this region is Eau Claire, population 17,517, situated at the junction of Eau Claire and Chippewa rivers. This city has numerous manufactories and sawmills, and is quite a railroad center. From its mouth to Chippewa Falls, Chippewa River is paralleled by the Chicago, Milwaukee and St. Paul Railway, and between Eau Claire and Chippewa Falls by the Chicago, St. Paul, Minneapolis and Omaha and the Wisconsin Central railways, besides an electric line. Chippewa River, above Chippewa Falls, is reached by the Chicago, St. Paul, Minneapolis and Omaha Railway for a distance of about 25 miles. In addition, the drainage area is crossed east and west by the Minneapolis, St. Paul and Sault Ste. Marie Railway and north and south by the Wisconsin Central Railway.

Several railroad lines are projected or being built in this section, and the agricultural and manufacturing interests are fast supplanting that of lumber. Where the timber has

been cut the land is being taken up by settlers, so that there is but little second-growth timber. The people seem prosperous, and numerous companies are on the point of investing large sums in the manufacturing interests of the neighborhood, thereby utilizing the undeveloped water powers.

RAINFALL AND RUN-OFF.

The extensive forests of this area combine with the numerous lakes and swamps to give a naturally uniform flow by preventing the rapid escape of the rainfall into the streams. Since 1903 the United States Geological Survey has maintained gaging stations near Eau Claire, on Chippewa River, and at Ladysmith, on the Flambeau. As a result of the operation of logging dams, the minimum discharge is found to be only 1.6 per cent of its maximum discharge for the year. The following tables give discharge data of Chippewa River at Eau Claire, covering the period from November 14, 1902, to August 12, 1905, and also a monthly summary of the same.

Discharge measurements of Chippewa River at highway bridge, Shawtown, near Eau Claire, Wis., 1902 to 1905.

Date.	Hydrographer.	Width	Area of section.	Mean velocity.	Gage height.	Discharge.
1902.		*Feet.*	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
November 13	L. R. Stockman		3,666	3.88	8.70	11,134
December 6	do		2,809	1.03	4.45	2,871
December 28	do		2,793	1.09	4.60	3,063
1903.						
January 17	L. R. Stockman		2,509	.79	4.15	[a] 1,979
February 10	do		2,315	.77	3.80	[a] 1,778
March 9	do		2,877	1.32	4.85	[b] 3,818
April 6	do				7.40	10,688
May 5	do		5,726	4.62	11.85	26,458
June 15	do		3,105	1.64	4.70	4,107
July 10	do		4,761	3.61	9.25	17,167
August 20	do		2,372	1.83	5.13	4,336
September 5	do		3,626	2.21	6.20	8,032
October 13	do		4,637	3.25	8.77	15,087
November 24	do		2,281	1.54	4.90	3,511
1904.						
January 11[a]	E. Johnson, jr	310	2,429	.99	3.80	2,454
May 14	do	385	4,272	3.42	8.40	14,610
May 24	Johnson and Hanna	370	4,074	3.10	7.60	12,630
June 7	E. Johnson, jr	426	5,815	4.52	11.25	26,270
July 13	do	354	3,770	2.10	6.55	7,918
August 28	do	322	2,766	.82	4.20	2,274
September 19	do	329	3,122	1.47	5.25	4,581
October 12	F. W. Hanna	495	7,118	5.43	14.80	38,680
October 13	do	457	6,137	4.76	13.10	29,200
November 29	E. Johnson, jr	324	2,847	.80	4.44	2,281
1905.						
May 22	S. K. Clapp	200	4,004	3.66	8.80	16,110
June 14	M. S. Brennan	427	5,131	3.83	10.72	19,665
July 12	do	355	3,585	2.09	6.55	7,489
August 12		335	3,062	1.29	5.00	3,948

[a] Frozen. [b] Partly frozen.

NOTE.—Width is the actual width of water surface, not including piers. Area of section is the total area of the measured section, including both moving and still water.

Mean daily gage height, in feet, of Chippewa River near Eau Claire, Wis., November 14, 1902, to December 31, 1905.

Day.	1902.		1903.											
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1			4.30	3.70	3.20	6.85	12.80	(a)	7.65	5.05	5.90	6.90	5.55	(a)
2			4.35	4.25	3.75	7.15	13.10	(a)	8.05	5.20	6.45	7.00	5.55	(a)
3			4.15	4.10	3.85	7.45	12.15	(a)	10.60	5.85	5.65	7.35	5.45	(a)
4			4.20	4.05	3.90	7.95	11.85	(a)	13.50	6.85	5.85	9.90	5.50	(a)
5		4.50	4.40	4.10	3.75	7.85	11.55	(a)	15.30	7.50	5.75	11.25	5.25	(a)
6		4.45	3.90	4.05	3.75	7.40	10.90	(a)	15.20	9.10	6.45	11.65	5.20	4.30
7		4.00	4.15	4.15	3.85	7.50	10.30	6.85	13.75	9.00	5.85	11.60	5.15	4.65
8		4.05	4.40	4.15	4.10	7.90	9.20	5.45	11.30	11.05	6.30	11.15	5.10	4.50
9		4.05	4.20	4.00	4.60	8.55	9.15	6.45	10.30	6.70	8.00	11.35	5.05	4.60
10		4.10	4.40	3.85	5.05	8.00	7.65	5.95	9.40	7.55	8.05	10.95	5.00	4.70
11		4.25	4.80	3.80	5.80	7.60	8.95	6.50	10.10	7.25	9.15	9.95	5.00	4.55
12		4.20	4.65	3.85	6.00	8.15	12.00	5.90	9.95	6.75	12.85	9.45	5.00	4.50
13		4.45	4.75	3.90	7.05	7.70	13.25	9.25	8.90	6.85	14.00	9.00	5.05	4.70
14	13.70	4.25	4.60	3.90	8.20	7.65	13.40	8.75	8.10	6.90	16.75	8.80	5.30	4.85
15	10.20	4.55	4.85	3.90	8.05	7.80	13.25	4.65	7.80	9.65	17.85	8.45	5.40	4.75
16	12.40	4.25	4.30	4.50	7.00	7.80	11.85	4.95	7.20	5.10	18.50	7.75	4.95	4.70
17	13.05	4.30	4.20	4.10	7.00	7.50	10.45	4.95	6.50	6.80	17.45	7.70	4.95	4.60
18	12.60	4.10	4.30	4.15	7.55	6.75	9.90	4.90	8.80	6.65	15.50	7.40	4.25	4.65
19	11.35	4.30	4.65	4.30	11.80	6.65	9.15	4.30	5.95	6.00	13.45	7.55	4.40	4.65
20	9.60	4.25	4.40	4.25	13.95	6.85	9.15	5.15	6.70	5.10	11.80	7.05	4.15	4.60
21	8.50	4.30	4.50	4.20	13.65	6.80	9.30	4.70	6.15	5.15	10.50	7.05	4.20	4.60
22	7.55	4.25	4.35	3.35	12.65	6.65	9.50	4.20	5.70	7.50	9.95	6.75	4.35	4.80
23	7.40	4.50	4.35	3.80	11.70	6.40	9.05	4.20	5.60	5.60	9.15	6.70	4.85	4.70
24	7.15	4.70	4.45	4.15	10.45	6.40	9.10	4.15	6.00	5.10	7.80	6.55	4.95	4.80
25	7.00	4.30	3.50	4.05	9.40	8.60	9.85	4.25	9.20	5.15	7.60	6.30	4.95	4.00
26	6.45	4.90	4.20	3.90	8.75	6.55	10.20	4.15	5.25	5.25	7.00	6.15	4.90	4.40
27	6.20	5.10	4.10	3.95	8.40	7.15	12.50	6.75	5.05	4.70	7.65	5.95	4.85	3.40
28	6.00	4.60	4.10	3.85	7.75	7.00	15.15	4.20	5.20	5.45	7.05	6.10	4.60	3.70
29	5.75	4.50	3.85	....	7.60	7.30	16.70	4.60	5.15	5.60	7.05	6.10	.....	3.60
30	5.55	4.85	4.15	.....	7.15	11.70	16.10	4.95	5.15	5.20	7.05	6.10	.....	3.60
31	.....	4.50	4.25	.....	6.80	.....	.....	.....	5.10	5.60	.....	5.90	.....	3.40

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904 [b]												
1	[c] 4.90	.....	.....	6.25	9.00	8.45	8.10	4.42	4.58	6.31	6.79	3.93
2	[c] 5.15	.....	.....	6.72	8.65	7.65	8.52	4.80	5.05	5.24	6.84	3.92
3	.....	.....	.....	6.50	8.63	7.65	8.28	4.38	8.18	8.27	6.80	3.93
4	[c] 5.00	.....	.....	6.52	8.28	8.85	8.02	4.78	7.52	5.65	6.61	3.45
5	.....	.....	[d] 4.80	6.60	8.10	9.00	10.32	4.32	8.30	5.30	5.91	4.42
6	.....	[e] 4.80	.....	7.17	8.03	10.95	10.12	4.12	7.30	5.27	6.41	4.28
7	.....	.....	.....	7.60	10.13	11.30	9.63	3.45	7.52	4.82	6.08	4.26
8	.....	.....	.....	9.10	8.50	10.85	8.93	4.62	7.12	9.12	5.35	4.28
9	[c] 4.80	.....	.....	9.67	8.83	9.85	7.22	5.10	6.72	7.86	5.35	4.37
10	.....	.....	.....	9.72	9.35	8.92	7.10	5.42	7.95	13.35	5.60	4.36
11	.....	.....	.....	9.70	9.25	7.95	7.20	5.35	5.03	15.07	5.36	4.20
12	.....	.....	[e] 4.95	9.32	8.85	7.80	6.72	4.38	5.28	14.93	5.02	4.34
13	.....	[d] 5.00	.....	9.05	8.78	7.80	6.60	4.12	5.42	13.15	6.27	4.39
14	.....	.....	.....	8.82	10.20	7.45	5.88	3.50	5.35	11.38	4.82	4.20

[a] Observer absent.
[b] River frozen over January 1 to March 18, 1904, but open about 200 to 300 feet above and one-fourth mile below bridge.
[c] Ice 2.0 feet thick at gage; 1.0 foot in middle of channel.
[d] Ice 2.5 feet thick at gage; 2.5 feet in middle of channel.
[e] Ice 2.0 feet thick at gage; 2.0 feet in middle of channel.

Mean daily gage height, in feet, of Chippewa River near Eau Claire, Wis., November 14, 1902, to December 31, 1905—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
15	.....	.....	.....	8.50	8.00	7.80	5.07	3.80	5.38	10.30	6.26	4.34
16	[a] 5.00	.....	.....	7.55	8.20	8.35	5.55	4.55	5.42	9.17	5.42	4.32
17	.....	.....	.....	7.25	7.55	6.25	5.35	4.82	7.10	8.10	5.30	4.15
18	.....	.....	.....	7.50	7.22	5.50	5.60	4.65	4.80	8.00	5.47	4.19
19	.....	[b] 5.10	4.45	8.38	7.55	5.10	5.50	4.78	4.80	7.08	5.20	4.53
20	.....	.....	4.07	8.20	6.93	6.20	5.10	7.20	4.27	6.85	4.98	4.29
21	.....	.....	4.45	8.13	10.30	6.50	5.47	5.25	4.30	8.35	5.28	4.34
22	.....	.....	4.37	7.45	6.30	5.90	5.05	4.75	4.35	9.25	5.23	4.37
23	[a] 5.00	.....	4.32	8.05	6.83	5.80	4.75	4.68	5.10	9.42	5.74	4.55
24	.....	.....	5.62	8.50	7.33	5.50	3.93	4.60	4.24	9.00	4.77	4.38
25	.....	.....	5.95	9.65	9.20	8.95	4.07	5.00	5.76	8.78	4.94	3.31
26	.....	.....	6.45	10.63	12.00	5.55	4.90	5.40	8.18	7.81	5.10	4.19
27	.....	[b] 5.30	6.10	10.45	13.48	7.75	4.80	8.15	7.61	8.02	4.85	4.55
28	.....	.....	5.72	9.18	13.63	7.60	5.00	3.58	6.93	7.22	4.55	[c]
29	[d] 4.70	.....	5.05	9.55	12.02	7.75	4.88	5.55	9.81	7.55	4.54	.....
30	.....	.....	5.10	9.03	10.67	7.50	6.45	4.92	6.65	7.30	4.46	.....
31	.....	.....	5.32	.....	9.20	.....	5.00	4.52	.....	6.85	.....	.....
1905.												
1	[e]	.....	.....	12.00	6.80	6.30	6.80	6.80	6.50	5.15	5.70	4.75
2	4.36	.....	.....	10.20	5.80	6.80	7.40	5.75	6.20	5.55	6.15	5.15
3	.....	.....	.....	11.20	5.90	6.50	6.30	4.35	5.30	7.80	5.45	4.85
4	.....	.....	.....	10.50	6.50	8.20	6.20	4.35	6.10	5.55	5.75	5.65
5	.....	4.80	4.20	10.40	7.50	12.10	6.90	4.75	6.80	4.90	5.65	4.40
6	.....	.....	.....	10.80	6.60	19.20	10.40	5.10	6.50	4.90	5.75	5.40
7	.....	.....	.....	10.20	7.30	.....	10.60	5.25	6.10	7.50	6.10	5.40
8	.....	.....	.....	9.80	7.60	19.60	11.30	5.05	5.65	5.00	6.30	5.90
9	4.40	.....	4.50	9.20	7.30	17.30	10.10	5.30	5.75	4.85	6.05	5.85
10	.....	.....	.....	8.90	8.80	14.50	7.00	5.90	5.10	4.80	6.10	5.35
11	.....	.....	.....	8.70	7.80	13.00	8.10	4.90	4.90	5.50	6.50	5.30
12	.....	.....	4.30	7.40	7.90	12.60	6.90	5.45	5.35	7.90	5.50	5.30
13	.....	5.30	4.30	5.75	7.50	11.50	6.90	5.10	6.90	6.20	5.70	5.30
14	.....	.....	4.25	5.65	9.50	10.00	7.20	5.35	5.85	5.90	5.80	5.25
15	4.80	.....	4.10	6.10	10.70	9.40	7.10	5.70	5.40	5.25	5.20	5.00
16	.....	.....	4.50	5.75	12.20	8.80	7.60	4.45	5.55	6.40	6.20	4.60
17	.....	.....	4.50	6.20	12.90	8.70	6.80	4.45	7.70	7.35	5.50	4.70
18	.....	5.36	4.65	7.00	12.00	10.20	6.50	5.60	10.70	7.80	6.00	4.80
19	.....	.....	4.40	5.60	10.60	12.20	6.60	5.25	7.00	7.90	5.50	4.70
20	.....	.....	4.45	5.45	10.20	11.30	6.70	7.40	10.10	8.95	5.45	4.70
21	.....	.....	4.55	5.40	9.20	10.50	6.00	7.30	10.80	8.50	5.40	4.65
22	4.67	.....	5.50	5.40	8.60	9.10	6.40	8.90	10.30	8.65	4.60	4.85
23	.....	.....	6.20	5.05	8.60	9.00	5.70	5.85	9.20	8.35	5.20	4.55
24	.....	.....	7.10	5.30	8.00	8.80	6.10	6.20	8.40	7.90	5.00	4.60
25	.....	4.95	7.80	5.30	8.10	8.20	5.75	6.40	6.50	7.55	5.20	4.10
26	.....	.....	8.90	6.30	7.50	7.30	5.55	8.30	8.50	7.20	5.70	4.80
27	.....	.....	10.40	5.50	7.70	7.50	4.90	5.30	6.00	7.10	6.05	4.60
28	.....	.....	11.80	4.80	7.00	8.70	4.45	5.00	6.00	7.00	5.70	4.65
29	5.17	.....	13.20	5.05	7.10	7.80	5.30	7.80	7.90	6.60	5.70	4.55
30	.....	.....	13.60	4.85	7.20	5.75	4.45	6.20	6.20	6.50	5.00	4.70
31	.....	.....	12.90	.....	6.90	.....	4.35	6.20	.....	6.40	.....	4.70

[a] Ice 2.0 feet thicker at gage; 1.0 foot in middle of channel.
[b] Ice 2.5 feet thick at gage; 2.5 feet in middle of channel.
[c] River frozen December 28 to 31.
[d] Ice 2.0 feet thick at gage; 2.0 feet in middle of channel.
[e] River frozen entirely across at gage January 1 to February 28; March 1 to 17, ice gradually disappeared. Thickness of ice, 2 to 2.5 feet. Gage heights are to water surface in a hole in the ice.

Rating table for Chippewa River near Eau Claire, Wis., from November 30, 1902, to March 12, 1903.a

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.2	840	4.0	1,985	4.7	3,370	5.4	5,150
3.3	940	4.1	2,165	4.8	3,610	5.5	5,410
3.4	1,055	4.2	2,345	4.9	3,850	5.6	5,670
3.5	1,190	4.3	2,535	5.0	4,110	5.7	5,930
3.6	1,335	4.4	2,735	5.1	4,370	5.8	6,190
3.7	1,490	4.5	2,940	5.2	4,630	5.9	6,450
3.8	1,655	4.6	3,150	5.3	4,890	6.0	6,710
3.9	1,825						

a To be used only when river is frozen.

Rating table for Chippewa River near Eau Claire, Wis., from March 12, 1903, to December 1, 1903.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.8	2,160	5.7	6,290	7.6	11,310	11.0	23,310
3.9	2,340	5.8	6,530	7.7	11,610	11.2	24,070
4.0	2,530	5.9	6,770	7.8	11,910	11.4	24,830
4.1	2,730	6.0	7,010	7.9	12,210	11.6	25,500
4.2	2,930	6.1	7,270	8.0	12,510	11.8	26,350
4.3	3,130	6.2	7,530	8.2	13,150	12.0	27,110
4.4	3,330	6.3	7,790	8.4	13,790	12.5	29,010
4.5	3,540	6.4	8,050	8.6	14,450	13.0	30,910
4.6	3,760	6.5	8,310	8.8	15,130	13.5	32,810
4.7	3,980	6.6	8,570	9.0	15,810	14.0	34,710
4.8	4,200	6.7	8,830	9.2	16,530	14.5	36,610
4.9	4,420	6.8	9,090	9.4	17,250	15.0	38,510
5.0	4,640	6.9	9,350	9.6	17,990	15.5	40,410
5.1	4,860	7.0	9,610	9.8	18,750	16.0	42,310
5.2	5,090	7.1	9,890	10.0	19,510	16.5	44,210
5.3	5,330	7.2	10,170	10.2	20,270	17.0	46,110
5.4	5,570	7.3	10,450	10.4	21,030	17.5	48,010
5.5	5,810	7.4	10,730	10.6	21,790	18.0	49,910
5.6	6,050	7.5	11,010	10.8	22,550		

Rating table for Chippewa River near Eau Claire, Wis., from January 1 to December 31, 1904.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
4.0	1,780	5.1	4,390	6.4	8,100	9.0	16,680
4.1	1,980	5.2	4,660	6.6	8,720	9.5	18,380
4.2	2,180	5.3	4,930	6.8	9,350	10.0	20,080
4.3	2,390	5.4	5,200	7.0	9,990	10.5	21,780
4.4	2,610	5.5	5,480	7.2	10,650	11.0	23,480
4.5	2,840	5.6	5,760	7.4	11,310	11.5	25,210
4.6	3,080	5.7	6,040	7.6	11,970	12.0	26,960
4.7	3,330	5.8	6,320	7.8	12,630	13.0	30,500
4.8	3,590	5.9	6,610	8.0	13,290	14.0	34,480
4.9	3,850	6.0	6,900	8.5	14,980	15.0	40,000
5.0	4,120	6.2	7,490				

Rating table for Chippewa River near Eau Claire, Wis., from January 1 to December 31, 1905.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.50	750	5.40	4,830	7.60	10,290	11.40	22,410
3.60	960	5.50	5,050	7.80	10,870	11.60	23,160
3.70	1,170	5.60	5,280	8.00	11,450	11.80	23,950
3.80	1,380	5.70	5,510	8.20	12,030	12.00	24,750
3.90	1,590	5.80	5,740	8.40	12,610	12.20	25,550
4.00	1,800	5.90	5,970	8.60	13,200	12.40	26,350
4.10	2,010	6.00	6,200	8.80	13,800	12.60	27,150
4.20	2,220	6.10	6,430	9.00	14,400	12.80	27,950
4.30	2,430	6.20	6,660	9.20	15,000	13.00	28,750
4.40	2,640	6.30	6,900	9.40	15,620	13.20	29,560
4.50	2,850	6.40	7,140	9.60	16,260	13.40	30,390
4.60	3,070	6.50	7,380	9.80	16,920	13.60	31,240
4.70	3,290	6.60	7,630	10.00	17,600	13.80	32,110
4.80	3,510	6.70	7,880	10.20	18,280	14.00	33,000
4.90	3,730	6.80	8,130	10.40	18,960	14.20	33,900
5.00	3,950	6.90	8,390	10.60	19,640	14.40	34,800
5.10	4,170	7.00	8,650	10.80	20,320	14.60	35,700
5.20	4,390	7.20	9,180	11.00	21,000	14.80	36,600
5.30	4,610	7.40	9,720	11.20	21,690		

The above table is applicable only for open-channel conditions. It is based on 15 discharge measurements made during 1904–5. It is well defined between gage heights 5 feet and 13 feet. The table has been extended beyond these limits.

Estimated monthly discharge of Chippewa River at Eau Claire, Wis., 1902 to 1905.

[Drainage area, 6,740 square miles.]

Date.	Discharge.			Run-off.		Rainfall.[a]
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1902.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
November 14–29			14,835	2.20	1.39	5.82
December 5–31			2,789	.41	.41	1.92
1903.						
January	3,730	1,190	2,593	.38	.44	.45
February	2,940	995	2,023	.30	.31	.86
March	34,520	840	11,573	1.72	1.98	2.28
April	25,970	8,050	11,240	1.67	1.86	3.07
May[b]	44,970	11,460	24,761	3.67	4.23	6.45
June[c]	36,990	2,070	8,720	1.29	1.44	1.95
July	39,650	4,750	14,698	2.18	2.51	7.70
August	23,500	3,980	8,602	1.28	1.48	5.35
September	51,810	6,170	19,584	2.90	3.24	7.58
October	25,780	6,770	13,524	2.01	2.32	3.57

[a] Rainfall for 1902 and 1903 is the average of the recorded precipitation at the following stations: Butternut, Hayward, Medford, Barron, and Eau Claire; that for 1904 includes the same stations with the addition of Stanley and Prentice.

[b] May 31 estimated.

[c] 1 to 6, inclusive, estimated.

Estimated monthly discharge of Chippewa River at Eau Claire, Wis., 1902 to 1905—Continued.

Date.	Discharge.			Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.	Per square inch.	Depth.	
1903.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
November	5,930	2,830	4,562	0.68	0.76	0.96
December	3,980	1,055	2,855	.42	.48	.84
The year	51,810	840	10,395	1.54	21.05	41.77
1904.						
January						.51
February						1.05
March 19–31	8,255	1,920	4,622	.686	.332	1.56
April	22,220	7,640	14,550	2.16	2.41	2.01
May	32,900	7,790	16,960	2.52	2.90	4.33
June	24,510	4,390	12,600	1.87	2.09	6.14
July	21,170	1,647	8,525	1.26	1.45	3.13
August	13,790	650	3,778	.561	.647	4.27
September	19,430	2,264	7,801	1.16	1.29	4.86
October	40,400	3,642	15,170	2.25	2.59	5.59
November	9,478	2,748	5,576	.827	.923	.17
December 1–27	2,960	380	2,230	.331	.332	1.79
The year						35.41
1905.						
March 18–31		31,240	2,640	13,510	2.00	1.04
April		24,750	3,510	10,184	1.51	1.68
May		28,350	5,740	12,666	1.88	2.17
June		60,520	5,625	20,368	3.02	3.26
July		22,050	2,535	8,626	1.28	1.48
August		14,100	2,535	5,867	.870	1.00
September		20,320	3,730	8,970	1.33	1.48
October		14,250	3,510	8,041	1.19	1.37
November		7,380	3,070	5,437	.807	.900
December		5,970	2,010	3,821	.567	.654

WATER POWERS.

CHIPPEWA BELOW JUNCTION OF FLAMBEAU RIVER.

Topography and drainage.—The following descriptions of the water powers on Chippewa River between its mouth and the junction with Flambeau River were largely obtained from a manuscript report of a hypsometric survey of this part of the river made by the United States Geological Survey during the summer of 1903.[a] Between the mouth of the river and Chippewa Falls a very careful primary level was run, while between Chippewa Falls and the mouth of the Flambeau, in addition to taking levels, a topographic survey was made of the river bank and the area immediately adjacent. Between the mouth of the Chippewa and that of the Eau Claire, a distance of 48.4 miles, this survey showed that there was a descent at low water of about 106 feet, or about 2.3 feet per mile. Because of the uniformity of this low gradient, and also because of the width of the stream and of the adjacent bottom lands, there are no opportunities for water powers until Eau Claire is reached. Details of descent and apportionment of drainage areas are shown in the following tables:

[a] The survey of that portion of the river between Watkins Landing, Minnesota, and Chippewa Falls, Wis., was under the charge of Geographer J. H. Renshaw. Above Chippewa Falls the work was in charge of Geographer H. M. Wilson.

Profile of Chippewa River from its mouth to sources of East and West branches.[a]

No.	Station.	Distance.		Elevation above sea-level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Reeds Landing	0	0	[b] 680.0 [c] 664.0	.....	0
2	Shawtown	45.5	45.5	770.0	106.0	2.3
3	Eau Claire River, mouth	48.8	3.3	770.0	.0	.0
	Dalles paper mills:					
4	Foot of dam	49.4	.6	772.0	2.0	3.3
5	Head of dam	49.4	10.0	793.0	21.0	.....
	Chippewa Falls:					
6	Foot of dam	64.4	14.5	806.0	14.0	1.0
7	Head of dam	64.4	50.0	839.0	33.0	.....
8	Yellow River, mouth	69.9	5.5	852.0	13.0	2.4
	Eagle rapids:					
9	Foot	72.4	2.5	854.0	2.0	.8
10	Head	73.6	1.2	867.0	13.0	10.8
11	Water level	75.1	1.5	871.0	4.0	2.7
12	Rapids, foot	77.4	2.3	881.0	10.0	4.3
	Jim Falls:					
13	Foot	80.1	2.7	901.0	20.0	7.4
14	Head	81.0	.9	936.0	35.0	39.0
	Colton rapids:					
15	Foot	82.3	1.3	942.0	6.0	4.6
16	Head	83.6	1.3	945.0	3.0	2.3
17	Bob Creek	87.3	3.7	954.0	9.0	2.4
	Chevalley rapids:					
18	Foot	90.1	2.8	961.0	7.0	2.5
19	Head	91.3	1.2	966.0	5.0	4.2
	Brunett Falls:					
20	Foot	91.4	.1	967.0	1.0	10.0
21	Head	92.4	1.0	993.0	26.0	26.0
22	Fisher River, mouth	93.9	1.5	995.0	2.0	1.3
	Holcombe rapids:					
23	Foot	97.1	3.2	1,004.0	9.0	2.7
24	Foot of dam	97.6	.5	1,020.0	16.0	32.0
25	Head of dam, water level	97.6	.0	1,036.0	16.0	.....
26	Deertail Creek, mouth	104.1	6.5	1,036.0	.0	.0
27	Flambeau River junction	107.7	3.6	1,050.0	14.0	4.0
28	Bruce, sec. 28, T. 32 N., R. 6 W	124.2	16.5	1,059.0	9.0	.5
29	East and West branches junction	162.7	38.5	1,280.0	221.0	5.6
	EAST BRANCH.					
30	Goose Eye rapids head (foot Little Chief Lake)	164.7	2.0	1,323.4	43.4	21.7
	Snaptail rapids (Hunters Lake):					
31	Foot	166.7	2.0	1,325.2	1.8	.9
32	Head	168.2	1.5	1,368.8	43.6	29.0
33	Blaisdells Lake	170.7	2.5	1,374.5	5.7	2.3
	Cedar rapids:					
34	Foot	173.2	2.5	1,404.0	29.5	11.8
35	Head	175.7	2.5	1,420.0	16.0	6.4
36	Bear Lake	178.2	2.5	1,432.9	12.9	5.1

[a] Authority: Nos. 1, Mississippi River Commission; 2–27, U. S. Geol. Survey; 28, David Kirk; 29–47 U. S. engineers.
[b] High water.
[c] Low water.

Profile of Chippewa River from its mouth to sources of East and West branches.—Continued.

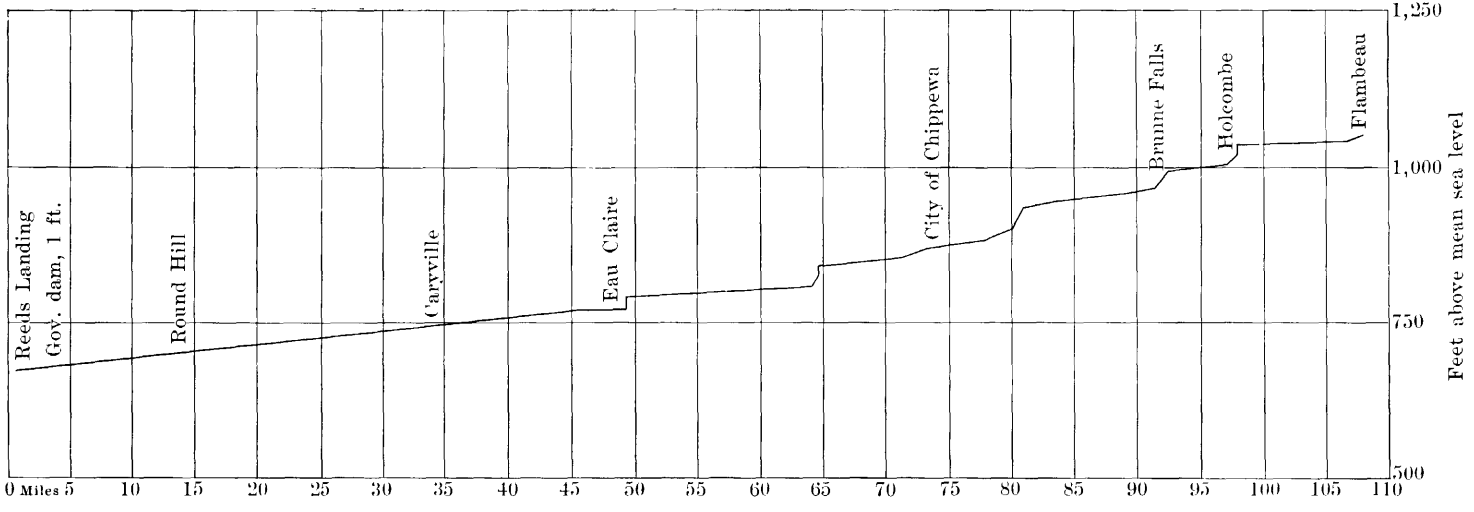
No	Station.	Distance.		Elevation above sea-level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
	EAST BRANCH.—Continued.	*Miles.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*
37	River, water level	181.7	3.5	1,442.0	9.1	2.6
38	Pelican Lake	186.7	5.0	1,462.0	20.0	4.0
39	River, water level, sec. 19, T. 42 N., R. 2 W	190.2	3.5	1,463.8	1.8	.5
40	Glidden Station	201.7	11.5	1,509.3	45.5	4.0
41	Source of river	223.7	22.0±			
	WEST BRANCH.					
42	Proposed U. S. dam	164.5	1.8	1,286.0	6.0	3.3
43	Pakwawang Lake	168.7	6.0	1,287.2	1.2	.2
	Moose Lake:					
44	Proposed U. S. dam	178.7	10.0	1,358.8	71.6	7.2
45	Water level	178.7	.0	1,361.9	3.1	
46	Partridge Crop Lake	185.7	7.0	1,384.4	22.5	3.2
47	Source of river	205.7	20.0±			

Distances and drainage areas of Chippewa River.

River.[a]	Distance from the junction of East and West branches, map measure.	Drainage area above station.
	Miles.	*Sq. miles.*
East and West branches (junction)	0	757
Court Oreilles	14	988
Thornapple (above mouth)	36	1,383
Flambeau:		
Above mouth	53	1,777
Mouth	53	3,761
Yellow:		
Above mouth	90	4,926
Mouth	90	5,384
Eau Claire:		
Above mouth	113	5,760
Mouth	113	6,659
Red Cedar:		
Above mouth	142	7,004
Mouth	142	8,961
Chippewa	165	9,573

[a] Station is at mouth of river, unless otherwise stated.

Eau Claire.—The first dam site is located about 2½ miles below the mouth of Eau Claire River. According to a recent survey by the city engineer, a head of 7 feet could be obtained here. On account of its proximity to the city of Eau Claire, this power would have especial value. Before improvement there were two rapids in the river between Eau Claire and Chippewa Falls, one 1.25 miles above the Eau Claire, called the Lower Dalles, with a descent of 10½ feet in a little over 2 miles; the other about 4 miles below Chippewa Falls, called the Upper Dalles, with a descent of 9 feet in about 2 miles.



PROFILE OF CHIPPEWA RIVER FROM REEDS LANDING, MINN., TO FLAMBEAU, WIS.

The dam 2 miles above Eau Claire, owned by the Dells Paper and Pulp Company, is of the square-timber, crib type on a sandstone foundation. It is about 600 feet long, 19 feet high, 3 feet wide at the top, and with a base of about 8 feet. Eight splash boards are used on the crest when necessary, giving a head of 26 feet. It would be possible to increase the height of the dam so as to develop 32 feet, and a bill authorizing this increase is now (March, 1905) pending before the State legislature. Such a dam would back the water nearly to Chippewa Falls, 15 miles above, greatly adding to an already very large pondage. This is the most important manufacturing plant on the river. The turbine installation is reported as follows:

Dells Paper and Pulp Company's turbine installation, 2 miles above Eau Claire.

Purpose.	Horsepower.
Paper mill	1,396
Pulp mill	4,918
Electric light and power	1,632
Waterworks	300
	8,246

Chippewa Falls.—In the 14½ miles between the Dells dam and Chippewa Falls no power sites are found, the river having a nearly uniform slope of 1 foot to the mile. At the latter place, however, is a wooden dam 800 feet long, with a head of 30 feet, owned by the Chippewa Falls Lumber and Boom Company. This dam supplies power for a large sawmill and also a plant furnishing the city of Chippewa Falls with water and electric light. The dam could be made several feet higher, as the local conditions are favorable, but this would interfere with a proposed plant at Paint Creek rapids, 2½ miles upstream, to which point the water now backs. The owners have developed only about 20 feet of head, but this could be increased to the full head of 30 feet by blasting and cleaning out the river to the wagon bridge below. The power and light company leases 1,000 horsepower, using a head of 29 feet.

The next rapids, known as Paint Creek rapids, are 2½ miles above the Chippewa Falls dam. A flooding dam 526 feet long, with a crest 10½ feet above low water, was formerly maintained here. A dam about 800 feet long, with a head of 14 feet, could be constructed at the foot of the rapids at this point. The banks and bed appear to be sand, intermingled with large bowlders. Stone for construction is abundant and near at hand, and it is likely that a rock foundation could be easily obtained.

Eagle rapids, 4½ miles farther upstream, in lot 3, sec. 16, T. 29 N., R. 8 W., is a good site for a dam, owned by F. G. & C. A. Stanley, of Chippewa Falls. A dam 60 feet long and 20 feet high would back the water three fourths of a mile above the city of Chippewa Falls, where O'Neils Creek enters from the west. One mile above the mouth of O'Neils Creek, in sec. 10, T. 29 N., R. 8 W., is a gorge 700 feet wide, where a 25-foot dam would have solid sandstone for foundations and abutments and would back the water almost to the foot of Jim Falls, 5 miles above. Such a dam would develop 5,000 theoretical horsepower.

Jim Falls.—Near the small station of Jim Falls, on the Chicago and Northwestern Railway, occurs the best opportunity for water-power development on Chippewa River. It is owned by W. L. Davis, of Eau Claire. Formerly an old flooding dam was located here. The river flows over a series of granite ledges 1 to 4 feet high, while the banks seem to be of the same rock, covered by a few feet of sandy soil. This power is now under development, a company having purchased all the land needed. The proposed dam, 28 feet high, will be located at the head of the rapids. It is designed to furnish power for a pulp mill near the foot. The total head obtained by this plant will be 55 feet. Fig. 4 shows the plan of the proposed development. Water is to be conducted from the dam by a canal extending on the left bank for a distance of about 5,000 feet to high bluffs 100 feet from the river bank. The power house will be on the river bank immediately below. The dam will back

the water nearly to Brunett Falls, 9½ miles above, and will cover the Colton and Chevalley rapids.

Brunett Falls.—One of the best powers on Chippewa River, and one most cheaply developed, is found at Brunett Falls (Pl. III, *B*), located in sec. 18, T. 31 N., R. 6 W. It belongs

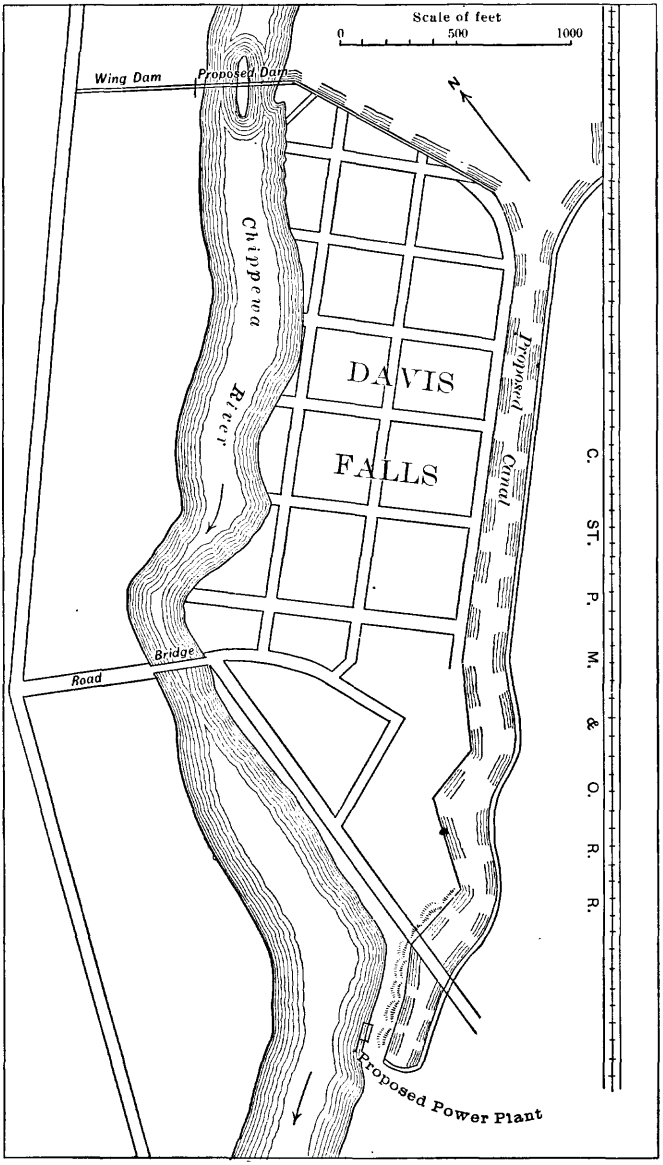


FIG. 4.—Plan of proposed water-power development at Jim Falls (Davis Falls).

to Cornell University, which also owns the adjacent land as well as the water rights. The best location for the dam would be about 650 feet above the foot of the rapids, where a 35-foot dam would back the water up to the rapids at Holcombe, 5½ miles above. The river at the dam site is narrow (70 or 80 feet), while the banks are high, granite ledges.

A dam here would create a large reservoir. It is stated that the plans contemplate a dam 200 feet long. A steel wagon bridge has recently been built across the river immediately below the dam site.

Holcombe dam.—The next power is at Holcombe, about 3 miles below the mouth of Jump River, where the Chippewa Falls Lumber and Boom Company maintains a timber dam, with a head of about 17 feet. This is the third dam that has been built here, the others having been washed out by freshets. As the lumber interests are fast declining, the present dam is being allowed to decay. For power purposes it should be replaced by a more substantial structure. The river here has a rock bottom, with rather low clay sides, but an 18-foot dam could be constructed on the site of the present structure, which, together with a 15-foot dam at the foot of the rapids just below (sometimes called Little Falls), would develop about all the head at this point and would not flood any more valuable lands above. This would back the water above Deertail Creek and furnish considerable storage.

Mouth of Flambeau.—Of the 14 feet of descent in Chippewa River between Holcombe and the mouth of the Flambeau 10 feet are concentrated in the first mile below the latter point. It is very likely that a dam on this reach would easily develop 15 feet of head.

It is worthy of note that all the water powers on Chippewa River thus far described are reached by one or more railroads. Because of their availability many of the above powers are likely to be developed in the near future. Their importance is emphasized by the following statement: Of the 244 feet descent in the Chippewa between Chippewa Falls and the mouth of the Flambeau, 116 feet are concentrated in 5 falls and rapids. The building of 10 dams would economically develop a total of 213 feet head in this distance of 43 miles. When fully developed these powers will rival in importance the extensive developments on lower Fox River between Appleton and Green Bay.

BRANCHES AND UPPER WATERS.

Topography and drainage.—The following statements in regard to the water powers of upper Chippewa River, not being based on a hydrographic survey, are necessarily incomplete. Statements concerning profile, etc., are based on the survey and maps of this region made in 1880 by United States engineers in connection with the reservoir surveys. Distance and drainage area data are shown in the following table:

Length and drainage area of the upper tributaries of Chippewa River.

River.	Length (map measure).	Drainage area.
	Miles.	*Sq. miles.*
West Branch of Chippewa	35	480
East Branch of Chippewa	60	278
Court Oreilles	20	176
Flambeau	155	1,983
Jump	65	721
Yellow	65	458
Eau Claire	65	899
Red Cedar	95	1,957

In the 16½ miles between the mouth of the Flambeau and Bruce Chippewa River descends only 0.8 foot per mile, but in the 38½ miles between Bruce and the confluence of East and West branches of the Chippewa, in sec. 2, T. 39 N., R. 6 W., the river descends 216 feet, an average of 5.6 feet per mile. This steep gradient is certain to produce many good powers. This reach is, however, devoid of railroads except a few logging roads. One of these undeveloped powers, called Belills Falls, is located in sec. 26, T. 38 N., R. 7 W. Its owner, the John Arpin Lumber Company, reports that this power is capable

of producing a head of about 30 feet. It is near Radison, on the Chicago, St. Paul, Minneapolis and Omaha Railway.

East Branch of Chippewa.—Three important rapids occur in East Branch of Chippewa River. Between Little Chief Lake and the confluence of East and West branches, a distance of 2.7 miles, there is a descent of 43 feet. Between these points there is a series of rapids, "the bed of the river being literally paved with bowlders. The banks are from 10 to 20 feet high and the drift a reddish clay." These are known as the Goose Eye rapids. Two or three dams could develop a head of about 40 feet.

Above Hunters Lake, in secs. 22 and 23, T. 40 N., R 5 E., occur the Snaptail rapids, with an aggregate descent of 43.6 feet.

Cedar rapids, the last of importance on this branch, with a descent of 16 feet, are located in sec. 9, T. 40 N., R. 4 W., and in the 2 miles above. The total descent between Blaisdell and Bear lakes is about 58 feet, all in a distance of 7½ miles. Between Bear and Little Chief lakes the banks vary from 4 to 50 feet in height. A logging dam has been maintained at the head of the rapids, in sec. 26, T. 41 N., R. 4 W., which had a height of 10 feet. Measurements made here by United States engineers on June 20 and July 12, 1879, with the river respectively 0.6 and 2.1 feet above low-water mark, showed a discharge of 381 and 472 second-feet. The river at this point is 153 feet wide.

West Branch of Chippewa.—West Branch of the Chippewa River has a drainage area of 480 square miles, or 200 square miles more than East Branch, but its descent is considerably less rapid. The river has its source in several large lakes at about 1,380 feet above sea level. The first undeveloped power is located about 1½ miles above the confluence of the two branches, in sec. 34, T. 40 N., R. 6 W., where the hills approach within 900 feet. The river at this point has a width of 121 feet, and here United States engineers made surveys for a dam with a head of 25½ feet, which gave a very large reservoir area. A 15-foot head could probably be obtained at reasonable expense. Four measurements made by United States engineers on August 6, 1879, at a stage only 0.2 foot above low water gave a mean discharge of 360 second-feet, or 0.75 second-feet per square mile of drainage area. This large low-water run-off is double that estimated for this drainage area. The excess may be explained by the steadying action of the large lakes near the headwaters of this river.

In the 10 miles between Moose and Pakwawang lakes West Branch descends 71.6 feet, including a series of rapids with sluggish water between. The banks are generally from 20 to 30 feet high, with clay soil.[a]

Court Oreilles River.—Court Oreilles River has its source at an elevation of 1,287 feet in a lake of the same name. The group of lakes forming its headwaters have a total area of about 16 square miles. A dam at this outlet would need to have a length of 260 feet to secure a head of 5 feet, and would store a supply sufficient to deliver 255 second-feet for ninety days at times of low water. The river is from 50 to 60 feet wide, and in the first 3 miles of its course is sluggish. Thence to its mouth it furnishes a series of rapids, with still reaches between. The most important rapids, known as the Court Oreilles, are situated within 3 miles from the mouth of the river, which at this point flows over ledges of the pre-Cambrian rocks. The river is crossed at its middle point by the Chicago, St. Paul, Minneapolis and Omaha Railway, where the water surface has an elevation of 1,240 feet. This shows a descent of 47 feet in 10 miles between this point and the lake. The lower half of the river is reached by the above railway. Unlike either East Branch, West Branch, or any other neighboring branches of the Chippewa, Court Oreilles River drains a region with a very open sandy soil. A measurement made by United States engineers, October 25, 1879, at a stage 0.3 foot above low water, showed a discharge at the mouth of Lake Court Oreilles of only 28 second-feet from a drainage area of 114 square miles. It seems likely that, because of the character of the soil, part of the run-off escapes underground to the west into Namekagon River.

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[a] Rept. Chief Eng. U. S. Army, 1880, p. 1562.

Upper powers.—Because of their present isolation from railroads, the chief use of dams which have been maintained on the upper headwaters of Chippewa River would lie in their operation as reservoirs to improve the powers below. Their location is shown in the following table:

Dams on upper waters of Chippewa River.[a]

	Location.	Dimensions.[b]		Reservoir capacity.
		Height.	Length.	
	Chippewa River:	*Feet.*	*Feet.*	*Cubic feet.*
1	NW. ¼ sec. 28, T. 32 N., R. 6 W.	21	625	133,333,000
2	Sec. 22, T. 33 N., R. 8 W.	9	.....	153,331,000
3	Sec. 28, T. 32 N., R. 6 W.	17	.....	334,536,000
	West Branch:			
4	SW. ¼ SW. ¼ sec. 32, T. 42 N., R. 5 W.	8	123	.....
5	Sec. 12 [illegible]. 42 N., R. 5 W.	*20	*300	.....
6	NE ¼ SE. ¼ sec. 14, T. 41 N., R. 6 W.	7	347	430,000,000
7	Outlet to Pokegama Lake, NW. ¼ NW. ¼ sec. 32, T. 40 N., R. 6 W.	8	108	.....
8	Little Chief River, NE. ¼ NE. ¼ sec. 26, T. 40 N., R. 7 W.	6	142	.....
9	East Branch, NW. ¼ SE. ¼ sec. 26, T. 41 N., R. 4 W.	10	564	300,000,000
	Thornapple River:			
10	Sec. 10, T. 35 N., R. 6 W.	*18	*800	.....
11	Sec. 4, T. 36 N., R. 5 W.	*18	*400	.....
12	Sec. 20, T. 38 N., R. 4 W.	*12	*250	.....
13	Sec. 4, T. 38 N., R. 4 W.	*15	*250	.....
14	Brunett River, sec. 17, T. 38 N., R. 5 W.	*15	*325	.....
15	Torch River, sec. 16, T. 42 N., R. 4 W.	*20	*300	.....

[a] Authority: Nos. 1–4 and 6–9, United States engineers; 5 and 10–15, Chippewa Lumber and Boom Company.
[b] Dimensions marked with an asterisk (*) were estimated by the owner, The Chippewa Lumber and Boom Company.

TRIBUTARIES OF CHIPPEWA RIVER.

FLAMBEAU RIVER.

Drainage and water powers.—In size of drainage area Flambeau River ranks first among the tributaries of the Chippewa. Indeed, because of its central location in the drainage basin, it might properly be regarded as the prolongation of the main stream itself. Regardless of its size, however, its water power must, in large part, continue for some time unused, because of its forested location and its lack of railroad facilities. The settling of this area will eventually justify the extension of present railroads and the building of new ones. Flambeau River is crossed near its mouth (at Ladysmith) by the Minneapolis, St. Paul and Sault Ste. Marie Railway, near its center (at Park Falls) by the Wisconsin Central Railway, and at its upper headwaters by the Chicago and Northwestern Railway. Between Park Falls and Ladysmith is a reach of 70 miles unserved by railroad, and yet with no point at a greater distance than 15 miles from the present railroads. It is significant that the two points with transportation facilities, Ladysmith and Park Falls, have established large paper and pulp mills and other manufactories. The unusually steady flow, the soft water, and the proximity of almost unlimited quantities of pulp wood should make this river a center of the paper and pulp industry. Transportation alone is lacking.

Flambeau River has its source in the largest number of lakes and connecting swamps with the greatest aggregate storage capacity of any river in the State. This storage capacity has been increased in many cases by lumbering dams built at the lake outlets, but as yet many opportunities for the storing of surplus waters remain unimproved. These lakes lie in the highest portion of the State, at elevations varying from 1,560 to 1,650 feet or more above the sea. The levels show that the river descends 570 feet in a distance of 150 miles,

or about 3.8 feet per mile. A large part of this fall is known to be concentrated at numerous falls and rapids. In the 19 miles between the mouth of the river and Ladysmith the descent is 42 feet. A company has recently been formed to construct a dam with a head of 20 feet at a point 6 miles below Ladysmith, in sec. 18, T. 34 N., R. 6 W., and the work of construction is already begun. The next developed power above the mouth is found at Ladysmith, where a timber dam 350 feet long develops a head of 16 feet. This power is used to run a paper and pulp mill and also for the manufacture of wooden ware.

There are no developed powers on Flambeau River for 70 miles above Ladysmith, but a fall of 353 feet in this distance insures many undeveloped powers. Two of these, Little Falls and Big Falls, are of special importance. The former is located in the NW. ¼ sec. 21, T. 35 N., R. 5 W., and is owned by A. J. McGilvary and B. D. Viles, of Chippewa Falls. A 15-foot dam at the head of the first rapids would give a head of about 25 feet at the foot of the rapids a short distance below. Big Falls, owned by the John Heim Company, of Tony, Wis., is located 6 miles above Little Falls, in sec. 35, T. 36 N., R. 5 W. There is a descent of 25 feet here in a short distance, concentrated in three pitches. A view of one is shown in Pl. V, *A*. No accurate survey has been made of either fall, but the owner of Big Falls estimates that a 25-foot dam at the head of the rapids and a canal about five-eighths of a mile to the end of the rapids would give a 60-foot head. Both falls occur over ledges of pre-Cambrian crystalline rock.

At Park Falls the Flambeau Paper Company has constructed two dams: one, half a mile above the railroad crossing, in sec. 13, T. 40 N., R. 1 W., and one about a mile below, in sec. 25, T. 40 N., R. 1 W. Each dam furnishes an average head of 16 feet. The upper plant has installed 13 turbines, rated at 1,300 horsepower, while at the lower plant about 1,100 horsepower has been installed.

There are other rapids in secs. 28, 32, and 33, T. 41 N., R. 1 E., and levels taken by United States engineers showed a fall here of 24 feet in 2 miles. Again, in secs. 3 and 4, T. 41 N., R. 2 E., below the junction of Turtle and Flambeau rivers, is a similar fall of 25 feet. Above this point the river is much smaller and has lower gradient, though bowlder rapids are of frequent occurrence.

The lack of railroad transportation on this watershed will postpone the utilization of its many large water powers until the region is more thickly settled and better served by railroads.

Profile.—No Government surveys have been made in the 46 miles above Big Falls, so that reliable data regarding water powers along this portion of the river are almost entirely lacking. Above Park Falls United States engineers have run levels in connection with the reservoir surveys, thus furnishing valuable hypsometric data. Information concerning the river profile from mouth to headwaters, with the exception noted above, is fairly complete, and is summarized in the following table:

Profile of Flambeau River from its mouth to Boulder Lake.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river	0.0	.....	1,050.0	.....	.....
2	SW. ¼ sec. 34, T. 34 N., R. 7 W	7.0	7.0	1,064.0	14.0	2.0
3	Ducomon rapids, NW. ¼ sec. 23, T. 34 N., R. 7 W	11.0	4.0	1,070.0	6.0	1.5
4	New dam, foot of rapids	15.0	4.0	1,081.0	11.0	2.7
5	SW. ¼ sec. 1, T. 34 N., R. 6 W	15.75	.75	1,088.4	7.4	10.0
6	Ladysmith, below dam	24.25	8.5	1,099.0	10.6	1.25

[a] Authority: No. 1–26, U. S. Geol. Survey; 27–30, U. S. engineers. Because of an error in the assigned elevation of the initial bench mark, 15 feet is added to the U. S. engineer elevation to correct to sea-level datum.

A. LOWER PITCH OF BIG FALLS, FLAMBEAU RIVER.

B. COPPER FALLS, BAD RIVER.

Profile of Flambeau River from its mouth to Boulder Lake—Continued.

No	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
7	Ladysmith, above dam	24.25	0.0	1,115.3	16.3	.....
8	NW. ¼ sec. 25, T. 35 N., R. 6 W	28.0	3.75	1,115.4	.1	.....
9	Little Falls, foot of	32.0	4.0	1,131.4	16.0	4.0
10	Little Falls, head of (sec. 21, T. 35 N., R. 5 W.)	32.8	.8	1,147.4	16.0	20.0
11	NE. ¼ sec. 15, T. 35 N., R. 5 W	36.8	4.0	1,166.7	19.3	4.8
12	Big Falls, foot of (NW. ¼ sec. 2, T. 35 N., R. 5 W.)	40.3	3.5	1,177.0	10.3	[a]3.0
13	NW. ¼ sec. 8, T. 39 N., R. 1 W	86.2	45.9	1,421.8	244.8	5.3
14	South line sec. 33, T. 40 N., R. 1 W	91.2	5.0	1,429.6	7.8	1.5
15	Sec. 35, T. 40 N., R. 1 W., west line of	94.2	3.0	1,438.0	8.4	2.8
16	Below dam, sec. 25, T. 40 N., R. 1 W., west line of	95.0	54.7	1,454.0+	.....	.....
17	Above dam	95.0	0.0	1,470.0+	.....	.....
18	Park Falls railroad bridge, west line sec. 24, T. 40 N., R. 1 W	96.6	1.6	1.470.0	.....	.....
19	Below tail race upper dam, Park Falls	98.3	.5	1,466.8	2.8	5.6
20	Above upper dam, Park Falls	98.5	.2	1,481.0	14.2	.....
21	Backwater, upper dam	104.3	5.8	1,482.5	1.5	.2
22	Center sec. 28, T. 41 N., R. 1 E	107.1	2.8	1,499.2	16.7	6.0
23	Sec. 12, T. 41 N., R. 1 E., W. ¼ stake	112.5	5.4	1,510.8	11.6	2.0
24	Sec. 4, T. 41 N., R. 2 E., W. ¼ stake	115.8	3.3	1,516.0	6.2	1.8
25	Turtle River, mouth	119.0	3.2	1,541.4	25.4	7.6
26	Manitowish River, junction of Bear Creek	134.0	15.0	1,568.0	26.6	1.8
27	Rest Lake, mouth of (sec. 8, T. 42 N., R. 5 E.)	146.0	12.0	1,587.0	19.0	1.6
28	Island Lake, inlet of	153.5	7.5	1,592.0	5.0	.66
29	Boulder Lake	163.0	9.5	1,625.0	33.0	3.5

Rainfall and run-off.—Like all the northern rivers of the State the minimum flow of Flambeau River occurs in severe midwinter weather, or during very dry summers in the months of July and August. At present there are not sufficient discharge data covering periods when the river is frozen to construct an accurate rating curve for such periods. Because of the extensive forest and the numerous lakes and swamps, an ordinary flow of 0.8 second-foot per square mile of drainage area would seem conservative. By the proper regulation of present dams at the headwaters it is likely that this discharge could be considerably increased.

In February, 1903, the United States Geological Survey established an observing station at the Ladysmith dam, and has taken daily gage readings since. Discharge measurements are taken by current meters and are being continued so that in time an accurate estimate of the river's discharge will be available. The following tables give such daily observations:

discharge measurements, and computations as have become available since the establishment of the station, and also a record of rainfall for the corresponding period:

Discharge measurements of Flambeau River near Ladysmith, Wis., for 1903, 1904, and 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height	Discharge.
1903.		*Feet.*	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
February 13[a]	L. R. Stockman	325	472	1.64	16.20	773
March 19[b]	do	366	1,871	1.77	18.95	3,312
April 8	do	349	1,330	2.80	17.40	3,727
May 6	do	361	1,927	3.70	18.97	7,113
June 16	do	342	703	1.91	16.00	1,345
July 11	do	342	1,430	2.95	18.10	4,222
August 21	do	342	995	2.69	16.85	2,681
September 10	E. C. Murphy	364	1,579	3.36	18.05	5,303
October 23	L. R. Stockman	348	1,271	3.07	17.21	3,899
1904.						
May 16	E. Johnson, jr	350	1,333	3.15	17.88	4,203
June 3	do	350	1,448	2.99	17.45	4,321
August 29	do	349	733	2.07	16.06	1,517
September 20	do	343	702	2.21	16.01	1,554
October 12	F. W. Hanna	364	1,653	3.37	18.58	5,588
1905.						
April 8	S. K. Clapp	129	1,537	3.49	18.27	5,367
May 23	do	357	1,292	2.69	17.60	3,474
June 14	M. S. Brennan	354	1,232	2.67	17.35	3,288
July 12	do	353	1,015	2.54	16.80	2,576
August 12	do	345	623	1.84	15.66	1,144
September 23	F. W. Hanna	353	1,404	3.02	17.75	4,236

[a] Frozen. [b] Log jam below.

Mean daily gage height, in feet, of Flambeau River near Ladysmith, Wis., February 15, 1903, to December 31, 1905.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.											
1	.....	16.15	17.00	18.30	19.80	15.65	.....	17.00	17.20	16.00	15.90
2	.....	16.60	16.80	18.40	19.65	16.15	.....	16.70	17.30	16.25	15.75
3	.....	16.50	16.90	18.60	18.95	17.25	.....	16.80	17.60	15.85	15.95
4	.....	16.10	16.90	19.05	18.60	18.10	.....	16.30	19.65	15.85	15.60
5	.....	16.30	17.05	19.10	18.10	18.90	.....	16.80	19.70	15.85	15.80
6	.....	16.50	16.40	19.10	17.55	19.05	.....	16.90	19.35	15.85	15.80
7	.....	16.60	16.90	19.10	17.55	19.20	.....	16.90	19.25	15.90	16.95
8	.....	16.10	17.45	18.80	17.30	18.85	.....	17.30	19.25	15.65	15.80
9	.....	16.50	17.35	18.70	16.95	18.70	.....	18.20	19.30	15.70	14.70
10	.....	16.50	17.25	17.95	16.60	18.60	18.20	18.20	19.35	15.85	16.50
11	.....	16.05	17.25	18.25	16.75	18.75	18.00	18.00	18.95	16.00	16.35
12	.....	16.45	17.30	18.80	16.80	18.55	17.90	18.40	18.65	15.85	16.30
13	.....	16.35	17.25	19.55	16.30	18.30	17.80	19.00	18.45	15.85	16.50
14	.....	16.35	17.50	19.80	16.15	17.85	17.70	19.80	18.25	15.80	16.45
15	16.00	16.60	17.40	19.65	16.35	17.70	17.50	20.40	17.90	15.80	16.55
16	16.10	16.15	17.20	19.55	16.50	17.65	17.30	20.50	17.85	15.75	16.35
17	16.05	16.20	16.95	19.40	16.05	17.60	17.30	20.50	17.80	15.80	16.40
18	16.00	16.30	17.00	19.45	16.05	17.35	17.20	20.30	17.50	15.00	16.70
19	15.90	18.25	16.90	19.05	15.85	17.35	17.00	20.00	17.35	15.50	16.60

Profile of Flambeau River from its mouth to Boulder Lake—Continued.

No	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
7	Ladysmith, above dam	24.25	0.0	1,115.3	16.3	.....
8	NW. ¼ sec. 25, T. 35 N., R. 6 W	28.0	3.75	1,115.4	.1	.....
9	Little Falls, foot of	32.0	4.0	1,131.4	16.0	4.0
10	Little Falls, head of (sec. 21, T. 35 N., R. 5 W.)	32.8	.8	1,147.4	16.0	20.0
11	NE. ¼ sec. 15, T. 35 N., R. 5 W	36.8	4.0	1,166.7	19.3	4.8
12	Big Falls, foot of (NW. ¼ sec. 2, T. 35 N., R. 5 W.)	40.3	3.5	1,177.0	10.3	a 3.0
13	NW. ¼ sec. 8, T. 39 N., R. 1 W	86.2	45.9	1,421.8	244.8	5.3
14	South line sec. 33, T. 40 N., R. 1 W	91.2	5.0	1,429.6	7.8	1.5
15	Sec. 35, T. 40 N., R. 1 W., west line of	94.2	3.0	1,438.0	8.4	2.8
16	Below dam, sec. 25, T. 40 N., R. 1 W., west line of	95.0	54.7	1,454.0+	.....	.....
17	Above dam	95.0	0.0	1,470.0+	.....	.....
18	Park Falls railroad bridge, west line sec. 24, T. 40 N., R. 1 W	96.6	1.6	1,470.0	.....	.....
19	Below tail race upper dam, Park Falls	98.3	.5	1,466.8	2.8	5.6
20	Above upper dam, Park Falls	98.5	.2	1,481.0	14.2	.....
21	Backwater, upper dam	104.3	5.8	1,482.5	1.5	.2
22	Center sec. 28, T. 41 N., R. 1 E	107.1	2.8	1,499.2	16.7	6.0
23	Sec. 12, T. 41 N., R. 1 E., W. ¼ stake	112.5	5.4	1,510.8	11.6	2.0
24	Sec. 4, T. 41 N., R. 2 E., W. ¼ stake	115.8	3.3	1,516.0	6.2	1.8
25	Turtle River, mouth	119.0	3.2	1,541.4	25.4	7.6
26	Manitowish River, junction of Bear Creek	134.0	15.0	1,568.0	26.6	1.8
27	Rest Lake, mouth of (sec. 8, T. 42 N., R. 5 E.)	146.0	12.0	1,587.0	19.0	1.6
28	Island Lake, inlet of	153.5	7.5	1,592.0	5.0	.66
29	Boulder Lake	163.0	9.5	1,625.0	33.0	3.5

Rainfall and run-off.—Like all the northern rivers of the State the minimum flow of Flambeau River occurs in severe midwinter weather, or during very dry summers in the months of July and August. At present there are not sufficient discharge data covering periods when the river is frozen to construct an accurate rating curve for such periods. Because of the extensive forest and the numerous lakes and swamps, an ordinary flow of 0.8 second-foot per square mile of drainage area would seem conservative. By the proper regulation of present dams at the headwaters it is likely that this discharge could be considerably increased.

In February, 1903, the United States Geological Survey established an observing station at the Ladysmith dam, and has taken daily gage readings since. Discharge measurements are taken by current meters and are being continued so that in time an accurate estimate of the river's discharge will be available. The following tables give such daily observations:

discharge measurements, and computations as have become available since the establishment of the station, and also a record of rainfall for the corresponding period:

Discharge measurements of Flambeau River near Ladysmith, Wis., for 1903, 1904, and 1905.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height	Discharge.
1903.		*Feet.*	*Square feet.*	*Feet per second.*	*Feet.*	*Second-feet.*
February 13[a]	L. R. Stockman	325	472	1.64	16.20	773
March 19[b]	do	366	1,871	1.77	18.95	3,312
April 8	do	349	1,330	2.80	17.40	3,727
May 6	do	361	1,927	3.70	18.97	7,113
June 16	do	342	703	1.91	16.00	1,345
July 11	do	342	1,430	2.95	18.10	4,222
August 21	do	342	995	2.69	16.85	2,681
September 10	E. C. Murphy	364	1,579	3.36	18.05	5,303
October 23	L. R. Stockman	348	1,271	3.07	17.21	3,899
1904.						
May 16	E. Johnson, jr.	350	1,333	3.15	17.88	4,203
June 3	do	350	1,448	2.99	17.45	4,321
August 29	do	349	733	2.07	16.06	1,517
September 20	do	343	702	2.21	16.01	1,554
October 12	F. W. Hanna	364	1,653	3.37	18.58	5,588
1905.						
April 8	S. K. Clapp	129	1,537	3.49	18.27	5,367
May 23	do	357	1,292	2.69	17.60	3,474
June 14	M. S. Brennan	354	1,232	2.67	17.35	3,288
July 12	do	353	1,015	2.54	16.80	2,576
August 12	do	345	623	1.84	15.66	1,144
September 23	F. W. Hanna	353	1,404	3.02	17.75	4,236

[a] Frozen. [b] Log jam below.

Mean daily gage height, in feet, of Flambeau River near Ladysmith, Wis., February 15, 1903, to December 31, 1905.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.											
1	.....	16.15	17.00	18.30	19.80	15.65	.....	17.00	17.20	16.00	15.90
2	.....	16.60	16.80	18.40	19.65	16.15	.....	16.70	17.30	16.25	15.75
3	.....	16.50	16.90	18.60	18.95	17.25	.....	16.80	17.60	15.85	15.95
4	.....	16.10	16.90	19.05	18.60	18.10	.....	16.30	19.65	15.85	15.60
5	.....	16.30	17.05	19.10	18.10	18.90	.....	16.80	19.70	15.85	15.80
6	.....	16.50	16.40	19.10	17.55	19.05	.....	16.90	19.35	15.85	15.80
7	.....	16.60	16.90	19.10	17.55	19.20	.....	16.90	19.25	15.90	16.95
8	.....	16.10	17.45	18.80	17.30	18.85	.....	17.30	19.25	15.65	15.80
9	.....	16.50	17.35	18.70	16.95	18.70	.....	18.20	19.30	15.70	14.70
10	.....	16.50	17.25	17.95	16.60	18.60	18.20	18.20	19.35	15.85	16.50
11	.....	16.05	17.25	18.25	16.75	18.75	18.00	18.00	18.95	16.00	16.35
12	.....	16.45	17.30	18.80	16.80	18.55	17.90	18.40	18.65	15.85	16.30
13	.....	16.35	17.25	19.55	16.30	18.30	17.80	19.00	18.45	15.85	16.50
14	.....	16.35	17.50	19.80	16.15	17.85	17.70	19.80	18.25	15.80	16.45
15	16.00	16.60	17.40	19.65	16.35	17.70	17.50	20.40	17.90	15.80	16.55
16	16.10	16.15	17.20	19.55	16.50	17.65	17.30	20.50	17.85	15.75	16.35
17	16.05	16.20	16.95	19.40	16.05	17.60	17.30	20.50	17.80	15.80	16.40
18	16.00	16.30	17.00	19.45	16.05	17.35	17.20	20.30	17.50	15.00	16.70
19	15.90	18.25	16.90	19.05	15.85	17.35	17.00	20.00	17.35	15.50	16.60

Mean daily gage height, in feet, of Flambeau River near Ladysmith, Wis., February 15, 1903, to December 31, 1905—Continued.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.											
20	16.00	20.35	16.85	19.20	15.80	17.20	17.00	19.70	17.25	15.50	16.67
21	15.90	19.30	16.90	19.25	15.85	17.15	17.10	19.30	17.25	15.45	16.67
22	16.05	18.50	16.65	18.85	15.95	16.70	16.90	18.90	17.15	15.25	16.67
23	16.00	18.45	16.65	19.15	15.65	16.70	16.70	18.50	17.05	15.40	16.66
24	16.25	17.30	17.30	18.90	15.90	16.70	16.80	18.20	17.00	15.65	17.00
25	16.00	17.60	17.30	19.00	15.60	16.80	17.10	18.00	16.80	15.45	16.69
26	15.95	17.25	17.25	19.55	15.85	(a)	16.80	17.70	17.00	15.55	16.66
27	16.40	17.00	17.15	20.60	15.60	(a)	17.00	17.85	16.80	15.85	16.50
28	16.25	17.10	17.20	21.45	15.70	(a)	16.90	17.50	16.55	15.80	16.10
29	.....	17.00	17.40	21.45	15.95	(a)	16.80	17.30	16.65	15.80	16.80
30	.....	16.75	18.45	21.20	15.80	(a)	16.70	17.20	16.05	15.85	16.80
31	.....	16.60	.....	21.45	.....	(a)	16.80	.....	16.20	.....	16.70

Day.	Jan.[b]	Feb.[c]	Mar.[b]	Apr.[c]	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.[d]
1904.												
1	16.75	16.75	17.00	16.90	18.70	17.50	17.58	15.15	16.25	(e)	17.25	15.65
2	16.95	16.75	17.05	17.20	18.55	17.40	17.77	15.40	16.30	(e)	17.30	15.05
3	16.75	16.10	17.00	16.80	18.60	17.42	17.70	(f)	16.38	(e)	17.20	15.95
4	16.85	16.80	17.05	16.90	18.35	17.43	19.90	(f)	17.78	(e)	16.90	14.50
5	17.00	16.90	17.15	16.85	18.45	18.00	18.82	15.60	17.65	16.05	16.70	15.15
6	16.50	16.70	16.95	16.80	18.60	18.02	18.88	15.72	17.20	16.05	16.80	15.30
7	16.50	16.80	16.90	17.10	18.60	18.25	18.75	15.13	17.28	16.10	16.30	14.87
8	16.65	16.75	17.15	17.25	18.85	18.27	18.75	15.40	17.30	16.10	16.20	15.78
9	16.65	16.75	16.90	17.05	19.20	17.90	18.05	15.75	17.03	17.05	16.17	15.57
10	16.70	16.65	17.50	17.00	19.15	17.22	17.95	15.92	16.00	18.70	16.15	15.55
11	16.60	16.70	17.40	17.10	18.90	17.10	17.70	15.85	16.40	18.65	16.05	15.25
12	16.55	16.95	17.05	17.10	18.80	17.25	17.25	16.00	16.32	18.60	15.55	15.77
13	16.50	17.00	17.30	17.15	18.35	17.15	16.40	15.90	16.45	18.50	15.60	15.55
14	16.70	16.70	17.20	17.05	18.15	17.12	16.30	15.90	16.30	18.43	15.45	15.30
15	16.70	16.90	17.20	17.25	18.01	16.60	16.12	15.85	16.15	18.30	15.82	15.35
16	16.75	16.95	17.00	17.20	17.95	16.55	16.15	16.02	16.05	17.85	15.28	15.45
17	16.60	16.55	17.15	17.10	18.01	16.35	16.03	15.90	16.05	17.20	15.55	15.35
18	16.60	17.10	17.20	17.05	18.01	16.25	16.00	15.85	16.13	16.95	15.72	15.30
19	16.65	16.95	17.15	17.00	18.03	16.32	15.60	15.95	16.15	17.15	15.70	15.50
20	16.30	16.95	17.05	16.85	17.05	15.95	15.80	15.75	16.00	17.25	15.60	15.57
21	16.75	17.55	17.05	16.85	17.03	15.88	15.95	16.00	16.90	17.60	15.45	15.70
22	16.75	16.90	17.15	16.65	17.01	16.15	15.85	16.20	15.90	17.80	15.82	15.72
23	16.75	17.00	16.85	17.20	17.04	15.95	15.80	16.35	15.95	17.75	15.27	15.68
24	16.65	16.60	17.15	17.20	17.06	16.35	15.70	16.45	15.95	17.75	15.55	15.60
25	16.70	17.00	16.95	18.00	18.40	16.55	15.85	16.65	16.40	17.85	15.72	15.65
26	16.70	16.90	16.95	18.40	19.00	16.70	16.15	16.45	16.40	17.75	15.70	15.70
27	16.45	17.00	16.95	18.45	19.40	16.95	16.76	16.45	16.40	17.65	15.55	16.10
28	16.65	16.95	17.15	18.50	19.30	17.05	16.75	16.20	16.45	17.55	15.40	15.75
29	16.60	16.95	17.05	18.50	18.80	17.05	15.70	16.10	16.40	17.65	14.95	15.80
30	16.75	.....	16.45	18.90	18.40	17.20	15.25	16.27	16.45	17.70	15.55	16.30
31	16.65	.....	17.20	.....	17.80	.....	15.55	16.15	.....	17.22	.....	16.40

[a] Chain gage stolen.
[b] Frozen from January 1 to March 30, when ice begins to break. Ice varied from 6 to 18 inches in thickness.
[c] Ice conditions March 31 to about April 10.
[d] Ice conditions during December.
[e] Weight gone.
[f] Key lost; no gage height taken on August 3 and 4.

Mean daily gage height, in feet, of Flambeau River near Ladysmith, Wis., etc.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	(a)	.....	.....	18.80	16.8	17.40	17.70	15.80	16.90	16.55	16.40	16.15
2	.....	.....	.....	18.40	16.8	16.25	17.60	15.90	16.60	16.55	16.25	15.90
3	.....	.....	.....	19.00	16.8	16.40	17.50	15.80	16.90	16.35	16.15	15.85
4	.....	16.4	16.80	19.20	17.0	16.80	17.60	15.70	17.00	16.25	16.05	16.20
5	.....	.....	.....	18.90	17.3	17.80	18.60	15.75	17.00	16.20	16.20	15.95
6	.....	.....	.....	18.40	17.6	18.70	19.00	15.35	16.90	16.15	16.15	16.10
7	16.3	.....	.....	18.40	17.6	19.60	19.20	15.35	16.60	15.80	16.20	16.45
8	.....	.....	.....	18.20	17.4	19.30	18.80	15.30	16.70	15.95	16.15	16.15
9	.....	.....	.....	18.10	17.1	18.90	18.50	15.50	16.50	15.80	16.05	16.25
10	.....	.....	.....	17.80	17.4	18.70	18.20	15.30	16.40	15.95	15.95	16.25
11	.....	16.5	16.00	17.40	17.5	18.60	17.40	15.40	16.20	15.55	16.05	15.90
12	.....	.....	.....	17.20	17.8	18.60	17.00	15.55	16.20	16.20	16.30	15.80
13	.....	.....	.....	17.20	17.8	17.60	17.00	15.40	16.25	16.15	16.30	15.90
14	16.6	.....	.....	18.20	18.0	17.50	17.00	15.32	16.25	16.10	16.20	15.70
15	.....	.....	.....	18.10	18.3	17.60	16.70	15.45	16.45	16.40	16.10	15.70
16	.....	.....	.....	17.60	18.2	17.70	16.60	15.60	16.80	16.75	16.25	16.20
17	.....	.....	.....	17.20	18.4	18.00	16.35	15.55	17.10	16.75	16.05	16.40
18	.....	16.7	16.90	16.55	18.6	19.70	16.35	15.90	17.05	17.00	15.90	15.70
19	.....	.....	.....	16.55	18.6	19.60	16.40	16.80	17.70	17.65	15.90	15.95
20	.....	.....	.....	16.45	18.4	19.40	16.15	16.90	17.80	17.20	15.85	15.45
21	16.7	.....	.....	16.55	18.0	19.10	16.10	17.10	18.20	17.65	15.90	15.65
22	.....	.....	.....	17.00	18.0	18.90	16.20	16.90	18.40	17.35	15.70	15.60
23	.....	.....	.....	16.30	17.4	18.60	15.90	16.60	17.80	17.45	15.75	15.65
24	.....	.....	16.80	16.35	18.0	18.40	15.50	16.45	17.60	17.30	15.60	15.70
25	.....	16.6	16.45	16.15	17.6	18.00	15.90	16.80	17.30	17.10	16.00	16.75
26	.....	.....	16.35	16.05	17.4	18.00	15.75	16.35	17.20	16.85	16.60	16.10
27	.....	.....	16.25	17.40	17.2	18.00	15.80	16.25	16.80	16.85	16.10	15.60
28	16.6	.....	17.10	17.40	18.0	17.70	15.80	16.80	16.80	16.80	16.60	16.00
29	.....	.....	17.90	17.00	17.8	17.70	15.75	17.00	16.70	16.70	16.15	15.90
30	.....	.....	18.20	16.80	17.6	17.70	15.70	17.20	16.20	16.55	15.90	16.15
31	.....	.....	18.60	.....	17.4	.....	15.55	17.00	.....	16.30	.....	16.10

(a) River frozen entirely across January 1 to March 23. March 11-23 there was water on the ice. Gage heights are to water surface in a hole in the ice. The following comparative readings were also made:

Date.	Water surface.	Top of ice.	Thickness.
	Feet.	*Feet.*	*Feet.*
January 7	16.3	16.4	0.7
January 14	16.6	16.8	1.3
January 21	16.7	16.9	1.4
January 28	16.6	16.9	1.5
February 4	16.4	16.9	1.7
February 11	16.5	16.9	1.7
February 18	16.7	17.1	2.0
February 25	16.6	16.9	1.8
March 4	16.8	17.8	1.8

Rating table for Flambeau River near Ladysmith, Wis., from March 19, 1903, to December 1, 1903. [a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
15.0	530	16.3	1,765	17.6	4,280	18.8	6,920
15.1	555	16.4	1,925	17.7	4,500	18.9	7,140
15.2	600	16.5	2,085	17.8	4,720	19.0	7,360
15.3	665	16.6	2,245	17.9	4,940	19.2	7,800
15.4	745	16.7	2,405	18.0	5,160	19.4	8,240
15.5	825	16.8	2,575	18.1	5,380	19.6	8,680
15.6	915	16.9	2,755	18.2	5,600	19.8	9,120
15.7	1,010	17.0	2,960	18.3	5,820	20.0	9,560
15.8	1,110	17.1	3,180	18.4	6,040	20.2	10,000
15.9	1,220	17.2	3,400	18.5	6,260	20.4	10,440
16.0	1,340	17.3	3,620	18.6	6,480	20.6	10,880
16.1	1,465	17.4	3,840	18.7	6,700	21.0	11,760
16.2	1,610	17.5	4,060				

[a] Made from measurements between gage heights 16 and 18.95 feet. Curve above and below these points is approximate. To be used only for open river.

Rating table for Flambeau River near Ladysmith, Wis., from January 1, 1904, to December 31, 1904.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
15.0	567	16.0	1,399	17.0	2,841	18.4	5,291
15.1	596	16.1	1,542	17.1	2,990	18.6	5,704
15.2	637	16.2	1,686	17.2	3,143	18.8	6,120
15.3	690	16.3	1,830	17.3	3,300	19.0	6,539
15.4	755	16.4	1,974	17.4	3,461	19.2	6,959
15.5	832	16.5	2,118	17.5	3,626	19.4	7,379
15.6	921	16.6	2,262	17.6	3,795	19.6	7,799
15.7	1,022	16.7	2,406	17.8	4,145	19.8	8,219
15.8	1,135	16.8	2,550	18.0	4,511	20.0	8,639
15.9	1,260	16.9	2,695	18.2	4,893		

Rating table for Flambeau River near Ladysmith, Wis., from January 1 to December 31, 1905.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
15.00	600	16.20	1,735	17.40	3,510	18.50	5,770
15.10	670	16.30	1,855	17.50	3,700	18.60	5,980
15.20	745	16.40	1,980	17.60	3,890	18.70	6,190
15.30	825	16.50	2,110	17.70	4,090	18.80	6,400
15.40	910	16.60	2,245	17.80	4,300	18.90	6,610
15.50	1,000	16.70	2,385	17.90	4,510	19.00	6,820
15.60	1,090	16.80	2,530	18.00	4,720	19.20	7,240
15.70	1,185	16.90	2,680	18.10	4,930	19.40	7,680
15.80	1,285	17.00	2,835	18.20	5,140	19.60	8,120
15.90	1,390	17.10	2,995	18.30	5,350	19.80	8,560
16.00	1,500	17.20	3,160	18.40	5,560	20.00	9,000
16.10	1,615	17.30	3,330				

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1905. It is not very well defined.

Estimated monthly discharge of Flambeau River near Ladysmith, Wis., for 1903, 1904, and 1905.

[Drainage area, 2,120 square miles.]

Date.	Discharge.			Run-off.		Rainfall.[a]
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1903.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Inches.*	*Inches.*
January						0.46
February [b]			860	0.41	0.21	.90
March	10,330	833	2,736	1.29	1.49	2.57
April	6,150	1,925	3,266	1.54	1.72	3.69
May	12,750	5,050	8,187	3.86	4.45	6.04
June	9,120	915	2,749	1.30	1.45	1.64
July [c]			4,598	2.17	2.02	8.70
August [d]			3,431	1.62	1.33	5.66
September	10,660	1,765	5,777	2.72	3.03	8.53
October	8,900	1,400	4,807	2.27	2.62	3.23
November	1,685	530	1,054	.50	.56	.94
December						.87
The year						43.23
1904.						
January						.43
February						1.11
March						1.76
April [e]	6,339	2,334	3,389	1.60	1.78	1.77
May	7,379	2,856	5,183	2.44	2.81	4.64
June	5,034	1,234	2,890	1.36	1.52	5.64
July	8,429	662	2,834	1.34	1.54	2.14
August [f]	2,334	607	1,336	.630	.726	5.01
September	4,109	1,260	2,056	.970	1.08	4.70
October [f]	5,912	1,470	3,517	1.66	1.91	5.61
November	3,300	555	1,416	.668	.745	.19
December [e]	1,974	390	951	.449	.518	2.39
The year						35.43
1905. [g]						
March 24–31		5,980	1,795	3,384	1.60	.476
April		7,240	1,558	3,867	1.82	2.03
May		5,980	2,530	4,090	1.93	2.22
June		8,340	1,795	5,223	2.46	2.74
July		7,240	1,000	2,950	1.39	1.60
August		3,160	825	1,669	.787	.907
September		5,560	1,735	2,839	1.34	1.50
October		3,990	1,045	2,305	1.09	1.26
November		2,245	1,090	1,616	.762	.850
December		2,045	955	1,449	.683	.787

[a] Rainfall for 1903 is the average of the recorded rainfall at Butternut, Medford, and Eau Claire; that for 1904 omits Eau Claire and adds Prentice and Minocqua.
[b] February 15 to 28, inclusive.
[c] July 1 to 25, inclusive.
[d] August 10 to 31, inclusive.
[e] Estimates April and December made as if open channel.
[f] Discharge estimated for August 3 and 4 and October 1 to 4.
[g] No estimate for ice period.

Tributaries of Flambeau River.—Dore Flambeau River, the south branch of the Flambeau, rises at an elevation of 1,582 feet above the sea, in a group of a dozen lakes, the largest being Long Lake. Its total drainage area is 742 square miles. After a very rapid course of about 60 miles it joins the main stream in sec. 31, T. 37 N., R. 3 W. In the 27 miles between Long Lake and Fifield the river descends 146 feet, or 5.4 feet to the mile. Its gradient below Fifield has not been determined, but it is known to have many important falls and rapids. One of the largest of these, located in sec. 33, T. 37 N., R. 3 W., has a total fall of 35 feet. Owing to its lakes and swamps this river has a much more uniform flow than any of the Chippewa tributaries farther south. Dams are maintained by the Chippewa River Improvement Company at the outlet of Long Lake and at Fifield. The same company maintains logging dams on Elk River in sec. 11, T. 37 N., R. 2 W., and also in sec. 14, T. 37 N., R. 1 W., with flowage of 1½ and 2½ square miles, respectively. These and other logging dams within this drainage area are listed in the following table:

Logging dams maintained on tributaries of Flambeau River.[a]

No.	Location.	Dam.	
		Height.	Length.
	Dore Flambeau River:	*Feet.*	*Feet.*
1	Sec. 7, T. 39 N., R. 1 E; sec. 24, T. 40 N., R. 1 E	16	350
2	Sec. 16, T. 38 N., R. 1 W	.....	.....
3	Secs. 23–26, T. 40 N., R. 3 E	15	400
4	Flambeau Lake, sec. 2, T. 40 N., R. 4 E	6	24
	Manitowish River:		
5	Sec. 9, T. 42 N., R. 5 E	13	400
6	Sec. 24, T. 42 N., R. 6 E	17	300
7	Sec. 15, T. 42 N., R. 7 E	15	250
	Elk River:		
8	Sec. 11, T. 37 N., R. 2 W	10	450
9	Sec. 14, T. 37 N., R. 1 W	10	.....
10	Trout River, sec. 14, T. 41 N., R. 6 E	4	.....
11	Bear Creek, sec. 2, T. 40 N., R. 4 E	.....	.....

[a] Authority: Nos. 1 and 3, Wm. Irving, manager, Chippewa Lumber and Boom Co.; 4–8, Flambeau Lumber Co.; 9, J. R. Davis Lumber Co.; 10 and 11, E. S. Shepard. Owners: Nos. 1, 3, and 5–7, Chippewa Lumber and Boom Co.; 2, Lugar Lumber Co.; 4, Flambeau Lumber Co.; 8 and 9, Chippewa River Improvement Co.

RED CEDAR RIVER.

Drainage.—An area of 1,957 square miles in the extreme western part of Chippewa Valley is drained by Red Cedar River (sometimes called the Menomonie), which, unlike the other large tributaries of Chippewa River, does not reach the main stream until within a few miles from its mouth. Except at its headwaters, Red Cedar River drains a region underlain by the Cambrian sandstone. As a result, the greater part of the area has a sandy soil. A narrow belt of clayey loam, increasing in width southward, extends along the western limit of this area. The drainage area occupies the U-shaped region included between two terminal moraines, one near the eastern and one near the western border, which unite at the upper headwaters, giving rise to numerous lakes. Four of the largest of these have an area of about 20 square miles.

Profile.—A study of the profile of Red Cedar River shows that its total descent in the 90 miles above its mouth is 470 feet, or 5.2 feet per mile. This gives opportunity for a large number of water powers. There are about 25 old logging dams on the river, besides about an equal

number of sawmills and flouring mills. The following table has been compiled from actual surveys by competent engineers and from checked railroad levels:

Profile of Red Cedar River from its mouth to Red Cedar Lake.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river	0	.....	705.0	.....	.....
2	Dunnville	2.0	2.0	723.4	18.4	9.2
	Downsville dam:					
3	Foot	7.8	5.8	739.0	15.6	2.7
4	Crest	7.8	.0	758.2	19.2	
5	Irving	13.0	5.2	766.4	8.2	3.1
	Menomonie dam:					
6	Foot	16.6	3.6	788.3	21.9	
7	Crest	16.6	.0	803.9	15.6	8.0
8	"Omaha" bridge	18.9	2.3	806.7	2.8	
	Cedar rapids dam:					
9	Foot	23.4	4.5	823.3	16.6	3.7
10	Crest	23.4	.0	842.0	18.7	5.3
11	Hay River, mouth	30.2	6.8	859.3	17.3	
12	Colfax	35.0	4.8	895.0	35.7	7.4
13	Cameron (2 miles west)	70.0	35.0	1,068.0	173.0	5.0
14	Railroad crossing	74.0	4.0	1,116.0	48.0	12.0
15	Cedar Lake dam, sec. 22, T. 37 N., R. 10 W	90.0	16.0	1,191.0	75.0	4.7
16	Dam in sec. 25, T. 37 N., R. 10 W	96.0	6.0	.....	.....	.....

[a] Authority: No. 1, Chicago, Milwaukee and St. Paul Railway; 2–11, O'Keef & Orbison, Appleton, Wis.; 12, Wisconsin Central Railway; 13, Minneapolis, St. Paul, and Sault Ste. Marie Railway; 14 and 15, Chicago, St. Paul, Minneapolis and Omaha Railway.

A study of this table shows that Red Cedar River has a high gradient, averaging 5½ feet per mile in the last 74 miles, with frequent concentrations of descent. No gagings of the river have been made. Tributaries entering the river from the west flow through a clayey-loam soil, but the upper and eastern portions of the drainage area have a sandy-loam soil. It is therefore likely that this river has a fairly uniform flow. The decline of the lumbering interests greatly increases the value of the Red Cedar River as a power producer.

Water powers and dams.—In the 30 miles below Hay River the Red Cedar descends 154.3 feet, and as this region borders the prairie region and is thickly settled, the six powers here included will probably be developed to the full extent in the near future. This development includes: (1) The construction of a dam at Dunnville, 2 miles above the mouth of the river, giving a head of 15.6 feet and an estimated 1,685 horsepower; (2) the raising of the present dam at Downsville 4 feet, giving a total head of 23.2 feet and an estimated 2,480 horsepower; (3) the construction of a dam at Irving, with a total head of 21.9 feet, giving an estimated 2,260 horsepower; (4) the raising of the present dam at Menomonie 2.8 feet, thus obtaining a total head of 18.4 feet and an estimated 1,800 horsepower; (5) the building of a new dam near the "Omaha" bridge, 2.8 miles above Menomonie, with a head of 16.6 feet and an estimated 1,700 horsepower; (6) the raising of the present dam at Cedar rapids 21.3 feet, giving a total head of 40 feet and an estimated 3,800 horsepower.[a] Recently all the powers owned by Knapp, Stout & Co., including many of the most valuable on the river, have been

[a] This statement is based on a careful survey for the owners made by O'Keef & Orbison, hydraulic engineers, of Appleton, Wis., and an estimated run-off of 0.461 second-foot per square mile.

acquired by the Wisconsin Power Company, of Chicago, Ill. The location of 10 dams owned by this company is shown in the following table:

Dams on Red Cedar River owned by the Wisconsin Power Company.

Location.	Head.	Amount of flowage.	Authority.
	Feet.	*Cubic feet.*	
Sec. 25, T. 37 N., R. 10 W.	14.0	1,674,000,000	U. S. engineers.
Sec. 2, T. 36 N., R. 10 W.	7.0	405,000,000	Do.
Sec. 25, T. 36 N., R. 10 W.	12.0		
Sec. 30, T. 36 N., R. 9 W.	10.0	135,000,000	Do.
Sec. 29, T. 36 N., R. 9 W.	10.0		
Sec. 13, T. 34 N., R. 10 W.	12.0	40,500,000	Do.
Sec. 30, T. 33 N., R. 10 W.	10.0	810,000,000	Do.
Downsville	19.0		J. W. Orbison.
Menomonie	15.5		Do
Cedar Falls	18.7		Do.

Railroads.—Between the mouth of Red Cedar River and Menomonie the Chicago, Milwaukee and St. Paul Railway closely parallels the river. In this stretch of 17 miles are situated the most important powers. Above Menomonie the drainage is crossed by the Chicago, Milwaukee and St. Paul, the Chicago, St. Paul, Minneapolis and Omaha, the Wisconsin Central, and the Minneapolis, St. Paul and Sault Ste. Marie railways.

EAU CLAIRE RIVER.

Ranked in order of its drainage area (900 square miles), Eau Claire River is third among the tributaries of the Chippewa. The greater part of this area is underlain by the Cambrian sandstone, and all except the upper headwaters drain a sandy-loam soil, as will be seen from Pl. II. Like most of the neighboring rivers, the Eau Claire has been an important lumbering stream, with many flooding dams. Very few water powers have been utilized. The first developed water power is about 500 feet from the mouth of the river, where a dam 300 feet long develops a head of 11 feet to run a linen mill, which uses only part of the power thus furnished. About 3,000 feet farther upstream is a second dam, with an average head of 13½ feet, owned by the Northwestern Lumber Company. An installation of turbines of 420 horsepower is reported. This is used in running a sawmill, a machine shop, and dynamos. The same company reports the three following lumbering dams on this river, but none of the resulting water power is utilized at the present time. In the NW. ¼ NE. ¼ sec. 14, T. 27 N., R. 9 W., is a dam with a 7-foot head, capable at ordinary low water of furnishing 210 theoretical horsepower. In the SW. ¼ NE. ¼ sec. 13, T. 27 N., R. 8 W., is a timber dam with a head of 8 feet, which could easily and cheaply be increased to 20 feet, thus producing at ordinary low water 540 theoretical horsepower. The third dam, with a present head of 20 feet, is reported in the SW. ¼ SW. ¼ sec. 5, T. 26 N., R. 6 W. This dam has not been used for many years and is much in need of repairs. There are many other opportunities for developing water powers on the Eau Claire River, as well as on its tributaries.

JUMP RIVER.

As its name would imply, Jump River is a very rapid stream, with numerous falls and rapids, making a descent of nearly 500 feet in its entire length of 65 miles. Its drainage area of 720 square miles is a long and narrow one, and with only a few unimportant exceptions is devoid of lakes and swamps. As a result the river has a very uneven flow as compared with the Flambeau, which stream it resembles in flowing through a valley whose soil is a clayey loam. The main portion of the Jump River valley has no railroads and is

sparsely settled. A branch of the Wisconsin Central is now being built across this drainage. The most important falls on the river, 35 feet in height, are in sec. 20, T. 34 N., R. 2 W., about 1 mile east of the junction of North and South forks, but there are numerous other dam sites of 15 to 20 foot head, which will doubtless be utilized when this section is settled.

YELLOW RIVER.

The drainage area of Yellow River is 460 square miles, distributed in a long, narrow valley. The lower half of the valley has a sandy soil, the upper part a clayey loam. While the gradient of Yellow River is not so great as that of its neighbor, Jump River, it has a rapid current. As in the case of other rivers in this region the only dams built were for logging purposes. The Miller dam is said to be the only one remaining. Three other dams, one at Colburn, one in sec. 7, T. 29 N., R. 5 W., and one at Cadott, have all been carried away by floods. The river is crossed by three railroads.

SMALLER TRIBUTARIES.

Chippewa River has a host of smaller tributaries, nearly all of which, because of their rapid currents and high, rocky banks, can be cheaply developed. Duncan Creek is a good example of what can be done with this class of tributaries. Although only 25 miles long, it has five dams with an aggregate head of 68 feet. Four gristmills, with a total turbine capacity of over 500 horsepower, take their power from this creek. Below the "Star mills," in the city of Chippewa Falls, is an unimproved power of 14-foot head; and immediately below this site is a dam with a 9-foot head, belonging to the Gatzian Shoe Manufacturing Company. The significant point regarding powers of this class is that they are cheaply improved and very widely distributed. The locations of some of them are shown in the following table:

Dams on smaller tributaries of Chippewa River.

Location.	Owner and use.	Head.	Installation.
		Feet.	*H. P.*
Arkansaw Creek, Arkansaw	Mills & Son, gristmill	12	25
Bass Creek, Afton	Wm. Denoger, flouring mill	9	40
Bear Creek, Durand	Durand roller mill, flour	18	73
Bridge Creek:			
Augusta	Dells Milling Co., flour	20	60
Sec. 18, T. 26, R. 6 W	V. P. Waddell	20	(a)
Duncan Creek:			
Chippewa Falls	Gotzian Shoe Co.	9	(b)
Do	Leinenkugel Brewing Co.	14	(a)
Do	Leinenkugel Co., flour	16	350
Sec. 31, T. 29 N., R. 8 W	Glen mills, flour	20	100
Sec. 24, T. 29 N., R. 9 W	G. W. Lockin, Tilden flouring mills.	10	70
Sec. 8, T. 30 N., R. 9 W	Bloomer mills, flour	12	30
Eighteenmile Creek, Colfax	J. A. Anderson & Son, grist and saw mill.	14	60
Hay River, Prairie farm	P. F. Milling Co., grist	9	.....
Jump River:			
Sec. 20, T. 34 N., R. 2 W	.....	35	(a)
Westboro	.....	.....	.....
Lowes Creek, sec. 4, T. 26 N., R. 9 W	W. J. Davis	c 30	.....

a Undeveloped. b Unused. c Could be raised 8 feet.

Dams on smaller tributaries of Chippewa River—Continued.

Location.	Owner and use.	Head.	Installation.
		Feet.	*H. P.*
O'Neals Creek, west branch:			
Sec. 26, T. 31 N., R. 9 W.	Wm. Durch, grist and saw mill.	8	30
Near mouth	F. G. & C. A. Stanley, saw-mill.	22	50
Eagle Point	M. Rosmus, electric light	12	150
Otter Creek, Eau Claire	R. Clark, flour	18	95
Pine Creek:			
Lucas	T. Teegarden, grist and saw mill.	12	80
Sand Creek	A. F. Johnson, grist and saw mill.	6	96
Dalles	J. A. Anderson, grist and saw mill.	8	50
Plover River:			
Shantytown	S. Y. Bentley, sawmill	7	40
Jordan	A. Van Orden	14	100
Bevent	do	7	(a)
Rock Creek, sec. 22, T. 27 N., R. 11 W.	D. W. Andrews, flour	35	75
Tiffany Creek, Boyceville	A. A. Hoyr & Bro., grist	9	30

a Undeveloped.

ST. CROIX RIVER SYSTEM.

TOPOGRAPHY AND DRAINAGE.

St. Croix River rises at an elevation of 1,010 *a* feet, in St. Croix Lake, on the Lake Superior divide, only 20 miles from Lake Superior. The lower two-thirds of its length forms a part of the Minnesota boundary. In its total length of 168 miles it descends 344 feet, all but 20 feet of which is in the upper 116 miles, making the average for this upper portion nearly 3 feet per mile. This slope is fully six times the slope of Mississippi River above Minneapolis, and, according to United States engineers, has an important bearing on the relatively large run-off as compared with Mississippi Valley above. Another important feature of this region is its relatively small number of lakes, these forming only 3 per cent of the total drainage area as compared with 11 per cent in Mississippi Valley above Minneapolis. *a* Evaporation on lake surfaces is probably nearly equal to the precipitation for the corresponding period. The total drainage area comprises 7,576 square miles, the greater part of which is in Wisconsin. The Wisconsin portion has a width of 50 miles on its northern margin and extends southwesterly toward Mississippi River, a distance of about 150 miles.

The topography may be described under three heads—(1) the level area, (2) the rolling and swelling hill districts, and (3) the knoll and basin combination. The first includes the so-called "barrens" which border the streams and some elevated plateaus, together with smaller scattered areas. The third class may be described as a belt lying near the southeastern watershed and stretching from the vicinity of Lake Namekagon southwestward to the St. Croix. The second class includes most of the territory which remains. *b*

Marshes are quite as infrequent as the lakes and occur only on the river bottoms. Not half of the lakes are visibly connected with the rivers, but because of the open soil they are likely to have underground connection. There are usually lumbering dams on such lakes as have outlets, and these lakes, together with the numerous smaller depressions, play an important part in the preventing of freshets. The lakes of this region arrange themselves into two groups—one, lying mostly in the "barrens," adjacent and parallel to the upper St.

a Repts. Chief Eng. U. S. Army, 1881, 1883.
b Geol. Wisconsin, vol 3, 1880, p. 370.

Croix and extending southwest from its source to the point where the stream turns southward, and a second group in the extreme southeastern portion of this region, occurring in the depressions of the "Kettle moraine." As the water of this region flows almost exclusively over the crystalline rocks and sandstones, or the drift derived from them, it is in general soft, though usually amber colored. Springs are very common, many of the lakes being fed almost entirely by them. They are especially frequent in the Cambrian sandstone and tend to equalize the flow of all the streams.

The apportionment of drainage areas is shown in the following table:

Distances and drainage areas of St. Croix River.

River.[a]	Distance from source (map measure).	Drainage area above station.
	Miles.	*Sq. miles.*
St. Croix, source		
Eau Claire:		
Above mouth	6.5	117
Mouth	6.5	224
Namekagon	38.0	1,451
Yellow	50.0	2,084
Clam:		
Above mouth	64.0	2,428
Mouth	64.0	2,844
Kettle:		
Above mouth	75.0	3,046
Mouth	75.0	4,139
Snake	79.0	5,097
Wood	84.0	5,281
Sunrise	100.0	5,857
St. Croix, St. Croix rapids	120.0	6,202
Apple	138.0	6,951
Willow	151.0	7,301
St. Croix, mouth	168.0	7,576

[a] Station is at mouth of river, unless otherwise stated.

PROFILE.

The following table gives, upon the authority of United States engineers, elevations above the sea and gradients per mile of St. Croix River at twenty points between its mouth and its source:

Profile of St. Croix River from its mouth to St. Croix Lake.

Station.	Distance.		Elevation above sea level.	Descent between points.	
	From mouth.	Between points.		Total.	Per mile.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Prescott, mouth of river	0.0	.....	[a] 667.0	.....	.....
Kinnikinnic River, mouth	5.0	5.0	668.0	1.0	0.2
Apple River, mouth	28.0	23.0	672.0	4.0	.2
Osceola	42.0	14.0	683.0	11.0	.8
St. Croix Falls (head of navigation)	48.0	6.0	687.0	4.0	.7
Trade River, mouth	60.0	12.0	753.0	6.6	5.5
Sunrise River, mouth	65.0	5.0	758.5	5.5	1.1
Rush City, ferry	75.0	10.0	773.0	14.5	1.4
Sec. 35, T. 38 N., R. 20 W	79.0	4.0	±782.0	9.0	2.2
Snake River, mouth	86.0	7.0	±790.0	8.0	1.1
Kettle River rapids, foot	89.0	3.0	±801.0	11.0	3.7
Kettle River, mouth	90.0	1.0	±816.0	15.0	15.0
Kettle River rapids, head (proposed U. S. dam, sec. 2, T. 39 N., R. 19 W)	93.0	3.0	±850.0	34.0	11.3
Clam River, mouth	101.0	8.0	±868.0	18.0	2.2
Sec. 1, T. 40 N., R. 18 W	103.5	2.5	874.0	6.0	2.4
Yellow River, mouth	115.0	11.5	888.0	14.0	1.2
Namekagon River, mouth	127.0	12.0	908.0	20.0	1.7
Moose River, mouth	139.0	12.0	1,001.0	93.0	7.7
Sec. 35, T. 44 N., R. 13 W.:					
Below dam	144.0	5.0	1,001.5	.5	.1
Above dam	144.0	.0	1,005.3	3.8	.....
St. Croix Lake	160.0	16.0	1,010.0	4.7	.3

[a] Low-water elevation.

GEOLOGY.

Almost the entire watershed has been glaciated to such an extent that outcrops, except near the rivers, are very infrequent. According to the reports of the Wisconsin Geological Survey, the central and by far the greater portion of this area is underlain by the pre-Cambrian crystalline rocks known as the "Keweenawan." This belt narrows toward the south, giving way both on the east and west to the Cambrian sandstones. These pre-Cambrian crystalline rocks intersect St. Croix River at St. Croix Falls, and because of their greater hardness have caused the falls and rapids—the most important on the entire river—which extend for 6 or 7 miles above the city of Taylors Falls, Minn.

RAINFALL AND RUN-OFF.

The United States Geological Survey has maintained a gaging station 3½ miles above St. Croix Falls, Wis., since 1903. The gage heights are referred to four iron pins on the right bank just below the gaging station, the elevations of which are referred to the datum of the bench marks of the St. Croix River survey. Their elevations are as follows.

	Feet.
Pin No. 1	732.08
Pin No. 2	734.54
Pin No. 3	736.10
Pin No. 4	737.57

A large number of measurements were obtained during 1903, and the gage was read daily by V. H. Caneday. Discharge measurements were made from a boat held in place by a wire cable stretched across the river between two trees. The initial point for soundings is a ver-

tical rod on the left bank. The channel is straight for about 800 feet above and 1,000 feet below the station, while the banks are high and can not overflow. The section is regular, smooth, and permanent, and the velocity is never sluggish, making this on the whole a station at which good results are obtainable. The drainage area at this point is 6,370 square miles.

Discharge measurements of St. Croix River near St. Croix Falls, Wis., in 1903.

Date.	Hydrographer.	Gage height.	Discharge.
1903.		*Feet.*	*Second-feet.*
May 22	E. Johnson, jr	4.00	10,747
August 11	W. R. Hoag	2.70	7,470
October 9	L. R. Stockman	3.84	10,244

Discharge data relating to St. Croix River near St. Croix Falls, Wis., obtained through the United States Geological Survey, have been supplemented by data supplied by Loweth & Wolf, civil engineers, of St. Paul, Minn. The results are embodied in the following table:

Daily discharge, in second-feet, of St. Croix River near St. Croix Falls, Wis., January 10, 1902, to December 31, 1904.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	.....	1,820	2,425	2,910	3,930	5,150	6,690	2,270	1,725	2,330	5,190	2,480
2	.....	1,875	2,442	2,840	4,090	5,010	4,490	1,740	1,730	2,390	3,950	2,555
3	.....	1,930	2,460	300	3,910	4,480	4,830	1,790	1,680	2,395	3,290	.....
4	.....	1,700	2,300	400	3,920	9,798	4,700	1,825	1,840	1,685	4,740	.....
5	.....	1,760	2,370	2,750	3,935	11,871	7,350	1,870	1,700	2,150	3,910	.....
6	.....	1,755	2,420	2,515	4,900	10,956	5,200	2,035	2,560	2,445	4,180	.....
7	.....	1,750	2,270	2,280	3,980	10,610	12,106	2,260	2,550	2,390	4,030	.....
8	.....	1,770	.....	2,280	4,880	.....	11,693	1,980	2,220	2,290	4,740	.....
9	.....	1,765	.....	2,190	4,560	9,261	11,137	1,660	4,110	2,050	4,500	.....
10	1,895	1,760	.....	2,110	4,590	10,468	12,947	1,990	3,500	930	3,290	.....
11	1,910	1,750	.....	1,990	4,450	6,810	8,978	3,970	1,720	2,950	2,960	.....
12	1,860	1,750	.....	1,870	5,850	7,600	7,980	1,680	1,500	1,950	3,195	.....
13	1,850	1,815	.....	1,468	6,150	8,289	6,700	1,120	1,640	2,040	4,300	2,370
14	1,685	1,870	.....	2,065	5,250	4,780	6,060	1,015	1,550	2,000	4,530	2,260
15	1,765	1,990	.....	2,020	4,780	6,350	5,780	1,570	1,355	1,915	4,900	2,150
16	1,775	1,990	.....	2,170	4,875	4,220	4,860	1,590	1,355	800	4,600	2,080
17	1,795	1,990	.....	2,070	4,820	3,420	4,380	1,560	1,540	845	4,700	2,015
18	1,880	1,990	.....	5,190	4,940	3,580	3,800	1,500	1,480	3,600	4,580	2,110
19	1,860	1,990	4,650	1,510	5,065	6,350	5,210	1,510	1,120	1,940	5,160	2,180
20	1,920	1,990	4,995	1,005	5,300	3,780	2,850	1,500	510	1,925	3,690	2,085
21	1,875	1,990	4,650	500	5,870	960	3,405	1,480	2,800	2,040	4,665	2,040
22	1,930	1,990	4,600	5,540	7,080	3,300	3,530	1,480	2,070	1,980	4,160	2,000
23	1,860	2,027	4,035	440	9,600	3,400	3,600	1,575	2,540	2,040	4,250	2,090
24	1,950	2,065	3,470	510	7,250	6,000	3,185	1,495	2,365	850	4,060	.....
25	1,985	2,110	3,110	1,050	6,420	3,560	2,560	1,405	1,065	1,100	3,720	.....
26	1,975	2,180	3,117	2,760	5,585	4,145	7,250	3,850	1,135	2,300	3,555	.....
27	1,950	2,260	3,125	3,025	5,760	4,380	850	1,860	1,120	2,310	3,680	.....
28	1,930	2,480	3,125	3,290	5,090	4,200	750	1,740	3,050	2,660	3,060	.....
29	1,920	.....	3,125	3,480	6,070	2,550	2,515	1,465	2,210	2,890	3,050	2,080
30	1,905	.....	3,037	3,750	4,930	4,690	2,515	5,995	2,310	1,875	2,050	2,060
31	1,890	.....	2,950	.....	5,290	.....	2,610	1,795	.....	2,840	.....	2,045

Daily discharge, in second-feet, of St. Croix River near St. Croix Falls, Wis., January 10, 1902, to December 31, 1904—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
1....	2,055	1,950	1,940	6,770	8,920	7,680	251	4,570	.....	.....	.....	.....
2....	1,940	1,935	1,920	9,800	9,555	10,420	3,030	4,800	.....	.....	.....	.....
3....	1,940	1,760	1,920	10,750	.....	(9,490)	.....	5,050	.....	.....	.....	.....
4....	1,910	1,830	1,960	12,220	.....	8,560	.....	6,170	.....	.....	.....	.....
5....	1,880	1,900	1,965	.....	15,200	7,910	.....	6,710	.....	.....	.....	.....
6....	1,930	2,015	1,885	10,350	15,611	7,340	8,640	1,600	.....	.....	.....	.....
7....	1,945	1,930	1,990	8,850	15,176	(6,805)	.....	7,900	.....	.....	.....	.....
8....	2,010	1,915	2,050	11,645	13,835	6,270	8,880	(7,600)	.....	.....	.....	.....
9....	1,930	1,895	2,110	17,975	12,150	6,010	10,155	(7,280)	.....	.....	.....	.....
10....	1,850	1,945	.....	16,438	.....	5,760	10,870	7,170	.....	.....	.....	.....
11....	1,875	1,950	.....	18,272	9,245	5,160	11,630	4,830	.....	.....	.....	.....
12....	1,900	1,880	.....	20,166	10,157	6,190	(10,437)	5,510	.....	.....	.....	.....
13....	1,930	1,975	.....	.....	.....	7,320	9,245	5,340	.....	.....	.....	.....
14....	1,950	1,930	.....	.....	.....	(6,910)	7,250	5,350	.....	.....	.....	.....
15....	1,980	1,870	.....	15,382	.....	6,500	7,200	(4,792)	.....	.....	.....	.....
16....	1,870	1,840	.....	14,080	.....	5,825	6,915	4,235	.....	.....	.....	.....
17....	1,770	1,870	4,030	12,800	.....	5,130	6,790	4,150	.....	.....	.....	.....
18....	1,815	1,970	4,530	.....	.....	5,755	6,035	3,460	.....	.....	.....	.....
19....	1,870	1,850	6,480	12,540	.....	4,300	(5,592)	3,580	.....	.....	.....	.....
20....	1,780	1,700	9,890	10,260	13,830	.....	5,150	4,360	.....	.....	.....	.....
21....	1,980	1,745	11,440	.....	13,790	.....	4,540	4,740	.....	.....	.....	.....
22....	1,730	1,830	11,460	.....	10,580	1,542	4,375	.....	.....	.....	.....	.....
23....	1,820	1,910	11,480	.....	11,230	2,700	3,990	3,220	.....	.....	.....	.....
24....	1,800	1,950	10,740	6,800	11,665	2,710	1,830	.....	.....	.....	.....	.....
25....	1,865	1,945	9,660	9,740	12,100	2,640	5,590	.....	.....	.....	.....	.....
26....	1,930	1,820	10,100	9,265	9,580	2,545	(4,670)	.....	.....	.....	.....	.....
27....	1,990	1,880	9,530	8,790	12,020	(2,475)	3,750	.....	.....	.....	.....	.....
28....	2,050	1,970	8,725	10,460	12,640	(2,420)	4,770	.....	.....	.....	.....	.....
29....	1,980	.....	8,590	10,080	11,420	2,360	4,730	.....	.....	.....	.....	.....
30....	1,835	.....	8,445	8,925	10,640	907	4,485	.....	.....	.....	.....	.....
31....	1,970	.....	8,160	.....	(9,160)	.....	4,570	.....	.....	.....	.....	.....
1904.												
1....	2,390	2,110	2,580	5,560	8,400	6,340	6,170	840	.....	3,950	8,780	1,690
2....	2,390	2,090	2,570	6,130	7,590	5,520	5,850	1,080	4,530	(3,840)	8,040	1,760
3....	.....	2,060	2,520	(7,000)	7,540	6,050	(3,630)	1,480	4,610	3,720	7,590	2,210
4....	.....	2,040	2,390	8,080	7,480	7,950	1,410	3,460	(4,750)	3,360	6,780	(2,400)
5....	.....	2,080	2,290	9,873	7,380	(12,560)	(3,010)	2,250	4,900	11,310	3,280	2,620
6....	.....	2,070	2,390	12,390	8,290	17,180	4,610	1,990	4,870	1,240	(4,230)	2,740
7....	3,660	(2,040)	2,490	15,930	8,790	17,920	4,780	2,040	5,040	(2,800)	5,230	2,890
8....	3,140	2,020	2,600	16,900	(10,320)	17,460	4,610	2,100	4,690	4,690	5,440	2,970
9....	2,810	2,160	2,590	18,300	(11,850)	15,650	4,970	2,210	4,600	(3,400)	5,700	2,770
10....	(2,820)	2,110	2,560	(16,600)	13,370	12,940	2,960	2,100	(4,030)	2,120	4,900	2,820
11....	2,840	2,000	2,590	15,060	11,300	12,610	950	2,000	(3,460)	10,430	5,330	(2,820)
12....	2,600	2,160	2,640	14,010	9,490	(12,070)	3,480	2,300	2,820	15,020	5,600	2,830
13....	2,340	2,000	2,650	10,590	8,550	11,530	3,860	2,340	(2,380)	14,270	(5,540)	2,500
14....	2,660	(2,140)	2,660	7,910	8,980	11,320	3,750	(1,750)	1,940	13,800	5,470	2,420
15....	2,680	(2,280)	2,700	12,560	8,650	7,880	3,890	1,150	2,150	12,560	5,250	2,220
16....	2,630	2,430	2,740	10,010	8,310	8,540	3,990	950	3,480	.....	4,970	2,380
17....	(2,410)	2,430	2,690	(9,460)	7,280	7,628	(2,530)	1,430	3,190	10,060	4,770	2,330
18....	2,200	2,460	2,700	(8,920)	7,820	8,130	1,080	3,370	(3,160)	10,700	4,570	2,320
19....	2,480	2,410	2,750	8,380	6,860	8,710	1,140	1,920	3,140	10,310	4,480	2,300
20....	2,460	2,450	(a)	7,850	5,250	9,280	3,760	2,240	2,890	12,710	(4,340)	2,380

a March 20 to 25, ice going out.

Daily discharge, in second-feet, of St. Croix River near St. Croix Falls, Wis., January 10, 1902, to December 31, 1904—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
21	2,440	(2,370)	.....	7,490	6,390	6,730	3,420	(3,760)	2,750	(15,700)	4,190	2,160
22	2,630	2,290	.....	7,530	(6,900)	5,630	3,170	5,290	2,380	18,700	4,020	2,440
23	2,620	2,330	.....	11,260	(7,500)	5,820	3,270	4,390	2,490	(18,010)	4,000	2,340
24	(2,570)	2,230	.....	(10,810)	8,000	4,960	(2,240)	2,520	2,700	17,330	4,120	2,390
25	2,520	2,280	.....	10,360	7,790	5,190	1,210	2,970	(3,240)	16,180	3,720	(2,420)
26	2,330	2,410	3,090	11,170	8,760	(3,380)	1,050	2,510	3,790	15,540	3,710	2,450
27	2,390	2,460	(3,370)	11,230	8,030	1,570	2,580	2,480	3,330	12,710	(3,300)	2,460
28	2,280	2,480	3,660	10,769	7,390	4,850	2,780	(2,230)	3,500	12,910	2,890	(2,440)
29	2,270	2,520	3,300	10,850	(6,700)	5,330	2,720	1,960	3,580	10,590	2,800	(2,420)
30	2,250	.....	3,770	9,490	6,060	5,320	2,810	2,260	(3,880)	(10,410)	(2,250)	(2,400)
31	.....	.....	4,510	.....	6,440	.....	.....	(3,000)	.....	10,230	.....	2,380

Estimated monthly discharge of St. Croix River at St. Croix Falls, Wis., for 1902, 1903, and 1904.

[Drainage area, 6,370 square miles.]

Date.	Discharge.			Run-off.		Rainfall.[a]
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1902.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
January	1,980	1,680	1,880	0.31	0.36	0.90
February	2,480	1,700	1,880	.31	.36	.54
March	5,000	2,380	3,300	.60	.69	.69
April	5,560	200	2,220	.37	.41	2.08
May	9,000	4,100	2,020	.33	.38	3.09
June	11,870	960	5,950	.99	1.14	3.59
July	12,106	760	5,500	.92	1.06	6.30
August	6,000	1,020	1,860	.31	.36	2.82
September	4,100	400	1,860	.31	.36	3.26
October	3,600	800	2,000	.33	.38	1.58
November	5,200	2,550	4,080	.68	.77	2.76
December	2,550	2,020	2,100	.35	.40	2.16
The year	12,106	200	2,912	.48	6.67	29.77
1903.						
January	2,040	1,740	1,920	.32	.37	.59
February	2,020	1,700	1,880	.31	.36	.88
March	11,480	1,960	5,500	.92	1.05	1.97
April	20,185	5,800	12,000	2.00	2.30	2.78
May	16,157	8,920	12,700	2.12	2.43	5.78
June	7,900	906	5,050	.84	.96	1.69
July	11,620	251	6,360	1.06	1.21	6.75
August	7,900	1,600	4,850	.81	.92	4.77
September	14,918	6,960	11,750	1.96	2.26	7.27
October	29,611	5,740	12,780	2.13	2.44	4.11
November	7,000	850	4,270	.71	.81	.66
December	3,440	2,340	2,740	.46	.52	.97
The year	29,611	[b] 251	6,816	1.14	15.63	38.22

[a] This is the average of the recorded precipitation at Barron, Duluth, Grantsburg, Hayward, Osceola, and St. Paul.

[b] Low water due to the manipulation of a lumbering dam a few miles above.

Estimated monthly discharge of St. Croix River at St. Croix Falls, Wis., for 1902, 1903, and 1904—Continued.

Date.	Discharge.			Run-off.		Rainfall.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth.	
1904.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Inches.*	*Inches.*
January	2,840	2,200	2,600	.43	.48	.64
February	2,480	2,000	2,238	.37	.42	1.18
March	4,510	2,290	2,832	.47	.53	1.19
April	18,300	5,560	10,748	1.79	2.01	1.65
May	13,370	5,250	8,176	1.36	1.53	3.78
June	17,920	4,850	8,868	1.48	1.66	5.58
July	5,850	950	3,145	.52	.58	4.64
August	3,460	840	2,334	.39	.44	3.84
September	5,040	1,940	3,544	.59	.66	5.75
October	18,700	1,240	10,560	1.76	1.98	5.47
November	8,780	2,800	4,843	.80	.90	.05
December	2,970	1,690	2,441	.40	.45	.99
The year	18,700	840	5,194	10.36	11.65	34.77

WATER POWERS.

FALL.

In the lower 48 miles of its course the St. Croix River has its bed in the Cambrian sandstone or "Lower Magnesian" limestone, principally the former, which it has succeeded in wearing down nearly to base level, giving steamboat navigation from Taylors Falls, Minn., to Mississippi River. Its descent in this distance of 48 miles is only 20 feet at low stages, nearly all of which is found in the upper half between Stillwater and Taylors Falls. At Stillwater, 223 miles above the mouth of the river, the sandstone bluffs rise steeply on either side to a height of 150 to 200 feet, and the river rapidly narrows. The bluffs continue, generally with a flat on one side, between Taylors Falls and Stillwater. In the 24 miles below Stillwater the river averages about half a mile in width, with a maximum of 7,000 feet at the expansion of the river known as St. Croix Lake, below Stillwater. For several miles here, according to reports of United States engineers, the river is almost without gradient.

The portion of the St. Croix above Taylors Falls abounds in undeveloped powers. Except near the headwaters of St. Croix, Totogatic, and Namekagon rivers and a small area served by a branch line of the Northern Pacific, running to Grantsburg, this region is without railroad facilities. The following detailed description of the main river above St. Croix rapids, taken from the Tenth Census, 1880, gives the most trustworthy information of the region obtainable:

From the mouth of the Eau Claire to that of the Namekagon River there is a descent of 100 feet, or 4 feet per mile, and many rapids occur, among which Copper Mine rapids may be mentioned. Above the mouth of the Namekagon the ordinary low-water power under a head of 10 feet would be 150 horsepower. The Namekagon River increases this to 600 horsepower.

In the 12 miles from the mouth of the Namekagon to the Yellow River the total fall is 20 feet, including Big Island rapids, State Line rapids, and Bishops rapids. Each of the first two is described as affording fine opportunities for developing water powers. At Big Island rapids the river runs close to the bluffs on the left bank, but a dam would need to extend some distance across the flat on the right.

From the mouth of the Yellow River to the head of Kettle rapids, a distance of 21 miles, the average slope is 1.8 feet per mile, there being no rapids of special importance. It is very probable that available water-power sites can be found in this section.

ST. CROIX RAPIDS.

The St. Croix rapids offer fine opportunities for water power, and were used at one time, but now the river flows unemployed. There is a total descent of 55 feet in the 6 miles which may be included under the name of St. Croix rapids. Several local names are indefinitely applied at different points. At the foot are Taylors Falls, about three-quarters of a mile above are St. Croix Falls, then Turtle Falls, etc. Strictly speaking, there are no falls in the entire distance, only a more rapid decline in the bed at certain places.

The village of Taylors Falls is situated in Minnesota, at the foot of the rapids, about 50 miles above the mouth of the river, at the head of navigation. St. Croix Falls, a village of Wisconsin, is situated upon the slope overlooking the river from that side, nearly opposite Taylors Falls. Directly below the rapids the river enters the Dalles of the St. Croix, where for half a mile or more it passes between vertical cliffs of trap rock with sharp edges and bold angles. Just above the entrance into the Dalles the water way is so contracted that when the river is high the water forms a fall of nearly 5 feet before it can overcome the resistance, but there is no very rapid descent there in low water. It is to this portion of the river that the name of Taylors Falls is given.

Above the Dalles the rock continues in the bed, and to a certain extent in the banks of the river, but the valley spreads considerably. On the Minnesota side the bank rises steep from the river for 30 or 40 feet at the lower part of the rapids. Back from this for several hundred feet is a nearly level plain, swampy in places; and bounding this are the bluffs, rising fully 100 feet higher. At the foot of the rapids the plain narrows and is lost in the Dalles. On the Wisconsin side, in the vicinity of St. Croix Falls, the slope is rather more uniform up to the general level of the country. At the entrance into the Dalles the river is scarcely more than 100 feet wide. At St. Croix Falls, three-quarters of a mile above Taylors Falls, it is between 200 and 300 feet wide, the average width of the river in this part of its course.

The portion of the rapids known as St. Croix Falls presents the most favorable site for improvement of the power, and here a dam was once built and sawmills were run. The bed is solid rock, and the banks rise abruptly from the river on both sides. On the Minnesota side a large, high mass of trap rock stands out in the channel and forms a natural abutment for a dam; on the Wisconsin side the rock bank rises to a considerable height above the water in a rib, and back of it is a depression which leads to the slope upon which the village of St. Croix Falls is situated. The improvement, long since gone to ruin, consisted of a dam built across the river at the point described, and a race blasted through the rock in the line of the depression on the Wisconsin side and then carried down the slope along the river front, giving a head of 25 or 30 feet. The dam was a very extensive structure, raising the water to a height of 25 feet when in good condition. It was 300 feet long, 24 feet wide at the top, and only 60 feet wide at the base. . . . The same natural facilities exist for developing the water power as formerly. . . . If the dam were built so as to give a head of about 40 feet, which is practicable, a race could be carried down the plain on the Minnesota side for a long distance as readily as on the Wisconsin shore. The pond would probably back the water 4 or 5 miles, and would not overflow much land. With the ordinary low flow the power under a head of 30 feet is 7,811 theoretical horsepower, and under a head of 40 feet, 10,415 theoretical horsepower. With the yearly average flow it is 17,266 theoretical horsepower under a head of 30 feet, and 23,021 theoretical horsepower under 40 feet. There is about 5 feet of fall in the river from the site of the dam to Taylors Falls. Here is an excellent site for the construction of a dam, which would scarcely be more than 100 feet long, but the vertical cliffs come close to the river just below, leaving only room for a small steamboat landing, without space to erect extensive manufactories.

KETTLE RIVER RAPIDS.

The Kettle River rapids are, next to the St. Croix rapids, the most prominent on the river. They start 2½ miles above the mouth of the Kettle River, which enters from the west, and end 1½ miles below it. In this length of 4 miles the total fall is 49 feet, of which 34 feet is above the mouth of the Kettle River. Two islands from 1 mile to 2 miles long divide the river into two channels. The bed of the river is solid rock and it is practical to build several dams. Above the mouth of the Kettle River a head of 10 feet would afford 1,280 theoretical horsepower, with the ordinary low-water flow, and below the entrance of the Kettle River 1,737 theoretical horsepower, under the same conditions of flow, according to the estimates previously given.

Above the mouth of the Snake River, which enters 4½ miles below the Kettle River, there is 11 feet of fall from the foot of the rapids. Between Snake River and St. Croix rapids are the following rapids: The Otter Slide, just below the mouth of the Snake, the ordinary low-water power of which, under a head of 10 feet, is 2,140 theoretical horsepower; the Horse Race, 1 mile below; the Baltimore rapids, a mile below the mouth of the Wood River, the ordinary low-water power of which, under a head of 10 feet, is 2,220 theoretical horsepower; the Upper Big Rock rapids, about 1 mile below them; and the Yellow Pine rapids, about 3 miles above the mouth of the Sunrise River. The amount of fall at each of these rapids can not be determined from the data at hand. The total fall from the mouth of Snake River to St. Croix rapids is 111 feet and the average slope is 2.64 feet per mile. This must furnish opportunities to develop power with what will be a reasonable expense at some time in the future.

TRIBUTARIES OF ST. CROIX RIVER.

LENGTH AND DRAINAGE.

The length and drainage area of the principal tributaries of St. Croix River, including those entering from the western (Minnesota) side, are shown in the following table:

Principal tributaries of St. Croix River.

River.	Length (map measure).	Drainage area.
	Miles.	*Sq. miles.*
Eau Claire	25	107
Namekagon	85	1,002
Yellow	50	310
Clam	50	416
Kettle (Minnesota)	70	1,093
Snake (Minnesota)	78	937
Wood	30	168
Apple	55	427
Willow	35	246

YELLOW RIVER.

Yellow River rises in a large lake called Mud Lake, at an elevation of 1,085 feet,[a] and after a sinuous course of 50 miles joins the St. Croix at a point only half this distance from the source and at an elevation of 888 feet. This gives a descent of 197 feet, an average of nearly 4 feet per mile. This high gradient results in rapids at frequent intervals throughout its entire course. The slope in the upper third of its length is about 120 feet. Here springs and creeks are numerous. The river is known to have a remarkably constant stage, the natural rise and fall during the year varying only from 1½ to 3½ feet. This fact may be attributed to the springs and to the regulating effect of the large lakes, especially Yellow Lake, through which it flows. "Its valley is generally narrow, being from 200 to 800 feet in width, although in some places it widens into tamarack marshes of considerable extent. The first banks have a general elevation of 15 feet above low water, running back into high, broken ridges, covered with white Norway and jack pine. Little stone and few bowlders are found until reaching the rapids below Yellow Lake, which are almost continuous to the mouth of the stream."[a]

Near the mouth of the river the banks are high. A dam could be built in sec. 27, T. 41 N., R. 16, which would develop a head of 25 feet or more and still not back the water up to the Yellow Lake dam. This power could be combined in the same plant with that furnished by Loon Creek, which enters Yellow River near the proposed dam. Loon Creek is said to descend 50 to 75 feet in a distance of 1½ miles, and is therefore of considerable importance. A dam could also be located in Yellow River about a mile above Yellow Lake, which would develop a head of 20 feet by overflowing some good meadow lands between Yellow and Devils lakes.

[a] Rept. Chief Eng. U. S. Army, 1880.

The following profile of Yellow River suggests the possibility of developing other powers on this river because of its high gradient in ranges 14 and 13:

Profile of Yellow River from its mouth to Mud Lake dam.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river			888.0		
2	Yellow Lake dam	7.0	7.0	928.0	40.0	5.7
3	SW. ¼ sec. 2, T. 39 N., R. 16 W	15.0	8.0	938.4	10.4	1.3
4	Rice Lake dam (SW. ¼ sec. 16, T. 39, N., R. 14 W)	34.0	19.0	969.4	31.0	1.6
5	SE. ¼ sec. 25, T. 39 N., R. 14 W	39.5	5.5	994.4	25.0	4.5
6	Sec. 31 (near north ¼ stake), T. 39 N., R. 13 W	40.5	1.0	1,004.8	10.4	10.4
7	SW. ¼ sec. 32, T. 39 N., R. 13 W	41.5	1.0	1,011.6	6.8	6.8
8	Harts (SE. ¼ sec. 5, T. 38 N., R. 13)	42.5	1.0	1,019.0	8.4	8.4
9	Sec. 36 (near north-south ¼ line), T. 39 N., R. 13 W	47.5	5.0	1,046.8	27.8	5.6
10	Spooner	49.0	1.5	1,058.0	11.2	7.5
11	Mud Lake dam (above)	52.0	3.0	1,085.0	27.0	9.0

[a] Authority: Nos. 1-9 and 11, U. S. engineers; 10, Chicago, St. Paul, Minneapolis and Omaha Rwy.

Important logging dams are described by United States engineers as follows:

Logging dams on Yellow River.

Name.	Location.	Head.	Capacity.	Remarks.
		Feet.	*Cubic feet.*	
Mud Lake dam	Sec. 27, T. 39 N., R. 12 W	7.5	475,000,000	
Hector dam	Sec. 10, T. 38 N., R. 13 W	7.5		Small capacity.
Rice Lake dam	Sec. 20, T. 39 N., R. 14 W	10.0	700,000,000	Head could be increased to 15 feet.
Yellow Lake dam	Sec. 7, T. 40 N., R. 16 W	18.0	1,400,000,000	Raises water in Yellow Lake 3 feet.

EAU CLAIRE RIVER.

Eau Claire River has its source in lakes of the same name at an elevation of 1,122 feet [a] above sea level. These lakes are surrounded by high banks, so that at small expense a dam could be constructed at their outlet and made to store surplus waters, thus adding greatly to all water power on the river. In its short length of 25 miles this river descends 118 feet, including several rapids, 46 feet of this descent being concentrated in the first 6 miles below Eau Claire Lakes. The total drainage area of the river is 107 square miles.

APPLE RIVER.

Apple River, like the Willow, occupies a comparatively well-settled valley. It drains an area of 427 square miles. The Wisconsin Central, the Chicago, St. Paul, Minneapolis and Omaha, and the Minneapolis, St. Paul and Sault Ste. Marie railways are distant 1 to 5 miles from the river, the last-named road crossing it near Amery. The river has its source in 20 or more lakes, the largest 6 miles long and one-half to three-fourths of a mile wide. These lakes tend to equalize and increase the summer flow. The long and severe winters cause the minimum flow during the months of January and February.

Formerly most of the dams on Apple River were used in connection with logging operations, but the timber is now practically all cut. Flouring mills have been maintained at

[a] Rept. Chief Eng. U. S. Army, 1883.

a number of points, and at others the power is used for electric lighting. There are several projects at the present time which look to large improvements of some of these powers. The river in the first and last thirds of its course runs through the Cambrian sandstone, while its middle third is through the "Lower Magnesian" limestone. In the lower third of its course the river flows over a rocky bed between rocky banks, giving ideal conditions for dams. Most of the larger powers occur in this stretch, and some of these, developed and undeveloped, are described below:

1. The first power on the river is an undeveloped one located about 1½ miles from its mouth. A dam at this point would give a head of 15 feet.

2. The second power, owned by the St. Croix Power Company, is located about 2 miles from the mouth. Here a concrete dam of the arch type, 250 feet long and 47 feet high, develops a head of 82 feet.

3. Four miles from the mouth is a gristmill with a head of 11 feet, owned by E. E. Mason.

4. The next dam, located in sec. 35, T. 31 N., R. 19 W., develops a head of 18 feet.

5. Another dam, located in sec. 31, T. 31 N., R. 18 W., with a head of 22 feet, is owned, under the name of the Apple River Power Company, by the Western Gas and Investment Company of Chicago, which also owns No. 4, described above.

6. A dam 12 miles above the mouth of Apple River gives a head of 29 feet. The discharge at this point is about 80 per cent of the total flow measured at the mouth. This power is transmitted electrically to New Richmond, where it is used by mills and elevators.

The powers on Apple River of less importance are described in the following table:

Minor water powers on Apple River.

Location.	Owner and use.	Head.	Remarks.
Above mouth:		*Feet.*	
13 miles	H. L. Bixby, flour	11	Developed.
13½ miles	M. C. Duggles & Jewett	8	Undeveloped.
15½ miles (Star Prairie)	H. L. Bixby		Do.
25½ miles	J. C. Schnyder, flour	12	Developed.
Sec. 17, T. 12. N, R. 13 W	Winger & Winger	2	Do.
One-half mile above last site	J. Stucky, gristmill	12	Do.
Amery	Northern Supply Co., elevators.	12	One-half total discharge developed
Blakes Lake	Blake	12	Developed; can be made 18 feet

There are many other powers above Blakes Lake, with heads of from 6 to 20 feet, mostly old logging dams in poor condition. When the region becomes more settled some of these powers will be improved.

The following data on the discharge of Apple River for the year 1903 are furnished by John Pearson, superintendent of the St. Croix Power Company, Somerset, Wis. The computations are based on the capacity of turbines located at a point 2 miles from the mouth of Apple River. The average daily discharge for each month is as follows:

Estimated daily discharge of Apple River near Somerset, Wis., for 1903.

Month.	Discharge.	Month.	Discharge.	Month.	Discharge.
	Sec.-feet.		*Sec.-feet.*		*Sec.-feet.*
January	258	May	860	September	690
February	239	June	468	October	660
March	600	July	492	November	362
April	555	August	380	December	324

WILLOW RIVER.

Willow River, one of the smaller tributaries of the St. Croix, has a high gradient, due to the fact that its bed lies in the "Lower Magnesian" limestone for its entire length. It drains an area of only 246 square miles and has a length of about 35 miles. In the lower two-thirds of this distance, between Hudson and Jewett Mills, it descends 213 feet, giving many opportunities for water power. Many of these powers are improved, as the river traverses a fairly rich and well-settled country and is paralleled for a considerable distance either by the Wisconsin Central or the Chicago, St. Paul, Minneapolis and Omaha Railway. The powers are here briefly described in order, beginning at the mouth:

1. A timber dam at Hudson 100 feet long gives a head of 16 feet, and with improved machinery would develop 117 horsepower at ordinary low water. A part of this power is used occasionally for electric light when the power described as No. 3 is short of water.

2. Two miles from the mouth of Willow River a dam formerly developed a 9-foot head and was used for driving a flouring mill. At present this dam is washed out.

3. The 130-foot dam of the Willow River Electric Light and Power plant, 3½ miles from the mouth of the river, gives a head of 22 feet, sufficient to develop 200 theoretical horsepower at ordinary low-water flow. The power is used to generate electricity for lighting the city of Hudson, Wis., and for pumping its water supply.

4. A timber dam 100 feet long, 5½ miles from the mouth of Willow River, gives a head of 24 feet, sufficient to develop about 125 horsepower. This power is used for a flouring mill. About 1,200 feet below this dam there is a fall of about 47 feet, and at this point a new dam could be erected, which could be made to include the 24-foot dam above, giving a total head of 71 feet. Such a dam would need to be about 26 feet high and about 70 or 80 feet long. By carrying the water a short distance below in a penstock, a total head of 105 feet could be secured, sufficient to develop about 600 horsepower at ordinary flow of water. This site, being where the river bed changes from the "Lower Magnesian" limestone to the Cambrian sandstone, affords ideal conditions for a dam. The town of Burkhardt, on the Chicago, St. Paul, Minneapolis and Omaha Railway, is located about a mile distant.

5. Seven miles from the mouth of Willow River a 100-foot timber dam gives a head of 16 feet. This power is used to run dynamos.

6. Rapids occur 8½ miles from the mouth of Willow River. A dam 125 feet long at this point, located at comparatively small expense in a narrow limestone gorge, could be made to develop a head of 22 feet.

7. At a point about 11 miles from the mouth of Willow River the Boardman flouring mills were formerly located. The 80-foot timber dam at this point was washed out some time ago, but the mill still stands. If the dam were replaced, a head of 16 feet or more could be easily developed. All the above powers on Willow River are owned by C. Burkhardt, who has the right of flowage wherever needed along this stretch of 11 miles, giving an aggregate descent of nearly 200 feet.

8. The next power on Willow River is located at New Richmond. A timber dam 40 feet long, owned by the New Richmond roller mills, develops a head of 18 feet.

9. The last dam on this stream is located at Jewett, 5 miles east of New Richmond. Power afforded by a 10-foot head is owned by P. Newell & Hennesey and used in a feed mill and sawmill. Above this point Willow River is too small for water-power use.

CLAM RIVER.

Clam River drains an area of 416 square miles. It is formed by two branches—North Fork and South Fork—which unite near the center of the drainage area just above Clam Lake. The river descends about 350 feet in a total length of 50 miles, and, as much of this high gradient is concentrated at rapids, several good opportunities are offered for development. The river flows through a comparatively thinly settled region, which as yet has no railroads. Several railroads, however, cross the margins of the drainage. The

following statements regarding its principal water powers are based on information given the writer by Edward L. Peet, editor of the Journal, Grantsburg, Burnett County.

A large, unimproved water power exists in T. 40 N., near the line between Rs. 17 and 18 W. At this point the banks of Clam River are 80 to 150 feet high, and the land which would be flooded is low and of little value. Above the proposed dam the valley bottom will average half a mile wide, with a few expansions to 1½ miles. The bed of the river is clay and bowlders, mixed with sand. Plenty of timber for the construction of a dam grows in the swamps close at hand. Bowlders are also abundant at the dam site. The levels taken on a recent survey show that this power could be improved in the following ways: A dam 6 rods long at the range line would give a head of 20 feet. A dam 10 rods long built farther downstream would produce a head of 35 feet. By adding a 6-foot embankment for a distance of 20 rods this head could be increased to 28 feet; or a dam 60 rods long could be built across the valley with an average height of 40 feet and a maximum height of 85 feet. If the water were conducted by canal a distance of about a mile to the lowlands adjacent to St. Croix River, turbines could be installed with a head of 100 feet. This dam site is distant only 3 miles from other large, undeveloped powers on St. Croix and Yellow rivers, with which it could be easily and cheaply connected by electric transmission.

About half a mile below Clam Lake there is now a logging dam with a head of about 20 feet which raises the water in the lake 3 or 4 feet. This dam impounds the water from a drainage area of 283 square miles. United States engineers reported that a dam would need to be 560 feet long at this point to produce a head of 25 feet. Such a dam would have a capacity of 4,670,786,000 cubic feet,[a] and if properly regulated could be made to greatly increase the amount and value of the powers below. The engineers found that the bed of the river consisted of sand from 3 to 20 feet, at which depths soundings indicated hard materials, supposed to be clay and gravel.

Another large water power is found at Clam Falls, in sec. 13, T. 37 N., R. 16 W., where the river falls over a wide ledge of the "Keweenawan" rocks. A dam at this point impounds the drainage from an area of 45 square miles and develops a head of 34 feet. Between Clam Falls and Clam Lake the slope is small and the river valley half a mile to 1½ miles wide. The river profile is shown in the following table, compiled from surveys made by United States engineers:

Profile of Clam River from its mouth to Clam Falls.

Station.	Distance.		Elevation above sea level.	Descent between points.	
	From mouth.	Between points.		Total.	Per mile.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Mouth of river			868		
St. Croix, road crossing	6.0	6.0	881	13	2.2
Clam Lake, mouth	19.0	13.0	947	66	5.1
Sec. 35, T. 38 N., R. 16 W., south line	29.0	10.0	967	20	2.0
Clam Falls	32.5	3.5			

NAMEKAGON AND TOTOGATIC RIVERS.

Namekagon River rises in a large lake of the same name near the divide in the watersheds of Chippewa and Bad rivers. Its drainage area is second in extent of all the St. Croix tributaries. Namekagon Lake is formed by six or more connected lakes, occupying parts of 14 sections and surrounded by extensive cedar and tamarack marshes. In the upper 60 miles of its course the river is generally narrow and swift, stretches of rapids over

[a] Rept. Chief Eng. U. S. Army 1880, p. 1619.

pre-Cambrian crystalline rock being frequent.[a] There are also several vertical falls of 2 to 4 feet, which, together with the rapids, furnish good opportunities for water powers. The banks are high on either side, stretching away into high, broken ridges and sand barrens covered with timber. In the remaining 25 miles of its length the river is from 100 to 200 feet wide. In this reach it descends 130 feet, including several sharp pitches and rapids, the principal of which are Little and Big Bull rapids and Dupee flats. The average slope of the river is 5.3 feet per mile.

A good location for a dam is found 4 miles above the mouth of the river, where the high gravel banks approach within 600 feet. A head of 20 feet or more could be obtained here without overflowing much land, impounding the drainage from 1,000 square miles. With the ordinary low-water flow estimated at one-third of a second-foot per square mile, this would produce 740 theoretical horsepower. Because of the storage effect of the present dams above this point, the river at this site might be made to produce nearly 1,000 horsepower. Another good location for a dam is found at Veazie, on the Chicago, St. Paul, Minneapolis and Omaha Railway. By overflowing 6,000 acres, mostly railroad and Government land, a head of 30 feet could be obtained, according to United States engineers. A dam of 15 feet head would cause little overflow. Such a dam would have the run-off from about 800 square miles and at ordinary low water would produce 275 theoretical horsepower. Small dams are located at Stinnett and at the outlet of Lake Namekagon. A dam owned by the Hayward Electric Light and Power Company, located near Hayward, develops 200 horsepower and is used for light and power purposes in that city.

Additional information regarding undeveloped powers is given in the following profile:

Profile of Namekagon River from its mouth to Cable, Wis.[a]

No.	Station.	Distance.		Elevation above sea level.	Descent between points.	
		From mouth.	Between points.		Total.	Per mile.
		Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
1	Mouth of river			±908.0		
2	Sec. 33, T. 43 N., R. 14 W., east side	4.0	4.0	917.8	9.8	2.4
3	Totogatic River, mouth	5.0	1.0	918.0	.2	.2
4	McKinzie Creek, mouth, sec. 28, T. 42 N., R. 13 W.	13.0	8.0	944.0	26.0	3.2
5	Stuntz Brook, mouth, sec. 27, T. 42 N., R. 13 W.	15.0	2.0	952.0	8.0	4.0
6	N. E. ¼ sec. 34, T. 41 N., R. 13 W	16.0	1.0	958.0	6.0	6.0
7	NW. ¼ sec. 6, T. 40 N., R. 12 W	19.5	3.5	990.0	32.0	9.0
8	Sec. 18, T. 40 N., R. 12 W., near center	21.5	2.0	1,004.5	14.5	7.2
9	Sec. 39, T. 40 N., R. 12 W., near center	24.0	2.5	1,024.2	19.7	7.9
10	SW. ¼ sec. 27, T. 40 N., R. 12 W	25.5	1.5	1,025.2	1.0	.7
11	Veazie, sec. 36, T. 40 N., R. 12 W	28.5	3.0	1,039.0	13.8	4.6
12	River Jordan, mouth, sec. 21, T. 40 N., R. 11 W.	35.5	7.0	1,058.0	19.0	2.7
13	Spring Brook, mouth, sec. 15, T. 40 N., R. 11 W.	37.0	1.5	1,068.0	10.0	6.6
14	Chippenacia Creek, mouth, sec. 33, T. 40 N., R. 10 W	43.0	6.0	1,115.0	47.0	7.8
15	Stinnett	45.0	12.0	1,136.0	21.0	10.5
16	Little Puckanance	59.0	14.0	1,218.0	82.0	5.9
17	Cable, Bayfield County	70.0	11.0	1,303.0	85.0	7.7

[a] Authority: Nos. 1–14, and 16, U. S. engineers; 15 and 17, Chicago, St. Paul, Minneapolis and Omaha Railway.

In its length of 55 miles, Totogatic River, the principal tributary of the Namekagon, descends 350 feet. It enters the main stream only 5 miles above its mouth. The region is high and precipitous, with frequent ledges of pre-Cambrian crystalline rock and bowlders. As a result, the stream forms for miles a series of rapids with many vertical falls of 10 feet or more. Many logging dams already exist, the most important being located

[a] Simar, V. B., Asst. U. S. Engineer: Rept. Chief Eng. U. S. Army, 1889, p. 1616.

as follows: Sec. 13, T. 42 N., R. 10 W.; sec. 6, T. 42 N., R. 10 W.; and sec. 12, T. 43 N., R. 10 W. A good site for a dam is near the outlet of Gilmore Lake, in sec. 9, T. 42 N., R. 12 W.; and another in sec. 12, T. 42 N., R. 12 W. The following profile of Totogatic River is compiled from surveys made by United States engineers:

Profile of Totogatic River from its mouth to NE. ¼ sec. 15, T. 42 N., R. 9 W.

Station.	Distance.		Elevation above sea level.	Descent between points.	
	From mouth.	Between points.		Total.	Per mile.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Mouth of river			918.0		
Sec. 13, T. 42 N., R. 13 W., dam	11.5	11.5	975.5	57.5	5.0
NE. ¼ sec. 10, T. 42 N., R. 12 W	20.0	8.5	1,008.8	23.3	2.7
NE. ¼ sec. 3, T. 42 N., R. 10 W.	37.0	17.0	1,168.4	159.6	9.4
NE. ¼ sec. 13, T. 42 N., R. 10 W	40.0	3.0	1,241.6	73.2	24.4
NE. ¼ sec. 15, T. 42 N., R. 9 W	50.0	10.0	1,251.6	10.0	1.0

MINOR STREAMS.

Osceola Creek.—Emptying into St. Croix River a few miles south of Willow River is a small stream known as Osceola Creek. In the city of Osceola, near its mouth, is a water power with a head of 90 feet, owned by the Osceola Mill and Elevator Company. This dam furnishes the power to run a mill with a capacity of 175 barrels per day. One-fourth of a mile above is another dam with a head of 26 feet.

Kinnikinnic River.—A small river emptying into St. Croix River only 5 miles above its mouth bears this name. Its gradient is so high that there are a number of good sites for water powers. The descent in 10 miles is 190 feet. The following is a tabulated statement of its water power:

Water powers on Kinnikinnic River.[a]

No.	Location.	Owner and use.	Head.	Estimated horsepower.	Remarks.
			Feet		
1	2 miles from mouth	N. Kohl, flouring mill	10	70	Timber dam.
2	5 miles from mouth				Good dam location.
3	7 miles from mouth		20		
	River Falls:				
4	3 miles below		14		
5	1 mile below	City waterworks	15	60	Timber dam, 9 by 120.
6	River Falls	do	39	140	Timber dam.
7	do	Geo. Fortune, mill and elevator	8	40	Timber dam, 4 by 210.
8	do	Prairie mill and elevator	14	60	Timber dam, 12 by 180.
9	7 miles above River Falls.	Clapp's mill	10		Dam out.
10	South Branch, sec. 1, T. 27 N., R. 19 W.	W. H. Putnam, feed and flour	50	30	Timber dam, 26 by 114
11	1 mile above No. 10	Glass Bros., manufacturers	14		
12	Balsom Lake	J. W. Park, lumber and flour		180	

[a] Figures are low-water estimates. Nos. 1 and 5–12 developed; 2–4, undeveloped.

LAKE SUPERIOR DRAINAGE SYSTEM.

TOPOGRAPHY.

The watershed which limits the area of Lake Superior drainage in Wisconsin varies in elevation (above the level of Lake Superior) from 600 feet near the Minnesota line to over 1,000 feet near the Michigan line. Its average distance from Lake Superior is only 30 miles. For this reason the rivers are comparatively small; but owing to the fact that their high gradient, 600 to 1,000 feet, is largely concentrated at a few points, they offer many opportunities for water-power development. From a point near the center of the watershed a wide and nearly flat table-land, of which Bayfield Peninsula and the Apostle Islands form the northern prolongation, separates the drainage into eastern and western sections of nearly equal area. In both of these sections three distinct belts of topography are usually distinguished. The southernmost belt consists of a plateau in large part covered with swamps and lakes and is so flat that in many cases the water from the same swamps and lakes may flow either north to Lake Superior or south to the Mississippi.

From this flat watershed the descent northward is gradual until a range of mountains from 600 to 900 feet above the level of Lake Superior is reached. The northern slope of these mountains is much steeper than their southern slope, forming a marked though not continuous escarpment.

In the western section these mountains, known as Douglas Copper Range, reach a height of 400 to 600 feet above the lake and have a width of 1 to 4 miles. They extend in an east-northeast direction, gradually merging into the Bayfield moraine. From the crest of the mountains there is a sudden descent of 300 to 400 feet, caused by a faulting of the rocks. The Lake Superior rivers break through the ridges at this point, and here the greatest opportunities for water-power development are to be found.

In the eastern section the mountains, called the Penokee Iron Range, extend from a point on the Michigan boundary, 12 miles from Lake Superior, in a southwesterly direction for about 35 miles, gradually merging into the plateau. As in the western section, many falls and rapids occur in breaking through the hard "Huronian" rocks of which the range is composed. Smaller falls continue for a distance of 5 to 6 miles after crossing the Penokee Range, or until the Copper Range has been crossed.

To the north of the highlands and extending with a gradual slope northward to the shores of Lake Superior lies a plain with a width of 5 to 15 miles. Its northern portion reaches an elevation of 100 to 200 feet above Lake Superior or 700 to 800 feet above the sea. The entire belt is underlain by till and deep layers of red clays sometimes mixed with sand. The rivers, both large and small, have cut deep and narrow banks in the clay soil. As a result the surface is carved in every direction by narrow water courses whose steep sides have a height of 25 to 100 feet, making railroad and highway construction expensive. Very few swamps are found in this lowland area. Because of the gradual slope of the shallow rivers opportunities for water-power development in this belt are rare. In many cases, however, there are important falls at the immediate mouths of the rivers and over the red sandstone.

WATER POWERS.

CHARACTER.

Owing to the fact that the rivers of the Lake Superior system in Wisconsin have a total fall of 400 to 1,000 feet in the narrow belt of 30 miles separating the plateau region in which they rise from Lake Superior, their currents are characteristically rapid. As a result the rainfall is quickly discharged, the streams alternating between small creeks and torrential rivers. While the storage of surplus waters is important everywhere in the State for the economical development of water power, it is here doubly so. The fact that the most important falls and rapids are in the upper half of the drainage area increases the difficulty of storing a large proportion of the rainfall. With a storage of less than 5 to 15 per cent of the rainfall most of the rivers would furnish at low water an insignificant flow.

Rainfall data regarding this drainage area are scanty, but sufficient to show that the rainfall increases from the lake to the highlands. This fact is strikingly shown by the precipitation map published by the United States Weather Bureau and shown in fig. 1 (p. 16). It is here seen that the rainfall increases southward at the average rate of about 5 inches every 25 miles, the maximum not being reached until after the highlands are passed. This fact has an important bearing on the value of the water powers, because, as already stated, it necessitates the location of reservoirs to a large extent in this region of greatest rainfall. The most important water powers occur near the Copper ranges and the Penokee Iron Range, where future mining operations may render them of much economic importance.

ST. LOUIS RIVER.

Although the water powers of St. Louis River lie outside the State, they are located so near the Wisconsin boundary that development contemplates their extensive use in Supe-

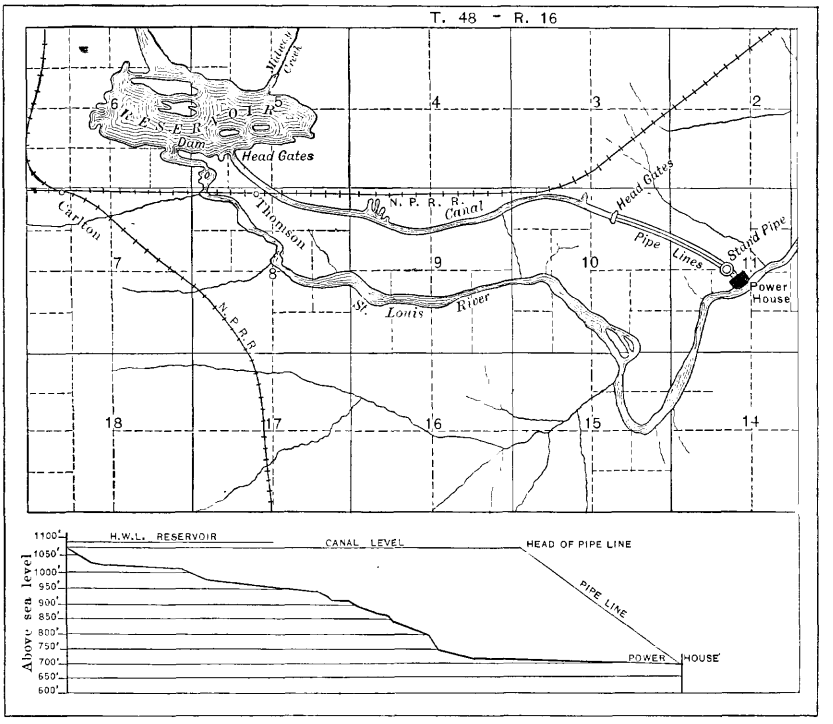

FIG. 5.—Plan of canal of Great Northern Power Company, St. Louis River.

rior and other Wisconsin cities. An important feature of St. Louis River is the concentration of its descent in the lower reaches, where its volume is greatest. This provides opportunities for water power which if distributed among its smaller tributaries would be in large part wasted. The upper portions of St. Louis River are sluggish, flowing through many lakes and swamps, but as the waters near the lake their speed is increased until at a point about 22 miles from Lake Superior, just above Fond du Lac, there is a series of falls and rapids extending 6 miles upstream from a point 2 miles from the Wisconsin boundary. In this distance of 6 miles the river descends 456 feet in a series of wild leaps over the upturned ledges of slate rock, forming a water power which has few superiors in the West. This power and the riparian rights are owned by the Great Northern Power Company. Mr.

F. A. Cokefair, chief engineer of the company, furnishes the following statement under date of January 23, 1904:

One steel gravity dam 36 feet high and 620 feet long has already been constructed near the village of Thompson. This dam conserves the water in a reservior of about 1 square mile of area, from which the water is led through a canal 2½ miles long, 62 feet wide, and 15 feet deep. (Fig. 5.) From the terminus of the canal the water is taken by iron pipes for a distance of about a mile and delivered under a head of 365 feet at the power house midway between Thompson and Fond du Lac. The capacity of this canal is sufficient to develop 100,000 horsepower. Final plans and designs are now completed, and work on the first station for the ultimate development of 100,000 horsepower will begin in the early spring. Bids have been asked from leading manufacturers for the first three wheels of 12,500 horsepower capacity each, the largest units ever yet built and similar to those in use at Niagara Falls. Transmission lines will carry the power to the neighboring cities of Duluth and Superior, and even farther to the Mesabi and other iron ranges, where it will augment or displace steam power.

NEMADJI AND BLACK RIVERS.[a]

Unlike other rivers of the Lake Superior watershed, Nemadji River flows northeast instead of north and does not rise in an elevated region. As a result it is devoid of important rapids or falls suitable for water power.

Black River, the most important tributary of the Nemadji, rises in an elevated country, its source being in a lake on the Minnesota boundary. It flows north and empties into Nemadji River about 10 miles from Lake Superior at an elevation of only 20 feet above the lake. In the upper two-thirds of its length Black River flows through many tamarack and cedar swamps, which give to its waters a distinct color and taste. Up to about 4 miles from the Douglas Copper Range it occupies a wide valley with small descent. As this range is approached the valley narrows and its gradient increases. In the SE. ¼ sec. 28, T. 47 N., R. 14 W. the hard layers of the "Keweenawan" rocks cross the river, producing a vertical fall of 31 feet A total head of 160 feet[b] could easily be obtained here for a dam site. As Black River has a drainage area of 80 square miles above these falls, an assumed run-off of 0.4 second-foot per square mile gives 560 theoretical horsepower. A company was formed some time ago to improve this power, and a franchise was secured from the city of Superior for lighting by electricity, but no construction has yet been done. The water at the head of the upper rapids is 387 feet above Lake Superior; at their foot, 50 yards beyond, the elevation is 227 feet. From this point the river passes for nearly a mile through a gorge 100 to 170 feet deep, below which the walls of the gorge are less elevated above the stream, but the current is very rapid until it joins Nemadji River 4 miles below. From the foot of Black River Falls to the junction with the Nemadji the total descent is 200 feet, an average of 50 feet to the mile.

BOIS BRULE RIVER.

Though over 33 miles long, Bois Brule River has a drainage area of only 200 square miles, practically all of which is in the highland district. It rises in a swamp, near St. Croix Lake, at an elevation of 420 feet above the level of Lake Superior. In sec. 15, T. 46 N., R. 10 W., at the Dalles, Bois Brule River is only 25 feet wide, with banks of clay and bowlders averaging 8 feet in height. Near this point there are swift rap ds, with a total descent of about 15 feet in 200 yards. Similar rapids about 3 miles farther north, near the township line, continue as far as the mouth of Nebagemain River, the most important tributary of the Bois Brule, in sec. 27, T. 47 N., R. 10 W. For the next 10 or 12 miles the current is very sluggish until the head of the lower rapids is reached, in sec. 26, T. 48 N., R. 10 W. From this point to within 1½ miles of Lake Superior rapids and small falls (the largest being 4 or 5 feet in height) occur almost continuously. These descend an aggregate of 200 feet over "Keweenawan" eruptives and sandstones. By constructing dams at the outlets of Lakes Nebagemain and Minnesung the surplus water could be held

[a] The authority for most of the statements concerning the Lake Superior rivers is Prof. R. D. Irving: Geology of Wisconsin, vol. 3, 1880.
[b] Sweet, E. T., Geol. Wisconsin, vol. 3, 1880, p. 319.

back and used at times of low water, thus adding greatly to the value of the water powers on the river. At present there are no dams. Mr. Howard Thomas, city engineer of Superior, Wis., states that the normal discharge of this river is 100 second-feet, and that at several points heads of 40 feet could be obtained by dams between bluffs or with dams and flumes along the banks. Such a head would give 450 theoretical horsepower. Because of its comparatively small watershed and the fact that the river is fed very largely by springs it is not subject to freshets.

MONTREAL AND GOGOSHUNGUN RIVERS.

For nearly its entire length Montreal River forms a part of the Michigan-Wisconsin boundary. It rises in a tangle of lakes and tamarack swamps near the boundary line at an elevation of about 1,600 feet above sea level, or 1,000 feet above Lake Superior. Its length is 50 miles, the highest gradient being concentrated in the last quarter of this distance. This exception to the general rule of the Lake Superior drainage area is due to the fact that here the Penokee Iron Range and its associated highlands of the "Keweenawan" series approach Lake Superior within a distance of only 3 miles, leaving no lowland region.

About 1,300 feet from its mouth, on the north line of sec. 7, T. 47 N., R. 1 E., is a vertical fall of 35 feet over sandstone. It is stated by an officer of the Duluth, South Shore and Atlantic Railway that a head of 55 feet could be developed here by constructing a flume 100 feet long. Because of the lakes and swamps at the headwaters of this river it is likely that at least 5 per cent of the annual rainfall could be stored in reservoirs. This would give, from its 280 square miles of drainage area, an ordinary flow of 140 second-feet, equivalent, with a head of 55 feet, to 868 theoretical horsepower. In the last five-eighths of a mile of its course Montreal River descends 90 feet. The railway official mentioned above also states that another power site is located in the NW. ¼ SW. ¼ sec. 21, T. 47 N., R. 1 E., at falls of 60 feet over the crystalline rocks. As the banks are high, a 20-foot dam, with a flume 250 feet long, would develop a head of 80 feet. Both of the above powers are within 4 miles of the Duluth, South Shore and Atlantic Railway. At Ironwood, about 2 miles above these falls, the river has an elevation of 880 feet. In the 5 miles above Ironwood the river descends only 30 feet, and for the remainder of its upper reaches its current is slow. At all the rapids on this river the conditions are favorable for the building of dams.

The Gogoshungun, a branch of the Montreal, is nearly as large as the upper Montreal, being about 30 miles long. Its total descent is 500 feet. Until the river reaches the Penokee Range its current is sluggish, being bordered by swamps. In its passage through the mountains, in sec. 27, T. 46 N., R. 2 E., a number of rapids and falls occur.

BAD RIVER.

MAIN RIVER.

The sources of Bad River lie in large swamps 8 miles south of the Penokee Iron Range, at an elevation of 900 feet above the level of Lake Superior. In this distance of 8 miles its descent is 110 feet, but its course is sinuous, as may be inferred from the fact that the Wisconsin Central Railway is forced to cross it eight times. About 1½ miles above Mellen are rapids called Copper Falls, which have a total descent of about 60 feet. (Pl. V, *B*.) The river at this point has a drainage area of about 144 square miles. According to a survey, 5 per cent of the annual rainfall could be easily stored in dams near the headwaters, which should provide an ordinary flow of 68 second-feet, equivalent to 460 theoretical horsepower.

Near the Penokee Range Bad River enters a gorge of pinkish granite, narrowing in places to a width of 10 feet and descending 20 feet in 30 rods, with a total descent of 50 feet in three-fourths of a mile. The river then widens and continues with reduced grade until Penokee Gap is reached, when it again contracts. Coming into contact with the "Huronian" rocks, it flows along their strike. In the next 4 miles occur many rapids and several

falls, including one of 35 feet. In the next 1,000 feet, in which the river descends 40 feet, Tylers Fork, the most important tributary, is reached. Directly at the junction Tylers Fork has a fall of 45 feet over the wall of a gorge 65 feet deep. This is in sec. 17, T. 45 N., R. 2 W. A competent engineer, reporting on this water power, states that dams could develop here a head of about 120 feet. The tributary drainage area is given at 234 square miles. On the assumption that the rainfall is only 32 inches and that reservoirs can be made to store 15 per cent of the rainfall, it was estimated that the river would furnish a continuous flow of 206 second-feet, equivalent to about 3,000 theoretical horsepower. It was proposed to conduct this power electrically to Ashland.

In the next 1,000 feet below Tylers Fork the river flows through a rocky gorge 100 feet deep, beyond which the rocks disappear and the stream flows between high banks of red clay, the ground rising rapidly on both sides. The total descent in sec. 17 is probably 135 feet. In the next 6 miles of its sinuous course, to the mouth of Maringouin River, the river descends about 30 feet to the mile. Both rivers at their confluence are broad and deep, with slow-moving, muddy currents and wide bottom lands—conditions which continue to the mouth of Bad River.

Farther north, 2¼ miles from this junction, Bad River receives the waters of Potato River. At this point its elevation is 80 feet above the level of Lake Superior. In sec. 25, T. 47 N., R. 3 W., occur some small falls, of 1 or 2 feet, over red sandstone and shale, which continue for perhaps 2 miles. Below these falls Bad River continues sluggish, deep, and tortuous, with bold and high clay banks, until White River is reached. For the remainder of its course the river finds its way to Lake Superior through swamps.

TRIBUTARIES.

The principal tributaries of Bad River, named in order from its mouth, are as follows: White River entering from the west; Potato River from the east; Maringouin or Mosquito River from the west, and Tylers Fork from the east.

White River.—This river, the largest tributary of Bad River, has a total length of about 45 miles, and drains an area of 400 square miles. It rises in Long Lake, at about 700 feet above the level of Lake Superior. Most of its descent is concentrated in its upper waters, where its discharge is least. It pursues a general northeasterly course, with many windings through high and steep clay banks, like those described on Bad River. Its only considerable falls are in sec. 6, T. 46 N., R. 4 W., where the river was originally obstructed by the edges of southward-dipping rocks. A dam with a 20-foot head has been maintained here for several years, and until October, 1903, furnished the power to run a paper mill. At that time the mill burned, and it has not been rebuilt. It had turbines rated at 710 horsepower. The owner, George Davidson, reports that he has a charter for a dam with 30-foot head, to be located about 1,300 feet upstream. The main dam as planned would be 125 feet long, with an embankment 10 to 12 feet high and 900 feet long. Mr. Davidson also states that about 500 feet below the present dam there is a location for a dam with a 9-foot head. At three dam sites the bed of the river is in sandstone which extends 10 feet above the water surface. The rock is overlain with red clay.

Maringouin River.—Maringouin River, sometimes also called Maringo (Mosquito) River, has a total length of about 40 miles and drains an area of 231 square miles. Four miles from its source it crosses the Penokee Range. Here, in the NW. ¼ sec. 23, T. 44 N., R. 5 W., the river descends, in a series of three falls, a total distance of 65 feet within a few rods. The two upper falls, of 15 and 25 feet, respectively, are only 50 feet apart. Nothing but the limited amount of water prevents this from being a valuable water power. For the remainder of its course the river is devoid of falls or rapids, flowing between high clay banks.

Within 6 miles of its junction with Bad River, the Maringouin receives several rapid tributaries, the most important of which is Brunsweiler Creek. This creek rises in the same swamp with Maringouin River, but, unlike it, has important falls north of the "Huroman" hills. Until Bladder Lake is passed in sec. 11, T. 44 N., R. 4 W., the cur-

rent is sluggish. The outlet of this lake is only 6 feet wide, with rock walls on either side. A dam which would greatly raise the water in the lake could be constructed here at slight expense. At the outlet of the lake there is a long series of chutes and rapids for a distance of over 6 miles. In this stretch the creek flows through a narrow valley with steep, rocky hills. The last important descent occurs near the north line of sec. 22, T. 45 N., R. 4 E., where the stream leaves the Copper Range, the slope being 30 feet in a distance of 130 feet.

Tylers Fork.—This tributary is the only one which joins Bad River before the lowlands are reached. Tylers Fork, nevertheless, has a length of 30 miles and a total descent of 700 feet. Until it reaches the Penokee Range its current is sluggish. In the NE. ¼ sec. 33, T. 45 N., R. 1 W., the river falls 20 feet over the hard "Huronian" rock. Less than a mile farther on, in sec. 28, occurs a series of low falls over black slate, the descent being 20 feet in a distance of 500 feet. On the north line of sec. 20 the river surface is 760 feet above the level of Lake Superior. In the next 10 miles of its course it descends 260 feet, but without any considerable rapids. On the west line of sec. 15, T. 45 N., R. 2 W., the elevation of the water is 485 feet. The current now becomes swifter and about a quarter of a mile below the east line of sec. 16 is a series of rapids which continues to its junction with Bad River, ending in the 45-foot fall already described (p. —). As these falls and rapids are within a mile of the Wisconsin Central Railway, they seem destined to become of some economic importance.

Potato River.—In its course of only 30 miles, Potato River has a total descent of over 900 feet. The river is small until it is joined in sec. 15, T. 46 N., R. 1 W., by Little Potato River. From this confluence a course nearly due west for 12 miles takes it to Bad River. Near the east line of sec. 17, T. 46 N., R. 1 W., at 428 feet above the level of Lake Superior, is a series of rapids followed by a series of cataracts. These rapids begin on the east line SE. ¼ SW. ¼ sec. 17, T. 46 N., R. 1 W., and are in the trap rock. In the next quarter mile abrupt descents of 10, 4, and 40 feet occur, with swift water between. A still larger fall of 60 feet or more is located near the west line of sec. 17, and as the banks are high and precipitous, a suitable dam would develop a head of nearly or quite 100 feet. On both sides of the west line of sec. 17, about 2,000 feet north of the southwest corner, is a series of bold falls having a total descent of 80 feet in a distance of 500 feet, with two leaps of 25 feet and 32 feet, respectively. The total fall in secs. 17 and 18 is 170 feet. These falls, being over solid rock of conglomerate and sandstone, furnish ideal conditions for dams. Below sec. 18 the river course is tortuous and slow.

MINOR RIVERS.

Aminicon, Middle, Poplar, and Iron rivers are small streams in Douglas County They are all swift streams with many small falls, but are subject to great variations of flow, being insignificant at low water. A corporation known as the Iron River Water, Light and Power Company has recently constructed a dam 135 feet long, with a head of 32 feet, on Iron River, in sec. 22, T. 47 N., R. 10 W., the intention being to install turbines of 1,000 horsepower, which will be transmitted to near-by towns.

RAILROADS.

All the falls which occur near the Penokee Range on Bad River and Tylers Fork are near the Wisconsin Central Railway. Montreal and White rivers are crossed by the Duluth, South Shore and Atlantic, the Chicago and Northwestern, and the Wisconsin Central railways. The western half of the Lake Superior watershed has good transportation facilities. Branches of the Great Northern Railway cross the valley of Black River and follow the valley of Nemadji River. Besides these the drainage is crossed by the Northern Pacific, the Chicago, St. Paul, Minneapolis and Omaha, and the Minneapolis, St. Paul, and Sault Ste. Marie railways, and by minor logging roads.

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