SHEBOYGAN RIVER.

Number of flouring- and grist-mills		7
Total power used by these	horse-power	269
Miscellaneous		3
Total power used by these	horse-power	150
Total power used on the river	do	419
Average power to each industry	do	41.9
Average head to each industry	feet	12.4
Maximum power used in one industry (wooden packing-boxes)	horse-power	90
Maximum head employed on the river	feet	17

MANITOWOC RIVER.

Number of flouring- and grist-mills		6
Total power used by these	horse-power	174
Number of saw-mills		5
Total power used by these	horse-power	108
Total power used on the river	do	282
Average power to each industry	do	25.6
Average head to each industry	feet	9.8
Maximum power used by one industry (flouring)	horse-power	54
Maximum head employed on the river	feet	27

ESTIMATED POWER.—As near as can be estimated from data given and the comparison of the drainage basins, the ordinary low-water power under 10 feet head along the lower portions of the river is, approximately: Milwaukee river, 250 theoretical horse-power; Sheboygan river, 220 theoretical horse-power; Manitowoc river, 165 theoretical horse-power. These figures can only be considered as approximate results.

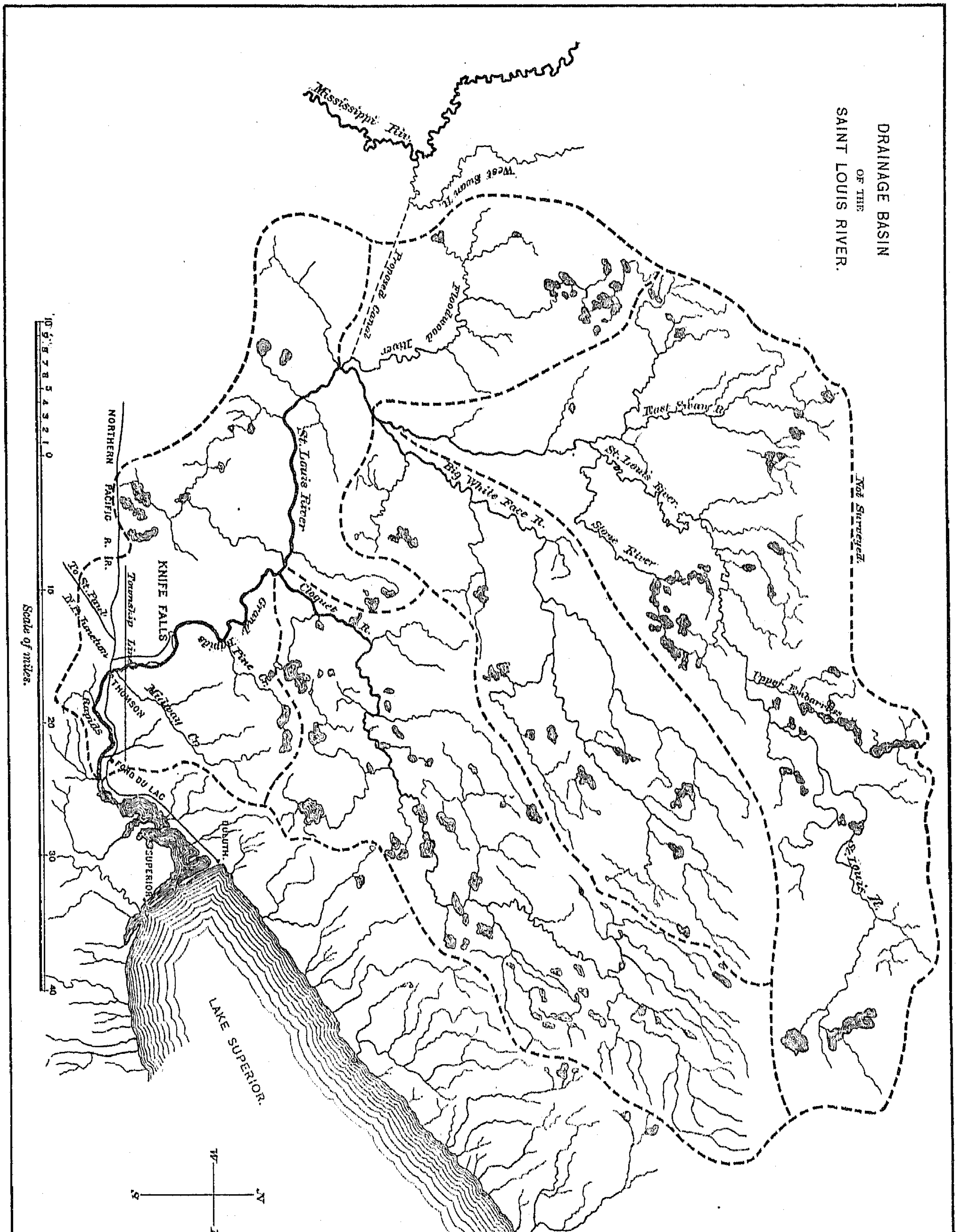
PECULIARITY OF THE MILWAUKEE RIVER.—It will be noticed that the course of the Milwaukee river is east in northern Ozaukee county until within 9 miles of lake Michigan, when it suddenly turns south and flows parallel with the lake above 30 miles to Milwaukee. Professor Chamberlain, in the geological report of this region, states that the river emptied into the lake at northern Ozaukee county, when the lake level was higher than now, at the time of the deposit of the lower red clay. The action of the waves threw up a beach line in front of the river mouth, and caused this to travel south in the endeavor of the water to force an outlet. Thus the river for the last 30 miles of its course flows behind an old lake beach. A similar case has been pointed out in the report on the Red River of the North, as occurring where the Otter Tail river empties into Otter Tail lake. Pike river and East Twin river, which empty at the west shore of lake Michigan, are also considered to have experienced similar conditions.

GENERAL REMARKS UPON RIVERS OF THE WESTERN PORTION OF LAKE SUPERIOR.

The streams tributary to western lake Superior are not of large size. The Saint Louis river, with a basin of 3,000 square miles, may perhaps be considered an exception, but it far exceeds any of its neighbors, and is claimed to be the second river of the entire lake in size.

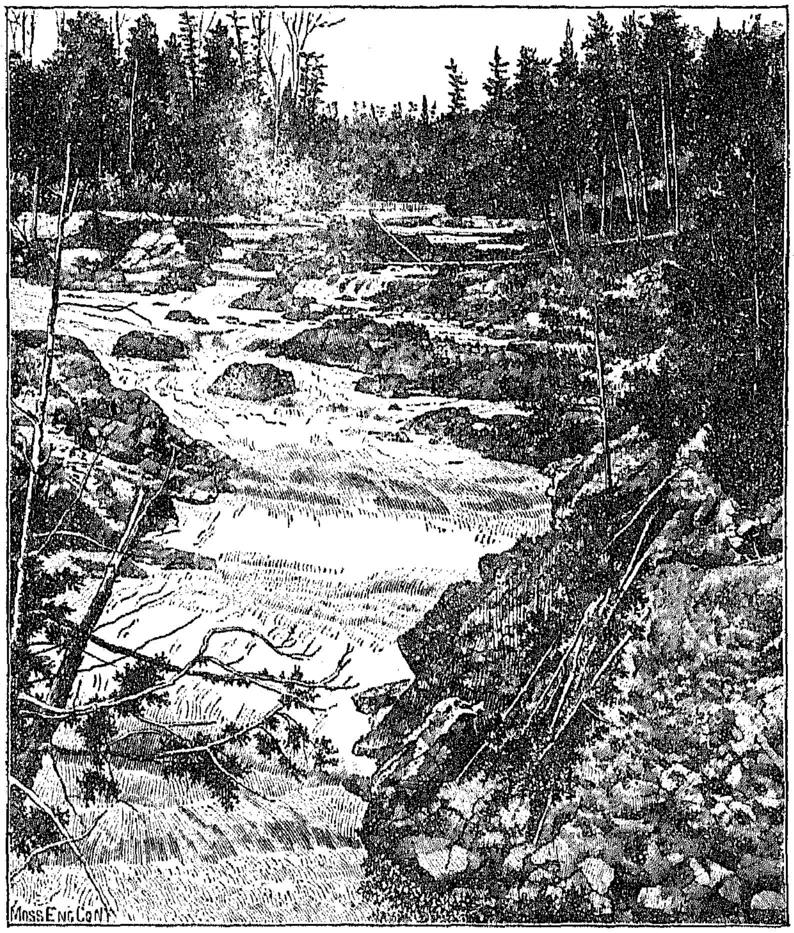
What the rivers of the western part of lake Superior lose in volume they make up, however, in fall, and to a certain extent this is an equivalent in water-power. The water-shed is near the lake on both sides, but it is also elevated 1,000 feet or more above the lake level, and, as a consequence, the streams are very rapid. This characteristic feature of the lake Superior streams is most strongly exemplified on the north shore, where for a long distance the water-shed is at an average distance of 8 or 9 miles from the lake, and the streams go rushing down a descent that must be nearly 1,000 feet. The rock of the north shore is largely igneous and very hard. Many falls and rapids crowd the water-courses, and often right at its mouth a stream will take a final leap. This is the case with the Pigeon river, which forms part of the boundary between Minnesota and the British possessions, and is one of the largest of these north-shore streams. It is a portion of the water system connecting the Lake of the Woods, Rainy lake, and innumerable smaller bodies of water with lake Superior. The outlets of these lakes are so undecided that it is extremely difficult to determine just what are the boundaries of its drainage basin.

Although there is an annual precipitation of 30 to 34 inches upon this region, and an enormous aggregate of water-power, yet the country is so inaccessible and little improved that the power is of little value except in particular localities. With the Saint Louis river, at the extreme western end of the lake, the case is different, and as peculiar circumstances surround that stream special attention will now be given to it. Succeeding the report on the Saint Louis river are some remarks on the south shore of lake Superior and its water-powers.


DRAINAGE BASIN
OF THE
SAINT LOUIS RIVER.
Mississippi River
West Swan R.
Proposed Canal
Floodwood River
St. Louis River
East Swan R.
St. Louis River
Big White Face R.
Stone River
Not Surveyed.
St. Louis R.
Cloquet R.
Grand Rapids
Pine Cr.
Midway Cr.
KNIFE FALLS
Township Line
NORTHERN PACIFIC R. R.
To St. Paul
N.P. Junction
THOMSON
Rapids
FOND DU LAC
DULUTH.
SUPERIOR.
LAKE SUPERIOR.
Scale of miles.
10 9 8 7 6 5 4 3 2 1 0 10 20 30 40
N.
W.
E.
S.

THE SAINT LOUIS RIVER.

The chain of great lakes, which makes the largest system of bodies of fresh water in the world, has its outlet in the Saint Lawrence river. The source of these lakes, on the principle that the headwaters are the continuation of the main body of water, may properly be considered to be the Saint Louis river, which flows into the extreme western end of lake Superior. On this account alone this river enjoys some distinction, but there are other considerations which with much more force turn attention toward it.



RAPIDS OF THE SAINT LOUIS RIVER.

IMPORTANCE OF ITS GEOGRAPHICAL POSITION.—Owing to its geographical position, at the extreme western terminus of the remarkable system of navigable waters which extend nearly half-way across the continent, the shores of the lower portion of the river have attracted much attention, and capital has been expended, not always with the happiest results, in building docks and laying out towns, in anticipation of a large business at the head of lake Superior. Thus the town of Superior, on the Wisconsin shore, was built by a company, houses erected, extensive docks planned, and everything made ready for a trade which never came. The buildings were abandoned, and are described as standing idle in this almost deserted village. At present, however, the horizon is brightening for Superior, and the prospects are that its former hopes may be in a measure realized.

On the opposite side of the lake, in Minnesota, Duluth was started as a city, houses were built, streets graded, etc., and a debt of \$400,000 was assumed, which made it a bankrupt city. Some of the inhabitants in the central portion of the place settled with the creditors on the basis of 25 cents on the dollar, issuing new bonds, and in order to prevent being made responsible for the entire debt they obtained a village charter for their part of the town. Duluth is now a village with a population of nearly 3,000, and, notwithstanding all its reverses, it is fast rising above its troubles, and bids fair to be an important point, especially as the Northwest is becoming so rapidly settled and brought under cultivation. In this lies the future prosperity as lake ports of the towns mentioned. The Northern Pacific railroad, which is one of the main channels for the shipment of grain from the great wheat-fields of Minnesota and Dakota, crosses the Saint Louis river at Thomson, follows the left bank of the stream, and has its present terminus at Duluth. There is situated a grain elevator, with a capacity of 1,000,000 bushels, and the company owning it has in contemplation the erection of two more of at least equal size. These will make Duluth an important shipping point for vessels navigating the great lakes. There is an extension of the Northern Pacific now being surveyed which will pass along the south shore of lake Superior, through the town of Superior, and through Ashland, on Chequamegon bay.

SPECIAL VALUE OF WATER-POWER.—From the above remarks it will be seen that the Saint Louis river occupies an exceptional position, lying right in the line of a traffic which, although already of large size, has scarcely begun its possible development. The character of the freight which passes east should be especially noted. If there is any water-power upon the lower portion of the Saint Louis river accessible, it would be especially valuable, as the wheat could be stopped in its passage East, manufactured into flour, and the finished product sent on to its destination. Mills would have the immense field of the Northwest to draw from through its natural arteries of trade, and unusual facilities of manufacture would be afforded.

Just the conditions necessary for such a state of affairs exist. The railroad passes close to the river, carrying the harvests of the vast prairie region lying westward, and on this river, right beside the railroad, are water-powers hardly second to any in the West. Flouring is mentioned because of the peculiar advantages for that branch of manufacture, but undoubtedly other forms of industry could be successfully prosecuted. For example, large quantities of material for the manufacture of wood pulp could be obtained. In view of these facts, all must admit that the Saint Louis river, with its fine undeveloped water-powers, is well worthy of attention.

TRANSPORTATION FACILITIES.—The means of transportation at the mouth of the Saint Louis river are the natural waterway of the great lakes to the east, the Northern Pacific and Saint Paul and Duluth railroads connecting those places, the latter running on the Northern Pacific track from the Northern Pacific junction east to Duluth.

PROPOSED CANAL.—As mentioned in treating of the Red River of the North, there is a desire among the inhabitants of northern Minnesota to establish a canal connecting lake Superior with the Red River of the North. The real object of the majority of the advocates of this scheme appears to be to have some means whereby to hold the railroads in check and keep down freight rates to a proper limit. With this canal they can effect that object. As one of them remarked, "The farmers of the Red River valley do not care if only ten boat-loads of grain pass through the canal in a season." They would have at hand an agent, which, like the governor controlling the engine, will regulate the freight charges. However, notwithstanding that the canal would be closed during the winter months, it seems possible that it would be of value in itself as a practicable water-route. In the report of a committee on the subject the statement is made that, used as a freight route, it would result in a saving of $1,000,000 yearly to the Red River valley alone.

There has been no regular survey as yet, although at one time a bill making an appropriation for this object was introduced in the United States Senate. The route is considered an eminently practicable one to construct, and is roughly estimated to cost $4,000,000. The plan is to run up the Saint Louis river to Silver Creek, then pass along the left bank of the river 4 miles, overcoming the ascent by a canal with thirty-one locks, and at Midway creek once more enter the Saint Louis river, and follow the stream to the mouth of Floodwood river. There a canal 14 miles long would be cut northwest across the divide to the West Swan river. Entering the Mississippi, the route would run up stream, crossing from Turtle lake into the source of the Red Lake river, and so down that stream to the Red River of the North at Grand Forks, from whence there are navigable waters north and south. This canal would be of undoubted benefit to Duluth, and to the water-power interests already indicated on the Saint Louis river. Its construction is a matter for the future to decide.

The country about the Saint Louis river must yet be classed among the undeveloped lands of the Northwest. It is true that in the immediate vicinity of its mouth civilization has made its mark, but the river flows from a forest-covered country, scarcely yet disturbed. The deer yet roam its banks, and in the winter of 1880–'81 the moose frequented the upper waters in considerable numbers.

LUMBER INTERESTS.—The heavy pine growth of ages still covers the region to the northward of Duluth. There are saw-mills at Knife Falls, which, by a branch road to the Northern Pacific, ship considerable lumber, but they have not made much inroad upon the timber north of them, and it is estimated that 10,000,000,000 board feet of the finest kind of pine are awaiting the ax and the saw. Until recently there has been no demand for this timber. The Minneapolis market could undersell it in the south, and Wisconsin and Michigan would take the Chicago trade. With the rapid settlement of the West a demand is springing up in Dakota and western Minnesota which the Saint Louis region can successfully supply, and a great activity in the lumber trade of that section may be confidently looked for. Already have lumber companies sent explorers along the streams of the Saint Louis basin spying out the land. There is a Saint Louis River Improvement Company, Mr. W. L. Benning, of Saint Paul, president, formed for the purpose of clearing out the river and systematizing the driving of logs. This company has done considerable blasting at the rapids below Thomson.

CHARACTER OF THE COUNTRY.—The country south of the Saint Louis river is rather poor. The soil is to a great extent light and sandy, and is covered with a growth of timber of only medium quality, from which the best pine on the streams of the Saint Croix has been already cut. The region lying west of the river is also poor as a general thing. It is the same drift region in which the headwaters of the Mississippi run. Tamarack swamps, low meadows, and sandy ridges are the prominent features in the scenery. The western and northern tributaries run principally in this region, but the eastern branches of the river rise in the rocky section which characterizes the north shore of lake Superior. This shore rises in places in immense rocky cliffs sheer from the water's edge; in others it is a rugged slope; but everywhere that vegetation can gain a foothold it is covered down to the surface of the lake with a dense growth, and explorers say it is but a step from the wide expanse of sunlit water to the gloom and quiet of a deep forest. In passing to the lake the streams of the north shore of lake Superior are all rapid, with many heavy falls. It is the continuation of this rocky belt southwest in Minnesota which forms the rapids of the Saint Louis, about to engage our attention.

UPPER AND LOWER SECTIONS.—The Saint Louis river runs through two sections of country, different in geological age and in character, and hence changing the nature of the stream to a very noticeable extent. Above the mouth of the Floodwood river the basin lies largely in a region receiving all its characteristics from the comparatively recent glacial age; below that the course of the river is over the rocks of the earliest geological times of which we have definite knowledge.

In the upper section the land is level or elevated in ridges; the soil, sand, clay, and gravel, and the streams are gentle in their flow over sand and gravel beds, with occasional rapids at accumulations of bowlders. In the lower section the country is rugged, and the hard igneous and metamorphic rocks, resisting the erosion of the stream, cause the river to foam in angry leaps and rapids in its descent to lake Superior.

ROCK OF THE LOWER SECTION.—The country through which the river runs near its mouth has been the scene of very violent action. Igneous rock was thrown out, breaking and upheaving the rocks previously formed, and to some extent changing their lithological character. Thus there is little uniformity in the occurrence of the different kinds of rock. Gabbro, an igneous rock, called granite at Duluth, but incorrectly so, is intruded, tilting the magnesian and argillaceous slates and the red sandstone, believed to be the equivalent of the Potsdam sandstone in the east, and in places actually fusing and converting them into a variety of red granite. This unevenness of the strata and the presence of dikes of igneous rock give a very wild character to the rapids of the Saint Louis river.

The rock about Duluth possesses considerable value as building material. This is specially true of the red sandstone, which is quarried in considerable quantity. It has somewhat the appearance of the brownstone quarried so extensively in New Jersey and Connecticut, but is not so rich in color, and has frequent white streaks running through it. The Huronian slates have been quarried for roofing purposes, but the enterprise was not successful, although the slate is of very fair quality. Recently (1881) new quarries have been opened in the state. The so-called granites of Duluth are also quarried for building purposes, but the stone has a poor cleavage, and is difficult to cut. The prospecting for iron ore in the region northeast of Duluth is probably caused by this rock, which is sometimes very rich with magnetite.

It is the opinion of the geologists who have explored that region that the country of the upper Saint Louis above the Floodwood river and about the Mississippi was once the bed of a lake long since drained. There is some fertile land, the deposit from this ancient lake. The water-shed between the Mississippi and the Saint Louis rivers runs for a portion of its course along a line of drift hills, and at Sandy lake the highest is 139 feet above the water. On the north the water-shed is determined by the Mesabi range of drift, the waters to the north of that running into the Rainy Lake system.

TRIBUTARIES.—A glance at the accompanying map will show that the basin under consideration is approximately oval in form, the major axis, lying parallel with the north shore of lake Superior, being about 80 miles long and the minor axis 50 miles. The main tributaries flow southwest. The Saint Louis itself runs southwest to the mouth of Floodwood river, then turns suddenly and flows in a generally southeast direction to lake Superior, intercepting the branch streams from the east.

The basins of the upper Saint Louis, the Big White Face, and the Cloquet rivers divide the total drainage basin approximately into three symmetrical portions, of which the Big White Face river occupies the middle one. The water-shed on the south has an average distance from lake Superior of about 8 miles, and all the streams which flow into the lake south of it are small. The tributaries on the west have little fall; those on the east are rapid in their upper portions, but when they strike the level and rolling region they, too, are moderate in their flow.

The chief tributaries, in the order of their occurrence from the source, are these:

Name.	Length (map measurement).	Drainage area.
	Miles.	*Square miles.*
Big White Face river	55	534
Floodwood river	34	257
Cloquet river	65	675

VOLUME OF THE SAINT LOUIS RIVER.—No accurate observations have been made of the flow ot the Saint Louis river. On May 24, 1870, Mr. James B. Francis made, as he states, a rough observation of the flow at Thomson, which he found to be about 5,600 cubic feet per second. "The river was then evidently above the minimum flow." The ordinary low-water flow has formerly been taken at 2,000 cubic feet per second in making calculations on the water-power of the Saint Louis river, but this estimate was stated to be a very rough approximation. With no measurements to aid us, it is impossible to arrive at a close result, but the data at hand lead to the conclusion that 2,000 cubic feet per second is too high an estimate.

ESTIMATION OF FLOW FROM THE RAINFALL.—The Saint Louis basin is largely similar to the country about the upper Mississippi, on which regular gaugings have been made. The latter has more lakes, but about the Saint Louis river are many marshes, especially on the west, and on the east the forest growth is denser and evaporation less. From the sand ridges many fine springs feed the streams, and these have an important effect upon the permanency of the flow. The amount of annual precipitation at the headwaters of the Mississippi, used in the estimates for the reservoir system on that river, is 25 inches, while on the Saint Louis basin it averages nearer 30 inches. At Duluth it is 33 inches. It is thought safe to conclude that the discharge per square mile of drainage area on the Saint Louis will be that on the upper Mississippi, increased by an amount due to the greater precipitation about the former stream.

The following data have been obtained on the Mississippi:

Area of basin above Grand rapids, 3,636 square miles; discharge at a stage 0.4 foot below mean low water, 969 cubic feet per second. Hence, discharge per square mile of drainage area, 0.27 cubic foot per second.

Area of basin above Aitkin, 5,715 square miles; discharge at a stage 0.2 foot below mean low water, 1,743 cubic feet per second. Hence, discharge per square mile of drainage area, 0.305 cubic foot per second.

Because these gaugings were made when the river was slightly below an ordinary low stage, it is thought best to assume the ordinary low-water flow to be 0.34 cubic foot per second per square mile of drainage area.

From this, allowing for the greater rainfall, it is concluded to assume the flow per square mile from the Saint Louis basin to be 0.4 foot at ordinary low water. This would give a discharge at Thomson of 1,223 cubic feet per second. In the absence of measurements, it cannot be positively stated that this is correct, but it is the result arrived at after comparison with the neighboring stream, the Mississippi, on which actual measurements have been made. The theoretical power with this discharge under 10 feet head would be 1,388 horse-power. Throughout a large portion of the year, in all probability, the power would be at least double this.

Tributary to the Cloquet river are four or five lakes, with an area of from 3 to 4 square miles each, and upon the extreme upper waters of the Saint Louis is about the same lake surface; but, compared with the Mississippi and the Red River of the North drainage basins, the lake system of the Saint Louis is unimportant. If the Saint Louis were an eastern river, however, it would be considered to be well supplied with lakes. It is very probable that if the water-power interest of the stream warranted the expenditure extensive reservoirs could be made in the swamps among the ridges and the low-water flow be very greatly increased.

TABLE OF POWER OF THE SAINT LOUIS RIVER.

Place.	Distance from preceding station (map measurement).	Tributary area above station.	Estimated ordinary low-water discharge per second.	Resulting theoretical horse-power under 10 feet head.	Effective horse-power under 10 feet head, at 75 per cent.
	Inches.	*Sq. miles.*	*Cubic feet.*		
Above Big White Face	75	1,044	418	474	356
Mouth of Big White Face	0	1,578	631	716	537
Mouth of Floodwood	6	1,835	734	833	625
Mouth of Cloquet	18	2,824	1,130	1,286	965
Knife Falls	12	2,926	1,170	1,328	996
Thomson	7	3,058	1,223	1,388	1,041
Fond du Lac	10	3,100	1,242	1,410	1,058

One peculiarity of the Saint Louis river is that its descent is concentrated upon the lower waters, where the volume of flow is largest. This is a very favorable condition for the water-power of the basin, as it concentrates the power which would otherwise be distributed in small streams. The upper portion of the Saint Louis is rather sluggish, but as the water nears the lake it increases its speed, until near the mouth it is a foaming torrent.

ABOVE THE BIG WHITE FACE.—Rapids are infrequent near the headwaters, and when they occur are over accumulations of bowlders. The drift hills usually come close to the river on one side, while on the other a timbered bottom forms the shore. In places both banks are low and flat.

A few miles above the mouth of the Big White Face river is a locality where, according to report, a head of 20 feet can be made available by building a dam.

The drainage area tributary to the Saint Louis river above the Big White Face river is approximately 1,044 square miles. The region is not yet fully surveyed. The estimated ordinary low-water flow above the mouth of the Big White Face river is 418 cubic feet per second, which, under 10 feet head, would give 474 theoretical horse-power.

BIG WHITE FACE TO FLOODWOOD RIVER.—Below the mouth of the Big White Face river the drainage area is increased to 1,578 square miles, the estimated ordinary low-water flow to 631 cubic feet per second, and the resulting power, under 10 feet head, to 716 theoretical horse-power.

FLOODWOOD TO CLOQUET RIVER.—By the entrance of the Floodwood river from the west 6 miles below the area tributary to the Saint Louis river is increased to 1,835 square miles, the ordinary low-water flow to 734 cubic feet per second, and the theoretical power under 10 feet head to 833 horse-power. From the mouth of Floodwood river for the first 2 or 3 miles there is little fall, and for the following 6 miles there is a fall of about 40 feet. From there down to Cloquet rapids, near the mouth of the river of that name, there is little descent. These rapids consist of a descent of 5 feet in about 1,300 feet distance.

GRAND RAPIDS.—Four or five miles below begin Grand rapids. There the river falls 75 feet in 5 miles, averaging 500 feet in width.

The drainage area tributary to the river above these rapids is about 2,834 square miles, the estimated ordinary low-water flow 1,133 cubic feet per second, and the resulting theoretical power, under 10 feet head, 1,286 horse-power. The total theoretical power with the 75-feet fall is 9,645 horse-power. Half a mile below the foot of Grand rapids is a small descent called Pine rapids. From there down to Knife Falls the descent is slight.

KNIFE FALLS TO THOMSON.—At Knife Falls there is a series of pitches over sharp upturned strata of slate rock. From the effect upon the moccasins of the traders and Indians originated the name. In Dr. David D. Owen's report the falls are stated to amount to a descent of 20 feet. The rapids make the total descent much larger. The total fall from above Knife Falls to the township line, about 1 mile north of Thomson, a distance of about 4½ miles, is 154 feet.

The drainage area tributary to the river above Knife Falls is 2,926 square miles, the estimated ordinary low-water flow 1,170 cubic feet per second, and the resulting theoretical power, under 10 feet head, 1,328 horse-power. This would make the total power, with the 154 feet head, 20,451 theoretical horse-power.

RAPIDS OF THE SAINT LOUIS RIVER.

From Thomson down to the sandstone quarry just above the village of Fond du Lac occur the rapids of the Saint Louis, which place it in the front rank among the rivers of the West as a water-power stream. A descent of 456 feet is made from the township line, 1 mile north of Thomson, down to Fond du Lac. Just above the railroad at Thomson the river is forced through a channel about 60 feet wide, between perpendicular walls of rock some 30 feet in height. Immediately on passing under the railroad bridge the stream veers to the east and commences a series of the wildest leaps over upturned ledges of slate rock. The dip of the strata is down stream about 40 degrees, and, as shown in the view, a series of jagged pockets is formed. Filling one, the water foams over the crest and falls into the next below.

RAPIDS OF THE SAINT LOUIS.

The Northern Pacific railroad follows the course of the river, and in going to Duluth the view from the rear of the train is very beautiful. At Thomson the river bed is near the general level of the country, but as it descends hills 200 to 500 feet high rise above the water, covered with a wild growth of pine and other timber. Through deep gorges small branches find their way to the main stream, and down at the bottom of its valley is the river, now foaming over its rocky bed in rapids such as those just described, now making a graceful sweep of gentle water around a projecting slope. Dr. Owen, in his report, made many years ago, distinguishes four series of falls in the course of the rapids of the Saint Louis thus:

The lower falls are 3 or 4 miles above Fond du Lac, where the old portage trail began, and consist of a series of ten or eleven cascades, from 6 to 10 feet high, running obliquely across the channel. These occupy a total distance of half a mile. He estimates the entire fall to be 103 feet.

The second falls are 1½ miles above the first; and although the total descent is only 76 feet, yet they are far more imposing. Solid walls of rock rise 30 to 40 feet, and extend far into the stream, really making the river to run on its edge, as it were. In one place the channel is 40 feet, and in another only 25 feet wide, while above and below it is 600 to 450 feet across.

The third falls are a series of cascades, with a total descent of 45 feet.

The fourth falls are very similar to the second, and consist of five large pitches and many smaller ones. The total descent is a little over 100 feet.

It will be seen by Dr. Owen's report that there is great variety in the nature of the river at the rapids; but it must not be supposed that the descent is confined to the falls, as grouped by him, with intervening still water. The river is more or less rapid all the way. In the contracted places, where the channel is deep and the velocity very great, it appears very small; but it averages 100 to 200 feet wide in the rapids, and at Fond du Lac spreads out into a stream several hundred feet wide, with a current of 4 miles per hour, and is navigable up to Fond du Lac.

The Saint Louis River Improvement Company, already alluded to, is engaged in building dams and reservoirs upon the upper section of the river for logging purposes, and has expended much work upon the Saint Louis rapids in blasting out the rocks, which would tear the logs into splinters. In high water the rocks are largely covered.

FALL AND POWER OF THE RAPIDS OF THE SAINT LOUIS.—It has been stated that the total fall from the township line north of Thomson down to Fond du Lac is 456 feet. Of this, 372 feet occur in the first 4 miles down to the mouth of Silver creek and 84 feet in the remaining 7 miles by river to Fond du Lac. Thus the heaviest fall of the stream is this 372 feet in 4 miles, an average of 93 feet per mile.

The drainage area tributary above Thomson is 3,058 square miles, and the estimated ordinary low-water flow is 1,223 cubic feet per second. Under 10 feet head this would give a theoretical power of 1,388 horse-power, and under the total head of 456 feet the theoretical power would be 63,293 horse-power. It was the opinion of Mr. James B. Francis that, while the total fall could not be available, undoubtedly three-fourths of it would be. Three-fourths of the fall is 342 feet, and this would give 47,469 theoretical horse-power at ordinary low water.

It was impracticable to make a complete observation of the lower portion of the river, but from what could be gathered by a hasty view and by conversation it seems that much the greater portion of the power is available. It is true that the river valley is wild and rocky in many places, but there are numerous localities suitable for the building of dams and canals, with limitless material near at hand, while access could be readily had to buildings stationed at the river. As to transportation facilities, enough has already been said to indicate the superior advantages afforded this water-power, with the navigation of the great lakes at its door and the railroad following the river.

WATER-POWER COMPANY.

The legal conditions of the water-power of the rapids of the Saint Louis in January, 1881, were these, as obtained from Mr. E. L. Craw, of Duluth:

For some time past a few capitalists, with Mr. Jay Cooke as the leader of the enterprise, have realized the future value of this power, and have lately obtained possession of it. For two years Mr. Craw was actively engaged in buying out the many former owners along the river, and when met had just received the last deed; so that the title is now clear to both banks of the stream from Fond du Lac to Knife Falls inclusive, a distance by river of about 17 miles. In January, 1881, the company was about to be incorporated, representing a capital of $3,000,000.

POWER OWNED BY THE COMPANY.—As may be estimated from the figures already given, the company own 610 feet fall. Of this, 154 feet are above the township line, 1 mile north of Thomson, and 456 feet from that line down to Fond du Lac. With the estimated ordinary low-water flow past Thomson of 1,223 cubic feet per second, the total theoretical power under 610 feet head is 84,668 horse-power, and, with an efficiency of 75 per cent., the available or effective power is 63,501 horse-power. Taking Mr. Francis' estimate that three-fourths of the fall could undoubtedly be utilized, the available head would then be 458 feet, the theoretical power 63,570 horse-power, and the effective power, with wheels giving an efficiency of 75 per cent., 47,678 horse-power. This is about 14,000 horse-power greater than the total effective power of the Lower Fox river in Wisconsin, and very nearly one-half the effective power available from the Mississippi river at Minneapolis under an efficiency of 75 per cent.

PROPOSED IMPROVEMENT.—The plan proposed by the company is eventually to build dams at different places along the river and utilize the power by canals extended along the banks. Mills would be located along these canals, and side-tracks run to them from the main railroad line. The chief industry toward which they must look for the success of their enterprise is the manufacture of flour.

About one-third of a mile above the railroad bridge Midway creek enters the river from the east. The plan is to throw a dam across the river a short distance below the mouth of Midway creek and back the water up into that stream. From Midway creek a canal will run past the village of Thomson, and, bending, follow along the railroad track, which will lie between it and the river. Mills will be stationed along this canal convenient to the railroad, with their tail-races tunneled out to the river. It is stated that 75 feet head of water can be obtained. Under this head the ordinary low-water power would be 10,410 theoretical horse-power. It is practicable to extend the canal about 5,000 feet along the river.

Mr. James B. Francis, in making some suggestions with relation to the improvement of the power, proposed that the canal should have a capacity of 1,500 cubic feet per second and a cross-sectional area of 500 square feet; that it should be 55 feet wide and 9 feet deep, with a mean velocity of 3 feet per second. The total depth, he states, should be 12 feet, to allow for ice.

RIVERS OF THE SOUTH SHORE OF LAKE SUPERIOR IN WISCONSIN.

This region derives some importance, and deserves consideration in this report, because of the intended extension of the Northern Pacific railroad east through its length. The country is yet a wilderness, but the time will come when, if there is anything to be developed, use will be made of it. It was in view of these facts that a trip was made on the Wisconsin Central railroad to Ashland, on Chequamagon bay (pronounced Shewamegon), to gain information concerning the water-power.

TOPOGRAPHY.—The water-shed runs near the lake, although not so close as on the north shore, previously alluded to, and is at an average distance of about 30 miles from the shore. On this account the streams are not large, the greatest, Bad river, having a drainage basin of 1,045 square miles. The average altitude of the water-shed is from 950 to 1,050 feet about the Red river, and 600 feet toward the end of the lake. It runs through a flat, swampy region, difficult to locate, and many of the tamarack swamps and lakes have two outlets—one into the rivers leading to the Mississippi, and the other toward lake Superior.

On a line from south to north about the Bad river the profile is this: From the water-shed line, in places 1,100 feet above the lake, the descent is very gradual to within about one-quarter of a mile of the Penokee iron range, when there is an ascent of 100 to 300 feet. From the crest of the Penokee range the descent is much more rapid for 100 to 300 feet to a ridgy section, which is elevated 500 or 600 feet above the lake. This terminates in what is called the Copper range, where there is a descent of 400 or 500 feet in about 3 miles. From there to the lake the descent is 100 to 200 feet, constituting the lowland area. At the western end of the lake the water-shed is about 600 feet above the lake. The descent is gradual, and then there is a gentle rise to the north for 1 or 2 miles to the Copper range, from 400 to 650 feet above the lake. From the ridgy country forming the Copper range there is a sudden descent of 300 or 400 feet, and from the foot of the range to the lake, a distance of from 5 to 10 miles, there is a gradual descent of from 100 to 250 feet.

ROCK AND SOIL.—The rock of this region belongs to the oldest formations of the globe. South of the Penokee iron range it is the old Laurentian base, which is the foundation for the superposition of the sedimentary rocks occurring further south in Wisconsin. Then comes the Huronian, of which the Penokee range is formed. It is made up of metamorphic rocks, consisting of schists, marbles, granites, etc., and contains extensive accumulations of magnetic iron ores. The name Penokee was derived from the Chippewa word *pewabic*, meaning iron, by the mistake of a printer. Succeeding the Huronian on the north is the Keweenaw system of rocks, a metamorphic system of later origin than the Huronian, according to the best authorities. This is the continuation of the Keweenaw Point ridge, and contains more or less copper. The Copper range belongs to the Keweenaw series, and north of this is the old red sandstone of lake Superior.

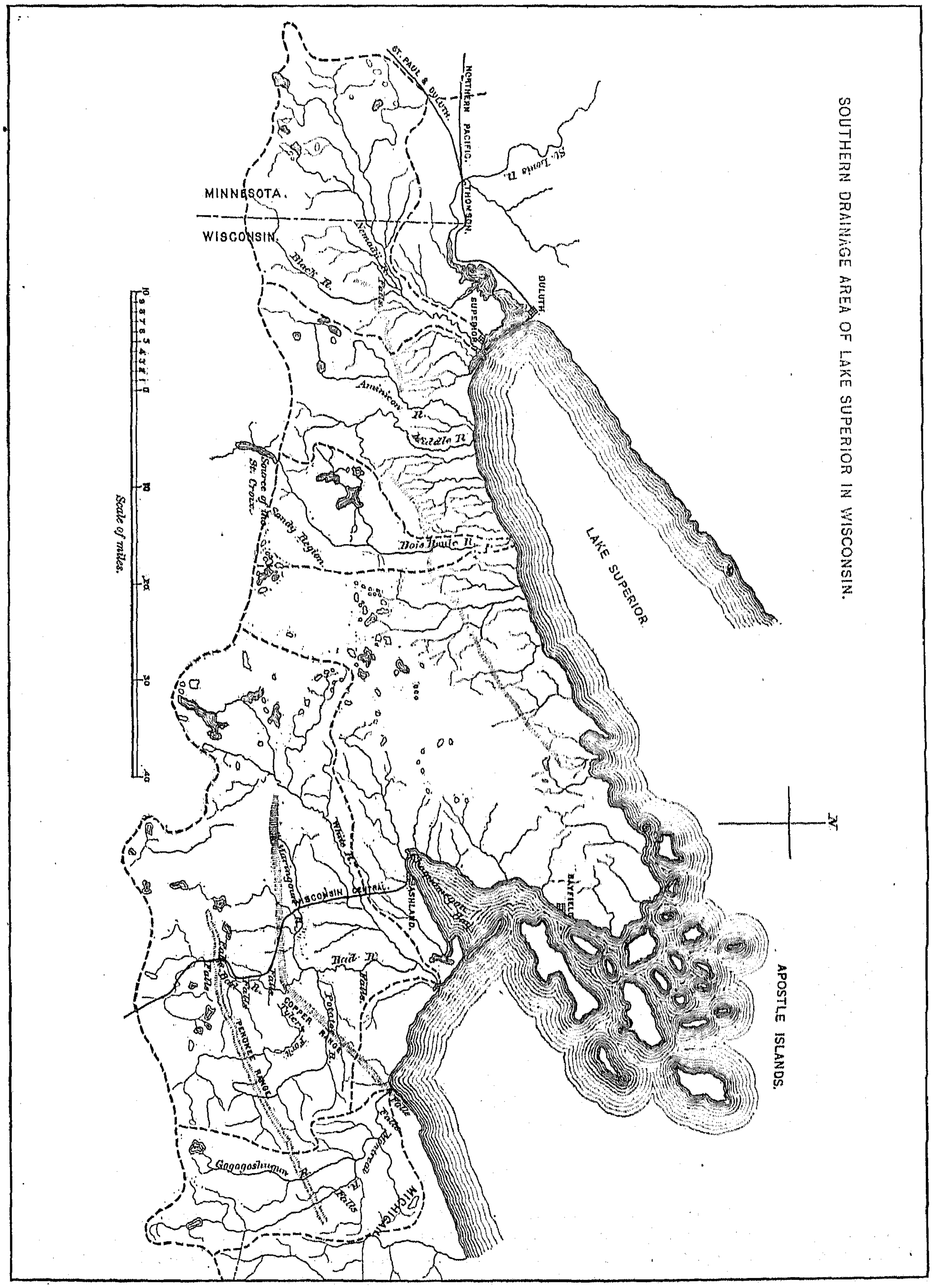
These rocks are very largely covered with glacial drift, and, especially in the section between the Copper range and the lake, with a heavy lacustrine clay deposit. There the streams have cut deep gorges in the clay, 25 to 100 feet in depth. There the Wisconsin Central railroad crosses the White river, a tributary of the Bad river, by a trestle 1,300 feet long and 100 feet high, called by the Indians the "Spider-web".

FLOW OF THE STREAMS.—The principal streams flowing into lake Superior from Wisconsin are these:

Name.	Drainage area.	Estimated ordinary low-water flow, per second.	Theoretical horse-power under 10 feet head.
	Square miles.	*Cubic feet.*	
Bad river	1,045	418	473
Nemadji river	439	176	200
Montreal river	284	114	129
Bois Brulé river	148	59	67

It is thought, by comparing with the neighboring streams, that the ordinary low-water flow approximates to 0.4 cubic foot per second per square mile of drainage area, for these reasons: The Upper Mississippi, with an annual precipitation of 25 inches, has about 0.34 cubic foot, and the Saint Louis, with a rainfall of about 30 inches, is estimated to have 0.4 cubic foot. The region now under discussion has an annual precipitation of from 30 to 35 inches, while it is not so retentive of moisture as the basins of the above-mentioned streams.

The streams given in the table would have little water-power were it not for their rapid descent to lake Superior. In passing through the Penokee and Copper ranges they are exceedingly rapid, and in many places are vertical falls.



SOUTHERN DRAINAGE AREA OF LAKE SUPERIOR IN WISCONSIN.

BAD RIVER.

The Bad river rises about 900 feet above the lake level, and the Wisconsin Central railroad passes down the valley, crossing the river at least fourteen times. The highest crossing is 895 feet above the lake, and there the stream is 20 feet wide. For the next 5 miles there is an average fall of 10 feet per mile, and then there is a descent averaging 25 feet per mile for 2 miles Below this is a fall of 52 feet in three-quarters of a mile, including a descent of 20 feet in 500 feet in less than a quarter of a mile, and below this is a fall of 17 feet. This is a sample of the course of the river, except that there are several falls of much greater magnitude below. In one place there is a perpendicular fall of 25 feet, and then a descent of 40 feet in 1,100 feet. This is just above the mouth of Tyler's fork. At the mouth of Tyler's fork the river is from 320 to 330 feet above the lake. For the next mile there is a rapid fall, the descent down to the mouth of the Maringoun river averaging 30 feet per mile. Below this there is 90 to 100 feet fall to the lake. The river now runs through the lowland. About half way between the Maringoun river and the lake is a series of falls of from 1 to 2 feet, over sandstone and shale, for a distance of about 1½ miles. The land about the mouth of the river is marshy, and in the lowland its bed is cut deep in the clay. In passing the ridge country the river runs through rocky gorges and valleys of no great depth as a usual thing, but it has little effect upon the hard rock forming its bed. The area tributary to the river above the mouth of the Potato river is 636 square miles, which would give an estimated ordinary low-water flow of 254 cubic feet per second and a theoretical power, under 10 feet head, of 288 horse-power. There are many favorable sites for improvement very close to the railroad, and, with the high heads available, considerable power can be obtained; but the stream is much smaller there, probably not over one-third the size that it is at the Potato river, giving, say, 75 horse-power under 10 feet head at an ordinary low stage. With 40 feet head the power would then be 300 theoretical horse-power. There are sharp bends in the stream, and by tunnels through the ridges a large fall could be utilized in some places. Apparently there is nothing in that region to induce the utilization of the power in advance of the improvements brought about by the railroads. The lowland area about the Bad river has a clay soil, which is reported to give good results in the raising of wheat, and the country is covered with a growth of hardwood, birch, and poplar, interspersed with pines. Considerable pine timber has been taken out along the main stream down the Bad river to the lake. Along the railroad the pine timber is inferior in quality, but is better further back, and along the upper waters of the larger streams tamarack and cedar swamps abound. Being directly on the line of the Wisconsin Central railroad, the Bad river has special advantages for manufacture not offered by the other streams. There was at one time a saw-mill, now in ruins, run by this river at the falls in the lowland region; but now there is no water-power used in that section.

The White river, entering near the mouth of the Bad river, is the largest tributary, having a basin nearly 400 square miles in extent. Its total fall is about 700 feet, mostly on the upper waters. The Maringoun and Potato rivers and Tyler's fork are the other important tributaries, and are all rapid streams.

MONTREAL RIVER.

Of all the larger streams flowing into lake Superior from Wisconsin the Montreal river is the most rapid. The sources are about 1,000 feet above lake Superior, and in a distance of about 50 miles it makes this descent. Most of the fall, unlike the Bad river, is situated upon the lower portion of the stream. The Copper range here comes close to the lake, and there is no lowland region. Thus, there is a fall of 90 feet about 1,300 feet from the mouth of the river. Two to three miles above are two vertical leaps and a rapid between, making a total of 78 feet. The lower one of these two falls is 40 feet. The mouth of the Gogogashugun is 503 feet above lake Superior, and about 4 miles above this river are three falls, 15, 35, and 25 feet high, consisting of vertical falls and rapids. Just about a mile above these falls the river is 910 feet above the lake. There are only two small rapids beyond this point. The headwaters are in tamarack swamps.

BOIS BRULÉ RIVER.

The Bois Brulé river heads in a sandy ridge of glacial origin, which absorbs the water and feeds the rivers flowing from it with fine springs. The water-shed along the sources of the Bois Brulé averages 600 feet above the lake, and many rapids occur in its course, especially in the lower portion.

NEMADJI RIVER.

The Nemadji river proper flows northeast, instead of north, like the streams just discussed, and does not rise in the elevated ridge region; hence it is a quiet stream without any rapids of importance. With its chief tributary, the Black river, the case is different. It rises in the elevated region and flows north. Where it leaves the Copper range there is a descent of 300 feet in about three-quarters of a mile. A portion of this is in a chute of 140 feet at an angle of 80 degrees and a fall of 50 to 60 feet at the foot.

RED RIVER OF THE NORTH AND ITS DRAINAGE BASIN.

GENERAL REMARKS.

COURSE OF THE RIVER.—Sixty miles east of the western boundary of Michigan, and about 9 miles north of latitude 47°, is a small sheet of water, 4 miles long and narrow, bent at right angles in the middle, to which is given the name of Elbow lake. From this runs a stream in a generally southern direction, called Otter Tail river, which finally discharges into the northeastern end of Otter Tail lake, about ten miles north of latitude 46° 30′.

At the opposite end of this lake, 40 miles east of the state line, and properly the continuation of Otter Tail river, starts the Red River of the North. Taking a west-southwest course to the border between Minnesota and Dakota, it suddenly turns sharp, and, flowing almost due north for about 190 miles by land, forms the boundary between Minnesota on the east and Dakota on the west; then, crossing the national boundary, it passes into Manitoba, losing its name in lake Winnipeg, but finally reaching the waters of the Atlantic by way of Nelson river and Hudson bay. Its waters first find the ocean in latitude 57°, four degrees north of the headwaters of the Columbia, one of our most northern streams.

PRODUCTION OF THE REGION.—The region of the United States lying about the Red River of the North is strictly a new country. Only within the past few years has the tide of emigration been directed to this region, and the land is being rapidly settled by foreigners of northern blood. It is eminently the land of wheat. In eastern Dakota, along the Northern Pacific railroad, are the vast Dalrymple farms, and along the immediate Red River valley, and up the valley of the Goose river, are raised remarkable crops of wheat. The winters are severe, the summers are mild, and growth is rapid. The warm air from the Japan current in the Pacific, flowing down the region of the Saskatchewan, spreads over the Northwest a softening influence, which forces back the piercing Arctic cold, and makes farming possible hundreds of miles north of Winnipeg. Even in winter, except in extraordinary seasons, the climate is comparatively mild.

TRANSPORTATION FACILITIES.—The local means of transportation are the Saint Paul, Minneapolis and Manitoba railroad to Saint Paul, the Northern Pacific railroad, and, in addition, for north and south transportation, the Red River of the North. One natural outlet of the region would seem to be east through the great lakes to the sea, and as geographical conditions are important factors in regulating transportation routes this course must be always a prominent one. There is prospect of a direct route in the future from Manitoba east by the Canadian Pacific, and the Northern Pacific Company is busy extending its road along the south shore of lake Superior, all the roads being eager to grasp the grain traffic of the Northwest. There is also a scheme proposed to open a canal at Duluth, at an estimated cost of about $4,000,000, west from lake Superior, and down the Red Lake river to the Red River of the North. This scheme is claimed to be practicable from an engineering point of view.

PHYSICAL GEOLOGY OF THE DRAINAGE BASIN.

As is characteristic of most of the drainage areas of the Northwest, the country tributary to the Red River of the North possesses none of the bold, picturesque mountain scenery of many of the eastern river valleys. On the contrary, the Red River valley in Dakota and Minnesota has been the subject of remark by all explorers along its course because of its extremely level prairie surface in all directions.

CHANGE IN DRAINAGE.—This stream and the country which it drains possesses especial interest from a physiographical standpoint. There is every indication that in comparatively recent geological times the waters of that region found an outlet by the valley now occupied by the Minnesota river, and, instead of entering Hudson bay, formed a part of the Mississippi system, emptying into the Gulf of Mexico, whose northern coast-line was then well up toward the present mouth of the Ohio river. General G. K. Warren's report, made in 1868 to the chief of engineers of the United States army, contains a map illustrating the then probable condition of the drainage system. For a full understanding of the Red River of the North, past and present, and its drainage basin, a brief description of the causes which led to the present condition of northwestern Minnesota and vicinity may be allowed.

GLACIAL ACTION.—After the epochs in which were deposited the sandstones, limestones, shales etc., and in the latter part of which there was a tropical climate in the north, according to the glacial theory, in what is called the early post-Pliocene period, the climate lowered to Arctic coldness, and a vast ice sheet covered the northern part of North America, gradually extending its front well down toward the present Ohio River region. As the ice accumulated thousands of feet thick in the colder region north its weight pressed the lower portion like a semi-fluid mass toward the south. This ground the soil and rock left by the preceding ages, carrying the material on its surface or in its mass in the slow movement southward, smoothing off the irregularities of the surface, and, in retreating, distributing the "drift", as the eroded material is called, in a generally uniform surface. Then it is thought that over the Northwest, at least, the ice-sheet receded, owing to a change in climate, and afterward advanced once more, rearranging the upper portion of the drift previously deposited, and, when the cold of the glacier age was finally conquered, leaving northwestern Minnesota much as we find it now so far as contour is concerned, although the rivers have since modified it to a slight extent. It is probable that during the recession of the second glacial sheet, if the term may be used, occurred the change whereby the drainage of the Red River region was diverted from the south to the north.

INDICATIONS OF THE CHANGE IN DRAINAGE.—It may be asked: What are the reasons for assuming that the Mississippi once received these waters? The prominent ones are these: The second glacier had in Minnesota its southern front from about the latitude of Saint Paul, west and northwest, through about the center of the western boundary of the state, and melted as fast as it was pushed down from the north. This must necessarily have given rise to enormous volumes of water, for after equilibrium had been established all the precipitation on the vast region north would have been melted along a narrow belt at the terminus of the glacier-cap. It would be surprising if these great floods had passed off without leaving some traces on the easily eroded drift deposited by the preceding ice-sheet. Nor are remarkable indications wanting of just such action on the largest scale. South of where the Red River of the North takes its final course northward are two long, narrow, and shallow lakes—lake Traverse (pronounced lake Travarre), and southeast of it about 5 miles Big Stone lake. The first flows into the Red River of the North, and the second is drained by the Minnesota river, and the water-shed between them is estimated by General G. K. Warren, with a possible error of 25 feet, as 995 feet above the sea, with an elevation of only 5 or 6 feet above lake Traverse. In very high floods on the Red River of the North a stream of water actually runs from lake Traverse to Big Stone lake. From Big Stone lake the Minnesota river runs southeast, and then northwest into the Mississippi river. In ascending the Minnesota from its mouth it is noticed that the course of the river is in a valley 1 to 4 miles wide, and varying in depth from 100 to 200 feet, or slightly more. There is a regular trough, cut out of the heavy bed of unmodified drift, or till, as it is called, and as the upper portion of the river is neared, and the stream grows smaller, one is more and more impressed with the fact that the present river could never have cut this vast channel. The dimensions of this trough continue the same, the present river meandering through the bottom, while at several places the till has been worn down to the old formation of rock which there underlies it, the solid granite rising out of the alluvium of the bottoms in domes and water-rounded masses many feet in height. Thus it is below the mouth of the Yellow Medicine, and at Granite Falls a great ridge of the metamorphic rock has been worn and broken through. Reaching Big Stone lake, we find still the same trough-like depression in the rather level prairie; in fact, both it and lake Traverse, with the intervening water-shed, lie in the continuation of this same valley; and at the upper part of lake Traverse the bluffs on either side fade away into the wider expanse of the Red River valley. Looking at the little stream, scarcely 20 feet wide, as it flows sluggishly from the end of Big Stone lake, it is apparent that in its present volume it could never have eroded this immense channel; indeed, it has hardly had any effect on the alluvial floor of the valley through which it flows.

It is evident that this Minnesota valley must have been carved out by some vast river; and it is equally as certain that, granting the glacial theory of Agassiz to be correct, which receives by far more credence than the iceberg theory alone, there must have been in this very locality in the post-Pliocene times immense volumes of water produced by the melting ice. Putting these two facts side by side, we are brought irresistibly to the conclusion that the region now drained by the Red River of the North once poured its vastly greater flood through the Mississippi basin into our southern seas. This fact was first pointed out by General G. K. Warren, United States corps of engineers, in his report of 1868.

CAUSE OF THE CHANGE IN DRAINAGE.—The Red River valley proper is a level plain from 10 to 20 miles wide on each side of the river, and is bounded by successive terraces and low hills, rising at the crest of the water-shed to several hundred feet above the river. This level prairie extends north to Lake Winnipeg, gradually widening out, and the slope of the ground is very uniform, about one foot per mile. The superficial deposit of the Red River valley and the traces of old beaches along the terraces point to the former existence of a lake, filling the whole Red River valley, and extending up the Assiniboine valley and over a large territory in Manitoba, 100 to 200 miles wide from lake Winnipeg west in Manitoba, 300 feet deep there and 200 feet deep at the national boundary. There are two theories as to the cause of this ancient body of water and of the change in the direction of the drainage.

GENERAL WARREN'S THEORY.—General Warren thinks that originally the summit at lake Traverse was lower than the land between lake Winnipeg and Hudson bay, which would cause a large lake, with the dimensions just given, and a southern outlet; that an elevation of the surface occurred at the south end of the lake, with perhaps a sinking of the land north; that at all events the south end was elevated enough to raise the water over the divide at the north, and soon the present channel to Hudson bay was cut out, drawing the old lake down below the level of the southern outlet, and finally draining it. Nelson river, before reaching Hudson bay, runs over very rough rapids and falls, the slightly worn rocks indicating a comparatively recent origin of the river.

PROFESSOR WINCHELL'S THEORY.—Another theory is given by Professor N. H. Winchell, state geologist of Minnesota. It is this: The vast quantities of water consequent on the melting of the ice-sheet were hemmed in on the north by the wall of ice and found a way of escape to the south, as already described. As the ice wall receded a lake was formed in the present Red River valley with a southern outlet, this lake gradually growing larger. Finally a time was reached when the ice had melted sufficiently far to allow the water to find a passage by way of the north, as at present, and when the water level was drawn down the southern outflow was stopped and the lake drained. This ancient lake, believed to be of glacial origin, has been named by Professor Winchell lake Agassiz.

Geological structure.—It is a fact that nowhere along the course of the Red River of the North is rock found "in place" until in the vicinity of lake Winnipeg, where the river strikes a light, buff-colored limestone. From its source to near its mouth the bed is in the drift left all over the surface of the rock in that region, and the only rocks met are the erratic bowlders, called "hard-heads", scattered through it. The glacier appears to have had its southern and southwestern terminus here, for western Dakota is a driftless region. Taking a cross-section of the valley in a line running east and west, the condition is found to be as follows (see Professor Winchell's article in the *Popular Science Monthly* for June and July, 1873). The divisions can hardly be called strata, although there is a general plan of superposition:

1. Alluvium of the modern river, increasing in thickness toward the north and rather sandy in its nature above the Red Lake river. It is largely restricted to the immediate river bottoms.

2. A finely-divided, loamy-colored clay, without stones, and evidently the deposit from the muddy waters of lake Agassiz. It is thickest at the north, and finally fades away, being unknown about lake Traverse, and hardly found south of Breckinridge. The deposit is of varying width, but is greatest at the north, and south of the national boundary is generally from 15 to 20 miles wide on each side of the river. It formerly covered most of the bed of lake Agassiz, but the changes in that lake disturbed it largely, and east of Moorhead it thins out rapidly, but is much thicker on the west side. The lacustrine deposit is a very peculiar feature of the region. This is the subsoil which has given fame to the Red River valley within late years as a wheat-producing country; and, although hardly superior in that respect to the coarser drift which outcrops east and west, it is making the valley renowned for its almost unparalleled productiveness. As a storehouse to supply the black loam above with the necessary salts it gives a wheat-growing soil claimed to be the equal of the celebrated Tchornoi Zem, or black-earth region of Russia and Hungary. It is also maintained by some that, owing to the cold winters, the frost will bring to the loam from the subsoil renewed vitality each year, making the ground inexhaustible.

3. A sand and gravel strata, caused by the lake waters dissolving the drift, which made its bed, and floating off the clay from the gravel and sand. This is only found under the lacustrine clay.

4. True unmodified drift or till, a blue hard-pan. This drift is spread in a bed of from 100 to 200 feet thick over a large part of northwestern Minnesota, and consists of an uncertain mixture of clay, sand, gravel, and bowlders, all the preceding layers being modifications of it. Of the stone found in it in the Red River region 75 per cent. belong to the Winnipeg limestone, and there are many granite bowlders. This limestone formed the bed and shores of lake Agassiz. Coming to the surface along the edges of the valley proper, 10 to 15 miles east and west of the river, it forms large, slightly undulating plains. South of Breckinridge the lacustrine clay, as already mentioned, thins out, and this drift comes to the surface. East and west it is then more irregular in surface, and is largely modified by action subsequent to its first deposition, forming the hilly, rolling regions about the water-sheds of the basin, the medial moraines about the headwaters of the river on the east, and in Dakota the Coteau des Prairies. As it emerges in the moraines just mentioned the nature is coarser, there being more sand and gravel and large quantities of bowlders. Some of the hills on the east are thickly covered with the rounded and glacier-worn "hard-heads".

5. A layer of bowlders and gravel, with some clay, and occasionally sand and gravel. There is in this considerable slate and lignite from the Cretaceous, which was broken up by the glacier. This layer is probably underlaid everywhere, except in inconsiderable areas, by the Cretaceous deposits, so far as Minnesota is concerned; but in Manitoba the Silurian rocks rise through the Cretaceous, and in places even through the drift appearing at the surface.

Of course there are variations from the above section. In places are found local layers of sand or gravel; then again beds of pure blue clay, etc. Where glacier streams have run down into lake Agassiz, carrying their mud and *debris*, they have formed deltas, now apparent as local modifications, and the modern streams have also had their effects, though the old beaches of lake Agassiz are yet traceable. There is a synclinal dip of the different layers toward the river, and this gives rise to artesian wells in the valley proper. Layers 3 and 5, but especially 5, and, when overlaid by the impervious blue clay, layer 4, give fine wells, the water entering the water-bearing layers in the rolling land. A well about 20 miles north of Crookston is said to throw a stream 5 inches in diameter 40 feet high.

The following section was given by Judge Ives, of Crookston, and probably represents the conditions in that valley:

1. Soil 16 to 30 inches thick, black loam, containing 8 to 13 per cent. of organic matter, and 3.8 to 5.2 per cent. of alkaline salts.

2. Marly clay subsoil, 6 to 10 feet deep, containing 40 to 55 per cent. of carbonate, sulphate, and phosphate of lime, and 5 to 8 per cent. of salts, consisting of sulphides, chlorides, and nitrates of potassa, soda, and magnesia. The balance is silicate of alumina.

3. Layer of sand and gravel from 3 inches to 10 feet thick, holding water.

4. Bowlder clay 40 to 120 feet thick, containing Cretaceous fossils, and in some places a stratum of sand and gravel. Where this sand stratum has not been met in the boring of wells the bed is from 100 to 120 feet deep.

5. A layer of brecciated sand and gravel.

6. Silurian sandstone in place, impervious to water.

Numbers 3 and 5, and the sand and gravel layer where present in number 4, are water-bearing, as mentioned in the geological section of the valley given previously. The great difficulty is to procure good water for domestic use, the surface water being strongly impregnated with alkaline salts. The waters flowing over the fresh-water deposit of the old lake are less highly charged than those whose beds are in the bowlder clay, the unmodified drift, which is largely derived from the marine deposit of the Cretaceous sea. Thus the tributaries further north are less alkaline than those nearer the headwaters of the river. The Bois de Sioux, which flows over the river bottom entirely, is purer than the Otter Tail, which runs through the rolling drift region. The farmers in the valley dig through the loam and marly clay to the water-bearing layer, number 3; if they strike a thin portion of the layer the supply of water is small, but if a thick layer is met it is abundant. It is not permissible to let the water be long in contact with the marly clay in which the well is dug, as it soon becomes saturated with alkaline salts; and accordingly the wells are cased, and this has been done with pine boards usually. It is noticed that the water of wells so cased becomes extremely offensive from the decay of organic matter, and are at times utterly unfit for use. The subject was investigated under the direction of Professor N. H. Winchell, and it was decided that there was no organic *débris* in the soil to produce this effect, but the pine casing used for the well as it decomposed was really the cause of the trouble. It is felt that this habit of casing the wells with wood liable to decomposition may be largely instrumental in producing the disease known as Red River fever. The water of wells dug in the prairie without casing may be charged with organic impurities in summer from the decay of the rank vegetation falling into it, and this is true of the smaller streams which are choked up with grass and weeds. All the surface water and small wells through this region are too strongly mineral to be really good in quality for domestic purposes, but there is a great resource left in the excellent facilities for artesian wells. The lower stratum of sand and gravel, underlaid by the solid rock and capped by the impervious layer of bowlder clay, forms a reservoir all under the valley fed by the rains on the higher lands east and west. Then the sand and gravel stratum in the clay above, where occurring, is liable to contain water. Wells bored into the bowlder clay sometimes strike water, but it is advisable to continue to the lower stratum below the clay, where there is almost a surety of good results.

In the valley proper, as already mentioned, this water-bearing stratum is about 120 feet below the surface, but east and west, on the terraces the depth is of course greater. In the early part of 1881 there had been three wells bored in Polk county—one on the south side of Red Lake river, near Crookston, 190 feet deep, and two 20 miles farther south, 145 feet deep, all throwing copious streams of fine soft water from 25 to 40 feet high. One at least of those south of Crookston gives a stream 5 inches in diameter and 40 feet high.

GENERAL DESCRIPTION OF THE BASIN.

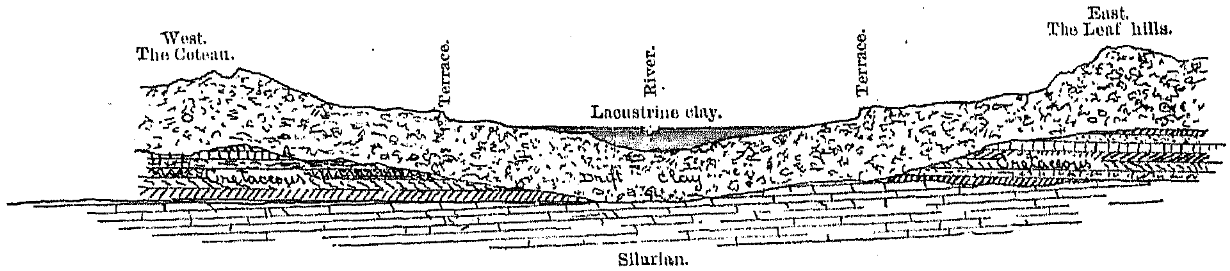
The discussion just completed of the geology of the district will enable a more ready understanding of the topography, hydrography, and other physical characteristics of this drainage basin. It would be difficult to find a river owing its surrounding features more completely to the geological period immediately preceding the present one. The very drainage area is to a certain degree limited in extent by the moraines shoved in front of the advancing ice-sheets already mentioned, and in nearly all places of which information can be obtained for this report the summit line of the basin is determined by a glacial moraine.

LIMITS OF THE BASIN.—From the geological reports it can be gathered that a rough, hilly section running southwest from the eastern side of Red lake forms the dividing line between the White Earth lake, which empties into a tributary of the Red River of the North, and lake Itasca, at the headwaters of the Mississippi. This continues south a few miles to the east of Otter Tail river, where it is called Leaf hills, and is described as a medial moraine. Then turning southwest, so as to include West Battle lake and lake Clitherall in the basin, the Leaf hills, there considered a terminal moraine, merge into irregular belts of hilly land, which determine the dividing line between the basin and the Pomme de Terre river, which flows into the Minnesota. From there down to lake Traverse the water-shed seems to coincide very closely with the shore line of lake Agassiz as given in the state geological report, and, passing west, it makes the dividing ridge between lake Traverse and the Big Stone river. West of lake Traverse the basin is bounded by the Coteau des Prairies, from which the boundary crosses over to Coteau des Missouri, and so sweeps away up the North Saskatchewan river, 350 miles west of Winnipeg. This is the terminal moraine of the great ice-sheet on the west and southwest, and completes the boundary-line of the Red River basin.

CROSS-SECTION OF THE BASIN.—The best idea of the contour of the basin is to be obtained from the accompanying cross-section through Moorhead, copied from the state geological report of Minnesota for the year 1877. It is only claimed to be largely an ideal sketch.

It will be seen that east and west of the river extends a nearly level plain, the lacustrine clay bed, with a width of 10 or 15 miles on each side of the river along the upper portion, widening further north, and a very uniform slope of 1 foot per mile toward the north, sloping toward the river from both sides slightly; and at Breckinridge about 2½ feet per mile, with not a knoll, not a solitary bowlder, upon its surface to break the monotony of this prairie plain, only the trees, confined to the alluvium along the river, appearing above the prairie grass, excepting the rapidly increasing number of farmers' houses.

This is the wonderful Red River Valley wheat region. At the national boundary it is about 800 feet above the sea-level, and at Breckinridge about 960 feet above the sea. Succeeding the plain on each side is a terrace, probably



SECTIONS ACROSS THE VALLEY OF THE RED RIVER OF THE NORTH AT MOORHEAD (Geological Report of Minnesota, 1877).

the shore line in front of lake Agassiz, rising on the east in a few miles 200 or 300 feet, and beyond this is an undulating surface leading to the hilly moraines which form the dividing ridges. This undulating and hilly portion is prairie country, with groves scattered in places among the knolls, and is fine farming land. From White Earth lake, lying west of Itasca lake, down to the river, the profile is this: The land around the lake is about 1,600 feet above the sea. In the first 4 miles west from White Earth agency the land descends 300 feet to an extensive undulating plain. This plain runs west 25 miles, falling 100 feet; then there is a descent of 300 feet in a few miles to the lacustrine plain adjoining the river. The undulating country on the east is made up of the moraines. Beside the Leaf hills, mentioned as forming the boundary of the basin on the east, is a prominent medial moraine running through the Detroit Lake region, and forming the eastern boundary of the Pelican River basin, a tributary of the Red River of the North. About Detroit the hills are 50 to 100 feet high, and south the moraine is 6 to 7 miles wide, and along the Pelican river the hills are 100 to 150 feet above the water. From Fergus Falls the moraine sweeps southeast and merges into the Leaf hills. In the 25 miles from lake Lida north to Fergus Falls the general surface falls about 100 feet.

ELEVATIONS.—The following are some of the elevations above the sea, obtained mostly from the geological reports. There is a possible error of 25 or 50 feet in them:

	Feet.
Crookston	859
Hill-tops about Detroit	1,500 to 1,600
Perham, Northern Pacific railroad	1,375
New York mills, Northern Pacific railroad	1,418
Otter Tail river at crossing of Northern Pacific railroad	1,327
Pelican river at crossing of Northern Pacific railroad	1,346
Otter Tail and Rush lakes	1,325
East and West Leaf lakes	1,340
Red River of the North at Fergus Falls	1,181
Bridge at Dayton, below Fergus Falls	1,071
Water-shed between lakes Traverse and Big Stone	995
Saint Olaff, on the Saint Paul, Minneapolis and Manitoba railroad	1,344
Lake Clitherall, about	1,341
East and West Battle lakes	1,338
Nidaros plain, southeast of lake Clitherall	1,455
Average elevation of southeast Otter Tail country	1,378 to 1,400
Leaf hills about Eagle lake	1,400 to 1,500
Lund and Millerville townships; in Douglas county	1,500 to 1,600
Leaf Mountain township	1,550 to 1,650
Northwest Effington	1,600 to 1,700
Highest summit of Leaf hills, probably in section 32, township 132, range 38, about	1,750
Thence 7 miles northeast	1,600 to 1,650
About Leaf river crossing	1,425
Thence 6 miles north to second crossing of Leaf river	1,450 to 1,640

No elevations were obtainable of the region in Dakota, and, in fact, a large part of the water-shed in that region has been little surveyed, the land-office maps representing the territory about the headwaters of the Sheyenne and Moose rivers almost in blank.

TWO-FOLD HYDROGRAPHICAL DIVISION OF THE BASIN.

It is evident from the above remarks that the Red River basin can be considered as consisting of two divisions: The plain, constituting the Red River valley proper, and what may be called the hill country, from which most of the tributaries run. Though both are prairie land, they still have very different appearances; one, a level sea of grass, except where the streams run; the other, at least on the east, consisting of rolling and even hilly prairie, interspersed with an astonishing number of lakes, and in some localities with groves of trees. This division will also serve as a geographical division of the water-power of the basin. All the water-power, with scarcely an exception, is in the hill country, and omitting a possible power at Goose rapids all the available water-power of the river proper is from Dayton, east of Breckinridge, up to the headwaters.

THE LAKES.—The lakes, which almost cover the surface of central and western Minnesota, are a very prominent feature in the scenery of the hill country of the basin, and one of them has given its name to the county and river flowing through it. This lake, called Otter Tail by the Indians, and one of the largest in western Minnesota, is 8 miles long, and averages 2½ miles wide, rather square at the ends. Its area is 20 square miles, and the long axis lies in a southwest and northeast direction. The Red River of the North is the outlet at the southwest end, and the Otter Tail river enters at the other extremity. The bed and shores are sandy, and the lake is quite shallow, Dr. D. D. Owen in his report stating that it is only 4 feet deep half a mile out from the west bank. The Otter Tail river flows southwest to the lake shore, and then suddenly turns at right angles to the southeast, flows parallel with the end shore of the lake for a mile, only separated from it by a narrow sand ridge 5 or 6 feet high, and finally enters the lake. This ridge has the form of an otter's tail; hence the name of the river. It is evident that two forces have been struggling for the mastery: the lake, under the action of the southwest wind, churning up the sand of the lake shore, perhaps brought down by the river itself, and the river endeavoring to break through this barrier. Under their combined action a bar has been formed, and finally a sand ridge, the river running along back of it and the mouth moving southeast down the shore with the growth of the bar, until now it is at the southeast corner of the lake. The lakes, being as they are in the water-power region, exert a very important effect upon the value of the streams, and are merely the filling by water of the innumerable basins and closed valleys left in the drift by the recession of the ice, as will be described in another place. The total number of lakes in the Red River basin in Minnesota, as given on a large and detailed state map, is 700, varying from about 250 square miles in extent (Red lake) to the veriest pool (see map of river). Of these, 241 are counted in the water-shed tributary to the river above Fergus Falls. Many have no apparent outlet, but there is a probability of their filtering through the sandy shores, where such occur, into neighboring lakes or streams. In some of them the evaporation probably equals the supply. Many of these lakes afford fine fishing and hunting, and at the proper season ducks and wild geese abound.

TIMBER.—The timber is mainly confined to the river courses, but in the hill country there are scattered groves. In the valley proper the timber is along the main stream and tributaries entirely, and it is there confined to the river alluvium. On leaving the rolling land, for twenty miles, down to Breckinridge, there is no timber. The geological report states that in the first 10 miles below Breckinridge the river is fringed with groves of burr oak, ash, box-elder, elm, and basswood. Poplar and willow are also seen. Going north from McCauleyville the timber becomes larger, and is found in greater quantities. Between Frog Point and Grand Forks the timber, oak, ash, and elm runs east 2 miles, while on the west it is included within a tangent along the bends of the river. From Grand Forks north for 9 miles the timber belt is narrow on each side, and in the next 9 miles it is 2 miles wide on the Dakota side and three-fourths of a mile wide on the Minnesota side. The same kind of timber occurs as is found up stream. From there down to Big Salt river the timber belt is about 1 mile wide on each side, but fire has injured it on the east; but below this the timber becomes poorer in quality, and is very inferior nearer the national boundary. The matter of fuel supply is a troublesome one to the inhabitants, and in severe winters there has been much suffering in places away from the railroad.

THE RIVER FROM THE NORTH TO WHERE IT ENTERS THE HILL COUNTRY EAST OF BRECKINRIDGE.

At the end of the report on this river are tables giving the lengths and drainage areas of the tributaries, the rainfall, etc.

The interests of navigation have caused several surveys along the river from Breckinridge to the national boundary, and much of the description of that portion of the stream is obtained from the United States engineers' reports. The distance in a straight line from where the river crosses the national boundary to Breckinridge, as measured on a United States land-office map, is 188 miles; and although it does not depart over 6 miles from this line on the west and 3 miles on the east, yet the course is so winding—in some places 1 mile by river accomplishing only 300 feet of northing—that the total distance by river from the south line of Manitoba to Breckinridge is 394 miles, 18 miles more than twice the bee-line distance.

Assuming the river in low stage at Breckinridge to be 957 feet above the sea, and at the national boundary 792 feet above sea-level, the intervening fall would equal 165 feet, making the average slope per mile 0.418 feet. The heaviest slope is probably in a part of Goose rapids, at the mouth of Goose river, where the river falls 4.563 feet in 2.84 miles, equal to 1.6 feet per mile.

SYSTEM OF IMPROVEMENT.—The river channel is cut in the clay of the valley and into the old drift-bed below; hence a portion of the bed is clay, and in places gravel and bowlders are met. The pools are deep enough for navigation, and the chief problem in improvement for navigation is the removal of snags and the deepening of the channel over clay bars. A peculiarity of the stream is that in the bends the deepest water is nearest the convex bank. This is owing to a clay bar running out from the concave bank. The bar is derived from the bank by cracks forming, into which the rains soak, loosening the clay and sliding off masses into the water. Below Moorhead the banks slope up from this cause within 200 feet from the river to the full height of the surrounding prairie, 40 feet above. The system pursued has been to excavate a channel through the bars 60 feet wide and place the excavated material as a wing-dam on the bars in the bends, thus turning the water toward the convex bank.

For the first 20 miles south from lake Winnipeg the river is said to run through swamps. Twelve miles north of the city of Winnipeg is Andrew's rapids, the first locality where the river strikes the rock in place, which is a light, buff-colored sandstone, the same as is found scattered through the drift farther north. This rock is quarried and used for building purposes in Winnipeg.

From a finely-executed tracing and levels kindly presented for this report by Mr. Thomas Rosser, chief engineer of the Canadian Pacific railway, it is ascertained that the distance from lake Winnipeg to the city of Winnipeg by river is 48 miles and the intervening fall 12 feet, while from the city of Winnipeg to the national boundary the distance by river is 106 miles and the intervening fall 23 feet.

From the national boundary up the worst obstructions to navigation are Goose rapids, at the mouth of Goose river, Turtle River bars, 9 miles above Turtle river, and Pelican bars, 28 miles south of the national boundary. The last two consist of successions of pools and riffles over stiff clay bars, which the river is unable to wash away. The first is described further on. The natural depth of the channel in low water varies from 10 feet in places to 2½ feet or even less.

WIDTH OF THE RIVER.—This varies from 225 to 300 feet below Grand Forks, and above that immediately diminishes from 230 feet to 137 feet, owing to the entrance of the Red Lake river, the largest tributary. Between Grand Forks and Moorhead the width varies from 100 to 200 feet, but above there for many miles the width is about 95 feet and the depth 6 to 10 feet, and near Breckinridge the river widens to 125 feet.

SLOPE OF THE RIVER.—The slope is greatest in the upper portion, averaging 0.74 foot per mile. Between Grand Forks and Frog Point it is 0.365 foot per mile, then further north 0.293 foot per mile, and near the national boundary 0.194 foot per mile. Below the national boundary the slope is about 0.23 foot per mile.

BED OF THE RIVER.—The bed is clay through a large portion of the course, but in places there are gravel and bowlders, as at Goose rapids and between Grand Forks and Frog Point. A few miles below Breckinridge the gravel and bowlders are again met. The banks are about 10 feet high at Breckinridge, and from there down gradually increase to 40 feet or more below Moorhead.

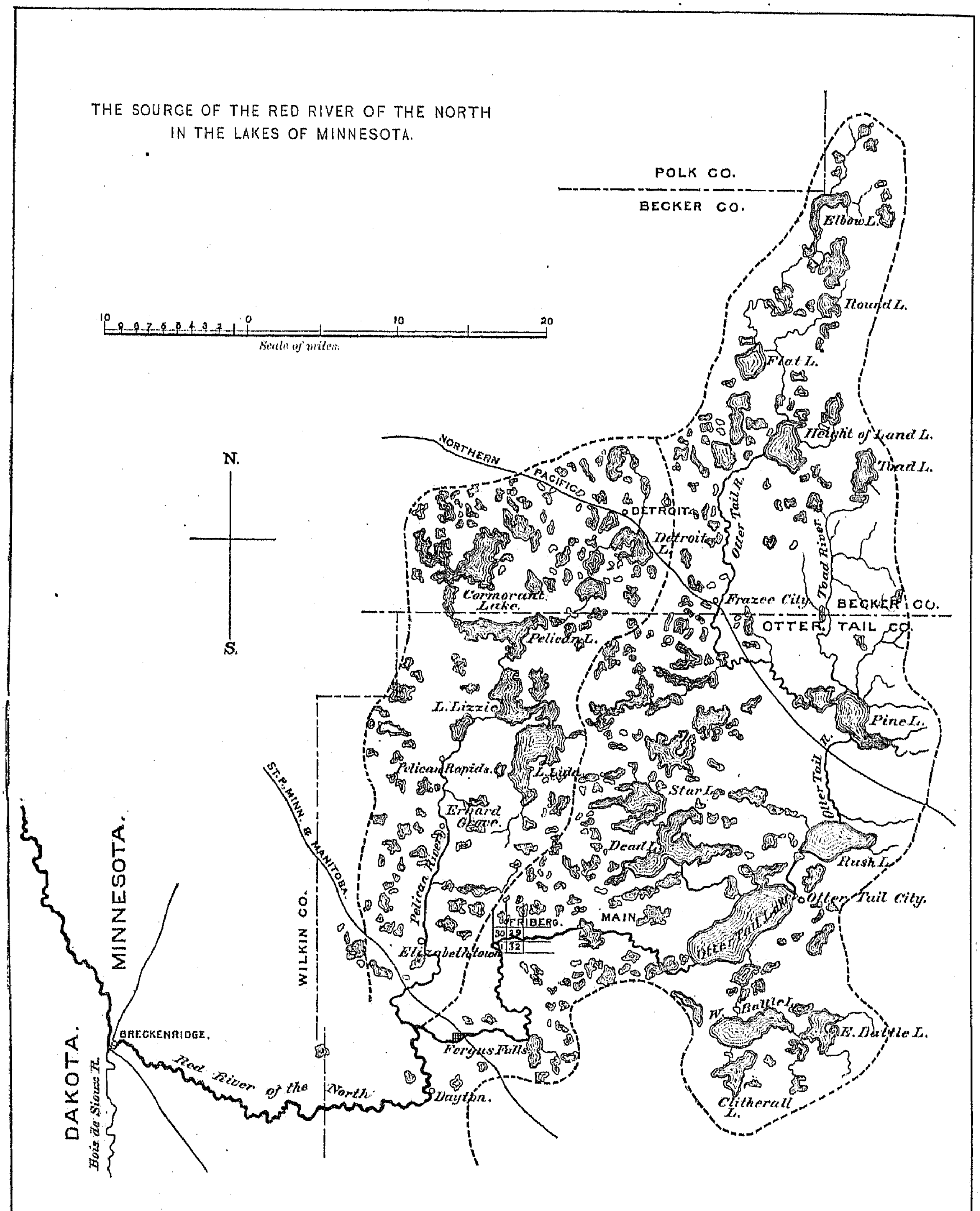
FLOODS AND THEIR CAUSE.—One feature, unknown in the hill country, is the tremendous floods which sometimes inundate nearly the whole width of the immediate river valley, so that steamboats have been known to ride out over the wheat-fields. The extreme range at Breckinridge is 16 feet, and at Moorhead 28 feet, but below Moorhead the rise is as great as 40 feet. The ice melts on the southern part of the basin before it does further north, and the river, swollen by the melting snows, carries it down to gorge upon the yet solid portion. The result is very similar to the state of affairs when lake Agassiz filled the valley. According to the second theory mentioned, the water backs up over the plain, and in high floods even rises over the water-shed beyond lake Traverse, and pursues the course taken by the old lake, which it strives to imitate. This, of course, does not occur every season. In 1880 the river was clear of ice on April 14, and in 1879 was open and free for 208 days.

GOOSE RIVER RAPIDS.—The Goose River rapids, which are the greatest impediment to navigation on the river, extend down stream 13½ miles from the mouth of Goose river, making in that distance a total descent of 12.666 feet. The bed is gravel and bowlders. The following is a table of distances and fall in the stream at these rapids:

		Feet.
From Goose river 1.0 mile down the fall is		1.422
For the next 1.82 mile down		1.444
For the next 1.94 mile down		1.226
For the next 2.84 miles down		4.563
For the next 1.74 mile down		1.246
For the next 1.66 mile down		0.660
For the next 1.82 mile down		1.555
For the next 1.14 mile down		0.550
Total distance 13.36	Total fall	12.666

Some improvement in the interests of navigation is necessary. The fall is too great for dredging and the use of wing-dams, and it has been proposed to build a dam at the foot of the rapids of 12 feet rise to flood them out, with a lock for the passage of boats at one side. On account of the very high freshets a movable dam is recommended.

WATER-POWER OF GOOSE RIVER RAPIDS.—There has been talk in the past of utilizing the rapids for water-power, but nothing has been done in that direction. As the government is about to improve them, it will be perhaps feasible to make use of the dam for water-power, and if the arrangements are such that this could be done without interfering in any way with the government interests it is probable that terms could be made for its utilization.



Taking the low-water discharge there at 1,100 cubic feet per second, the total theoretical power under 12 feet head is 1,498 horse-power, the available power, at 75 per cent., 1,123 horse-power, and the average flow 1,500 cubic feet per second. A very serious disadvantage is the great floods previously mentioned. The valley proper of the river there averages one mile wide. The banks of this valley slope back for 200 or 300 feet to the level of the prairie, 40 feet above, and the floods fill this trough sometimes to the brim. It is the opinion of Mr. C. J. A. Morris, engineer of the Saint Anthony Falls Water-Power Company, who has kindly furnished information on the subject, that the only feasible method of using the power would be by wire-rope transmission to mills situated on the bluffs above, out of reach of the floods. He does not think that the power will ever be improved unless a dam is built by the government.

At Breckinridge the river course turns, the stream flowing from the east.

BOIS DE SIOUX RIVER.—The Bois de Sioux, the outlet of lake Traverse, enters here, and is the continuation in a southerly direction of the main river, but it is a small, sluggish stream, only a few feet wide, and furnishes only 5 per cent. of the flow below the junction. This is estimated at 1,000 cubic feet per second in low water; hence the flow of the Bois de Sioux is 50 cubic feet per second in low water, while that of the main stream above is 950 cubic feet. From Breckinridge, in passing east up the stream, the course is through the same level prairie for about 10 miles by land, but the slope of the river is much more rapid, two or more feet per mile. Then the hill country is entered, and the river takes the characteristics of a hill stream, rapids occurring in many places.

DESCRIPTION OF THE RIVER IN THE HILL COUNTRY OR WATER-POWER REGION.

DISTRIBUTION OF THE FALL.—There is from Otter Tail lake to Breckinridge a total fall of 368 feet, and nearly all of this is in the hilly portion of the river's course, which falls off below Dayton, crossing into the flat plain of the valley proper. This 368 feet fall, then, is practically concentrated in the 34 miles (map measurement) from Otter Tail lake to Dayton, and, as it is still further concentrated in local rapids, there are many fine water-power sites. The banks are usually high enough to hold ponds, and the hard till forming them and the bed make a good foundation for dams.

UNIFORMITY OF FLOW.—One great advantage possessed by this stream from the standpoint of water-power is its extreme steadiness, owing to the large number of lakes, which act as storage reservoirs for it. The river drains above Fergus Falls twenty-five or thirty good-sized lakes, particularly Otter Tail lake; and the Pelican river, which enters 4 miles below Fergus Falls, itself receives the water of ten lakes, each of several miles extent, and three of them 6 or more miles long. The result is that the river scarcely ever varies at Fergus Falls, and below, in the hill country, the variation is rarely more than 2 feet in height from the lowest to the highest stage in ordinary seasons. This is very different from the great backwater floods on the plain below, previously described. Another point which makes these lakes of great value to the water-power, much more than if they occurred in a mild climate, is that while streams fed by swamps and small springs would freeze up solid in winter, as is sometimes the case, this river and many of its tributaries flow steadily on during the cold weather, hardly affected by any freezing of their headwaters.

FLOW AND POWER.—The ordinary low-water flow below the mouth of the Pelican river is gauged at 950 cubic feet per second. This gives, at 10 feet head, 1,078 theoretical horse-power. Above the Pelican river the ordinary low-water flow, estimated from the power at Fergus Falls, is 662 cubic feet per second, giving, with 10 feet head, 750 theoretical horse-power. It is probable that the flow of the stream is nearly as much clear up to Otter Tail lake.

From the border of the hill country up to Fergus Falls there is no utilized fall, but the river is rapid, as most of the 224 feet descent of the river from Fergus Falls to Breckinridge occurs in that distance.

DAYTON TO FERGUS FALLS.—Although there are slight rapids below Dayton, there is no available power until it is reached, where there is a good power of 16 feet head unimproved. The place is so small as scarcely to be called a village. Above Dayton the river passes through rolling prairie, and many bowlders are met, and sometimes, where the river has worn against a hill, the bank will be 50 feet or more in height. Above Dayton the course of the river is north and south for 4 or 5 miles by land. At the upper end of this stretch the Pelican river, with a low-water flow of 288 cubic feet per second, enters from the north. From there the river's course is east about 4 miles to Fergus Falls, and in that distance, 3 miles below the town, occurs a water-power site, unimproved, where at least 12 feet head can be obtained. The banks are good, and the bed is the stiff bowlder clay common to this portion of the river.

FERGUS FALLS.

This is the location of the greatest water-power of the Red River basin, in the United States at least, and is without doubt the largest available water-power in the country west of the upper Mississippi and east of the Missouri basins. It is the lowest power improved upon the river. The total fall in the stream at the village is 83 feet, and this is so situated that it is possible to use all of it. With the ordinary low-water flow of 662 cubic feet per second, giving, with 10 feet head, 750 theoretical horse-power, the total theoretical power at Fergus Falls, with 83 feet head, is 6,225 horse-power, or, at 75 per cent., 4,669 available horse-power. The descent is so located as to form five falls. Of these the upper three only are utilized. The banks are from 10 to 30 feet high, and are lowest at the upper portion of the descent. They mostly rise sharply from the river to the general level of the country, and the situation is such that by a system of dams and canals from the different levels the full power could be utilized. The first fall is about three-quarters of a mile from the main portion of the town; the second lies close to the main street, which there runs parallel with the river. Below the third fall the river takes a strong bend to the right.

TABLE OF HEADS AND ORDINARY LOW-WATER POWERS AT THE DIFFERENT LEVELS OF FERGUS FALLS.

Locality.	Head utilized.	Head available.	Theoretical power available with present improvement.	Total theoretical power.	Total effective power (efficiency=75 per cent.)
	Feet.	*Feet.*	*Horse-power.*	*Horse-power.*	*Horse-power.*
First fall	16.0	30	1,200	2,250	1,688
Second fall	12.5	14	938	1,050	788
Third fall	10.0	10	750	750	563
Fourth fall	Not utilized.	About 13		975	731
Fifth fall	Not utilized.	16		1,200	900
Totals	38.5	83	2,888	6,225	4,670

FIRST FALL.—On the upper fall the owners, Messrs. Austin & Newcomb, have 16 feet head, and a new flouring-mill of 150 barrels capacity. They intend eventually to increase the head from 16 to at least 27 feet, making the largest improvement on the river. The plan is to run races down from the dam and locate mills upon them.

SECOND FALL.—At the second fall the power is used by an establishment on the right bank, called the Bee Hive, embracing a saw-mill, carding-mill, planing-mill, and one or two little industries. The head could be raised to 14 feet, but more than that would cause overflow into a small portion of the village.

THIRD FALL.—The lowest utilized power is at the third fall, where, on the right bank of the stream in descending, is a flouring-mill, newly erected, intended to have a capacity of from two to three hundred barrels per day. The head used is 10 feet.

FOURTH AND FIFTH FALLS.—These two falls below are yet in their natural condition. It is evident that the possibilities at Fergus Falls are by no means developed. At the second fall, when seen in the winter, the water was rushing over the crest of the dam in a heavy body while the wheels were running, and at the third fall the one flouring-mill could not begin to exhaust the flow. As stated before, the comprehensive system of races along the banks from the different levels would be mostly feasible, and it appears to be the proper way to fully improve the power. The bed of the river is a hard clay and gravel, with big bowlders of granite and other rock, the till before described, and must be firm, or the rapids would have been long ago worn away.

The nature of dam exclusively used on the stream is a log crib-work. A crib is built sometimes extending 120 feet up stream, setting back each course in a series of steps. The face is planked over, and brush and gravel are filled in on the toe of the dam and up the back.

LOCATION OF THE TOWN.—The town is situated on the Fergus Falls division of the Saint Paul, Minneapolis and Manitoba railroad, and is the most important place in that region of country. Being situated in the midst of the grain country and on the railroad, there is every facility for the manufacture of flour.

THE RIVER ABOVE FERGUS FALLS.

LOCATION OF THE POWER.—The level of Otter Tail lake is 144 feet above the river at Fergus Falls. The greater part of this fall is located in the 15 miles by river (map measurement) below section 29, in southwestern Friberg township. For all this distance there is a good current, with several rapids, some of which could be utilized for power, but as yet nothing has been done. Within 3 miles of the village of Fergus Falls, and above the first fall, is an unutilized power of 13 feet available head, beside the 14 feet unutilized at the first fall. The knolls along the stream rise 30 or 40 feet above the water. In sections 29, 30, and 31 of Friberg township the rapids are heavier, and the stream is a succession of rapids for 2 miles or more. The bed is clay and bowlders, and the banks are not all high. In one place there is a good bank upon one side, but a low meadow on the other. However, there are one or two good sites there; one especially, where there is a fall of 30 feet, probably the most of it available. Above section 29 of Friberg the river is sluggish and widens out into several lakes. There is no fall of any consequence until the stream is ascended up to the southeast part of Main township, in section 35, where there is an unimproved fall of about 12 feet, called Monitor falls. These have a bowlder bed, and are described by Dr. Owen in his report as heavy rapids. One or two miles above the river emerges from Lost lake, which is 2 or 3 miles long. About 1 mile from Lost lake is Otter Tail lake, the source of the Red River of the North.

TRIBUTARIES OF THE RED RIVER OF THE NORTH.

The water-power upon these tributaries is practically in the hill country, as is the case with the main stream. The larger ones, especially on the east side, are usually steady in their flow, because fed by lakes to so great an extent; but the smaller ones, starting below the lake region, partake more of the character of a typical prairie stream swollen high by the melting snows, but dwindling low in summer and in winter freezing up. The only ones that merit particular attention in a water-power report are the Red Lake, Otter Tail, Pelican, and Sheyenne rivers.

OTTER TAIL RIVER.

This is treated first, not because it is the largest, but because above Otter Tail lake it corresponds with the main river. The source is Elbow lake. Thirty-eight miles below (map measurement) are the two Pine lakes. Into Pine lake empties Toad river, about 15 miles long, and the outlet of several small lakes. From the head of Pine lake to Rush lake is 12 miles, and from the head of Rush lake to the head of Otter Tail lake the river runs 6 miles. Otter Tail lake is about 8½ miles long. There is very little water-power upon the Otter Tail river, the only utilized one being at Frazee City, on the Northern Pacific railroad, where the elevation of the river bed is stated in the geological reports to be 1,327 feet, while Otter Tail lake is 1,325 feet above the sea. There are several feet of possible error in these elevations, which probably accounts for the slight difference of 2 feet in elevation; but it goes to show that there is very little fall in the river below Frazee City. Below Frazee City, in Hobart township, the river is extremely crooked, and between Pine and Rush lakes is wide and swampy. About Frazee City it is from 20 to 40 feet wide. There is some slight fall above Frazee City, but the stream is of little consequence so far up.

UTILIZED POWER.—At Frazee City are a flouring-mill and a saw-mill under 12 feet head, the flouring-mill using 60 horse-power, and the saw-mill, which only runs in summer, having a capacity of 75 horse-power. Mr. Frazee, the owner of the flouring-mill, states that the total available power of the river at Frazee City, under 12 feet head, is 100 horse-power in ordinary stages of the river, which would require a flow of 97.9 cubic feet per second, considering the efficiency 75 per cent. This estimate is probably slightly less than the actual discharge, as with the methods in vogue the utilized power is, in all probability, less than 75 per cent. of the theoretical power. Mr. Frazee says that the high-water flow is about four times the volume of the low-water discharge, but they have no heavy freshets. There is a small power on Toad river, running a flour-mill of about 40 horse-power size.

PELICAN RIVER.

This river rises in some small lakes just north of Detroit lake and flows south 43 miles (map measurement) into the Red River of the North. From Detroit lake to its mouth the fall is not far from 260 feet. The low-water discharge at the mouth is about 288 cubic feet per second, giving, with 10 feet head, 326 theoretical horse-power. The river in the lower part of its course is from 30 to 40 feet wide, and the flow is increased somewhat, below Detroit lake, by the discharge from lakes on the east. The stream drains at least ten lakes, and, owing to these, is steady in its flow, although it is not quite so reliable as the main river. The variation in height at Detroit during the year is stated to be 18 inches, the highest water being in April, when the snows melt. As on the main stream, the banks and bed consist of clay, gravel, and bowlders. The country about it is quite hilly.

IMPROVED POWERS.—The first power improved on the upper part of the stream is at Detroit, on the Northern Pacific railroad, just above Detroit lake, where is a flour-mill called the Detroit Lake mills. They have three run of stones under 12 feet head, but in midwinter use steam. Being near the headwaters, the flow becomes small in cold weather. Six miles below this is a good power, unimproved, of 10 feet head. Twenty miles from Detroit is Pelican rapids, where there is a flouring-mill and a saw-mill under 10 feet head, using 40 horse-power each. The owners of the property estimate the total available power of the river there, under 10 feet head, at 200 horse-power. There are two or three unimproved powers at the place. In Erhard's Grove township there is some available power untouched. Below this a stream enters from the east, the outlet of Long and Jewett lakes. The next improved power is at Elizabeth, where there is a four-run flouring-mill, using about 60 horse-power at 15 feet head. The discharge there must be about the same as at the mouth, giving 326 theoretical horse-power with 10 feet head, or 245 available horse-power. According to the proprietors of the mill, the available power at 10 feet head is about 283 horse-power.

RED LAKE RIVER.

This river is by far the largest tributary stream of the basin in the United States, and from a water-power point of view is nearly as important as the main river, for the reason that it lies very largely in the hill country, while the Red River of the North has all its water-power upon the upper waters. The mouth is just below latitude 48° north, and the general course is west from Red lake, which lies in latitude 48°. The source is about 30 miles southeast from Red lake, in a lake three-quarters by half a mile in extent, within a few miles of the upper waters of the Mississippi. The distance from source to mouth in a straight line is 105 miles; by river it is over 200 miles. The total area of the water-shed is 6,518 square miles.

RED LAKE.—Red lake, which serves a very important office to the water-power of the river in steadying the flow, is the largest lake lying wholly in Minnesota, and, next to lake Superior and the far northern Lake of the Woods, is the largest sheet of water connected with the state. It consists of two parts, one lying northeast of the other, connected by a strait about 2½ miles wide. The area, as estimated from the United States postal map, is a little over 250 square miles. The lake is described as being shallow in proportion to its size, and as having no islands. Many tributaries enter it from various directions, and it is really the feeder and regulator of the Red Lake river, as the stream emptying into the lake which bears that name is a small, crooked brook, hardly more than 15 feet wide, although deep enough to allow of canoe navigation. The river below Red lake is very crooked, one stretch of 33 miles by land including about 100 miles by river. The width in the lower part averages about 150 feet. It is considered navigable up to and above Crookston. Starting from Fisher's landing, about 7 miles from the mouth by land, is an old channel of the river, 25 or 30 miles long, with the mouth about 12 miles below the present mouth of the river. This, called Grand Marais, is now a swamp, on which hay is cut. The largest tributaries are the Clearwater, entering from the south 18 miles by road above Crookston, and, about the same distance above the Clearwater, the Thief river, from the north. Below the two is the Black river, entering from the north, the smallest of the three.

FALL.—In a report on a proposed transportation route to lake Superior the total descent from the Thief river mouth to Crookston is stated to be 230 feet, while above Thief river the stream is deep and sluggish, and it seems probable from the elevation of White Earth lake, given in preceding pages, and from the direction of the streams between it and Red lake, that the total descent from Red lake to the mouth of the river is not less than 400 feet. At all events, there is enough fall to give rise to many available powers. The bed and banks are the drift, as usual in this region, and considerable sand is carried down, it is said, into the Red River of the North. The banks are from 10 to 30 feet high and usually steep, so that ponds would be mostly confined to the course of the stream.

FLOW AND POWER.—Owing to Red lake's forming so excellent a reservoir, the variation in the height of the river is seldom over 4 feet at an ordinary section of the bed and bank; but at rare intervals there is a heavy freshet, due to the rapid melting of the snow. The highest rise known at Crookston was 20 feet. The discharge was carefully estimated by Mr. James D. Skinner, a civil engineer, residing at Saint Paul, who states it at 982.86 cubic feet per second when near the lowest stage, an amount only about 17 cubic feet per second smaller than the flow of the Red River of the North below Breckinridge. This flow would give, with 10 feet head, a theoretical power of 1,115 horse-power.

AVAILABLE POWERS.—There are as yet no utilized powers upon the stream, but there are thirty or more available ones. In the innumerable bends there are frequent opportunities for cutting across a neck and utilizing the intervening fall. The reason for the power of the river lying idle is the unimproved state of the country, with the little demand for water-power. Claims are being taken up, and the land broken, so that Polk county probably has a fine future in store for it.

There is a scheme, already mentioned, for connecting the Red River of the North with lake Superior by means of a canal to Red lake, and so down the Red Lake river. If this is ever accomplished, there will be restriction in the use of the water-power of the stream.

POWER AT CROOKSTON.—The county-seat, Crookston, a town of about 2,000 people, is situated on the Saint Paul, Minneapolis and Manitoba railroad, and also on the river. There is an unimproved power there, and in December, 1880, steps were being taken by the citizens to form an hydraulic stock company to take the matter in hand. The total expense of the improvement was estimated at $40,000. In passing the town the river takes a wide sweep around it. The beginning of this curve is only a short distance from the outskirts of the town, and from that point a depression in the ground, evidently an old river channel, runs for about 3,600 feet across the neck to the river bank below, which it meets a short distance below the railroad crossing.

PLAN OF IMPROVEMENT AT CROOKSTON.—The scheme is to build a dam at the beginning of this old channel and run a hydraulic canal along the side, stationing manufactories at the lower end near the river and using the lower part of the old channel for a tail-race. The plan is a good one. The greatest amount of excavation would be right at the head of the canal, where for a few rods the channel is filled up. The site was surveyed in the fall of 1880 by Mr. Skinner, of Saint Paul, who made the following estimates, as printed in one of the Crookston papers: Discharge of river at low water, 982.86 cubic feet per second; mean velocity of the river, 1,353 feet per second; theoretical power at 12 feet head, 1,336.165 horse-power. To conduct this amount of water through the depression to where it would be used would require a canal with a sectional area of 300 square feet and a slope of 1 in 3,000. The fall of the river from the dam site to the water surface at the proposed tail-race is 4.49 feet. In Mr. Skinner's report it was proposed to build a dam with a head of 8 feet, for which the site is well adapted. The river there is about 150 feet wide, and it bends sharp to the left in its course. The concave bank is some 30 feet high just below, but at the old channel, which starts from the concave bank at the bend, it is not more than 10 or 15 feet high. The left or convex bank is much lower, sloping off more gradually, but will allow an 8-foot dam. With the 4.49 feet natural fall and an 8-foot head raised by the dam, the total head is 12.49 feet, or, allowing for the fall in the canal, somewhat less than 12 feet. To get 12 feet available head it would probably be necessary to raise the dam at least a foot more. It is proposed to build a pile-dam, at a cost of about $8,000, and a canal 3,600 long. The mills and manufactories would be near the line of railroad to Saint Paul, and could easily be connected by side-tracks.

UNIMPROVED POWER ABOVE CROOKSTON.—About 1 mile above Crookston is a bend in the stream, where there is a power lying idle. This would, of course, be destroyed if the other power below was improved. The facts about it were stated by a gentleman interested to be these: The available head is 12 feet. There is an old channel across a bend, as in the location below, and the plan would be to use this for a tail-race, building mills along a short canal at the side. The river is there 120 feet wide and 3 feet deep. The pond would be 1 mile long, averaging 650 feet wide and 12 feet deep; hence the head of water at the dam would be about 9 feet. The whole improvement was estimated to cost $15,000. When interviewed, the informant was on the train on a journey with the object of getting capitalists interested in the power. Above Crookston are many good powers, which will be valuable when the country becomes more settled.

CLEARWATER RIVER.

The Clearwater is the largest tributary, and has the only utilized power in the basin of Red Lake river. It is not so reliable as the Red Lake river, as it is fed largely by swamps, which freeze in winter, instead of by lakes; but it is nevertheless a very good stream. There are many good powers improved. The only improved one is at Red Lake falls, 1 mile from the mouth. There the water passes in a succession of falls and rapids over a clay, gravel, and bowlder bed. The river falls 26 feet in a distance of 1,350 feet. There are a grist-mill and a saw-mill upon it, using 30 horse-power each, under a head of 7 feet. The dam is a brush dam, 2 feet high and 50 feet long. The power of the river in ordinary stages is considered at Red Lake falls to be at least 200 horse-power under 7 feet head.

SHEYENNE RIVER.

This river rises in Sheridan county, Dakota, about latitude 47° 30′ north, and, flowing in a general southeast direction 308 miles (map measurement), enters the Red River of the North 12 miles by land north of Moorhead, in latitude 47° north. The headwaters are only a few miles removed from the James river (called Jim River), which flows into the Missouri, and for nearly four-fifths of its course it flows almost parallel with that stream in an east and south direction; then, suddenly turning, it runs northeast to the Red River of the North. Valley City, a promising young town on the Northern Pacific railroad, is on the river, 135 miles from the mouth (map measurement). In a straight line it is 55 miles a little south of west of the mouth. The most southern point of the river is 40 miles south of this line. The country about the upper waters has never been surveyed, so far as ascertained, but it is known that the river runs throughout in the prairie region of Dakota. From the mouth to Norman, a distance of some 30 miles (map measurement), the river runs in the level plain of the Red River valley proper; there the course changes, flowing more from the southwest, and above Norman it lies in the region corresponding to the hill country on the east side of the Red River basin, although less undulating. Above Norman there is a more rapid descent than below, and, although the current is moderate, still there is considerable fall in the stream. It is said that 9 or 10 feet fall can be obtained every 5 or 6 miles. Below Norman, where the river flows in the lacustrine plain, the slope is only about 1 foot per mile.

The western tributaries of the Red River of the North are not, as a rule, so steady in their flow as those on the east, and it is very natural that this should be the case, because the greater number of them approach in character the true prairie stream. The Sheyenne is probably one of the most reliable. This river never freezes up in the severe winter so as to make it entirely useless for water-power. This may be due to lake Minne-wa-kan, or Devil's lake, a sheet of fresh water some 30 miles long by 5 broad, which, although it is claimed to have no visible outlet, probably drains into the Sheyenne. Still the water-shed is narrow there, and the discharge of this lake must be rather small. The bed of the stream, in the lower half at least, is in the true drift, the bowlder clay consisting of clay, gravel, and bowlders. The last 30 miles is in the lacustrine deposit described on preceding pages. About Valley City the river winds along through a flat plain of varying width, bordered by bluffs over 50 feet in height. This is probably characteristic of the greater portion of the river. Below Norman the banks are from 12 to 20 feet high. The channel is very winding, causing many places where races could be easily cut across necks of land. The rim banks are usually of good height, and would prevent large overflows from ponds, and the fall of the river appears to be largely concentrated in small distances. There will be a long still water, and then a small riffle over a bowlder bed. Thirty-five miles below Valley City there is good timber along the river, oak, elm, etc. At Valley City there is also timber along the river, and up the bluffs to some extent. It is again heavier below. The land is very fine for wheat. At Valley City the river will average perhaps 50 feet wide, and below Norman, at the crossing of the Northern Pacific railroad, somewhat less. Although not a very rapid stream, there are many places where, owing to the favorable banks, a small power can be obtained, but very few of them are utilized.

POWER.—About Valley City the millers say that with 9 feet fall they can depend on 25 horse-power for ten months of the year, which, with their methods, will turn three run of stones and the necessary machinery. Sometimes they have 200 horse-power, and occasionally the power runs very low in winter. Considering that they use 75 per cent. of the theoretical power, this would give an ordinary low-water flow of 2,056 cubic feet per minute, or 34.26 cubic feet per second, which seems a very low estimate for a river of that length; but it must not be forgotten that the water-shed is narrow and the rainfall light in that section.

UTILIZED POWER.—There is no utilized power above Valley City. There is a good situation near fort Totten, at lake Minne-wa-kan, just above where the old road crosses, where a 12-foot head is available. The first improved power is at Valley City, where there is a small mill, with 9 feet head, backing the pond up some 6 miles. Six miles below there is a mill, and 6 miles further down another. These have each about 10 feet head. At fort Ransom, a few miles above the southern bend of the river, where 17 feet head is obtainable, there is prospect of a mill being erected. Although the slope is so slight below Norman, the banks are high enough to allow of making ponds and getting a moderate head of water. This has been done just below the Northern Pacific railroad crossing, where there is a dam, but no further improvement.

CONSTRUCTION OF DAM.—The form of dam that appears most suitable for this region is a spar dam, or else brush dam. The timber, brush, gravel, and bowlders are at hand for its construction. The dam at Valley City was thus built: A row of logs was laid on the bed in the direction of the current; a stringer was put across these at the face of the dam, and another course of spars laid on this, the intervening spaces being filled in with "hard heads". This was continued, bolting the stringers to the spars, until the required height was reached, and then the back of the dam was planked. The river banks are high there, giving good clay abutments. A quantity of gravel was thrown in around the ends of the dam, to prevent the crawfish from boring holes in the clay and weakening the abutments. The river is there about 50 feet wide.

The principal tributary of the Sheyenne is the Maple river, entering about 10 miles from the mouth. It is a small stream of no special importance, nearly freezing up in winter, like the upper James river.

TABLES OF TRIBUTARY STREAMS, DRAINAGE AREAS, RAINFALL, ETC., OF THE BASIN OF THE RED RIVER OF THE NORTH.

These tables are necessarily fragmentary in part, as incomplete information was at hand. The records of rainfall and temperatures are obtained from the valuable publications of the Smithsonian Institution at Washington. The lengths of the rivers were estimated from the state maps, published by the United States land-office, except where designated as survey measurements. The drainage areas were also largely obtained from these maps. The rainfall, as given for the basin of each tributary, is an approximation based on the Smithsonian reports and charts.

EXPLANATION OF THE DIFFERENCE BETWEEN THE EASTERN AND WESTERN TRIBUTARIES.—On an examination of the tables a curious fact is apparent: the drainage area tributary on the east of the main stream has over 33 per cent. greater annual precipitation than that in Dakota. This is because the Red River of the North lies near and almost parallel with the western margin line of the effect of the moist winds from the Gulf of Mexico. The western tributaries, notably the Sheyenne, rise in a section having a very small precipitation of about 15 inches per annum, while the larger ones of the eastern tributaries have their headwaters in a section supplied with about 25 inches each year. This, taken in connection with the difference of topography, explains why it is that the tributaries from the west are so much smaller in proportion to the areas drained than those on the east. That portion of the basin in Minnesota is largely covered with lakes, many of which act as storage reservoirs, while in Dakota are few lakes, and the general level is more uniform than that on the east side of the main stream. The consequence is that the evaporation bears a much larger proportion to the precipitation on the west than it does on the east side of the river. Taking into account the less rainfall and the greater percentage of evaporation to the rainfall it is easy to understand the peculiarities shown in the tables.

COMPARISON OF THE UPPER PORTION OF THE RIVER WITH THE BOIS DE SIOUX.—For example, the area tributary to the main stream above Breckinridge is 2,751 square miles. At Breckinridge the Bois de Sioux enters, with a drainage area of 1,996 square miles, increasing the area tributary to the river to 4,747 square miles. The ordinary low-water flow of the main river above Breckinridge is 950 cubic feet per second, while that of the Bois de Sioux is only 50 cubic feet. The basin of the Bois de Sioux is nearly 75 per cent. of that belonging to the main stream above Breckinridge, while its ordinary low-water flow is only 5¼ per cent. of that of the main stream. This is accounted for by the fact that the annual precipitation on the upper waters of the Red River of the North is at least 25 inches, while about the Bois de Sioux it certainly does not average over 20 inches. Also on the basin of the latter the evaporation is nearly the equal of the precipitation in Dakota and in the marshes about lake Traverse. It must not be forgotten that the Bois de Sioux is not so steady in flow as the main river, and hence the difference would not be so great were the average instead of the ordinary low-water discharge taken into consideration.

COMPARISON OF DIFFERENT SECTIONS OF THE RIVER.—Again, the volume of the main stream does not increase in nearly so great a ratio as the drainage area tributary to it. The United States engineers give the *average* discharge below the mouth of the Sheyenne as 2,000 cubic feet per second. Comparing this with the *ordinary low-water* flow at Breckinridge, we find it to be just double that, while the drainage area above the mouth of the Sheyenne is over three times as great as that tributary to the river at Breckinridge. The Sheyenne, although its drainage basin may be assumed from the map to be 8,300 square miles, is really a very inconsiderable addition to the main stream in low water.

The peculiarities stated above are all illustrated in the last column of the table of the Red River of the North. Under ordinary circumstances the ordinary low-water discharge per square mile of drainage area increases as the area increases, while here the reverse is the case, and it is explained by the distribution of the rainfall and of the lakes. It will be noticed that on receiving the discharge of the Pelican river, whose basin abounds in lakes, the discharge per square mile increases and is at that place the largest.

MEAN PRECIPITATION IN RAIN AND MELTED SNOW AND TEMPERATURE AT PLACES IN THE BASIN OF THE RED RIVER OF THE NORTH.

Place.	Spring.	Summer.	Autumn.	Winter.	Year.	Length of observations.	Summer temperature.	Winter temperature.	Length of observations.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		° ′	° ′	
White Earth agency	......	......	......	......	24.74	Sept. 1869, to Mar., 1870	71.46	0.21	Sept., 1869, to Mar., 1870.
Douglas county	13.97	13.61	9.96	5.82	43.36	May, 1859, to May, 1861	......	......	
Breckinridge	5.41	12.05	3.17	2.45	23.08	Oct., 1872, to June, 1876	......	......	
Fort Abercrombie	4.87	8.67	3.46	1.85	18.85	Aug., 1860, to Oct., 1874	70.94	7.95	Feb., 1859, to Dec., 1870.
Fort Ransom	5.14	4.96	3.38	1.82	15.30	Dec., 1868, to Nov., 1871	67.08	10.38	Dec., 1868, to Dec., 1870.
Pembina	4.02	7.24	2.71	1.53	15.50	Aug., 1871, to June, 1876	70.42	14.63	1851, to 1853.
Winnipeg	4.36	9.28	5.00	2.66	21.30	Jan., 1869, to Dec., 1876	64.07	7.66	Jan., 1869, to Dec., 1870.

RED RIVER OF THE NORTH.

Station.	Distance by river to station designated by number.	Intervening slope per mile to station designated by number.	Tributary area above station.	Gauged flow at ordinary low stage, per second.	Ordinary low-water flow per square mile of drainage area, per second.
	Miles.	*Feet.*	*Square miles.*	*Cubic feet.*	*Cubic feet.*
1. Foot of Ottawa lake	......	......	1,442	......	......
2. Fergus Falls	*26 (1)	......	1,613	662	0.410
3. Mouth of Pelican river	*4 (2)	......	2,281	950	0.416
4. Breckinridge	*30 (3)	......	4,747	1,000	0.217
5. Mouth of upper Wild Rice river	†79 (4)	......	6,178	......	......
6. Moorhead	†18 (5)	......	6,283	......	......
7. Mouth of Sheyenne river	......	......	14,612	......	......
8. Frog point	†118.5 (6)	......	19,702	......	......
9. Grand Forks	†35 (8)	0.365 (8)	26,870	‡2,000	0.074
10. Mouth of Turtle river	†25 (9)	0.403 (9)	27,721	......	......
11. Mouth of Big Salt river	†30.5 (10)	......	28,648	......	......
12. Foot of Pelican bars	†40 (11)	0.293 (10)	31,669	......	......
13. National boundary	†48 (12)	0.194 (12)	39,577	‡2,800	0.070
14. City of Winnipeg	166 (13)	0.217 (13)	......	......	......
15. Lake Winnipeg	48. (14)	0.250 (14)	......	......	......

* Map measurement. † Survey. ‡ Approximate.

TRIBUTARIES OF THE RED RIVER OF THE NORTH DOWN TO THE NATIONAL BOUNDARY.

Name.	Length along general course.	Drainage area.	Annual precipitation.	Name.	Length along general course.	Drainage area.	Annual precipitation.
	Miles.	*Sq. miles.*	*Inches.*		*Miles.*	*Sq. miles.*	*Inches.*
Otter Tail river and lake	56	1,442	25	Red Lake	135	6,518	22
Pelican river	43	668	25	Turtle river	48	790	15
Bois de Sioux river	27	1,966	20	Big Salt river	50	840	15
Upper Wild Rice river	75	1,215	18	Park river	50	1,271	15
Sheyenne river	308	8,302	15	Swamp river	4	1,013	20
Buffalo river	63	1,003	22	Tamarack river	40	637	20
Lower Wild Rice river	85	1,091	22	Two Rivers	30	901	20
Goose river	50	878	15	Pembina river	130	6,700	15
Sand Hill river	55	644	20				

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