28, 1878. The needs of navigation and the damage resulting from the unsystematic workings of the dams on the river and tributaries above Chippewa Falls are fully set forth in those reports. The Court Oreille, an important tributary, flows in from the west above Chippewa Falls, as does the Yellow River from the east. Besides, there are a number of smaller tributaries, all of which are used, more or less, for logging purposes.

The area of watershed above the junction of the Flambeau and Chippewa is about 3,761 square miles, but, on account of the formation of the country, the narrow valleys through which many of the streams flow for long distances, with heavy slopes, &c., only a portion of this watershed becomes available, as the choice of sites for dams becomes thereby limited. Dams of great height can be thrown across the narrow valleys, to pond up, above each, a few days' supply of water, but the benefits to result therefrom would not warrant the expenditure of money.

The party for the examination of the sources of this river was in charge of Mr. J. H. Dager, assistant engineer, assisted by R. T. Parker and W. W. Strong, assistant engineers. The latter soon left the party, and the force was increased by Assistants W. W. Redfield and G. O. Foss. The party proceeded by rail to Fifield, on the Wisconsin Central Railroad, and thence to an examination of the watershed of the Flambeau. The details of work and description of the country are to be found in the appended report, and can be seen by inspection of the maps. The party, after finishing the Flambeau, was to cross to the headwaters of the Tomahawk, an important tributary to the Wisconsin, which they were expected to reach early in October. They did not reach this ground, however, until the middle of November—a severe dissappointment to me. I immediately reorganized the party for the survey of the Tomahawk. The area of watershed above the junction of the Flambeau and Chippewa is—

	Square miles
Of the Flambeau	1,960
Of the West Fork of the Chippewa	1,801
Total	3,761

but the available watershed of the former is only 712 square miles, and of the latter 700 square miles; a total of 1,412 square miles.

Three dams and reservoirs were located. The first, at Butternut Lake, has a drainage area of 1,533,312,000 square feet, affording a supply of 1,272,648,960 cubic feet, assuming that 10 inches of rainfall can be made available; the dam to be 10 feet high. The capacity of reservoir 585,446,400 cubic feet; leaving a surplus of 687,202,560 cubic feet. This reservoir possesses little value.

The next, at Park Lake, just above the 30-foot falls on Turtle River. The area of its watershed is 4,850,841,600 square feet; affording, on a basis of 10 inches, 4,026,198,428 cubic feet. The capacity, with a 15-foot dam, is 620,782,720 cubic feet; leaving a surplus of 3,405,415,708 cubic feet.

Rest Lake reservoir, the next, to be created by a dam 25 feet high, will have a capacity of 5,661,462,400 cubic feet; the supply being 4,897,100,264 cubic feet.

The result of the examination thus far, covering only a very small portion of the basin, shows that there can be supplied from the North Fork of the Flambeau alone 887 cubic feet of water, for a period of 90 days, per second; while, could the surplus be retained, 1,412 cubic feet per second could be maintained.

Below Chippewa Falls are important tributaries also, viz, the Eau Claire, the Menomonie, and Eau Gallé, from which additional supplies can probably be drawn, although the Eau Claire and Menomonie are controlled by private parties as seems to be the case with many of the streams in Wisconsin and on the eastern slope of Minnesota above Taylor's Falls.

The drainage area of the basin above Chippewa Falls is about 5,600 square miles; the total area drained by the river being about 9,600 square miles. Assuming 10 inches as the available rainfall, we should have, for the area above Chippewa Falls, a volume corresponding to a mean flow of, per second, about 4,125 cubic feet; and, adding to this the supply tributary to the river below, we should have a volume corresponding to a flow of 7,060 cubic feet per second through the jetties at the mouth. The area of watershed for the entire river, here given, is taken from the report upon bridging the Mississippi River.

From observations during the past season it would appear that when 3,200 cubic feet per second pass Eau Claire, and 4,500 cubic feet per second pass between the jetties, a navigation of 3 feet on the bars and crossings can be generally maintained, although from the shifting nature of the bed and banks, defensive works, jetties, &c., will probably be required in addition to a steady flow, supposing that the latter can be maintained. Beef Slough, about 20 miles above the mouth, draws off largely from the supply going to the jetties. To close the entrance to the slough would undoubtedly benefit navigation between this point and the mouth of the river, but it would injure the Beef Slough Company, which company uses the slough for booming grounds. Any water diverted from the slough through the jetties would add to the quantity passing down the Mississippi from the jetties to the mouth of Beef Slough, of course not adding any quantity to the Mississippi below the mouth of the slough. As to the propriety of closing the entrance to the slough, much may be said pro and con. Navigation would be benefitted by such a course. The slough, about 35 miles in length, is a mass of sand bars and banks, between and among which a considerable volume of water finds its way, ultimately discharging into the Mississippi River about 10 miles below the Chippewa. Much of the sand is undoubtedly carried into the Mississippi. The protection of the Yellow Banks on the Chippewa River, referred to in my report of December 28, would arrest, in great measure, the movement of sand down that stream, and probably affect the supply going to the slough, but to what extent further study and examination must determine.

A plotting of 12 sounded areas, the soundings taken on 4 consecutive days on 3 cross-sections, the latter 100 feet apart and between the jetties, shows to some extent the movement of sand, &c., forming the bed, and a plotting of synchronous gauge-readings at Eau Claire and the mouth shows fluctuations of water-surface mostly due to the working of the dams.

It is not assumed that any extensive deductions can follow the observations on the Chippewa and Saint Croïx for a single season; but the system of observations begun will, if carried out thoroughly, afford the means of drawing up, intelligently, plans for the improvement of the streams.

A continuous survey of the river from Chippewa Falls to the mouth, independently of the examination of the sources, is desirable.

EXAMINATION OF THE SOURCES OF THE WISCONSIN.

The party for the survey of the sources of this river was placed in charge of Assistant Wanzer, who, assisted by Mr. R. T. Parker, com-

pleted the survey of the Tomahawk Basin in about 22 days, locating two dam sites, and obtaining, otherwise, information of value.

Below the Tomahawk there seem to be no suitable sites for reservoirs, if we may rely upon information thus far obtained. Two good sites are reported for dams, which will control the whole watershed above the mouth of Pelican River, the drainage area being 830 square miles, the reservoirs estimated to control 2,470 cubic feet per second for a period of 90 days. Of these two sites, Assistant Skinner says:

> Two dams have already been erected, one just above the mouth of Pelican River and another 30 miles above, below the mouth of Eagle River, at a point which is known as Otter Rapids. The first has a watershed of 444 square miles, the latter one of 386. The data that I have been able to obtain as to the operations of these dams are as follows: The upper, or Otter dam, has raised the water above it to a height of 4 feet above ordinary level. I am informed that it can easily be raised 12 feet. The lower, or Pelican dam, allows of a rise of 9 feet, and can be also raised so as to admit of 12 feet. This last dam, when the water is raised 9 feet, backs up the water 22 miles, or within 8 miles of the Otter dam. The upper reservoir, with 4 feet head, when the gates are opened, requires from a week to ten days to empty itself. When it has discharged its contents into the Pelican dam, below, the latter reservoir is raised to a height of 8 feet 10 inches, and when the gates of this are opened, a rise of 4 feet at Jenny, 65 miles below, and a rise of 3 feet at Wausau, another 65 miles farther down, ensues. These are the facts given me by the lumbermen.

Of the dams on the Tomahawk, the first, or upper dam, to be 18 feet in height, will form a reservoir of 2,000,000,000 cubic feet capacity, the area of basin being 200 square miles, which, with an available supply of 10 inches from rainfall, will give 4,627,714,400 cubic feet, and a surplus of 2,627,714,400 cubic feet. The second, or lower dam, to be 14 feet high, will afford a reservoir capacity of 1,043,516,880 cubic feet, the area of watershed being 380 square miles and the supply 8,792,847,360 cubic feet, giving a surplus of 7,749,330,480 cubic feet, which cannot, probably, be collected at any point below. We have, then, on this supposition, the control of only 391 cubic feet per second for 90 days from the reservoirs on the Tomahawk.

So large an area of the watershed of the Wisconsin above Wausau yet remains to be examined, that it is not possible as yet to express any opinion as to the effect of reservoirs upon the navigation of the Wisconsin or upon that of the Mississippi. The area of the Wisconsin River watershed is, as given by General Warren in his report upon bridging the Mississippi River, 11,850 square miles. Assuming for this area an available supply from rainfall of 10 inches per annum, we have a quantity of water corresponding to a mean flow of 8,730 cubic feet per second at the mouth of the river. The flow of water per second, corresponding to good navigation on the Wisconsin, can be given by the officer in charge of the improvement of that stream.

It is to be hoped that further survey of the sources of this river will not be impeded from lack of appropriations by Congress.

A few points suggest themselves before going further. If the water be ponded up in reservoirs, the affluents below will contribute their supplies of sand, gravel, &c., as usual; the total quantity may be decreased by that kept back above, although the quantities of water let out from the reservoir may result in erosion of the banks, and restore, perhaps increase, the quantity of sand, &c., to be dealt with. Now, by disturbing the usual flow, increasing it during the season of low water, the rate of motion of bars, &c., will be effected. The direction of the channel, especially in the Mississippi River below Saint Paul, changes from high to low water, at, or just preceding, the latter stage, cutting out a path for itself along, in general, the lines of least resistance. At mean or tolerably high stages, the river, flowing through an alluvial bed, flattens out the bars, so that an increase in depth does not always follow a rise on the gauge. During floods, and just as they are subsiding, the river bed is in a state of disturbance; bars move, banks cave, sediment is brought in. Without going into an analysis, which would trespass too much upon the space proper for this report, it can be seen that circumspection is necessary in the projection of any plan for improvement of sand-bearing rivers.

To appreciate the subject fully, careful observation and study are required.*

The effect, upon rainfall, by the denudation of the country of forests, and that upon the flow into the streams following increased cultivation of the ground, I cannot hazard an opinion about. The weight of evidence collected by various writers upon the subject of rainfall seems to indicate that reforesting of extensive areas of country is followed by a more equable distribution of the rainfall throughout the year.

Information as to rainfall, evaporation, infiltration, &c., was sought from all authorities within reach. But, as every catchment basin has its own data, observations on the ground for a period of years afford the only safe means of accumulating such information.

In order to fully carry out the investigations ordered by Congress, at least $25,000 should be appropriated for the purpose in addition, to the allotment already referred to.

RECAPITULATION.

For further examination of the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin Rivers, the sum of $25,000.

For the construction of the dam at Lake Winnebigoshish, to test the system of reservoirs at the sources of the Mississippi and the effect upon navigation, the sum of $70,000.

I wish to acknowledge my indebtedness to the Surgeon-General of the Army for meteorological records; also, to Lieutenant Maguire, of the Corps of Engineers, for voluntary asistance rendered by him in connection with the completion of maps.

Full appendixes are forwarded concerning the Mississippi River from the sources to Saint Paul, for the reason that the examinations pertaining to this portion of the river have been sufficient to warrant a recommendation.

Accompanying this report are the following appendixes, maps, and plottings:

Report of J. D. Skinner, assistant engineer, January 1, 1879.
Report of J. P. Frizell, assistant engineer, December 20, 1878.
Copy of meteorological records from office of the Surgeon-General, United States Army.
Seventeen tracings and maps, viz: One general map of the system of dams on the Upper Mississippi and four detail maps; one general map of watersheds in Wisconsin, together with three progress maps and eight detail sheets pertaining to said watersheds.
Nine plottings of gauge-readings, soundings, &c.
In all, 29 inclosures.

Regretting that time has not admitted of my putting this report into better shape for transmittal,

I am, very respectfully, your obedient servant,

CHAS. J. ALLEN,
Captain of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

* Chapter No. 4, of General Warren's report on the Wisconsin River, and the report of Major Suter on the Lower Mississippi River, dated February 18, 1875, can be read with profit.

REPORT OF MR. JAMES D. SKINNER, ASSISTANT ENGINEER.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Paul, Minn., January 1, 1879.

MAJOR: I have the honor to submit the following report of examinations and surveys, made by parties under my charge, in pursuance of your order of August 16, 1878. These consisted of detailed surveys of the different dam-sites on the Upper Mississippi River above the mouth of Crow Wing River, examinations and surveys of the headwaters of the Saint Croix River and tributaries, like examinations and surveys for the headwaters of the Chippewa River, and similar work on the headwaters of the Wisconsin River.

The season at which the parties could take the field was so advanced (after the 20th of August), and the amount to be expended so small in comparison with the vast and difficult region of country to be examined, that it was impossible to cover the ground specified in the "act of Congress approved June 18, 1878."

We were therefore confined to making all the exhaustive surveys of dam-sites and reservoirs on the three last-named rivers that were possible, and to gathering such information, by examinations and inquiry from those familiar with the streams of that wild region, as we could collect.

The case was different as regards the Upper Mississippi River. There we had the ground-work of a completed survey, with a connected line of levels, made in 1874, to work from, and one party successfully finished the work assigned them.

Starting, as we did, so late in the season, in order to have accomplished much, at least four parties should have been put in the field to examine and survey the other rivers. Lack of funds, however, rendered it possible to put only two parties at work, and the longest period that either of them was able to remain in the field was two and one-half months.

The results, though meager as far as regards the completed work, are still quite as great as could have been expected, and form a good ground-work for intelligent action another season.

It must be borne in mind that the country examined was entirely new to the parties engaged, transportation most difficult and expensive, and the obstacles in the way of obtaining accurate instrumental results as great as I have ever seen in this country.

Maps, both general and detailed, of all the country examined have been prepared, and these show all the information obtained.

The details of these surveys and the results deduced will be reported on elsewhere.

I propose to take up the districts in the order in which they have been before mentioned, and, first, the Mississippi River above Pokegama Falls. As has been before mentioned, a very complete survey was made of this whole region in 1874. A complete line of tested levels was run from the mouth of Crow Wing River, and from Brainerd, the crossing of the Mississippi River by the Northern Pacific Railroad, to Leech Lake, thence through Cass and Winnebigoshish Lakes, down the Mississippi River to the point of beginning. An accurate survey was made of all the reservoirs and rivers, showing contour and flowage lines, the fall and discharge of streams, and all the data were acquired from which to locate the system of dams, and derive the capacity of the reservoirs, and the area of their watersheds.

All of this work, with a full description of the lakes and country through which the river flows, with the supply of water to be obtained from the different reservoirs, were fully reported to Col. F. U. Farquhar, United States Engineers, and these and the results deduced from them by him are condensed and fully described in his report dated February 4, 1875, contained in the Report of the Chief of Engineers for 1875.

Full tracings of maps of all the work done were forwarded to Washington, and as these can be referred to, it will be unnecessary for me to go over this ground again. I shall therefore confine myself to describing the work done this season; recapitulating the amounts of water to be obtained from the reservoirs and their capacity; enumerating and describing the different dam-sites; giving a comparison of the gaugings of the river; an estimate of the amount of water that can be furnished per second at Saint Paul, stating the damage done to property by overflow; and, lastly, an estimate of the cost of constructing the different dams.

Tabular statements showing amount of rainfall, details connected with each reservoir, and showing basis of calculation for each; observations on evaporation; a table of elevations above sea-level of the water surface of the Mississippi River from Cass Lake to Saint Paul; gaugings of the river in 1874 and 1878; and plotted gauge-readings for both years, are appended to this report.

DESCRIPTION OF THE WORK.

The dam-sites above Pokegama Falls were, in 1874, necessarily located upon the map after the notes had been worked up. Of those at and below the Falls full detailed surveys were made, and all work done that was necessary prior to construction. The party this

year, under Mr. John McCalman, assistant in charge, and Assistant R. Davenport had, as their duty, to make accurate detailed surveys of the sites on which it had been proposed to construct dams, to select the best location for the dam, and, this done, to give an accurate cross-section on the line, followed by frequent borings and soundings, to ascertain the nature of the bottom underlying the proposed dam. This work was very laborious, requiring long and numerous transit and level lines, the country so abounding in sloughs and islands of timber that were apparently the main land, that the country for miles on either side the location had to be instrumentally examined, to make sure that there were no passages back of either end of the dam that could connect the water above the dam, when raised to the desired height, with that below. Indeed, these examinations developed the fact, which would otherwise have escaped ordinary notice, that short and low dikes will, in some cases, be necessary. The borings were made through 2-inch gas-pipe, driven as the auger descended, and specimes of the material passed through at different depths were preserved and sent to this office. This portion of the work was difficult and tedious. Field maps were made as the work progressed, and on the completion of any one survey a tracing was forwarded to this office for inspection. The results obtained were most satisfactory. Blue clay of the best quality was found to underlie all of the dam-sites and to exist in the banks, and it is reasonably accessible for purposes of construction. The rivers were carefully gauged near each dam-site, and the water, as well as all the levels, referred to the levels of 1874, the bench-marks belonging to which were numerous along the river. These gaugings were in the close vicinity of those made in 1874, and as the water during the whole of that season was unusually high, and during this autumn as low as ever known, a good basis of comparison was afforded. A reference to the table of discharges, marked D, hereto appended, will give the differences in height of water and discharge at the points where the river was ganged. We have, what is much to be desired, the high and low water discharge of the rivers at various points from *actual* measurements, which enables us to estimate the amount of water furnished by each reservoir in two different and independent ways. The first method of estimating the supply was by simply taking the area of the watershed tributary to each reservoir and multiplying it by one-third of the mean annual rainfall. This was assumed for the district under consideration at 25 inches. A glance at the table of rainfall at different points, hereto appended and marked A, will show that the mean annual rainfall at Fort Snelling, Fort Ripley, Fort Ridgeley, and Saint Paul, derived from all the records kept up to date, is 26.41 inches, while the mean observations at Forts Abercrombie and Pembina is only 17.67 inches, from which it is to be inferred that the rainfall decreases as we go towards the west. Indeed, on the Missouri River, the mean is still less than on the Red River of the North, viz, 15.51 inches. Now, this district lying so much to the westward of Forts Ripley and Snelling, it would not be safe to assume more than 25 inches as the mean. The second method of computing the supply is as follows: The reservoir considered is supposed to be completely closed from December 1 to July 1, before which time very low water rarely occurs. The measured low-water flow during the months of December, January, February, and March is then taken as a factor. Three-fourths of the mean precipitation (rain and melted snow) taken from the table of monthly means is then added, it being considered that—the ground being frozen—at least that amount finds its way into the reservoir, and finally one-half of the rainfall during April, May, and June. These three added together give the amount on hand July 1.

The proportions above assumed have been adopted after careful examination and consultations with persons most familiar with this subject. The results from these so widely different methods agree very closely in the total amount, though in one or two instances they differ somewhat, as will be seen by a reference to the summary hereafter given.

The totals for the district above Pokegama Falls are:

	Cubic feet.
By the first method	71,522,027,920
By the second method	69,890,548,635
A difference of	1,631,479,285

Evaporation has been allowed for only in Leech Lake; in all the others the supply from rainfall from July 1 to November 1 being more than sufficient to compensate for all losses from that source, while in the case of Leech Lake it is but half the loss by evaporation, owing to its very large surface and the very slight height to which the water can be raised. In this connection, it will be proper to refer to the observations taken for determining the amount of evaporation. These were taken daily at morning and evening. The evaporator used consisted of a double pan 6 inches in depth, so arranged that the bottom and circumference of the inner pan were always surrounded by 2 inches of water. Three of these were used: one was exposed to the direct rays of the sun, one was placed in absolute shade, and the third was sunk to the level of the water in a marsh exposed to the sun.

The readings and means derived from them are given for each pan in the table hereto appended, marked B. From these observations, though only taken during August, September, and October, it is inferred that the amount of evaporation from April 1 to November 1 will average at least one-tenth of an inch per diem.

EXAMINATIONS OF DAMS ABOVE POKEGAMA FALLS.

Before enumerating these dams, I would remark that all the details on which the results here given are based, and the calculations by which they are arrived at, will be found in the "Table of details of reservoirs," hereto attached and marked C, and descriptions of the kind of dam recommended will be given under the head of "Cost of construction of dams."

The rise of water mentioned is always to be taken as above the high-water of 1874. The table before referred to, and the accompanying detail maps, will always show what this was. These maps will also show the locations of all the dams.

LEECH LAKE DAM.

This will be 3,300 feet in length, but will be calculated for a rise of 4 feet. The water could indeed be raised 6 feet, but it would be entirely useless to do so, as its capacity at 4 feet is largely in excess of any probable supply.

	Cubic feet.
Capacity at 4 feet rise	22,567,564,800
Supply by first method	19,534,394,880
Supply by second method	15,460,977,021

MUD LAKE DAM.

This is of moderate length, its length on top being less than 1,000 feet, and will be easy to construct.

	Cubic feet.
The capacity, with a rise of 6 feet, will be	2,885,414,400
Supply by first method	3,122,380,800
Supply by second method	3,137,855,040
Surplus by first method	236,966,400
Surplus by second method	252,440,640

NOTE.—This surplus is counted in total surplus for Vermillion Dam.

LAKE WINNEBIGOSHISH DAM.

This is the dam of the principal reservoir. It is 1,114 feet long, and is calculated for a rise of 14 feet.

	Cubic feet.
Capacity at 14 feet	45,754,204,380
Supply by first method	36,922,152,960
Supply by second method	37,773,739,000

leaving ample room for unusually high water. To raise or lower the surface, when the reservoir is filled, one foot, will require 4,312,701,360 cubic feet. This dam backs up the water into Cass Lake. (See Colonel Farquhar's report, 1875.)

VERMILLION RIVER DAM.

This is situated on the Mississippi River, just below the mouth of Vermillion River (see map). It is calculated for a rise of 10 feet.

	Cubic feet.
Capacity at 10 feet	5,770,828,800
Supply by first method	8,449,942,760
Supply by second method	8,400,321,448
Total surplus by first method	2,916,080,360
Total surplus by second method	2,881,933,388

This surplus is counted in total surplus for Pokegama Dam.

POKEGAMA FALLS DAM.

This is the distributing reservoir, and is situated at the head of the Falls. It is calculated for a rise of 7 feet.

	Cubic feet.
Capacity at 7 feet rise	3,751,791,436
Supply by first method	3,493,156,520
Supply by second method	5,117,636,126
Total surplus by first method	2,657,445,444
Total surplus by second method	4,247,778,348

This last surplus gives for 90 days the quantity last given, or per day, 47,197,537 cubic feet; or per second, 547 cubic feet.

Summary to supply of water to reservoirs above Pokegama Falls.

Name of reservoir.	By first method.	By second method.
	Cubic feet.	*Cubic feet.*
Leech Lake	19,534,394,880	15,460,977,021
Mud Lake	3,122,380,800	3,137,855,040
Lake Winnebigoshish	36,922,152,960	37,773,739,000
Vermillion	8,449,942,760	8,400,321,448
Pokegama Falls	3,493,156,520	5,117,636,126
Total supply	71,522,027,920	69,890,528,635

The second method of calculation has been adopted, so that we may say that, in round numbers, we have a supply of 70,000,000,000 cubic feet on hand on the 1st of July.

Now, it is believed that the lower river, above Aitken, can take care of itself before July 1, as its watershed is upward of 2,500 square miles and its affluents numerous; but let us suppose the worst case possible, viz, that after May 1, the earliest date that navigation ever begins, we have to supply the lower river as far as Aitken. We know from careful observations, in 1874, that 2,500 cubic feet per second discharged at Pokegama Falls gives excellent navigation as far as Aitken, and, it is to be presumed, for a much greater distance down, as the river is deep, except in a few instances, where obstructions, such as small rapids, &c., exist, to below the mouth of the Crow Wing River. Now, from May 1 to November 1, six months, or 180 days, will require, at 2,500 feet per second, in round numbers, about 37,500,000,000 cubic feet, leaving us with 32,500,000,000 cubic feet in store to supply the lower river in addition, for a period of 120 days, from July 1 to November 1, which gives us 3,135 feet per second.

But we have, further, a constant supply from Pine and Gull Lake Rivers, as shown by the surveys of 1874 (see Colonel Farquhar's report, 1875), of 1,062 feet per second, which being added gives us a total supply of 4,197 cubic feet per second, and this while 2,500 cubic feet per second was being added to all the resources of the river below Pokegama Falls. Mille Lacs might possibly furnish a small further supply, but I do not think it safe to count it. Further, in the case under consideration, were the dams opened on May 1, in order to supply the 2,500 cubic feet, there would be no surplus, as it would not have collected. We are, therefore, entitled to add the amount of that surplus, viz, 547 cubic feet, which gives us a total of 4,744 cubic feet per second.

Now, from accurate gauging, in 1875, of the Mississippi River above the Falls of Saint Anthony, and the Minnesota River at its mouth, we know that we can set the low-water discharge at Saint Paul at 5,800 cubic feet per second. Now we can add to this 4,744 cubic feet from the reservoirs, making a total amount passing Saint Paul at extreme low-water of 10,544 cubic feet per second.

It must be borne in mind that the case supposed on which these estimates are based can never occur, as the river below the Falls and above Aitken must always have some water running. I think it would be perfectly safe to add one-half of the amount allowed (2,500 cubic feet per second) to the foregoing estimate. We would then have—

	Cubic feet.
Former amount	4,744
Added	1,250
Total amount furnished at Saint Paul	5,994
w-water discharge	5,800
Total amount passing Saint Paul at low-water, cubic feet per second	11,794

There is still further reason, amounting almost to a certainty, for the belief that the Mississippi River below Pokegama Falls can be supplied from its own watershed with ample water for all purposes of navigation prior to July 1, and it is absolutely certain that before that time the river below Aitken is entirely independent of the discharge at Pokegama.

The character of the two districts is entirely different. Above the falls the whole country is, in a certain sense, a reservoir. It receives and retains vast quantities of water, which drain off slowly. Large lakes, with very slight differences of level, and immense marshes bordering them, retain the waters from the higher portions of the basin and part with them slowly. There are no freshets, no sudden rise or fall in the surface of the lakes or streams. All changes are so gradual as to be scarcely perceptible. The extreme range of Leech Lake is only 1.7 feet, and this is only the gradual change from a very wet season to a very dry one, and is due largely to evaporation. A reference to the general map on file in Washington will show the character of the

region, and it will be seen from the sheets of gauge-readings hereto attached that at and above Grand Rapids the gauge current is practically an unkroken line. Below Grand Raids the whole country is different. The river becomes a true river, with defined banks, and is fed by numerous tributaries, while above there are only a few small streams that lose themselves in swamps before they join the river. Three miles below Grand Rapids is Prairie River, a rapid stream, which at times of high-water discharges large volumes and is subject to freshets. It produces such an effect on the river at Grand Rapids, that when the gauge above the Falls showed a steady decline the gauge at the foot of Grand Rapids has been known to mark a rise of a foot. The Split Hand, Wild Swan, Sandy Lake, Rice, Mud, and Willow Rivers are important tributaries. This last drains a very large area, as will be seen from the map. A reference to the gauge-readings and a comparison of the curves above and below will show plainly the wide difference in the character of the two portions of the river. The upper are almost unvarying; the lower subject to sudden changes. As to the date set, July 1, it is not too much to say that low-water has never occurred at or before that time. It will be seen, by a reference to Table A, that May and June have the largest rain-fall in the year, and that June is notably the month with the largest mean. It is, besides, universally known as the high-water month. A decline to low-water by the 1st of July is almost impossible. It has at least never occurred. We have a fair right, therefore, to conclude that July 1 will never find the upper river without sufficient water for purposes of navigation.

There is only one place at which any continuous record of gauge-readings has been kept in this district, and that is at Saint Paul, where the Signal Service records extend over a period of seven years, from 1872 to 1878, and this includes some years of very low water, and the highest does not reach midway the range between high and low water. The mean reading for July 1 is 6 feet 2 inches above low-water, while the gauge at Aitken on July 15 was 7½ feet above low-water, 1874. We have before said that the area of the watershed below Pokegama and above Aitken is 2,500 square miles. Now, using the second method of computation before described, which comparisons given would seem to establish as just, this will furnish at Aitken, continuously, up to July 1, 4,362 cubic feet per second, while in 1874 a discharge (measured) at the same place of 3,088 feet per second gave much more than the necessary depth of water required for navigation. It would seem, then, that it is abundantly established that we can shut off the entire river above Pokegama Falls up to July 1 without interfering with navigation below. But in that case we should have a surplus of 547 cubic feet per second to be added to the volume below, which would enable us to add 1,250 cubic feet per second to the last amount before given as passing Saint Paul, viz, 11,794 cubic feet per second, making the total amount 13,044 cubic feet per second, or, deducting the low-water flow at Saint Paul, 5,800 cubic feet per second, we can supply from the reservoirs above Pokegama Falls 7,244 cubic feet per second for a period of 120 days after July 1.

COST OF DAMS.

There has been no time as yet to make detailed drawings and plans for the different dams. Careful estimates have been made from the different cross-sections, and I have been able to find nothing to lead me to alter the estimates made by me in 1874, except in the case of the Leech Lake dam.

The cost of this our examinations this year enables me to reduce to $55,000. The estimate as corrected would stand—

Leech Lake	$55,000 00
Mud Lake	31,737 20
Lake Winnebigoshish	59,969 80
Vermillion River	56,245 20
Pokegama Falls (masonry and movable dam)	75,334 00
Pine River	32,386 20
Gull Lake River	25,786 20
Total cost of system of dams	336,458 60

Should only sufficient money be appropriated for the building of one dam, it would be advisable to erect that at Lake Winnebigoshish first. It is the principal reservoir, containing more than half of the water to be withheld above Pokegama Falls. It is in a very favorable position as far as timber, convenience for sheltering men, and delivering supplies, and for the same amount of money would better than any other illustrate the working of the proposed system.

DAMAGE RESULTING TO PROPERTY FROM OVERFLOW.

The land overflowed is almost entirely on the Indian reservation above the Vermillion Dam. There is no land under cultivation, but some hay-meadows would be submerged, and the wild rice, on which the Chippewas largely subsist, would for a few

seasons be drowned out. This, however, would probably find its way to the surface in time and be as luxuriant as ever. Below Vermillion River are extensive meadows along the river owned by lumbermen, from which they derive annually their hay for their stock during their winter logging operations. This, after the erection of the dam at Pokegama Falls, would be cut off and the meadows ruined. Hay, however, could be obtained elsewhere, though with less convenience. Of course provision would have to be made for the passage of logs through the several dams. This is all the damage that could be sustained, the country being entirely given up to Indians and lumbermen.

Before leaving this part of my report, I would express my conviction of the entire feasibility of the proposed system, and also that efficient aid would be given to the navigation of the Mississippi River at least as far as the head of Lake Pepin. I would also acknowledge the intelligence and zeal with which Assistants McCalman and Davenport discharged the duties assigned them.

SAINT CROIX RIVER.

We come now to the consideration of the Saint Croix River, and the practicability of constructing reservoirs on its headwaters, with a view to beneficially aiding the navigation of the Mississippi below their junction. The party engaged in making the surveys necessary to determine this was under the charge of Mr. H. S. Treherne, assistant engineer. Their duty was to select the most suitable dam-sites, to make a thorough instrumental examination of the country each side of the proposed dam, to run a line of levels sufficiently far up-stream to determine height of the dam, if not limited by natural features at the site, to make a detailed survey of the latter, to establish the flowage line and contours of the whole reservoir, and to gauge the streams in the vicinity of the dams and at other points. He was also instructed to obtain as much information as possible as to the location of lumbermen's dams and their operations, the general features of the country, and the character of streams which the limited time would not admit of his surveying. It was not possible to run a connected line of levels, but a datum was assumed for each locality surveyed and numerous benches left in prominent and accessible places for use another season, when the whole system could be connected and the levels carried down to the Saint Croix River and connected with some point on the Saint Paul and Duluth Railroad, thus reducing all elevations to the sea-level. Before enumerating the different localities examined, it would be well to give a description of the country through which the Saint Croix River and its tributaries flow, both on the Wisconsin and Minnesota sides. This last was not examined this year, but is well known to me.

DESCRIPTION OF THE COUNTRY.

The Saint Croix River rises in Upper Lake Saint Croix, a sheet of water about 4½ miles long and a half mile wide, lying at the foot of the ridge that divides the waters flowing into Lake Superior from those reaching the Gulf. This ridge is 1½ miles wide and its lowest summit elevation is 14 feet above Lake Saint Croix. It is full of springs, the two principal ones being 25 feet apart and their waters running in opposite directions. The banks and bed of the lake are also filled with springs. The tracing of progress map No. 3 will show its course and direction. Its main tributaries are on the Wisconsin side—the Eau Claire, Totogatic, Namekagon, Yellow, and Clam Rivers; and, on the Minnesota side, the Kettle and Snake Rivers. The country through which the two latter pass is very different from the Wisconsin side. It is a heavily-wooded district, white and Norway pine alternating with hard-wood timber. The soil is of a much better character than on the other side. Extensive lumbering operations are carried on on both these streams, and on Snake River large dams are erected for milling and log-driving purposes. On the Wisconsin side numerous dams are built on the river proper and its tributaries for driving purposes, a full list and description of which is given in the report of Assistant Treherne, on file in this office. There also is on file a full list and description of these dams, with their discharge and the effect on the reservoirs on opening the gates, given by Mr. A. W. Chase, superintendent of dams on the Saint Croix, to whom I am under great obligations for valuable information furnished the party before taking and while in the field. These dams are all marked on the progress map, and lettered *a b c* in red. The three located dam-sites and reservoirs are marked A, B, and C on the progress map.

Of the valley of the Saint Croix Assistant Treherne says: "In the bed and on the banks of Lake Saint Croix there are numberless springs. The banks on the east and west are 20 to 25 feet high; on the north is a large hay meadow, north of which is a very large cedar swamp, extending over the dividing ridge between the Saint Croix River and the Bois Brulé River, and for some miles down the latter stream. The Saint Croix River above its junction with Moose River is not very rapid. From Upper Saint Croix Lake to half a mile north of the junction of the Saint Croix and Eau Claire