noiter the position, and, after assuming a height for the dam, to ascertain by level and transmit the capacity of the reservoir and the line of flowage, understanding by the latter the line in which a plane of true level passed through the crest of the dam would intersect the surface of the country above the dam and adjoining. The swell or amplitude was not taken into consideration.

Each party was provided with apparatus for measuring rainfall and evaporation. The results from these observations are, of course, meager, yet it was thought that such data would be so much gained, the absence of which might in future be regretted.

Each party was also instructed to gauge the discharge of streams, to note the location and dimensions of all existing dams in the country passed over, to collect information as to building materials, and, in fine, to neglect no item of information pertinent to the subject.

The report of Assistant Skinner, hereto appended, gives the details of operations and also describes the natural features of the different basins, so that it is only necessary to refer to it for those items.

The methods of computation and the means of arriving at results have been discussed almost daily by myself and assistants.

A report by Mr. J. P. Frizell, assistant engineer, giving the results of his researches upon rainfall, evaporation &c., is also appended. This paper is of value, Mr. Frizell having had several years' experience in planning and constructing supply reservoirs in the Eastern States.

THE SOURCES OF THE MISSISSIPPI.

The examinations of 1874 resulted in the recommendation of several dams for reservoir purposes at Leech Lake, Mud Lake, Lake Winnebigoshish, below the mouth of Vermillion River, at Pokegama Falls, on Pine River, and at Gull Lake. The sites at Gull Lake and on Pine River were not re-examined this year. Our examinations at the sites of the others proved the correctness of judgment in the selection of those points and in the heights of dams proposed. Our more extended investigations resulted in slight changes as to location, and caused also slight changes in dimensions of the dams. Borings were made at the proposed sites for the dams at Leech, Mud, and Winnebigoshish lakes, and also for the Vermillion River Dam. These borings showed the existence of a stiff blue clay underlying the sand and other alluvion. The depths are shown on the accompanying tracings. No borings were made at any other points. The Pokegama Falls Dam can be constucted upon solid rock.

The dams found practicable are—

1. *At the efflux from Lake Winnebigoshish.*—A dam to be 14 feet high and 1,114 feet in length, the estimated cost of which is $59,969.80. This dam will pond the water up into Cass Lake through the Mississippi River, affording a reservoir capacity of 45,754,204,380 cubic feet, the area of reservoir surface being 4,312,701,360 square feet, and the area of the basin from which it draws its supply 527,459,328,800 square feet.

2. *Leech Lake.*—A dam at its efflux in Leech Lake River, 4 feet high and 3,300 feet long, affording reservoir capacity of 22,567,564,800 cubic feet; the surface area of reservoir being 6,091,430,400 square feet, and the area of supply basin 27,906,278,400 square feet. To cost $55,000.

3. *Mud Lake Dam.*—On Leech Lake River, just below the wild rice fields known as Mud Lake. The dam to be 6 feet high and 1,000 feet long, causing a reservoir capacity of 2,885,414,400 cubic feet; the area of reservoir being 480,902,400 square feet, and the area of basin from which it draws its supply of rainfall 4,460,544,000 square feet. To cost $31,737.20. This dam will pond up the water to the foot of the Leech Lake Dam.

4. *Dam on the Mississippi River below the mouth of Vermillion River.*—To be 10 feet high and 2,300 feet long. Capacity of reservoir, 5,770,828,800 cubic feet. Area of reservoir 961,804,800 square feet, and area of supply basin 12,071,346,800 square feet. To cost $56,245.20. This dam will pond the water up into Leech Lake River, Ball Club, and Stephen's Lakes.

5. *Dam at Pokegama Falls.*—To be 7 feet high and 400 feet long Capacity of reservoir, 3,751,791,436 cubic feet. Area of reservoir surface, 658,209,024 square feet. Area of basin, 4,990,223,600 square feet. To cost $75,334. This dam will probably pond the water up close to the foot of Vermillion Dam. This dam can only be raised to a height of 7 feet above the stage of water of 1874; if raised to a greater height, there would be danger of the ponded-up water in Pokegama Lake flanking the dam and finding egress through the depression, and across the sand ridge, near the end of the southeast arm of the lake. This is fully described in the report of February 4, 1875, and can be appreciated by an inspection of the maps.

6. *Dam at Pine River.*—To cost $32,386.20. Major Farquhar says of this dam:

> A good storage-ground for water was found on the Pine River (see Detail Map No. 3). Pine River runs through a series of connecting lakes. Just below Cross Lake there is a good place to build a dam. The watershed above the outlet of Cross Lake has an area of 551 square miles. Estimating the annual rainfall at 25 inches, and that 8⅓ can be relied upon, there will result a total discharge per year of 10,752.698,880 cubic feet. The banks of the lakes are generally high, and have a surface area of 491,301,043 square feet. If it were desirable to hold all the above water, it would require a dam 24 feet high, but from present information it would not be practicable to construct so high a dam. An additional dam at the mouth of Whitefish Lake might be constructed, 20 feet high, and the other at the outlet of Cross Lake, 12 feet high. The latter dam would create a reservoir of 4,913,000,000 cubic feet capacity, which, during the low-water season of the Mississippi River, August, September, and October, would furnish 630 cubic feet per second.

7. *Gull Lake Dam.*—To cost $25,786.20. Of this, the same officer reports:

> The system of lakes, of which Gull Lake is the center (see Detail Map No. 2), and which discharge their waters into the Crow-Wing River through the Gull Lake River, form an excellent storage for water. The discharge of Gull Lake River was on the 10th of November last 330 feet per second. The area of the watershed of the Gull River above the outlet of Gull Lake is 7,582,924,800 square feet, and assuming that one-third of the annual rainfall can be collected in the reservoirs and discharged therefrom, we would have 5,262,920,000 cubic feet. The area of Gull and adjacent lakes that can be used for storage purpose is 501,841,200 square feet, on which the water can be stored for an average depth of 10 feet, and 223,027,200 square feet on which an average depth of 5 feet can be stored, giving a total capacity of 6,133,548,000 cubic feet. A dam 12 feet high can be easily constructed to obtain the above capacity of reservoir.

Having determined the areas of watersheds, areas of reservoir surfaces, and the capacities of reservoirs, the next step was to deduce the available amount of water, or the supply. In this calculation two methods were employed.

The first consisted in assuming, from an examination of all the records of rainfall at points bordering or within the watershed, a mean annual precipitation. (Tables of rainfall are appended.) The mean annual rainfall for the sources of the Mississippi was assumed at 25 inches, and for the available quantity, that which actually finds its way into the streams, 0.7 foot was assumed, a figure that must certainly lie within the limits of safety. The area of watershed tributary to the river at Pokegama Falls being 102,174,325,600 square feet, the product of this by 0.7 foot would be 71,522,027,920 cubic feet, a quantity equivalent to a flow of about 6,800 cubic feet per second for 120 days.

In the second method of computation, we assumed the reservoirs to be completely closed from December to July 1, before the low-water period could set in. The measured low-water discharge for the months of December, January, February, and March is then supposed to be impounded. Three-fourths of the mean precipitation (rain and snow) is then added, it being supposed that, on account of the ground being frozen, at least that quantity will flow into the reservoir; and, finally, one-half of the rainfall during April, May, and June. These all added together will give the quantity on hand July 1.

The results from these two methods can be seen by inspection of the following table.

These methods, I should add, have only been applied to the five reservoirs spoken of at the headwaters of the Mississippi. For the Gull Lake and Pine River reservoirs the figures are taken from the report of 1875.

Locality.	Height above reduced stage of 1874.	Length of dam.	Area of basin.	Area of reservoir.	Capacity of reservoir.	Supply in cubic feet.	
						First method.	Second method.
	Feet.	*Feet.*	*Square feet.*	*Square feet.*	*Cubic feet.*		
Winnebigoshish	14	1,114	52,745,932,800	4,312,701,360	45,754,204,380	36,923,152,960	37,773,739,008
Leech Lake......	4	3,300	27,906,278,400	6,091,430,400	22,567,564,800	19,534,394,880	15,460,977,021
Mud Lake......	6	1,000	4,460,544,000	480,902,400	2,885,414,400	3,122,380,800	3,137,885,040
Vermillion......	10	2,300	12,071,346,800	961,804,800	5,770,828,800	8,449,942,760	8,562,762,188
Pokegama......	7	400	4,990,223,600	658,209,024	3,751,791,436	3,493,156,520	5,117,636,396
Total......	......	......	102,174,325,600	12,505,047,984	80,729,803,816	71,522,027,920	70,052,999,653
Add to this from dams at—							
Gull Lake...	12	450	7,582,924,800	724 868,400	6,133,548,000	5,265 920,000	....
Pine River..	12	600	15,360,998,400	....	4,913,000,000	10,667,353,750	....

Both methods of calculation show a surplus for Mud Lake and Vermillion reservoirs. By the second method a total surplus is carried to the Pokegama reservoir of 4,247,778,348 cubic feet, or, per second, 548 cubic feet to be discharged from the latter reservoir. It will also be seen from the table that Pine River reservoir will furnish a large surplus. We have in round numbers from the reservoirs for Winnebigoshish, Leech Lake, Mud Lake, Vermillion River, and Pokegama, 70,000,000,000 cubic feet.*

Leech Lake reservoir is tributary to that at Mud Lake and to that at Vermillion. Winnebigoshish is also tributary to Vermillion, and the last tributary to the Pokegama reservoir, which becomes, consequently, the distributing reservoir above Aitken.

Low-water occurring after the 1st of July, seldom before the 15th, we have from this supply—neglecting the 548 cubic feet per second of surplus water flowing over the Pokegama Dam, for a period of 120 days, leading us into the middle of November, by which time navigation on

*If we make a further reduction, by regarding the evaporation from the surfaces of the reservoirs as equal to the entire rainfall of the basin, we have 12,505,047,984 × 0.7 foot (we have already subtracted 2.083−0.700=1.383 from the rainfall),= 8,753,533,588 cubic feet, which, deducted from the 70,000,000,000, leaves us about 7,100 cubic feet per second for a period of 100 days. But it is thought that in taking 0.7 foot as the available rainfall over the entire basin, enough reduction has been made.

the river above Hastings generally begins to close—6,750 cubic feet per second.

Two questions arise here:

1st. Will there be channel capacity to enable this impounded water to flow from reservoir to reservoir, and from the lowest reservoir down the Mississippi above Brainerd?

2d. Will the impounding of the water previous to July 1 injuriously affect the navigation of the river above Aitken and Brainerd before any supply is drawn off from the reservoirs? the navigation from Brainerd to Aitken, and particularly from the latter place to Grand Rapids, 3 miles below the Falls of Pokegama, being of importance, as the lumber camps are largely supplied by steamers plying to Grand Rapids.

As regards the first question, the Pokegama reservoir being the distributing one we should expect, when needed, the full discharge per second through the dam (a needle-dam is under consideration at this point). The dam rising to a height of 7 feet above the high-water of 1874, at which time there was a depth of 4 feet of water at the dam site, with hard rock bottom, the fall below the dam being 14 feet on a distance of about 900 feet, no trouble is anticipated in discharging the necessary quantity of water per second. Of course, as the surface of water in the reservoir lowers, toward the latter part of the season, the flow will be diminished. The Pokegama reservoir will have to be constantly supplied from that at Vermillion. The width of the dam at the latter place is sufficient to provide for the discharge.

A glance at the map will show that there is ample space for the water to move from Vermillion to Pokegama, for the least area of flood-section between these points would be 3,500 square feet.

Above Vermillion there will be required channel capacity for 6,750 cubic feet per second from the junction of Leech Lake River. The narrowest part of the flooded channel would be just below the junction of the Leech Lake and Mississippi Rivers, where not more that 600 feet in width can be obtained for a distance of about a mile. A sounded cross-section taken here in 1874, when the stream was just within banks, and 170 feet to 200 feet in width, gave an area of cross-section of 1,200 square feet. A rise of 2 feet above the surface of the river at that point would add 1,200 square feet to the cross-section, ample for a discharge of 6,750 cubic feet. The fall, in 1874, from the junction to White Oak Point, a distance of 15 miles, was 3.6 feet. The loss of head, on this distance, from bend effect, might rise as high as 1 foot, leaving 2.6 feet available fall over this distance; but, as the surface of water rises, we may look for an increase in the mean velocity, the distance between the points, for the flow of water, being shortened. After leaving this narrow portion of the river the valley widens out and we enter a broad savannah.

Above the junction of Leech Lake River with the Mississippi the supply will come from two sources, viz, from Leech and Mud Lake reservoirs, and from the Lake Winnebigoshish. Dividing the 6,750 cubic feet, we have about 3,400 cubic feet to be drawn at times from each source. By reference to the maps and sections it will be seen that ample channel capacity exists. The management is a matter of detail. This is under the supposition of a systematic working of all the dams so as to keep the Vermillion and Pokegama reservoirs full. If it should be decided to build the dam at Winnebigoshish in order to test the effect upon navigation, it would probably be necessary to draw 6,000 to 7,000 cubic feet per second from it, for which sufficient channel capacity exists, as can be seen from the maps and sections. The swell, or backwater, produced by the dams, has not been considered further than to regard the surface of the water ponded up as level surface. The data at hand are insufficient to allow of such calculations.

As regards the dam at Pokegama, Major Farquhar reports (see report of 1875):

At Pokegama Falls it is proposed to put in a needle-dam on the left chute, at the head of the falls, and a solid masonry weir over the other (see detail map). By blasting out the head of the ledge, a greater aperture of discharge can be gained.

The channel below Pokegama Falls has sufficient capacity. Its width from Pokegama to Brainerd was, in 1874, seldom less than 200 feet; at Grand Rapids it was only 130 feet, but here the fall was 5 feet in 1,750 feet of distance. At Sandy Lake River, 86 miles below Grand Rapids, the discharge was October 27, 1874, 2,950 cubic feet per second, the gauge at Aitken, 61 miles below, being 3.8 feet above low-water. Below Willow River, 39 miles below Sandy Lake River, the measured discharge on the 3d of November, 1874, was, 3,784 cubic feet, the gauge at Aitken showing a stage of water of 3.3 feet. The Aitken gauge has shown a stage of 10 feet. A measured discharge at Brainerd June 4, 1875, showed 13,500 cubic feet per second as the quantity of water passing that point, and the gauge at the same place has indicated a higher stage of water. When we add to this the fact that from Pokegama Falls to Brainerd, the latter at the crossing of the Mississippi River by the Northern Pacific Railroad, the banks rise from 8 feet to 10 feet above low-water, all doubt as to the capacity of the channel to both carry off the necessary quantity of water and to retain ordinary flood discharges may be dismissed. The removal of bowlders from the channels above and below Pokegama Falls would, doubtless, facilitate the flow, and, below the falls, aid the navigation materially. It is possible that siphons, especially at the Winnebigoshish Dam, properly constructed and built into the dam, would take the place of a portion of the gates and sluices.

As regards the second question:

The area of watershed tributary to the river above Aitken and below Pokegama is 2,500 square miles. Assuming the same coefficient that we did in making our calculations for supply by the first method, and applying it to the mean precipitation for the months of April, May, and June, we have a quantity of water passing Aitken equivalent to 2,005 cubic feet per second; adding to this the surplus from the Pokegama reservoir, we obtain a total of 2,553 cubic feet per second. And taking, further, the available amount of rainfall and snow for the months of December, January, February, and March at 2 inches, a safe figure, we have a quantity of water equivalent to 3,300 cubic feet per second, round numbers, passing Aitken. This flow, as it approaches Brainerd, is re-enforced by the contributions from the watershed below Aitken. Good navigation obtains above Brainerd, when the flow per second equals 3,000 cubic feet, excepting where some few natural obstructions exist. Of course, as we proceed from Aitken to Grand Rapids above, the area of watershed tributary to the portion of the stream decreases until we reach a point where the supply may become too small, requiring us to draw off from the reservoir; 1,000 to 1,500 cubic feet per second for a time. But, as before said, we can spare from the reservoirs during April, May, and June the 548 cubic feet per second which we should have to count as surplus water after July 1. Assistant Skinner reports upon this as follows:

Now, it is believed that the lower river, above Aitken, can take care of itself before July 1, as its watershed is upwards 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, 6 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 amount	1,250
Total amount furnished at Saint Paul	5,994
Low-water discharge at Saint Paul	5,800
Total amount per second passing Saint Paul, low-water	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 water shed, 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 curve is practically an unbroken line. Below Grand Rapids 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 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 reference to Table A, that May and June have the largest mean rainfall, 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 the 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 7 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 Aitkin on July 15 was 7½ feet above low-water of 1874. We have before said that the area of the watershed below Pokegama Falls 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 Aitkin, 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 feet per second, for a period of 120 days after July 1.

The past season has been one of unusually low water; many of the smaller streams almost dry. It may take an unusually wet season to establish a favorable order of affairs at the sources, supposing the reservoirs to be created. A measurement of the discharge past Saint Paul, in October last, gave 6,150 cubic feet per second. In this discharge, as in previous low-water measurements at the Falls of St. Anthony, must be included the contributions from the upper river past Pokegama Falls, and from Pine and Gull Rivers, the former, as already stated, however, being able to furnish a surplus from its reservoir.

Taking into consideration all of the items of diminution of supply, it seems clear that a discharge of 12,500 cubic feet, at least, can be maintained past Saint Paul for a period of 100 days. There is no doubt that good navigation exists in all the navigable reaches above the Falls of Saint Anthony, when the discharge at the falls is from 11,000 to 12,000 cubic feet per second. An increment of 6,500 to 7,000 cubic feet per second cannot fail to prove of benefit to navigation between Saint Paul and Hastings, and, if so, the outlay for the creation of reservoirs will be amply returned. As the quantity of water at and below Saint Paul is increased from sources below Pokegama, the increment from the reservoirs will, of course, add to the beneficial effect until a certain limit is reached, when the proportion of the increment to the whole will be too small for the increment to be appreciated. When this limit is reached, the dams can be shut and the accumulation of water will go on.

The mean discharge of the Mississippi past Saint Louis is 225,000 cubic feet per second. To those who are only accustomed to dealing with such large volumes of water, an increase of 7,000 cubic feet per second appears very small. Yet, beyond a certain limit, width of channel is of small importance to light-draught steamers, depth being then the most important factor so far as navigation is concerned.

There can be no doubt that the control of the flow past Pokegama would render unnecessary many of the jetties and wing-dams between that point and Minneapolis, an estimate of cost of which is contained in the report of February 8, above alluded to.

The total cost of constructing the dams for creating reservoirs at the sources of the Mississippi is $336,458.60, an amount which includes contingencies of engineering, &c.

The cost of maintenance, understanding by this the repairs, would not, probably, exceed $10,000 per annum for the entire system for the first 10 years.

The cost of operating each dam would probably be as follows:

One dam-tender, at $800 per annum; 2 laborers, at $40 per month, each, for 4 months in the year, $320, or, in all, $1,120 per annum for each dam, and $7,840 per annum for the entire system.

To operate the entire system to best advantage the reservoirs would have to come within telegraphic communication. The probable cost of telegraph lines, starting from stations on the Northern Pacific Railroad, would be $13,500, this sum including batteries, &c. The operators could act as dam-tenders and also keep meteorological records.

The damage to property would consist, so far as can be ascertained, in the overflow of hay-meadows, of small value, and the overflow of fields of wild rice upon which the Indians depend, but these latter would, as the adjoining lands come under the influence of the prolonged rise of water, be simply transferred. From the best information attainable at present, I do not think that more than 2,500 acres of entered land would be overflowed, though this estimate is held subject to revision. The land at present is of little value. It is possible, though, that the prospect of the erection of dams, developing the water-power, may cause some of the adjoining lands to be held at a high figure.

The distance from Saint Paul to Pokegama is 350 miles. If the water be drawn off from the Pokegama reservoir at too late a moment it will be some days before any good effect can be felt at Saint Paul. By means of telegraphic communication, and a proper system of gauges, the date at which the gates should be opened can be predicted.

It has been claimed by those opposed to the reservoir system that the additional water discharged from the reservoirs will evaporate before it can reach Saint Paul. It hardly seems worth the while to reply, yet, perhaps, they are entitled to one. The rate of evaporation is directly as the area of surface exposed. If the surface be disturbed, or corrugated, from any cause, of course the area is increased. If the increment of water does not result in increasing the width of river surface, no more evaporation will result than would before any increase in volume obtained. This question of loss by evaporation may be dismissed.

The lakes at the sources of the Mississippi furnish a compact reservoir system, almost as if laid out by an engineer.

I think that it would be well worth the expense to test the efficacy of a system by constructing the dam at Lake Winnebigoshish, for which an appropriation, made in bulk, of $70,000 would be necessary. This sum is named because in building only one of the system, the expense of building and testing the effect will be greater, relatively, than if all were to be built. Should this dam be built, as a test, no prolonged benefits to navigation ought to be expected from a solitary reservoir.

No estimate is submitted herewith for locks in order to pass these dams, as full data are not at hand, and, besides, there is nothing at present, beyond canoe navigation, above Pokegama, if we except a small steamer that has plied on Leech Lake. Log-chutes will have to be provided for. Time has not admitted of making any detailed drawings of the proposed dams, or of revising any heretofore made. Timber is easily accessible, and rock in place is found at Pokegama. Scattering bowlders exist in the beds of the streams.

The immediate examinations were made by Mr. John McCalman, assistant engineer, assisted by Mr. Rufus Davenport, assistant engineer, both of whom are entitled to credit for faithful and zealous performance of duty.

EXAMINATION OF THE SOURCES OF THE SAINT CROIX.

The party engaged in examining the sources of this stream was under the charge of Mr. H. S. Treherne, assistant engineer, assisted by Mr. George R. Stunz and Mr. M. L. Lum, assistant engineers. The work was well done. The party proceeded, via Taylor's Falls, to the Upper Lake Saint Croix, reconnoitering the country on the way. The Upper Saint Croix was thoroughly examined. Thence the party moved to the Totogatic, and finally closed operations for the season by an examination of Yellow River and its basin. Permanent bench-marks were left for future reference, the flow of the streams gauged, and such observations for rainfall and evaporation made as allowed of. A large amount of information was collected, which cannot, at present, be utilized. The party to gauge the discharge of the Saint Croix from the Namakagon to Taylor's Falls, under Mr. W. H. Fuller, assistant engineer, assisted by Mr. James Allard, took the field about the 1st of October. The Eau Claire, Clam, and Namakagon, the latter the principal affluent from the east, and the Snake and Kettle rivers from the west, both large affluents, require thorough examination, as does also the valley tributary to that portion of the main stream below Taylor's Falls. In fact, the river from Taylor's Falls to the mouth should be thoroughly surveyed, the survey made some years ago having been, from lack of means, incomplete. The need of such a survey, as well as its cost, together with a statement of the features of this portion of the stream and the improvements needed, are given in my report dated December 9, 1878.

For a description of the country examined, I would respectfully refer to the report of Assistant Skinner. Extensive lumbering operations are carried on throughout the whole valley of the Saint Croix, and, from Taylor's Falls, the head of navigation, to the junction of the river with the Mississippi, several steamers run daily. The tributaries above Taylor's Falls are encumbered by large dams for logging purposes. The "drive" of logs through the Dalles, and thence down to the booming grounds above Stillwater, in May and June, is so great as frequently to shut the steamers completely out.

As the result of our examinations, three sites for dams have been selected and the capacities of the reservoirs ascertained, viz, one about a mile below what is known as the "Big Dam," on the Upper Saint Croix River, one on the Totogatic, and one on the Yellow River, below the outlet of Yellow Lake.

The Upper Saint Croix Lake reservoir has a surface area of 459,792,-500 square feet, the capacity being 4,698,269,800 cubic feet, the dam to be 25 feet in height; the area of basin from which the supply is drawn being 8,084,736,000 square feet. The available supply, assuming 25 inches as the rainfall, and taking one-third of it as available, will be 5,659,315,200 cubic feet, leaving a surplus of 961,045,400 cubic feet, which can probably be retained by a dam at some other point.

The Totogatic reservoir has a watershed of 9,199,872,000 square feet, giving as available supply 6,439,910,400 cubic feet. The capacity of reservoir being only 2,881,095,000 cubic feet, we have a surplus of 3,558,815,400 cubic feet, which can probably be retained by means of another dam, yet to be located. Yellow Lake reservoir has a watershed of 8,962,905,600 square feet, furnishing as an available supply 6,274,033,920 cubic feet. The reservoir capacity being only 3,402,712,000 cubic feet, we have a surplus of 2,871,321,920 cubic feet.

The summation can be stated as follows: From the three reservoirs already located, we can deliver to the river below Taylor's Falls, in the interest of navigation, 1,412 cubic feet for a period of 90 days, and, could we retain the surplus, we could furnish for that period a total of 2,362 cubic feet per second. It must be borne in mind that five considerable affluents yet remain unexamined, so that it is not possible as yet to hazard an opinion as to the practicability of aiding navigation on this stream or the Mississippi by means of reservoirs.

A lock and dam at Prescott, for the double purpose of benefiting the navigation of the river below the falls, and to create a huge reservoir, instead of many smaller ones, have been frequently suggested. This would undoubtedly reduce the time and cost of surveys, and simplify the problem, but to what extent it would benefit the interests of the valley, I am unable at present to state.

We have assumed, in our calculations, the value of the rainfall as 25 inches, and taken one third of it as a factor, as the watershed lies partly in Minnesota. We have not yet been able to determine with sufficient precision the value of either.

The total area of watershed above the Dalles (Taylor's Falls) is about 6,000 square miles, for which, if we assume 10 inches as the available amount of rainfall, we have, passing the Dalles, for the entire year, a quantity equivalent to a mean flow of about 4,500 cubic feet per second; to this must be added the quantity feeding the navigable portion of the stream, below Taylor's Falls, from the watershed (about 1,600 square miles) tributary to this portion. During the past season 3 feet of depth existed on the bars when the quantity of water passing the Dalles was 3,500 cubic feet per second. It is safe to say that good navigation will be found when 4,000 feet of water pass the Dalles; a steady flow of 5,000 cubic feet per second, from this stream into the Mississippi River, could not fail to aid the navigation of the latter for many miles below, especially when joined to a steady flow of 12,000 to 13,000 cubic feet past Saint Paul.

A plotting of gauge readings at Taylor's Falls, Osceola, and Stillwater, and of soundings on the principal bars between the latter point and Taylor's Falls, covering the same period as the gauge readings, herewith submitted, shows the relation that existed, during the low-water system of 1878, between the stage of water and the depths on bars and crossings; it also shows that the bed of the river changes. The fluctuations of water surface, as indicated by the gauge curves, are mainly due to the opening and closing of the large dams on the tributaries above.

EXAMINATION OF THE SOURCES OF THE CHIPPEWA.

This is a difficult region to survey for sites of reservoirs, the country being so cut up by small streams and interspersed with lakes, the latter sometimes forming, apparently, independent systems unconnected by streams.

The Chippewa rises among the small streams and lakes along the south side of the ridge dividing its watershed from that of the streams flowing into Lake Superior. The principal tributary is the Flambeau, coming in from the northeast and uniting with the Chippewa above a point known as Flambeau Farms. The Flambeau, having much the larger volume of the two forks, ought to give its name to the whole stream. From the Flambeau, down to Chippewa Falls, the stream is known as the Wild Chippewa, from the number of rapids, bars, &c. The stream below Chippewa Falls is described in the report of Major Farquhar of January 30, 1875, and also in my own report of December