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DEPARTMENT OF THE INTERIOR
TED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

ALITY OF SURFACE WATERS IN MINNESOTA

BY

R. B. DOLE AND F. F. WESBROOK

WASHINGTON
GOVERNMENT PRINTING OFFICE
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THE QUALITY OF SURFACE WATERS IN MINNESOTA.

By R. B. Dole and F. F. Wesbrook.

INTRODUCTION.

The following paper outlines the general characteristics of surface waters in Minnesota and the various factors that tend to modify the quality of the drainage. It includes the results of nearly two years' field and laboratory work done by the United States Geological Survey in cooperation with the Minnesota State board of health. First the general features, both natural and economic, that influence the quality of the meteoric water and impart to the lakes and streams their essential characteristics are reviewed. Next each drainage area is considered in detail, the streams are described, the sources of pollution are discussed, and the results of chemical analyses and bacteriological examinations are given. Statistics are presented regarding practically all of the municipal water supplies in the State, and the relative value of the surface and ground waters for general consumption is discussed. At the end is a description of the laboratory methods employed in the chemical and bacteriological work.

During the summer of 1903 arrangements were made whereby a study of Minnesota surface waters was commenced jointly by the United States Geological Survey, the Minnesota State board of health, and the chemical department of the University of Minnesota. Certain sections of the State were assigned to each party of the agreement for investigation. In pursuance of this project samples were collected at Brainerd, Hastings, Mankato, Prescott, Rochester, St. Cloud, Sauk Rapids, and Wabasha, during the fall of 1903, by representatives of the Minnesota State board of health. Three trips over the territory assigned to the United States Geological Survey were made by R. B. Dole, assistant hydrographer, between November 25, 1903, and May 22, 1904, during which time samples were collected at Aitkin, Bemidji, Biwabik, Brainerd, Cass Lake, Cloquet, Crookston, Ely, Eveleth, Grand Rapids, Hibbing, Sparta, Tower, and Virginia. During the first seven months of 1904 samples were collected by representatives of the State board of health at Anoka, Fort Snelling, Granite Falls, Hastings, Mankato, Montevideo, New Ulm, Ortonville, Prescott, Redwood Falls, Rochester, and Wabasha. (Pl. I.) At each place visited samples were collected in glass bottles and forwarded by express for chemical analysis to the State laboratories, where they were examined by H. C. Carel, assistant professor in medical chemistry, University of Minnesota, who was employed by the State board of health to perform the chemical examinations of water. Samples for bacteriological examination were also collected at the same time and plated in the field and the cultures were sent by express to the laboratory for incubation and examination. In addition, field tests were made for certain constituents at the time of collection.

In the summer of 1904 an agreement between the United States Geological Survey and the State board of health was made, by which an employee of the Survey was detailed by the Survey and appointed by the board to do such chemical work from August 1, 1904, to July 31, 1905, inclusive, as might be necessary in an extended examination of waters of the lakes and streams of Minnesota. During that period the chemical analyses were performed by R. B. Dole, assistant hydrographer, in a laboratory at Minneapolis specially equipped for the purpose by the State board of health. The bacteriological examination of the water samples was conducted as formerly in the laboratory of the State board of health, by Dr. E. H. Beckman, assistant bacteriologist to the board. Both the chemical and the bacteriological work were, during the entire cooperation, under the immediate supervision of Dr. F. F. Wesbrook, director of the laboratories of the State board of health of Minnesota. In order to continue the comprehensive survey of the surface waters in the State, points were selected in each drainage area at which samples should be taken at regular intervals for examination. Sixty-five stations were thus established, at which samples were taken in regular series—one sample during the fall of 1904, one during the winter of 1904–5, and one during the spring of 1905.

In addition to the results obtained by the laboratory work thus performed, it was considered especially important to procure all available information concerning matters of hydro-economic importance in the sections visited, and a large amount of time was expended in gathering data concerning every feature of municipal activity which in any way affects water in its relation to public health or public utilities. At every place where it was possible, a personal inspection was made of waterworks systems, sewerage, and effluent-discharging factories, and detailed information was obtained concerning water and sewerage systems, ice supply, sewage-disposal works, water-borne diseases, and general water resources. In this manner information was procured regarding a majority of the principal cities and villages. In the spring of 1905 correspondence was carried on with reliable persons in such important settlements as had not been visited in order to procure the same kind of information, so that by the end of July, 1905, data were on file concerning practically every settlement in the State having a population of more than 1,000 according to the census of 1900, and also concerning practically every waterworks system in the State. Active field work was discontinued on June 30, 1905.

For many courtesies extended and for information given, acknowledgments are here made to the health officers, waterworks superintendents, city clerks, and others who collaborated with the authors in this investigation. Special thanks are due to Dr. H. M. Bracken, secretary of the State board of health, for his enthusiastic support and for his vast local and general knowledge of the State, which was at all times made available by him in the work; thanks are also due to the individual members of the State board of health, who supported the work heartily throughout and by their interest made it possible, and to the individual members of the staff of the laboratories of the State board of health, who rendered every assistance whenever it was desired. Mr. Marshall O. Leighton, chief hydrographer, water resources branch U. S. Geological Survey, originally suggested the work and has followed it carefully throughout, guiding it and helping in the correlation of the practical and scientific sides at all times.

NATURAL FEATURES.

TOPOGRAPHY.

The greater part of Minnesota is slightly rolling prairie, forest, or swamp land lying between 1,000 and 1,500 feet above sea level. Its watersheds are usually morainic in character, elevated but little above the surrounding country. The northeastern section, above Lake Superior, is the only part that can be called mountainous. There a series of ridges comprising the Sawteeth and Mesabi ranges, extends from the international boundary, near Gunflint Lake, southwestward to Mississippi River at Grand Rapids, through Cook, Lake, St. Louis, and Itasca counties. It includes the Vermilion and Mesabi iron-bearing districts. The highest recorded elevation is 2,230 feet[a] above the sea in the Misquah Hills, Cook County. The next highest section of elevated topography, known as the Leaf Hills, extends in a nearly north-south line through Ottertail and Douglas counties. These hills stretch northward through Becker and Clearwater counties in a plateau; on the east and the west they slope gently to the broad valleys of Mississippi River and Red River, respectively. The highest part of this tract is not over 1,750 feet above sea level. In the southwestern part of the State the Coteau des Prairies, commonly known as the Dakota foothills, enter from South Dakota and extend southeastward through Lyon, Murray, and Nobles counties to the Iowa boundary. They are composed of drift deposits and in Minnesota

[a] Winchell, N. H., Geol. and Natural History Survey of Minnesota, Final Rept., vol. 4, p. 317.

reach a maximum elevation of about 2,000 feet above the sea. Low and comparatively insignificant ridges, generally glacial in origin, form the watersheds throughout the rest of the State. The lowest parts of the State are the points at which the three great drainage systems cross its boundary. St. Louis River enters Lake Superior at an elevation of 602 feet[a] above sea level; Red River leaves the State at a mean elevation of 767 feet;[b] and Mississippi River is 617 feet[c] above the sea at the southern border.

HYDROGRAPHY.

RIVERS.

Minnesota contains within its boundaries the headwaters of three great drainage systems. Approximately one-tenth of its surface, comprising the St. Louis drainage area and the small streams entering Lake Superior, is in the Laurentian basin. The Hudson Bay system, through its great tributaries, Red River and Rainy River, drains about three-tenths of the State's area in the north and west sections. The rest of Minnesota is tributary to Mississippi River either directly or through its large branches, Missouri, Des Moines, Cedar, St. Croix, and Minnesota rivers.

In this report the water conditions are discussed under the following headings: (1) Mississippi River basin above Minnesota River; (2) Minnesota River basin; (3) St. Croix River basin; (4) Mississippi River basin between Minnesota River and the Iowa line; (5) Red River basin; (6) St. Louis River basin; (7) Rainy River basin; (8) Missouri River basin; (9) Des Moines River basin; (10) Cedar River basin.

Mississippi River drainage area above Minnesota River includes the river from its source to Fort Snelling and comprises the broad, gently sloping, forested and deforested lands in the north-central part of the State. (See Pl. II.)

Minnesota River drainage area comprises a broad tract extending across the State from South Dakota to the confluence of this river with Mississippi River at Fort Snelling. It includes parts of northeastern South Dakota and northern Iowa. (See Pl. III.)

St. Croix River drainage area includes part of eastern Minnesota and a large part of northwestern Wisconsin. The area tributary to Mississippi River above the southern boundary of Minnesota comprises more than three-quarters of Wisconsin, together with the country considered under St. Croix River, Minnesota River, and Mississippi River above Minnesota River. Therefore a discussion of this lower section and the main stream must necessarily have frequent reference to the rivers above mentioned. (See Pl. IV.)

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[a] Gannett, Henry, Dictionary of altitudes in the United States: Bull. U. S. Geol. Survey No. 274.
[b] Final Rept. Minnesota Geol. and Nat. Hist. Survey, vol. 1, p. 122.
[c] Mississippi River Commission. Charts of Mississippi River.

The Lake Superior basin in Minnesota is a comparatively small area, 20 to 100 miles wide, along the north and west shores of Lake Superior. Most of the streams are short and flow through an unsettled section of the State. The St. Louis drainage area comprises the greater part of this basin. (See Pl. VI.)

Red River drainage area in Minnesota extends from the middle of the western boundary north to Canada and east beyond Red Lake. North Dakota as far west as Devils Lake is tributary to Red River. A small tract in the northwestern corner of South Dakota lies in the basin of Red River. (See Pl. VII.)

Rainy River has tributary to it a strip of the northern part of Minnesota along the international boundary, extending from North Lake, a few miles northwest of Lake Superior, to Lake of the Woods.

Missouri River receives the drainage from a small area in the southwest corner of the State that is traversed by Rock and Little Sioux rivers.

Des Moines River has its headwaters in the southwestern part of Minnesota. Its drainage area includes parts of Pipestone, Murray, Nobles, Cottonwood, Jackson, and Martin counties.

Cedar River flows south through Freeborn, Mower, and Dodge counties near the southern boundary of the State.

LAKES.

Minnesota contains probably a larger number of lakes than any other State in the Union. The latest authority gives 84,682 square miles as the total area of the State, of which 3,824 square miles, or about 4.4 per cent, is water.[a] In addition to the above area 2,514 square miles of Lake Superior are within the State. Lake of the Woods forms part of the northern boundary. Lake Traverse and Bigstone Lake form part of the western boundary. Lake Pepin, an enlargement of Mississippi River, about 23 miles long and 3 miles wide, forms part of the eastern boundary. The following table shows the names, location, and areas of the principal lakes in the State:

TABLE 1. *Principal lakes of Minnesota.*

Lake.	County.	Drainage area.	Water surface.
			Sq. miles.
Albert Lea	Freeborn	Cedar	
Alexander	Morrison	Mississippi	
Bass	Itasca	Mississippi	
Basswood	Lake	Rainy	
Bemidji	Beltrami	Mississippi	[b] 9.5
Benton	Lincoln	Minnesota	
Bigstone	Bigstone	Minnesota	[c] 18.5

[a] Gannett, Henry, The areas of the United States, the States, and the Territories: Bull. U. S. Geol. Survey No. 302, 1906, p. 5.
[b] Measured with planimeter from best available maps.
[c] Ann. Rept. Chief of Engrs. U. S. A. for 1898, p. 1838.

TABLE 1.—*Principal lakes of Minnesota*—Continued.

Lake.	County.	Drainage area.	Water surface.
			Sq. miles.
Bow String	Itasca	Rainy	a 18
Brule	Cook	Lake Superior	
Burntside	St. Louis	Rainy	a 14
Cass	Cass	Mississippi	a 29
Cormorant	Becker	Red	
Crooked	St. Louis	Rainy	
Dead	Ottertail	Red	
Fish	Crow Wing	Mississippi	
Green	Kandiyohi	Mississippi	
Greenwood	Cook	Lake Superior	
Gull	Cass	Mississippi	a 15
Gun Flint	Cook	Rainy	
Heron	Jackson	Des Moines	
Ida	Douglas	Mississippi	
Itasca	Clearwater	Mississippi	a 1.5
Kabetogama	St. Louis	Rainy	a 40
La Croix	St. Louis	Rainy	
Leech	Cass	Mississippi	b 233.80 c 173.19
Lida	Ottertail	Red	
Long	St. Louis	Rainy	
Loone	St. Louis	Rainy	
Millelacs	Millelacs	Mississippi	d 200
Miltona	Douglas	Mississippi	
Minnetonka	Hennepin	Mississippi	a 21
Minnewaska	Pope	Minnesota	a 11
Namekan	St. Louis	Rainy	
Nequowuon	St. Louis	Rainy	
Net	Itasca	Rainy	a 16
Osakis	Todd	Mississippi	
Ottertail	Ottertail	Red	a 23
Pelican	Crow Wing	Mississippi	a 16
Pelican	St. Louis	Rainy	a 21
Pepin	Goodhue	Mississippi	
Pine	Ottertail	Red	
Pokegama	Cass	Mississippi	c 12.20
Rainy	Itasca	Rainy	
Red (upper)	Beltrami	Red	a 207
Red (lower)	Beltrami	Red	a 287
St. Croix	Washington	St. Croix	
Saganaga	Cook	Rainy	
Sandy	Aitkin	Mississippi	b 16.52 c 8.00
Snowbank	Lake	Rainy	
Swan	Nicollet	Minnesota	a 16
Thief	Marshall	Red	
Traverse	Traverse	Red	e 13.8
Trout	St. Louis	Rainy	a 14
Vermilion	St. Louis	Rainy	a 66
West Battle	Ottertail	Red	
White Bear	Ramsey	Mississippi	
White Fish	Crow Wing	Mississippi	a 13
Winnibigoshish	Itasca	Mississippi	b 161.26 c 117.00

a Measured with planimeter from best available maps.
b High water; see p. 38.
c Low water; see p. 38.
d Geol. and Nat. Hist. Survey Minnesota, Final Rept., vol. 11, p. 613.
e Ann. Rept. Chief of Engrs. U. S. A. for 1898, p. 1838.

Most of the lakes are shallow and of glacial origin and are being gradually eliminated by silting, drainage, and perhaps other modifying agencies, so that it is only a question of time when their number will be greatly reduced.

DRAINAGE DITCHES.

On account of their unaccented topography large sections of the State contain extensive swamp areas which are agriculturally useless until they have been artificially drained. Some rivers are dispersed in large swamps covered with decaying black spruce, tamaracks, mosses, reeds, and small shrubs. In order to convert these areas into cultivable lands, canals and networks of drainage ditches have been dug. In 1893[a] the State legislature appropriated $100,000 for drainage work in Red River Valley and at the same time created a body known as the Red River Valley Drainage Commission, which, under the act of 1901, was reorganized as the drainage commission of the State of Minnesota. At the end of 1899 the commission had completed 117.47 miles of ditches in Clay, Grant, Kittson, Marshall, Norman, Polk, Traverse, and Wilkin counties. Since 1901 considerable work has been done in Wadena and Aitkin counties and in other sections. The total number of miles of ditches built by the State at the end of 1904 was 206.25. The work is by no means completed. Large swamp sections still remain in the unsettled portions of the Rainy Lake area and the upper Mississippi Valley. In addition to the work done by the State most of the counties in Minnesota have expended more or less money in draining lands within their borders and large areas have been drained by private corporations.

FLOODS.

The melting of snow in the spring and the accompanying heavy rainfall cause general floods throughout the State. In the fall heavy rains frequently cause the streams to run very high. During these floods the water, which is then in its worst condition from a sanitary standpoint, is most difficult to purify. A large quantity of organic matter that has accumulated on the surface of the ground is washed into the streams, together with disintegrated soil. With the rise of water and the consequent acceleration of stream velocity the sediment in the beds of the rivers is removed and carried on by the freshet. The enormous influx of soft water causes a diminution in the relative mineral content of the water, for while the turbidity of the streams is increased the percentage of dissolved matter is decreased. Fortunately, the absence of steep slopes in the greater part of the State prevents such disastrous floods as occur in mountainous regions; but

[a] Ralph, George A., Engineer's Rept. on State Drainage Work in Minnesota. Crookston, Minn., 1904.

the streams, nevertheless, sometimes show a marked general rise. The following table, compiled from records of stream measurements, shows the fluctuations of the principal rivers:

TABLE 2.—*Annual fluctuation of river level in Minnesota, in feet.*

River.	Place.	1901.	1902.	1903.	1904.	1905.	Maximum variation.
Mississippi	Aitkin[a]		11.8	11.4			14.0
Do	Sauk Rapids[b]			6.2	6.3	9.0	
Do	St. Paul[c]	6.2	6.4	10.5	7.3		20.6
Do	Hastings[a]		7.3	12.3	9.6		18.7
Do	Red Wing[c]	6.3	5.	8.9	6.4		15.3
Do	Reeds Landing[c]	8.	5.9	11.	7.6		15.8
Do	Winona[a]		5.5	12.3	7.6		18.2
Minnesota	Mankato[b]			16.8	6.5	10.7	
Red Lake	Crookston[b]		5.7	4.1	16.7	10.0	
Red	Grand Forks[b]			25.0	34.6	19.6	
Do	Moorhead[c]		3.7	6.9	14.3	11.2	33.4

[a] Mississippi River Commission. Stages of Mississippi River, 1901–1904.
[b] Report of progress of stream measurements, 1901–1905. Water Sup. and Irr. Papers, U. S. Geol. Survey.
[c] Daily river stages of the principal rivers of the United States, Weather Bureau, U. S. Dept. Agriculture, Pt. VII, W. B. No. 339.

Red River shows the greatest variation between high and low water. There are several reasons for this: (1) The land in the basin of this stream, though it is not mountainous, slopes gently to the principal water courses, and in level areas or places where there is opportunity for the water to collect in swamps ditches have been dug to assist in its rapid removal; (2) there are no forest trees in the greater part of the area to prevent rapid run-off and quick melting of snows and ice during a rise of temperature; (3) the area contains no large storage reservoirs except Red Lake. As a result of these factors the entire region has a quick run-off. The spring flood on Red River, as shown by gagings made by the United States Geological Survey at Grand Forks, N. Dak., occurs during the month of April and is the most important rise of the year. During the other spring months and in October heavy rainfall sometimes causes floods of less magnitude. The same condition exists on Minnesota River, the drainage area of which is in many respects similar to that of Red River.

Mississippi River in its upper part, as shown by gagings at Aitkin and at Sauk Rapids, is subject to a series of floods, which generally begin in April and last until the latter part of June. Summer rains cause freshets, but these are of much less importance than those on Red River. Heavy rains in September and October sometimes cause nearly as great freshets as those that occur in the spring. The conditions in the Mississippi drainage area are distinctly different from those in the Red River region, namely: (1) Much of the upper section of the valley is forested; (2) the area comprises large swamps; (3) extensive impounding reservoirs have been constructed for the purpose of holding back flood waters. Therefore floods on the Mississippi are not particularly high. Gagings of the lower river between St. Paul and the southern boundary of the State present a very complex series of floods. At Winona, Minn., there is a rise in the latter part of March, another in April, and a still larger one during May. Doubtless these separate freshets are due to the fact that the ice and snow on different tributaries melt at different times. Heavy rainfalls usually cause freshets in September, October, or November.

CLIMATE.

Six climatological stations of the United States Weather Bureau are situated within or near the area under consideration: Duluth, Minn., at the head of Lake Superior, is in Lake Superior basin; Moorhead, Minn., about midway between the north and south boundaries of the State on its western border, is in Red River drainage area; Minneapolis and St. Paul, Minn., are situated in the eastern part of the State, near the confluence of Minnesota, upper Mississippi, and St. Croix rivers. Though Bismarck, N. Dak., is somewhat west of the region under study its climate may be considered typical of the western half of Red River drainage area. As a balance to this western station, La Crosse, Wis., near the southeastern corner of Minnesota, has been added.

TEMPERATURE.

The following table shows the mean temperature for each month throughout the year, calculated from the records of these stations, which have been established for periods ranging from fifteen to thirty-five years:

TABLE 3.—*Mean temperature in the Northwest, in degrees Fahrenheit.*[a]

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Duluth	10	13	24	38	48	58	66	65	57	45	29	17	39
Moorhead	3	5	22	42	55	64	68	66	56	44	25	12	38
Bismarck	6	9	22	42	55	64	69	68	57	44	27	15	40
St. Paul	12	15	28	46	58	67	72	71	60	48	31	19	44
Minneapolis	14	14	29	47	58	68	72	70	62	50	32	20	45
La Crosse	16	19	31	48	60	69	73	71	62	50	34	23	46
Mean	10	12	26	44	56	65	70	68	59	47	30	18	42

[a] From compiled records of the U. S. Weather Bureau, Washington, D. C.

The mean annual temperature for the entire region is 42° F. Though the variation from this figure from year to year is not large, the temperature reaches great extremes at certain seasons, so that the annual range considerably exceeds 100°, as is shown by Table 4.

TABLE 4.—*Extremes of temperature.*[a]

Station.	Highest observed.	Average maximum.	Lowest observed.	Average minimum.	Average annual range.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Duluth	99	90	−41	−27	117
Moorhead	101	95	−48	−30	125
Bismarck	106	100	−44	−32	132
St. Paul	104	95	−40	−24	119
Minneapolis	102	95	−33	−24	119
La Crosse	104	95	−43	−22	117

[a] From compiled records of the U. S. Weather Bureau, Washington, D. C.

The average maximum temperature is about 95° and the average minimum temperature about −27°. January, the coldest month in the year, has a mean of 10°, and July, the warmest, a mean of 70°. The coldest section is Red River valley, and here also are found the greatest extremes of temperature. The region around Lake Superior, doubtless on account of its proximity to that large body of water, experiences the least changes. The portion having the highest average temperature is the southern half of Minnesota, in which the mean temperature is 45°.

PERIOD OF FROST.

In the northern section the temperature falls below freezing about the latter part of October and rises above that point early in April. The first severe frosts in autumn occur about the beginning of October and the last in spring about the first of May. The period during which the lakes and rivers are closed by ice is influenced not only by temperature, but by the velocity of flow and the size of the body of water and the percentage of ground water flowing into it. The following table gives approximately the period during which the principal rivers are closed at certain points:

TABLE 5.—*Ice period of principal rivers.*

River.	At—	Date closed.	Date opened.	Time closed. (months)
Red	Moorhead	Dec. 1	Mar. 20	3.5
Minnesota	Mankato	Dec. 1	Apr. 1	4
Mississippi	Aitkin	Nov. 20	Apr. 10	5
Mississippi	St. Paul	Dec. 5	Mar. 20	3.5
Mississippi	Red Wing	Dec. 5	Mar. 20	3.5

In general, lakes are frozen over during the 5 months of November, December, January, February, and March. The port of Duluth is closed about 4 months in the year on account of ice in the Great Lakes. Devils Lake, a large body of water in North Dakota, in Red River drainage area,[a] is generally frozen from the middle of November to the first of May, a period of 5½ months. The thickness of the ice in different lakes and rivers varies from 1 to 45 inches.

PRECIPITATION.

The mean annual precipitation is 27 inches of rain and melted snow, though this figure may vary considerably from year to year in different parts of the area. It has been known to be as low as 11.03 inches at Bismarck, N. Dak., and as high as 44.74 inches at La Crosse, Wis.

[a] Newell, F. H., Water Supply and Irr. Paper No. 85, U. S. Geol. Survey, p. 239.

These extremes show the extent of variation between wet and dry years. The average rainfall at 6 stations in the Northwest is shown in Table 6.

TABLE 6.—*Precipitation in the Northwest.*[a]

Station.	Jan.	Feb.	Mar.	April.	May.	June.
Duluth	0.98	1.02	1.55	2.12	3.31	4.23
Moorhead	.66	.67	1.04	2.36	3.02	4.14
Bismarck	.56	.53	1.08	1.92	2.34	3.56
St. Paul	.89	.87	1.59	2.34	3.31	4.41
Minneapolis	.65	.78	1.70	2.35	3.41	3.98
La Crosse	1.09	1.05	1.57	2.36	3.61	4.45
Mean	.80	.82	1.42	2.24	3.17	4.13

Station.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Duluth	3.75	3.44	3.67	2.71	1.53	1.26	29.98
Moorhead	3.93	3.10	2.23	2.09	.92	.67	24.60
Bismarck	2.20	1.97	1.19	1.03	.67	.61	18.14
St. Paul	3.48	3.68	3.28	2.41	1.24	1.09	28.42
Minneapolis	4.14	3.83	3.39	2.71	1.12	.93	28.65
La Crosse	4.04	3.49	4.03	2.50	1.47	1.31	30.83
Mean	3.59	3.25	2.96	2.24	1.16	.98	26.77

[a] From records compiled by U. S. Weather Bureau, Washington, D. C.

There is a period of heavy rainfall from May to September, inclusive. The precipitation is generally least in January, during which month it does not often exceed one inch. During the period of greatest precipitation there are frequent heavy rainstorms, which in the deforested and prairie regions cause the streams to rise rapidly. Snow falls in every part of the region. The average annual fall is 40 inches of dry snow, most of which is precipitated in the region around Lake Superior, though the severest blizzards, during which there is the greatest precipitation at one time, occur in the western part of Red River Valley. The heaviest storms occur generally during December and March. The precipitation during the later part of the winter causes heavy floods in the spring, for the rapid melting of the snow on the ground after the spring rise in temperature coincides with the heavy rains of April and May.

SUMMARY.

At many points throughout the region under consideration voluntary observers record the temperature and the precipitation. Unfortunately these records have not been continued long enough to furnish data for reliable deductions concerning the general weather conditions of each drainage area. Therefore the following figures, representing averages made from the records of 36 stations in Minnesota, North Dakota, and Wisconsin may be subject to change as further data are recorded.

TABLE 7.—*Mean annual temperature and precipitation.*[a]

Area.	Temperature.	Precipitation.
	Degrees F.	*Inches.*
Superior	39	30
Upper Mississippi	41	27
Minnesota	43	26
Lower Mississippi	45	31
St. Croix	41	30
Red	39	22

[a] Computed from records given in Ann. Repts. of Chief of Weather Bureau, 1892-1904, inclusive.

In general the climate of Minnesota is typical of the central part of the temperate zone. Since there are no high mountains to protect the State, it is exposed to the cold winds of Canada and to the warm waves of the lower Mississippi Valley. The treeless plains of its western section experience the greatest extremes of temperature and receive the least rainfall. The region around the Great Lakes has the least variation of temperature and a high total precipitation. There is measurable precipitation on about ten days in each month in every part of the area; and the year can not, therefore, be divided into a rainy and a dry season. To this even distribution of the rain throughout the warmer half of the year this section owes its remarkable fertility and its adaptability to many kinds of crops. The ground freezes in November and thaws in the latter part of March or the first of April. During the period of low temperature the rivers and lakes throughout the State are frozen. In the spring heavy rains accompany the rise of temperature that causes the melting of the accumulated snow and ice.

The following table summarizes the important weather conditions in the region considered:

TABLE 8.—*Summary of weather conditions in the Minnesota region.*

Station.	Temperature, °F.		Precipitation in inches.		Dates for severe frosts.	
	Mean.	Range.	Average total.	Average snowfall.	Fall.	Spring.
Duluth	39	117	29.98	54	Oct. 4	May 3
Moorhead	38	125	24.60	38	Sept. 22	May 14
Bismarck	40	132	18.14	34	Sept. 15	May 15
St. Paul	44	119	28.42	38	Oct. 5	May 6
Minneapolis	45	119	28.65	40	Sept. 30	May 2
La Crosse	46	117	30.83	39	Oct. 5	May 1
Entire area	42	122	26.77	42	Sept. 28	May 7

GEOLOGIC FORMATIONS AND SOILS.

Probably no other natural feature has more profound influence on the character of surface waters than the chemical composition of the rocks over or through which they flow. At all seasons of the year a certain percentage of the stream flow above ground is derived by seepage from the water-bearing strata that outcrop along the banks of the rivers and in lake bottoms. In winter, when the surface of the ground is frozen and there is no surface drainage, the stream supply, except that which is produced by irregular and intermittent thaws, is derived from underground water. Therefore the nature of the geologic formations and the character of the water contained in them are important features to be considered in a study of surface waters. The soil and the subsoil also have great influence on the character of the water of streams and lakes, because rain water dissolves more or less of the soluble soil constituents and is thus modified in its chemical composition before it finds its way to the water courses.

GEOLOGIC FORMATIONS.

Geologically, Minnesota may be divided into three sections: (1) A northeastern division, embracing the districts adjacent to Lake Superior; (2) an eastern and southeastern division, reaching, with one slight interruption, from the head of Lake Superior southward into Iowa, and (3) a western district, embracing the remainder of the State.[a]

The northeastern division, embracing the Mesabi and Vermilion iron-bearing districts, includes the Laurentian basin and that part of Rainy River drainage area that lies directly north of it. The formations are mainly crystalline, consisting of quartz, gneisses, schists, and other igneous and metamorphic rocks. There are valuable outcrops of these earlier formations at St. Cloud and in the area northeast of that city.

At many places along Minnesota River the bed of the stream is granite in place. The ore deposits in the iron districts contain large quantities of water, which, on one hand, embarrass miners, and, on the other, afford water supplies for neighboring municipalities. None of these rocks except the ore deposits transmits much water. The early formations are covered by a deposit of drift, of variable thickness, which affords a supply of water for shallow wells.

The eastern and southeastern division, extending from Lake Superior to the Iowa boundary, is underlain by Cambrian and Ordovician rocks. The belt comprising these formations gradually widens toward the east and west in its extension southward from the northern section of this region, in upper St. Croix valley. These rocks consist of a succession of sandstones, shales, dolomites, and dolomitic limestones, of variable thickness, which dip generally southward. The lowest water-bearing stratum is the basal sandstone, sometimes locally known as the "Potsdam." This is overlain by a succession of shales and dolomites called the "St. Lawrence formation," above

[a] Hall, C. W., Hydrology of Minnesota: Water-Sup. and Irr. Paper No. 102, U. S. Geol. Survey, p. 441.

which lies in turn the "Jordan" sandstone, a strong artesian bed over 100 feet thick. The next rock containing water is the New Richmond sandstone, of variable thickness and locally absent, which is separated from the "Jordan" below by the Oneota limestone ("Lower Oneota"). The St. Peter sandstone is separated from the New Richmond by the Shakopee limestone ("Upper Oneota"). Both the Oneota and the Shakopee are beds of impervious dolomite and contain no water. The St. Peter sandstone is a strong water-bearing body, of varying thickness, extending from the region around St. Paul continuously southward beneath the surface through the State of Iowa, where it affords a supply for many artesian wells. It is covered by an impervious limestone which has been classed as the "Trenton-Galena."

The western division includes the upper part of Minnesota River Valley, all of Red River Valley, and part of upper Mississippi Valley. It is covered by rocks of the Cretaceous system, named in succession,[a] beginning with the earliest, the Dakota, Benton, Niobrara, and Pierre formations. These consist, respectively, of sandstone of considerable thickness containing a few scattered beds of shale and lignite; alternating shales and clays with some limestone; calcareous marl blending into the limestone of the Benton; and shales and clays, sandstones, and sandy shales. The Dakota sandstone is the source of the supply of the famed artesian basin of the Dakotas. The Cretaceous beds overlie Archean and Algonkian rocks in an area in the northern part of Minnesota that extends as far east as Allen Junction, south of the Mesabi range, and cover Cambrian and Ordovician rocks in the southwestern part of the State. Deposits of drift lie at the surface throughout the State of Minnesota except in a comparatively small area in its southeast corner that forms a part of the "Driftless Area," which comprises portions of Minnesota, Wisconsin, Iowa, and Illinois. The Pleistocene deposits vary considerably from place to place in thickness and character, and the waters they contain are therefore more variable chemically than those that occur in the lower rocks.

Waters derived from the Cretaceous rocks are strongly alkaline, and the fact that they contain many saline deposits is shown by the character of the water coming from some portions of Red River Valley. Waters obtained from the sandstones in the eastern part of the State are much less strongly mineralized than those coming from the sandstones of the western part, though their hardness is influenced by contiguous limestones and dolomites. Waters from the older rocks naturally show the least mineralization, and waters from the ore bodies in the iron ranges do not contain ingredients that make their economic use undesirable, such as appear in mine drainage in many other sections of the country.

[a] Upham, Warren, The Glacial Lake Agassiz: Mon. U. S. Geol. Survey, vol. 25, pp. 81-82.

SOIL AND SUBSOIL.

Four distinct kinds of subsoil are found within the State:[a] (1) Blue till, (2) red till, (3) gravel and sand, (4) clay or clay loam. These different kinds of soil owe their general characteristics to contiguous earlier formations, and these characteristics in turn determine or influence the condition of the soil and the drainage in the region where each predominates.

The blue till, derived principally from the disintegration of rocks of the Cretaceous formations, is strongly impregnated with salts of the alkalies and of the alkaline earths. The prairie part of Minnesota is characterized by soils of blue till, except in parts of Red River Valley, where the soils are derived from lacustrine clays, and in a few places where they are derived from loess loam. These soils correspond, in general, to the section of Cretaceous rocks, though their alkaline content decreases toward the east as they become modified by the minerals of other systems.

The red till contains a large amount of iron oxide, practically no alkaline salts, and somewhat less alkaline-earth compounds than the blue till. Red-till subsoils extend from the northeast corner of the State southwestward to St. Paul, where they begin gradually to blend into the blue-till subsoils of the western portion of the State and the clay loams of the Driftless Area.

The gravel and sand subsoils consist of modified till, their local character being determined by the character of the till in the regions where they occur. They are abundant in parts of the morainic deposits known as the Leaf Hills.

Clay or clay-loam subsoils were deposited from the great sheets of fresh water that once covered large sections of the State. They owe their predominating characteristics to the character of the tills from which they were derived, but contain much less alkaline material. They appear throughout the lower part of Red River Valley. Clay-loam subsoils are also found in lower Mississippi Valley and in the lower section of St. Louis Valley.

ECONOMIC DEVELOPMENT.

POPULATION.

The rapid increase of population in Minnesota is a most important element to be considered in studying the resultant inevitable increase in the pollution of its lakes and streams. Before the first quarter of the nineteenth century the region was practically an unsettled wilderness, containing only a few scattered trading posts belonging to the Hudson Bay Company. In 1819 a military reservation, now known

[a] Winchell, N. H., Final Rept. Geol. and Nat. Hist. Survey Minnesota, vol. 1, pp. 125–128.

as Fort Snelling, was established by the United States Government at the confluence of Minnesota and Mississippi rivers. Settlement has steadily progressed from that time to the present. Prairie land of great fertility, easy of access by water, attracted pioneers from all over the world. At the end of 30 years it was deemed advisable to set apart from Wisconsin the territory of Minnesota. In 1858 the State of Minnesota was admitted to the Union. The following table, giving the population for the area now included within its boundaries, shows how rapidly the increase has taken place:

TABLE 9.—*Total population of Minnesota from 1850 to 1905.*[a]

Census.	Population.	Per cent increase.	Inhabitants per square mile.
1850	6,077	....	0.03
1860	172,023	2,730.7	2.2
1870	439,706	155.6	5.6
1880	780,773	77.6	9.9
1890	1,301,826	66.7	16.5
1900	1,751,394	33.8	22.1
1905	1,979,912	[b]13	25

[a] Figures for 1850–1900 are from U. S. Census; those for 1905 are from State Census.
[b] Percentage increase in five years.

At the time of the first official census, taken soon after the organization of the Territory, the population was concentrated in the region lying within a few miles of St. Paul and in a settlement on Red River in Pembina (now Kittson) County. Between 1850 and 1870 there was an enormous influx of settlers to the southern and central parts of the State. Since that time the percentage of increase has been always considerably higher than the average for the rest of the United States. The number of inhabitants per square mile is rapidly increasing. In spite of this growth, however, the State is still a pioneer country. Its density of population is little more than half that of the general average for the basin of Mississippi River, the most thickly settled portion is still in the region near St. Paul and Minneapolis, while in the Rainy River drainage area the population is considerably less than one person per square mile, and many townships are practically uninhabited. That this region will not long remain in its present unsettled condition is shown by the constant migration to it. The prospective removal of forests and the drainage of swamps will undoubtedly result in the establishment of farms with their attendant trading centers and, from a sanitary standpoint, other foci of pollution.

PRINCIPAL INDUSTRIES.

AGRICULTURE.

The chief reason for the progress and development of the State in general has been the abundance of inexpensive land remarkably well suited to the cultivation of cereals.

TABLE 10.—*Chief agricultural products in Minnesota, 1899.* [a]

	Bushels.
Wheat	95,278,660
Corn	47,256,920
Oats	74,054,150
Potatoes	14,643,327

At present Minnesota is the greatest wheat-growing State in this country, about 12 per cent of its area producing that crop. Corn is extensively raised in the southern tier of counties, along the Iowa line. Oats, barley, rye, and potatoes are also largely cultivated. Red River Valley west of Thief River Falls and Minnesota River drainage area and the territory south of it, or about 40 per cent of the total area of the State are prairie lands with rich soil, requiring small investment for the production of large crops. Upper Mississippi Valley below Brainerd, now practically deforested, contains many farms. As soon as the northern counties are cleared of their timber it is probable that the entire section will become wheat-raising farms, similar to the part now under cultivation.

LUMBERING.

One of the greatest attractions in Minnesota for explorers and settlers was the great wealth of timber, principally white pine. Originally a line extending from Thief River Falls southeastward to the mouth of St. Croix River would have marked the southern boundary of the great pine region, along the edge of which stretched a belt of hard-wood forest 50 to 100 miles wide. At present the greater part of the standing timber is in the northern region, in Beltrami, Itasca, St. Louis, Lake, and Cook counties, and on the Indian reservations. St. Louis, St. Croix, and Mississippi rivers, the principal outlets for the lumber, afford easy access to sawmills and cheap conveyance for the sawed material. The amount of organic matter introduced into these streams and their tributaries by reason of the lumber industry is an important factor in the consideration of the value of surface water from the forested regions. A greater or less number of logs at all seasons of the year are floated in the rivers and lakes, which dissolve the resinous matter. Sawdust from the mills is a serious source of stream pollution. The total amount of lumber cut in Minnesota during 1899 was 1,934,157,000 feet B. M., which is a fair average for the cut from year to year. From 500,000,000 to 700,000,000 feet are cut annually on the upper Mississippi alone and this enormous industry will continue until the pine forests of the State have been exhausted. The result of this removal on the quality and amount of surface water can not be predicted.

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[a] Twelfth Census U. S.

COMMERCE.

The principal trading centers of Minnesota are Duluth, Minneapolis, and St. Paul. The first of these, situated at the head of Lake Superior, owes its importance principally to its enormous traffic in iron ore, which is received by rail from the Mesabi and Vermilion districts and shipped across the Great Lakes. It is also a shipping point for grain and lumber and has a large import trade. It is the center of commerce for the northeastern part of the State and has considerable through traffic with the Pacific coast.

TABLE 11.—*Chief shipments by water from Duluth, 1903–5.*[a]

Product.	1903.	1904.	1905.
Grain ... bushels..	11,229,703	11,560,083	16,938,549
Lumber ... feet B. M..	355,712,000	344,109,000	357,814,000
Iron ore ... gross tons..	5,362,731	4,342,782	8,731,227

[a] Monthly Summary of Commerce and Finance, Bureau of Statistics, Department of Commerce and Labor, December, 1904, pp. 906–907; December, 1905, pp. 706–721.

Minneapolis owes much of its growth to the water power of St. Anthony Falls, by means of which this city has developed the largest flour mills in the world. Its principal trade is in wheat and lumber; it is a distributing point for all sorts of manufactured products throughout the Northwest.

St. Paul, at present the head of navigation on Mississippi River, is the transfer point of a great transcontinental traffic. It has a large commerce in lumber, live stock, and general merchandise. Regular lines of steamers run from St. Paul to lower ports on Mississippi River, and a considerable traffic is carried on by other vessels. Lumber is floated in enormous rafts down Mississippi River to St. Louis and other southern ports.

Besides the three cities above mentioned, points of minor commercial importance are: Winona, a distributing point for southeastern Minnesota; Mankato, the metropolis of Minnesota Valley; Fergus Falls, on Ottertail River, and Crookston, which has a large trade in wheat, lumber, and agricultural implements.

MINING.

Iron is the only metal that is extensively mined in Minnesota. The discovered deposits are included almost entirely within St. Louis County, north of Duluth. The Mesabi district, which extends generally northeast and southwest across the county and forms a great part of the north boundary of St. Louis River basin, was opened in 1892 and quickly became the largest ore-producing district in the Lake Superior region. In 1904 the output of this one district alone was over 40 per cent of the total production in the United States.

North and somewhat east of the Mesabi range is the Vermilion iron-bearing district, which was opened in 1884. Its annual output is from one million to two million tons of ore.

TABLE 12.—*Production of iron ores in Minnesota, 1899–1904.*[a]

[Long tons.]

Year.	Vermilion range.	Mesabi range.
1899	1,643,984	6,517,305
1900	1,675,949	8,158,450
1901	1,805,996	9,303,541
1902	2,057,532	13,080,118
1903	1,918,584	13,452,812
1904	1,056,430	11,672,405

[a] Birkinbine, John, The production of iron ores in 1904: Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905.

On account of the structure of the ore deposits, water traverses them readily, so that wherever mining is done the water must be removed. The use of mine water in this section does not present serious troubles from an industrial standpoint. The amount of dissolved solids it contains is comparatively small, though it varies considerably, depending upon the length of time it has been in contact with the underground strata. The rapid development of this enormous industry, however, has more bearing on the resultant stream pollution by the constantly increasing population. In 1880 the total population of St. Louis County was 4,504. North of Duluth lay a wilderness that was invaded only now and then by lumbermen. With the opening of the Mesabi range there was a sudden influx of prospectors and miners to this region and towns sprang up there as if by magic. In 1890 the population of the county, excluding Duluth, was 11,746; in 1900 there were nine settlements in the iron districts, having a population exceeding 1,000, and the total number of inhabitants in the county had doubled in ten years; in the period from 1900 to 1905 the total population increased by more than 35,000. With this rapid growth concentrated in mining towns, there was neglect of sanitary precautions and a disinclination to heed the experience of similar settlements elsewhere. Sewerage systems were constructed only after harsh lessons. Water supplies were taken in the least expensive way from the most convenient sources, generally from mine sumps or small creeks. An inevitable result of this disregard for hygienic measures was the occurrence of severe epidemics of typhoid fever.

WATER-BORNE DISEASES.

GENERAL DISCUSSION.

The value of water as a municipal resource is greatly affected by its liability to transmit disease from one locality to another. Until recently the belief was more or less general and even yet the opinion is not entirely eradicated, that the danger of water lies in part in "miasmatic vapors" or "fever fogs," which may affect those who breathe the air in the vicinity of swamps or other stagnant water. This paludal or miasmatic poison, vague or indeterminable in its origin and character, was believed to be the direct exciting cause of malaria or ague and even of other febrile humors, and was supposed besides to favor the spread of contagions and epidemics in general. More certain knowledge has gradually been gained concerning the cause, the means of spread, and the methods of preventing disease, and it is now known that water may carry living organisms or other substances that produce disease. Chemical substances when dissolved in water may act in a toxic or poisonous way. Even comparatively pure water, especially soft water, may prove dangerous by reason of its solvent action upon lead pipe if that is used for its transmission. Biological and clinical studies have determined beyond doubt the relationship of marshy districts to such diseases as malaria and yellow fever. It is now well known that the danger from swamps is due to the facilities which they afford mosquitoes for breeding, since the virus of these two diseases, and probably also of filariasis, is transmitted by mosquitoes. In passing, it may be stated that two methods of protecting the public health should be combined—namely, the extermination of mosquitoes of certain or all varieties and the protection of the sick from mosquito bites.

Sanitarians are justly concerned with a certain group of water-borne diseases, of which typhoid fever, cholera, and possibly certain diarrheal diseases are types. The infecting bacteria in these diseases may live for some hours or days in water. Certain of these diseases, particularly typhoid fever, are so prevalent in this country that in almost every community there are some infected persons whose dejecta carry pathogenic germs. Since there is so much difference in the relative resistance of individuals to infective organisms, it frequently happens that patients who are suffering from the disease are not aware of it, nor are their friends. Furthermore, the long persistence of the infecting micro-organisms of typhoid fever in the body of the patient, particularly in the urine, makes the infection of sewage very easy, and since the same care is not exercised in the disposal of the urine as of the feces, water supplies and milk or foodstuffs may easily be infected either directly or from the hands. Water into which sewage is discharged becomes, therefore, a vehicle for transmitting diseases from one place to another, and the germs of infection are therefore called water borne.

TYPHOID FEVER.

CAUSE AND PREVALENCE.

Of the diseases which are transmissible by water, typhoid fever merits special attention in Minnesota and in other newer communities. In Massachusetts, where the conservation of water supplies and the proper disposal of sewage have received attention for many years, milk-borne epidemics are more to be considered than in Minnesota. Even milk-borne epidemics, though they are perhaps most usually due to the fact that a typhoid patient or an attendant upon a typhoid patient is engaged in handling milk, may be spread by means of water when the infecting organism gains entrance to a water supply which is used for cleansing utensils or, in very rare instances, where the outside of the udder and teats of the cow are contaminated by sewage containing typhoid bacilli. There can now be no reasonable doubt that *B. typhosus*, the specific organism of typhoid fever, can exist for a considerable period of time in water. The studies of Jordan, Russell, and Zeit would seem to show that the organism dies in ordinary running water in three to eight days, but the difficulty of exactly reproducing natural conditions in the laboratory permits only very guarded conclusions from such experiments.

The relationship of typhoid-polluted sewage to outbreaks of the disease has been clearly demonstrated in this country at Plymouth and Butler, Pa., Ithaca, N. Y., and many other places. In Minnesota, as in other new regions which are being settled rapidly, typhoid fever is more or less prevalent and is one of the chief causes of death in the State. New communities are usually established with more regard to financial advantages than to sanitary conditions. The careful disposal of excreta and the selection and protection of safe water supplies and other hygienic improvements are neglected until their necessity is shown by costly epidemics. Even then, unless action is taken during the progress of an epidemic the matter is likely to be neglected, since the general interest in projects affecting the public welfare is likely to wane unless private stimulation be applied.

The principal settlements in Minnesota are on the shores of lakes or on the banks of running streams, to which the towns have recourse both for their domestic supply and for the disposal of their sewage.

Since 1887, when the care of vital statistics was transferred to the State board of health, the statistics of deaths from typhoid fever have been carefully compiled. Undoubtedly a considerable percentage of the typhoid mortality has not been recorded on account of neglect to report from all parts of the State and also on account of diversity of diagnosis. Whether the death rate from typhoid fever in Minnesota is lower than that in Massachusetts, New York, and other States can not be definitely affirmed, but it would appear that the disease is very much less virulent in Minnesota and the Dakotas. From observations made by competent clinical men during severe local epidemics it appears that the death rate as compared with the case rate is between 2 and 4 per cent. This low rate may be due to the diagnosis of cases as typhoid fever in Minnesota which would not be so classified in other communities. The Widal blood test is very extensively used throughout the State by private practitioners and by hospitals, and this test is made gratuitously by the State board of health and by the local boards of health of Minneapolis and St. Paul. This confirmatory examination probably results in the return of cases as typhoid fever which ordinarily would not be so classified.

The records of deaths received since 1888 are as follows:

TABLE 13.—*Deaths from typhoid fever in Minnesota per 100,000 population.*[a]

Year.	Entire State.	Cities exceeding 5,000.	State, excluding cities over 5,000.
1888	53.63	114	30
1889	45.7	76	32
1890	30.8	52.2	25
1891	39.23	64.8	28
1892	28.6	47.5	21
1893	38.5	63.0	27
1894	35.2	57	26
1895	35.9	57.3	27
1896	27.8	51.6	17.7
1897	25.7	50	15.5
1898	22.6	37.2	16
1899	18	30.4	12.8
1900	32.6	43.0	28.0
1901	26.0	41.8	19.3
1902	21.21	29.73	15.93
1903	19.9	32.7	14.2
1904	18.68	33.2	13.4
1905	14.6	22.0	11.2

[a] From the official records of the secretary of the State board of health. The population of the cities considered above is estimated by adding the average annual increase as shown by the United States and the State censuses to each preceding year.

The village and rural death rate from typhoid fever, shown by the fourth column, is much lower than the urban rate, but comparison of the second and fourth columns indicates that typhoid fever is extremely prevalent in rural districts. Allowance should be made for the fact that since the better hospitals are located in the large centers many serious cases of all forms of illness are taken to them from outlying districts, a factor which would disproportionately increase the total death rate for the cities. This is particularly true of Duluth, to which the settlements of the iron-bearing districts are tributary. Typhoid fever has been prevalent in these mining communities for a number of years, and since many cases are brought to Duluth the statistics of deaths from the disease in that city are thus greatly increased. In the smaller communities a difference of one or two deaths makes an enormous difference in the rate per hundred thousand.

These records show that there are from 300 to 800 deaths from typhoid fever in Minnesota every year. Assuming a ratio of 1 to 25[a] between the number of deaths and the number of cases, it would appear that approximately from 7,500 to 20,000 people are stricken annually with this disease, which can be and should be prevented. The official records show that from 1891 to 1900, inclusive, 4,532 persons died of typhoid fever in Minnesota.

In May, 1905, reports were made by the health officers of 166 settlements in the State in reply to the following questions:

1. During 1904 how many cases of typhoid fever occurred in your city?
2. How many cases of the disease in the city were personally seen by you?
3. How many other cases in the city were reported to you?
4. How many cases in the city were probably not reported to you?

According to these records and the official reports of Duluth, Minneapolis, and St. Paul, there were in Minnesota 1,062 cases of typhoid fever during the year 1904, but from other means of checking and by mathematical reckoning it seems probable that there were from five to ten times as many cases as were reported. As bearing upon this, it may be stated that in three months two towns situated on Red River—namely, Breckenridge, Minn., and Wahpeton, N. Dak., with a total population of 4,090—developed 200 cases of typhoid fever.

The highest mortality from typhoid fever occurs during October and the lowest during April, May, and June. During the summer months the death rate from this disease rises rapidly to its maximum in October and falls as rapidly. The average typhoid-fever death rate per hundred thousand for the entire State is 29.43, a little lower than the rate for the registration area (33.8), according to the Twelfth United States Census.

EPIDEMICS.

Hardly a community in Minnesota has escaped one or more epidemics of typhoid fever. Duluth suffered from a series of outbreaks which culminated in 1896. Investigation showed that the intake of the waterworks system, which was supposed to extend a considerable distance into Lake Superior, was defective, and that the water supply was being contaminated with more or less dilute sewage at a point within 300 feet of the outlet of one of the principal sewers. Repair of this defect and extension of the intake to Lakewood, 8 miles nearer

[a] In Massachusetts and older communities the death rate is about 10 per cent; that is, from two and one-half to four times as great as in Minnesota.

the main lake, has practically wiped out the disease, for the cases that have occurred since then are imported or are due to the use of infected well water or to the result of contact with imported or such local cases. The water supply at present seems to be satisfactory.

The largest epidemic of typhoid fever in Minneapolis occurred in 1881 and 1882, during which time there were 350 deaths. There was another serious outbreak in 1897, when there were 1,534 cases and 148 deaths. The disease has always been prevalent in the city, where several other well-marked epidemics have occurred, which have been attributed to the use of unfiltered river water.[a] Minneapolis has the unenviable distinction of having recorded nearly 50 per cent of the total deaths from typhoid fever in Minnesota during the past decade,[b] although its population is only a little over one-tenth of that of the State.

In 1898, while the United States Volunteers were encamped at the State Fair Grounds (Camp Ramsey) and at Fort Snelling, 406 cases of typhoid fever were reported for the Fifteenth Regiment Minnesota U. S. Volunteers, 346 of which occurred before its departure for Camp Meade, Pennsylvania.[c] A detailed account of the fever in this regiment is given in the special report of the Surgeon-General of the U. S. Army on typhoid fever among the volunteer regiments during the Spanish war of 1898.

As stated above, settlements in the mining districts of St. Louis County have been subject to typhoid fever, and notable epidemics have occurred at Eveleth, Hibbing, and Virginia, all of them probably due to impure water supplies.

IMPROVED CARE, CONTROL, AND REPORT OF TYPHOID FEVER.

Section 2131 of the Revised Laws of Minnesota, 1905, authorizes the State board of health of Minnesota to adopt, alter, and enforce reasonable regulations, which, after the approval of the attorney-general and due publication thereof, have the force of law, except in so far as they may conflict with a statute or with the charter or ordinances of a city of the first-class upon the same subject. In accordance with the authority thus delegated and upon realizing that Minnesota was suffering from a disease which is strictly preventable, the State board of health passed certain rules on the 14th day of July, 1906. Rules 45 to 54 deal with typhoid fever and may be quoted as follows:

RULE 45. Every physician engaged in the practice of medicine in the State of Minnesota shall submit to the secretary of the State board of health the full name, specific residence, and hygienic data, on blanks furnished by said board for that pur-

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[a] Rept. special commission appointed by the city council to investigate the Minneapolis water supply, 1904; also Corbett, Dr. J. F., Typhoid and water supply: Ann. Rept. Dept. Health, city of Minneapolis, for 1904, pp. 27–28.

[b] Public Health Reports, Public Health and Marine Hospital Service, Treasury Dept.

[c] Rept. Minn. State Board of Health, 1895–1898, p. 472.

pose, of every person under his treatment for typhoid fever or suspected typhoid fever, within one week after the application of such patient for treatment.

Physicians in cities and villages where they are required by ordinance or sanitary regulation to report typhoid fever cases to the local board of health will not be required to report such cases directly to the State board of health, provided the local health officer makes returns of all cases reported to him to the State board of health once a month on blanks furnished for that purpose by said board.

RULE 46. The secretary of the Minnesota State board of health shall keep a careful and accurate record of all reported cases of typhoid fever. The same shall not be for publication, but may be used by said board in the discharge of its duties.

RULE 47. Immediately after being notified of any case of typhoid fever the secretary of the Minnesota State board of health, or the local health officer, shall send to the address of the attending physician the printed matter published by the State board of health relative to the control of typhoid fever. Such physician shall thereupon deliver the same to those in charge of the patient.

RULE 48. No person affected with typhoid fever, or in charge of a typhoid fever patient, shall so dispose of the excreta or other infectious bodily secretion or excretion as to cause offense or danger to any other person or persons.

RULE 49. Any health officer receiving a complaint that the foregoing rule is being violated shall investigate the same, and if it appears that the violation complained of is such as to cause offense or danger to any person he shall serve notice upon the offending party, reciting the alleged cause of offense or danger and requiring that the bodily secretions or excretions complained of be disposed of in such a manner as to remove all reasonable cause of offense or danger.

RULE 50. It shall be the duty of those having charge of a typhoid fever patient or patients to see to it that the excreta, or other infectious bodily secretions or excretions, from such patients are properly disinfected.

RULE 51. The apartments occupied by any typhoid fever patient shall be deemed infected, and when vacated by death or removal of the patient shall, together with their contents, be thoroughly disinfected under the supervision of the local health officer. All disinfection prescribed in this rule shall be a part of the control of the disease.

RULE 52. It shall be the duty of any person having knowledge of the facts to notify the local health officer within twenty-four hours after the death or removal of a person affected with typhoid fever from any apartments.

RULE 53. Whenever typhoid fever prevails in a locality the local board of health shall immediately appoint a competent inspector or inspectors to patrol the city, village, or district involved. Such inspector or inspectors shall report to the local board of health all water-closets, privies, vaults, and cesspools which are not fly proof, with screened doors and windows; and all vaults and cesspools which are not water-tight, dark, and fly proof. The local board of health shall thereupon enter its proper order in the premises to the end that all such water-closets and privies shall be made fly proof, and all such vaults and cesspools water-tight, dark, and fly proof.

RULE 54. Any drinking-water supply shown to be a positive or probable source of disease shall be condemned either by the local board of health or by the Minnesota State board of health, and when so condemned, shall not be used again as a drinking-water supply until declared safe by the condemning party.

A blank to be used by physicians and health officers for reporting cases of typhoid fever has been prepared in the form of a card, the two sides of which are here reproduced.

REPORT OF A CASE OF TYPHOID FEVER.

Name in full ——— ———.

(Be specific in answering the following three questions, giving name of street, house number, or other definite statement, such as name of farm, camp, mine, etc., in order that the patient may be definitely located.)

Age ———. Sex ———. Occupation ———.
Residence when taken ill ———.
Place where employed when taken ill ———.
Present address ———.
First taken sick with typhoid fever: Year ———. Month ———. Day ———.
First seen by a physician: Year ———. Month ———. Day ———.
Name and address of first attending physician ——— ———.
Total number of people living in house when patient was taken ill ———.

[Reverse side.]

Where was patient living during the three weeks before illness began? ———.

(Name all places, with date of residence at each place.)

Are any intimate associates of patient sick with typhoid fever? ———.

(Father, mother, child, brother, sister, husband, wife, fellow boarder, etc.)

If so, give present address of such associates ———.
Source of milk used by patient ———.

(Name and address of milkmen.)

Source of drinking water used by patient before illness began ———.

(Name and location of well, stream, lake, or other water source.)

Present status of case: (Still sick; recovered; convalescing; dead).
Physician's view of source of infection ———.
Filled out by Dr. ——— of ———, Minn.
Date of report ———, 190—.

One of the chief difficulties in the control and arrest of typhoid fever is the failure on the part of local authorities to realize that it is preventable and to make a careful canvass of the localities for the purpose of obtaining accurate data, such as that required in the above blank.

The State board of health is frequently asked to make examinations of water as a basis for action or recommendation in a given locality when no data are available to show which, if any, water is the cause of disease. It is hoped that the habit of securing full and accurate data will result in the education of the people of the State at large concerning the various vehicles of infection in typhoid fever and the means of arresting it.

A notice similar to the following should prevent the spread of typhoid fever pending the determination of the exact cause of the disease. The wording of this notice was suggested by Dr. H. W. Hill, assistant director of the laboratories of the Minnesota State board of health, and has been found very efficient.

TO THE CITIZENS OF ——.

Typhoid fever is epidemic in ——. The Minnesota State board of health is investigating this epidemic to find its exact source. Meantime govern yourselves as follows:

1. Typhoid fever is contracted solely *through the mouth.* If you do not put the poison of typhoid fever into your mouth you will never contract typhoid fever. Therefore, *watch the mouth.*

2. Do not eat or drink anything (water, milk, oysters, fresh vegetables, or anything else) unless it has first been boiled, broiled, baked, roasted, fried, or otherwise thoroughly heated through and through.

3. Do without all food or drink which has not first been thus heated. Canned or bottled foods or drinks (other than milk or water) are not included in this.

4. If living in the same house with a typhoid patient, do not handle your own food or food intended for anyone else, even if it has been heated, except with hands that have been thoroughly washed with soap and very hot water; preferably also with antiseptics. (Ask your physician about the antiseptic to use.) Wasn before every meal in this way and before cooking, serving, or eating anything or putting the fingers in the mouth.

5. If there are flies, roaches. or other insects or vermin about, see that all food and drink is protected from them at all times. Flies and other insects often carry typhoid poison to foods and drinks.

6. The poison of typhoid fever does not show itself for *two weeks* after it enters the body. Therefore for the next two weeks typhoid cases may develop from typhoid poison already taken in; but any case which develops on and after (a date two weeks later than the date of the placard) will be due solely to neglect of this notice and failure to carry out minutely the directions here given.

OTHER WATER-BORNE DISEASES.

There is no evidence that there are any other important water-borne diseases in Minnesota. It is possible that hog cholera among animals should be considered in the category.

STREAM POLLUTION.

SEWAGE.

Fifty-seven settlements in the State are more or less completely equipped with sanitary sewerage systems. Most of the cities in the State are situated on flowing streams, which are thus convenient receptacles for city sewage. In 1885, recognizing the fact that this would result in dangerous pollution, the State legislature passed a law entitled "An act to prevent the pollution of rivers and sources of water supply,"[a] which prohibits the discharge of sewage, drainage, refuse, or other polluting matter dangerous to health into any surface waters used as a source of municipal supply. The act also gives the State board of health supervision over all municipal water supplies and the power to institute legal proceedings against violators of the statute. Notwithstanding the provisions of this law, sewage-purifica-

[a] Chapter 225, secs. 1-7, laws of 1885, approved March 7, 1885.

tion plants have not been generally established in the State, so that stream pollution has not been materially checked. At the State hospital for the insane at Rochester a system of precipitation and filtration was put into operation in 1890. Improvements are contemplated. In 1904 a purification system consisting of a septic tank combined with contact and intermittent sand filters was installed at the State insane asylum at Anoka. A few villages have made unsuccessful attempts to comply with the requirements of the statute by establishing sewage-purification plants. The large cities, however, without exception, discharge raw sewage into adjacent bodies of water.

INDUSTRIAL WASTES.

Dangerous effluents from manufacturing establishments are not yet of serious importance in Minnesota. In the spring of 1905 inquiry was made to ascertain to what extent manufacturing wastes cause stream pollution. From replies received from 174 municipalities the following list has been prepared:

TABLE 14.—*Industrial establishments causing stream pollution.*

Industry.	Establishments.	Industry.	Establishments.
Breweries	73	Slaughterhouses	224
Creameries	138	Soap works	8
Dyehouses	13	Starch factories	8
Gas works	14	Sugar factory	1
Paper mills	6	Tanneries	12
Rendering works	19	Woolen mills	12
Sawmills	98		

From this table it appears that there are in the State few factories that emit deleterious wastes. With the exception of the sawmills the establishments noted are generally small. Though probably some establishments were not reported because they are located outside of organized villages or cities, yet the list represents with fair accuracy the possible foci of pollution from industrial wastes. The kinds of plants whose wastes cause so much trouble in other sections of the country are either small or are entirely absent. No bleacheries, cotton mills, distilleries, galvanizing works, nitroglycerin factories, petroleum refineries, strawboard mills, or tin-plate works were reported from any part of the State. The effluents from the majority are not discharged directly into streams, but are either consumed or decomposed on the ground. In comparison with large manufacturing centers in the East, stream pollution by industrial wastes is an insignificant factor in Minnesota.

The trouble from sawmills is caused by three different classes of waste: First, by organic matter dissolved in the water from the logs which lie in the lakes and streams from the time they are run till they are sawed; second, by excreta from the lumbermen themselves, who are constantly in the water for the purpose of sorting and guiding the logs; third, by sawdust and other minute waste. The latter cause of trouble is the most evident one, and has the effect of forming nuclei for the growth of organisms and of obstructing the free flow of the water. In reports of the U. S. Engineering Corps it is stated that many of the bars in Mississippi River above Lake Pepin are composed largely of sawdust and that the material has been found by dredging as far south as Winona.[a] It is evident that the distribution of this material over the beds of streams is anything but favorable to the hydrolysis of other more dangerous pollutions, and in view of the fact that it has a certain commercial value, this disposal of it seems not only unsanitary, but wasteful.

MISSISSIPPI RIVER BASIN ABOVE MINNESOTA RIVER.

GENERAL DESCRIPTION.

BOUNDARIES.

Mississippi River basin above Minnesota River is bounded on the east by St. Louis and St. Croix drainage areas; on the north by Rainy River basin; on the west by the basin of Red River; on the south by Minnesota River drainage area. (See Pl. II.)

SOURCE, COURSE, AND SLOPE OF THE RIVER.

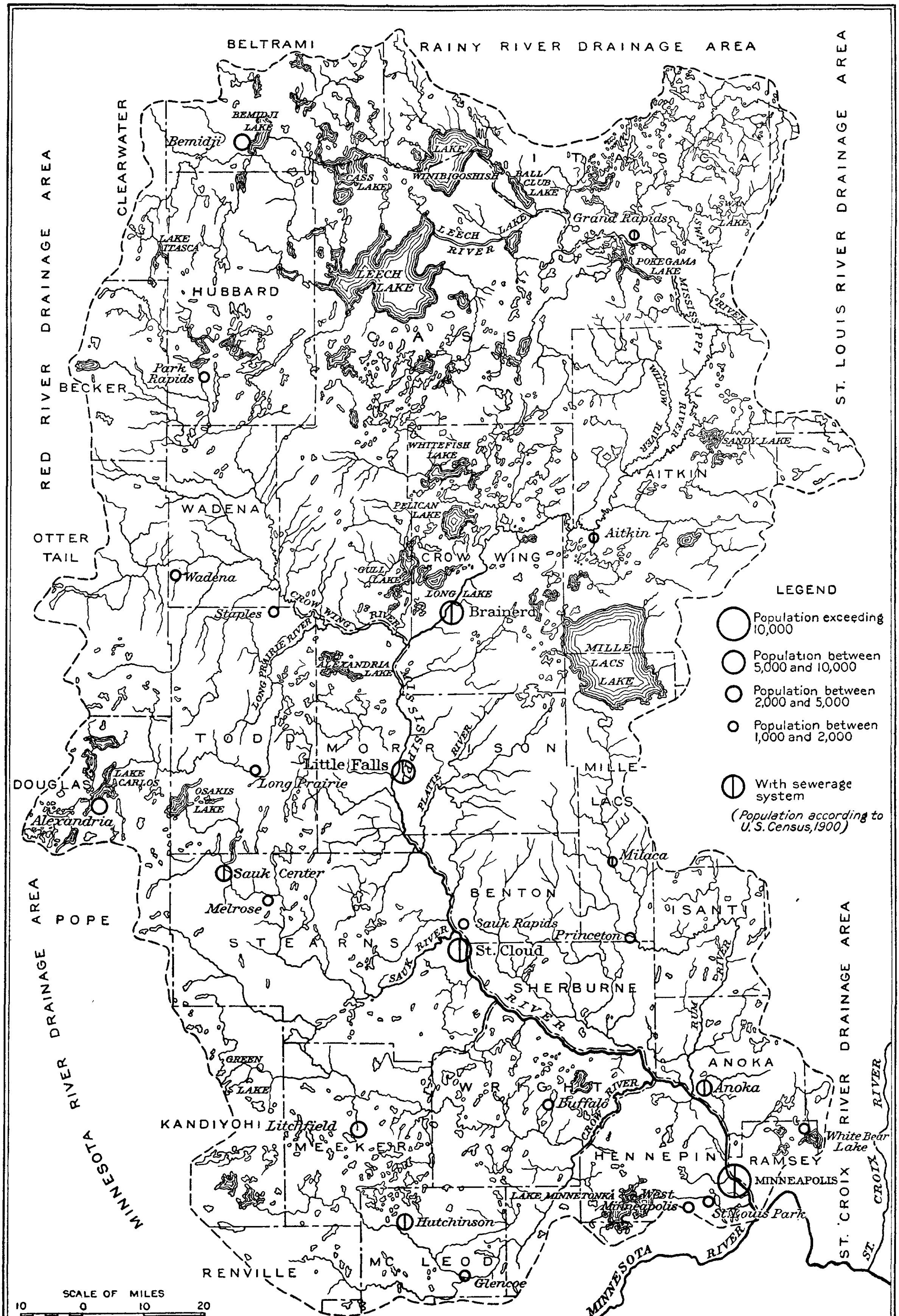
The determination of the primal source of Mississippi River has been the cause of much controversy among explorers and geographers, by whom one or another of various small lakes has been considered the body of water in the Mississippi system that lies most remote from the Gulf of Mexico and stands at the highest elevation above it. For the purposes of the present report it is sufficient to state that the headwaters of the Mississippi lie within Itasca State Park, a tract of reserved land in Clearwater County, a detailed survey of which was made by the Mississippi River Commission.[b] Lake Itasca, which is the largest body of water within this park and which may be regarded as the source of the river, is in its north-central portion. The lake is long and narrow and is divided at its upper or southern end into an east and a west fork, each of which is connected by small creeks with other bodies of water. It is about 7 miles long and one-half mile wide and has an average depth of 20 feet. Its shores are generally swampy; indeed, a great part of the Itasca reservation is wooded swamp land, in some parts of which it is difficult to determine the direction of the water flow.

[a] Ann. Rept. Chief of Engineers, U. S. Army, for 1882, p. 1750; also for 1881, p. 1679.
[b] Map of Lake Itasca Basin, Minnesota, within Itasca State Park, Mississippi River Commission, 1900.

The river is 10 to 20 feet wide where it issues from Lake Itasca, at the northern boundary of the park, whence it meanders through a narrow, marshy valley northeastward to Lake Irvine, 1 mile above which it is joined by Schoolcraft River, a small stream draining Lakes George and Plantagenet. Lake Irvine, which is nearly circular in outline, has an average diameter of 1 mile and a general depth of 20 feet. After leaving Lake Irvine the river traverses a narrow neck of land to Lake Bemidji, which is approximately 5½ miles long and 2½ miles wide at its widest part. There is a perceptible current across this lake in a channel having a depth of 50 feet. The river is 60 feet wide and 1 to 3 feet deep at the lake outlet, and falls over intermittent rapids by a tortuous course to Cass Lake, a body of water that measures 9 miles from the point of entrance of the river to its place of exit at the northeast corner. A marshy tract, which at ordinary stages has no definite current through it, connects this lake at its southern extremity with Pike Bay, an oval lake having a circumference of 25 miles. From Cass Lake the river flows in a tortuous course about 15 miles eastward to Lake Winnibigoshish, a rectangular body of water about 6 miles wide and 12 miles long. A dam is maintained at the outlet of this lake. From the northeast corner of Lake Winnibigoshish the river flows generally southeastward as a sluggish, meandering stream, through bogs and marshes, to Pokegama Falls, where a concrete dam has been constructed. Four miles below this point, at Grand Rapids, there is another fall.

Between Lake Winnibigoshish and Pokegama Falls, Vermilion River and Leech Lake River enter the Mississippi from the south. Leech Lake River is the outlet of Leech Lake, a large, irregular-shaped body lying south of Cass Lake in Cass County.

From Grand Rapids to Aitkin, a distance of 130 miles, the Mississippi is navigable for light-draft steamers, which make regular trips during the open season. Swan, Sandy Lake, and Mud rivers enter the Mississippi from the east above Aitkin. Between Aitkin and Brainerd there are several falls, the principal of which are Big Eddy, Island, and French Rapids. Pine River enters from the west between these two cities. Ten miles below Brainerd Crow Wing River enters from the west. From Brainerd to Little Falls the stream consists of short stretches of rapids with intervening reaches of still water. At Little Falls there is a developed head of 12 feet. The bed of the river from Little Falls to Minneapolis is steep and the current rapid as compared with the other parts. The average slope in this stretch is 2.6 feet per mile. (See fig. 1.) The descent is, however, by no means even or regular. From Little Falls to St. Cloud there are several series of rapids, and at St. Cloud there is a fall of 14.5 feet. Sauk River enters from the west just above St. Cloud. Rapids and still-water stretches occur alternately between St. Cloud and Anoka, where



RAINY RIVER DRAINAGE AREA
RED RIVER DRAINAGE AREA
ST. LOUIS RIVER DRAINAGE AREA
MINNESOTA RIVER DRAINAGE AREA
ST. CROIX RIVER DRAINAGE AREA
BELTRAMI
CLEARWATER
HUBBARD
BECKER
CASS
ITASCA
AITKIN
WADENA
OTTER TAIL
CROW WING
TODD
MORRISON
MILLE LACS
DOUGLAS
POPE
STEARNS
BENTON
ISANTI
SHERBURNE
ANOKA
WRIGHT
KANDIYOHI
MEEKER
HENNEPIN
RAMSEY
RENVILLE
MC LEOD
Bemidji
Park Rapids
Wadena
Staples
Brainerd
Grand Rapids
Aitkin
Little Falls
Long Prairie
Alexandria
Sauk Center
Melrose
Milaca
Sauk Rapids
St. Cloud
Princeton
Anoka
Buffalo
Litchfield
Hutchinson
Glencoe
MINNEAPOLIS
West Minneapolis
St. Louis Park
White Bear Lake
LEGEND
Population exceeding 10,000
Population between 5,000 and 10,000
Population between 2,000 and 5,000
Population between 1,000 and 2,000
With sewerage system
(Population according to U. S. Census, 1900)
SCALE OF MILES
10 0 10 20

Rum River, the outlet of Millelacs, enters. Crow River, an important stream draining much of the southern part of the upper Mississippi area, enters a few miles above Anoka. Below Anoka the descent of the Mississippi is rapid. At Minneapolis the river falls 77 feet in 4 miles, and in this stretch it enters the deep, wide valley of its lower course.

From Lake Itasca to Minnesota River, a distance of 540 miles, Mississippi River has a total fall of 776 feet, which is an average slope of 1.4 feet per mile. (See fig. 1.)

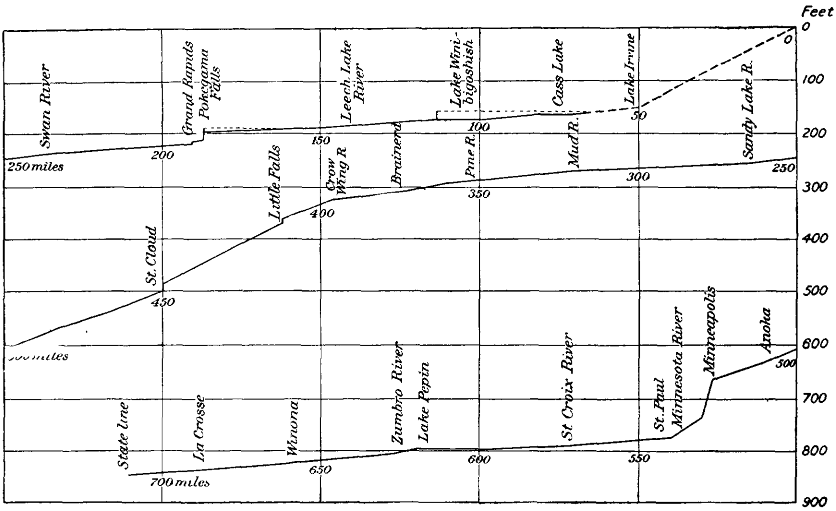


FIG. 1.—Profile of Mississippi River.

STORAGE RESERVOIRS.

The construction of dams in upper Mississippi Valley for the purpose of retaining flood waters was begun by the War Department in 1880. The original project [a] was to construct forty-one reservoirs in Minnesota and Wisconsin for the purpose of collecting surplus water to be released for the benefit of navigation during periods of low water. Between 1880 and 1895 five rock-filled timber-crib dams with earth embankments were built. In 1898 the replacement of these wooden dams by permanent concrete structures was commenced. After this part of the work has been completed probably no further reservoirs will be undertaken. Those now in operation are as follows:

1. Winnibigoshish dam, at foot of Lake Winnibigoshish.
2. Leech Lake dam, at foot of Leech Lake.
3. Pokegama dam, at Pokegama Falls, 4 miles above Grand Rapids.
4. Pine River dam, at foot of Cross Lake.
5. Sandy Lake dam, between Sandy Lake and Mississippi River.

[a] Ann. Rept. Chief of Engineers, U. S. Army, for 1904, pt. 1, p. 422.

TABLE 15.—*Storage reservoirs in upper Mississippi Valley.*[a]

Reservoir.	Area of watershed.	Area of reservoir surface.		Height of dam.	Reservoir capacity.[b]
		High water.	Low water.		
	Sq. miles.	*Sq. miles.*	*Sq. miles.*	*Feet.*	*Cubic feet.*
Winnibigoshish	1,442.43	161.26	117.00	14	45,000,000,000
Leech Lake	1,162.80	233.80	173.19	6	30,000,000,000
Pokegama	660.23	45.29	24.13	9	4,700,000,000
Pine River	562.07	23.76	18.30	17	7,500,000,000
Sandy Lake	421.50	16.52	8.00	7	3,158,000,000
					90,358,000,000

[a] Ann. Rept. Chief of Engineers for 1894, pt. 3, p. 1704.
[b] Ann. Rept. Chief of Engineers for 1900, p. 2798.

The total storage given above would be sufficient to supply the river with 11,000 second-feet for ninety days, though it is of course impossible to discharge the water at that rate, and the reservoirs are not filled to their maximum capacity. Records giving the dates for releasing the water and its effect at St. Paul[a] show that a release at Pokegama Falls is followed by a rise at St. Paul in seven or eight days, and that the full effect appears in twelve days, making the mean time ten days. The rise is about 1 foot at St. Paul. This would indicate that it takes eight days for water to travel from Pokegama Falls to St. Paul, a distance of 350 miles.

TRIBUTARIES OF MISSISSIPPI RIVER.

The drainage areas of the principal tributaries of Mississippi River above Minnesota River are given in the following table:

TABLE 16.—*Principal tributaries of Mississippi River above Minnesota River.*[b]

[Drainage area in square miles.]

Leech Lake	1,001
Pine	788
Crow Wing	3,562
Sauk	981
Crow	2,961
Rum	1,542

GEOLOGY.

The greater part of upper Mississippi Valley is underlain by Archean and Algonkian rocks, a few scattered outcrops of which appear in the beds of streams. Along the western border and in the northern third of the area alkaline formations of Cretaceous age overlie the early rocks. Cambrian and Ordovician limestones, sandstones, and dolomites occur in a comparatively small section of the southern part of the area. Drift covers the entire area to depths

[a] Ann. Repts. Chief of Engineers for 1895 and 1896.
[b] Ann. Rept. Chief of Engineers, U. S. Army, for 1875, pt. 2, p. 437.

ranging from 50 to 200 feet and furnishes the supply of water for most of the wells. The river channels above Minneapolis are excavated in drift. Below Minneapolis the Mississippi runs through a deep, wide gorge cut in sedimentary rocks, a gorge formed above Fort Snelling, probably, by the recession of St. Anthony Falls.[a]

SOIL AND SUBSOIL.

The upper layers of the drift here contain less soluble mineral matter than is contained in the drift of the prairie regions. This difference may be due both to difference in climate and to difference in the character of the underlying formations. From published analyses in bulletins of the agricultural experiment station, University of Minnesota, averages have been computed for samples of soil taken from points in all parts of the upper Mississippi area. The average composition of soils taken throughout the entire State is given for comparison.

TABLE 17.—*Chemical composition of soil and subsoil in upper Mississippi basin.*

	Surface soil.		Subsoil.	
	Upper Mississippi River basin.	Entire State.[a]	Upper Mississippi River basin.	Entire State.[a]
Insoluble in HCl	86.92	79.92	87.27	82.41
Volatile matter	5.88	8.98	3.33	5.33
Potassium oxide (K_2O)	.23	.43	.24	.40
Sodium oxide (Na_2O)	.29	.45	.25	.32
Calcium oxide (CaO)	.68	1.29	.92	1.78
Magnesium oxide (MgO)	.40	.61	.38	.80
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	4.88	7.20	5.85	8.32
Phosphoric anhydride (P_2O_5)	.19	.20	.17	.17
Sulphuric anhydride (SO_3)	.07	.10	.05	.06
Carbonic anhydride (CO_2)	.08	.62	.30	.93

[a] Snyder, H., Characteristic features of Minnesota soils and conservation of fertility: Bull. Chem. Div., Agric. Exp. Sta., University of Minnesota, No. 65, Nov., 1899, p. 69.

From Table 17 it is seen that all the alkaline and alkaline-earth ingredients of the soils of the upper Mississippi region are lower than the average in the soils throughout the State, and it appears, therefore, that the ground is less easily disintegrated and carried off in solution by the surface drainage. It will be noted, however, that there is enough calcium and magnesium to cause the hardness always observed in the water of Mississippi River. The soils in general contain sand, and the particles are larger than those in Red River Valley or in the southern part of the State. They are of much the same chemical composition as those in the valley of St. Croix River, though they usually contain more alkaline-earth compounds and more organic or volatile matter.

[a] Winchell, N. H., Geology of Hennepin County, Final Rept. Minnesota Geol. and Nat. Hist. Survey, vol. 2, p. 315.

INDUSTRIAL POLLUTION.

KINDS OF POLLUTION.

From reports received in June, 1905, the following list has been compiled to show the number of establishments likely to furnish deleterious or undesirable wastes to streams in this region.

TABLE 18.—*Industrial establishments causing stream pollution in upper Mississippi River basin.*

Breweries	18
Dye works	6
Gas works	1
Paper mills	5
Sawmills	36
Starch factories	4
Sugar factories	1
Tanneries	3
Woolen mills	3

LUMBERING.

Lumbering and its attendant industries are the sources of a great amount of the organic matter in the surface waters of this section. Almost the entire area was formerly covered by pine forest. At present nearly all the standing timber is north of Brainerd, comprising an area extending eastward from the headwaters of the Mississippi. The supply of lumber is rapidly diminishing, so that in a few years this enormous industry will no longer be first in rank. Table 19 shows the total number of feet of logs sawed in the second lumber district of Minnesota from 1891 to 1904. Though the figures include a small amount sawed at Red Wing and at Hastings on the lower river, they practically represent the sawmill industry of the region under consideration.

TABLE 19.—*Lumber sawed in second district of Minnesota, 1891–1904.*[a]

Year.	Feet B. M.	Year.	Feet B. M.
1891	425,765,260	1898	533,179,510
1892	505,407,898	1899	678,364,430
1893	428,172,360	1900	604,328,390
1894	459,862,756	1901	690,147,940
1895	539,012,678	1902	576,555,305
1896	385,312,226	1903	590,965,050
1897	527,367,710	1904	557,717,210

The total cut in the same region during the winter of 1903–4 was 674,981,820 feet B. M.; during the winter of 1904–5 it was 536,701,660 feet B. M. The amounts sawed at certain points during the calendar years 1903 and 1904 are shown on the page following.

TABLE 20.—*Lumber sawed in second district of Minnesota, 1903–4.*[a]

Place.	Feet B. M. 1903.	Feet B. M. 1904.	Number of employees in 1904.[b]
Akely	52,000,000	52,000,000	393
Bemidji	34,500,000	30,540,000	430
Brainerd	29,000,000	29,000,000	467
Cass Lake	15,500,000	20,000,000	136
Cohasset	1,200,000	1,200,000	....
Hastings[c]	6,000,000	4,000,000	75
Little Falls	57,366,620	60,284,440	361
Milaca	29,627,500	31,000,000	291
Minneapolis	328,434,590	293,574,590	2,887
Park Rapids	12,100,000	13,500,000	101
Red Wing[c]	6,500,000	7,500,000	100
Sauk Rapids	7,486,340	8,296,480	62
Ten Strike	....	533,000	....
Turtle River	3,250,000	2,288,700	....
Mills not included in above	8,000,000	4,000,000	....
	590,965,050	557,717,210	....

[a] Letter from surveyor-general of logs and lumber, second district of Minnesota.
[b] Ann. Rept. Comm. of Labor of Minnesota, 1903–4.
[c] On Mississippi River below St. Paul.

The preceding statistics show the magnitude of the lumber industry in this region. As noted on page 34, the three probable sources of pollution of streams by this industry are the logs, the sawdust or other waste, and the employees. Although the mills are provided with huge stacks in which great quantities of the waste are burned for steaming, much sawdust and bark reach the streams, especially during floods. This material deposits at certain places so as to obstruct the flow of the river; later it decays and gives the water a vegetable or a moldy odor.

The logs are kept in the water from the time they are first floated until they are sawed. It is probable that extract from the logs during this long-continued soaking forms an appreciable part of the vegetable matter in the water. It is worthy of note that the most highly colored surface waters are found in those areas in which lumbering is most extensively practiced.

The men who handle the logs, the "lumber jacks," practically inhabit the streams and are constantly in them. They commonly micturate and defecate in the streams or in places near them, whence their bodily excretions are directly transferred to the water. At Minneapolis, where several hundred men are employed in this manner, just above the principal water intake, efforts have been made by the city health commission to reduce this dangerous pollution by establishing closets on the banks of the river.[a]

[a] Rinker, Cappelen, Hazen, Report of commission appointed by the city council of the city of Minneapolis to investigate and report the best method of filtration of water from the Mississippi River, 1904, p. 5.

ment of pathogenic organisms. In most cases the effluents contain valuable ingredients for which research has found or will find some economical method of recovery.

MUNICIPAL POLLUTION.

PROBABILITY OF POLLUTION.

In the discussion of probable pollution from centers of population it should be remarked that there is always drainage of some sort from every collection of people, whether it consists of one family or ten thousand, and whether it is connected with an adjacent stream by sewers or by surface washing. The dejecta of one infected household has caused typhoid epidemics as disastrous as those originating from a sewered city, though the probability of infection is less. Therefore the surface water from an inhabited area is always liable to infection. The prospect of pollution is uncertain and depends upon many factors other than the population per square mile. Climate, geology, the chemical quality of the water, rate of stream flow, dilution, the virility of the organisms, as well as their food supply, and many other conditions influence the distance which the pathogenic bacteria may be borne by water. Recent investigators with cultures of *B. typhosus* in permeable sacs found the organism able to retain its vitality from six to ten days in the water of Lake Mendota, Wis., four to eight days in Lake Michigan water, three to five days in raw sewage, and one to three days in Chicago River. Other bacteriologists have found longer periods of survival.[a] In view of the fact, therefore, that the life period of *B. typhosus* in water is variable and at present not determinable with any degree of safety, it is well to assume that no surface water coming from an inhabited area should be used as a municipal supply without artificial purification. Cities that use raw stream water as a public supply are always in danger of typhoid epidemics and generally have higher typhoid rates than those that procure their domestic supplies in some other manner.

POPULATION.

Application of the general principle stated above to upper Mississippi River demonstrates that its waters are not suitable for municipal use without filtration. Table 22 shows the distribution of population by counties in the drainage area for the years 1890, 1900, and 1905. Table 23 shows the density of population in the region. The method used in dividing the total population of a county between two or more

[a] See Eng. Record, Dec. 24, 1904; Sept. 23, 1905; Jour. Infectious Diseases, vol. 1, No. 4; Testimony, State of Missouri *v.* Sanitary District of Chicago, p. 2600 et seq.

drainage areas was as follows: The population of villages and cities exceeding 1,000 was subtracted from the total population of the county, and the remainder was divided according to the areas of the county sections in each drainage basin; the population of each settlement was then added to that of the basin in which the settlement is located.

TABLE 22.—*Population in upper Mississippi River basin.*

County.	U. S. census of 1890.	U. S. census of 1900.	State census of 1905.
Aitkin	2,262	6,355	8,851
Anoka	9,884	10,939	11,673
Becker	2,630	3,772	5,063
Beltrami	212	5,132	[a] 7,304
Benton	6,284	9,912	11,256
Carlton	548	1,389	1,609
Cass	1,247	7,777	11,012
Carver	4,774	5,126	5,209
Clearwater	....	....	[a] 1,409
Crow Wing	8,852	14,250	16,731
Douglas	8,598	10,730	11,398
Hennepin	183,566	226,428	290,719
Hubbard	1,412	6,578	9,008
Isanti	7,372	11,303	12,489
Itasca	543	2,934	6,749
Kandiyohi	6,086	7,502	7,787
McLeod	14,594	16,795	16,556
Meeker	15,456	17,753	17,953
Millelacs	2,645	7,766	9,476
Morrison	13,325	22,891	24,584
Ottertail	9,693	12,358	13,025
Pope	1,881	2,289	2,329
Ramsey	3,320	3,745	4,654
Renville	4,106	5,412	5,696
Sherburne	5,908	7,281	7,961
Stearns	34,844	44,464	47,120
Todd	12,930	22,214	24,638
Wadena	4,053	7,921	9,317
Wright	24,163	29,157	29,467
Chippewa Reservation	(b)	(b)	1,920
	391,188	530,173	632,963

[a] Clearwater County organized from part of Beltrami County since 1900.
[b] Included under county populations in U. S. censuses.

TABLE 23.—*Density of population in upper Mississippi River basin.*

	Drainage area.	Inhabitants per square mile.		
		1890.	1900.	1905.
	Square miles.			
Above Grand Rapids:				
Entire area	[a] 3,665	0.6	3.9	6.3
Excluding chief settlements		.6	3.0	4.7
Above St. Cloud:				
Entire area	[a] 13,872	7.6	12.5	14.7
Excluding chief settlements		6.4	10.1	11.8
Above Minneapolis:				
Entire area	[b] 19,585	11.2	16.6	18.2
Excluding chief settlements		9.3	14.0	15.0
Above Minnesota River:				
Entire area	[c] 19,731	19.8	26.9	32.1
Excluding chief settlements		9.4	14.2	15.4

[a] Ann. Rept. Chief of Engineers, U. S. Army, 1875, pt. 2, p. 437.
[b] U. S. Water Power Census, vol. 2, 1880, p. 138.
[c] Ann. Rept. Chief of Engineers, U. S. Army, 1894, pt. 3, p. 1704.

The present density of population for the entire area is considerably higher than that for the State (25 per square mile). Excluding Minneapolis, the population of which is over one-third of the total, the density is about 20 persons per square mile. This is not high as compared with some parts of the United States. Since, however, nearly 50 per cent of the inhabitants are concentrated in cities and villages that stand on the banks of the principal streams and are sewered directly into them, there is abundant opportunity for water pollution. It should be noted that the population is rapidly increasing, so that the pollution is likely to be much greater.

CONDITIONS ON THE MISSISSIPPI.

General conditions.—Pl. II shows the hydrography of the region and the location of all settlements exceeding 1,000 population according to the census of 1900. Those which have established sewerage systems are indicated by a vertical bar within the population circle. The most noticeable features are as follows: (1) All the settlements except one are in direct stream connection with Mississippi River, since they are situated on the banks of either the main stream or one of its tributaries; (2) the majority of urban centers are in the southern half of the area; (3) the four larger cities, aggregating 285,385 inhabitants, or 45 per cent of the total population in the basin, are on the main stream and are connected directly with it by sewerage systems discharging sewage without purification.

Conditions at Grand Rapids.—The portion of the basin above Grand Rapids is one of the least populated areas in the State, and it may still be called an undeveloped region. Bemidji, on Lake Bemidji; Walker, on Leech Lake; and Cass Lake, on Cass Lake, are all small villages. Much of this area is included in Indian reservations and comprises considerable timber and swamp land. Three of the largest lakes in the State are situated in this section.

Conditions at St. Cloud.—The portion of the basin above St. Cloud, which includes about 70 per cent of the upper Mississippi basin, is principally deforested land now cultivated. The chief sources of river pollution above St. Cloud are given in Table 24.

TABLE 24.—*Principal settlements above St. Cloud.*

Name.	Stream.	Distance above St. Cloud. [a]	Population.		
			1890.	1900.	1905.
Aitkin	Mississippi River	130	737	1,719	1,896
Alexandria	Lake Agnes	160	2,118	2,681	3,051
Bemidji	Lake Bemidji	400		2,183	3,800
Brainerd	Mississippi River	75	5,703	7,524	8,133
Grand Rapids	Mississippi River	260		1,428	2,055
Little Falls	Mississippi River	38	2,354	5,774	5,856
Long Prairie	Long Prairie River	120	1,206	1,385	1,256
Melrose	Sauk River	50	780	1,768	2,151
Park Rapids	Fishhook River	140		1,313	1,719
Sauk Center	Sauk River	70	1,695	2,220	2,463
Sauk Rapids	Mississippi River	2	1,185	1,391	1,552
Staples	Crow Wing River	94	842	1,504	2,163
Wadena	Union Creek	110	895	1,520	1,868
Total urban population			17,515	32,410	37,963

[a] St. Cloud is 76 miles above Minneapolis.

Conditions at Minneapolis.—The pollution above Minneapolis has been discussed by the Minneapolis water commission, which recommended that Mississippi River at this point should be purified by slow sand filtration.[a] The length of time for the passage of water from Grand Rapids to St. Paul at low-water stage has been calculated by the U. S. Engineering Corps as eight days. From the slope of the river (fig. 1) and the fact that the typhoid bacillus has lived for three to ten days in water similar to that of Mississippi River, it may be considered probable that Minneapolis is not exempt from infection by several cities on its watershed. In addition to the urban pollution there are farmhouses and other isolated dwellings scattered along the river, infection from which might reach the city. The principal settlements on the stream, with the distance above Minneapolis, and their population, are given in the following table. Comparison of the populations for successive censuses shows that nearly all of these places are growing rapidly.

TABLE 25.—*Principal settlements above Minneapolis.*

Name.	Stream.	Distance above Minneapolis.	Population.		
			1890.	1900.	1905.
		Miles.			
Settlements above St. Cloud (See Table 24, above.)			17,515	32,410	37,963
Anoka	Rum River	17	4,252	3,769	4,053
Buffalo	Buffalo Lake	60	606	1,040	1,124
Glencoe	Buffalo Creek	85	1,649	1,780	1,805
Hutchinson	South Fork Crow River [b]	100	1,414	2,495	2,489
Litchfield	Jewett Creek	105	1,899	2,280	2,415
Milaca	Rum River	95	404	1,204	1,319
Princeton	Rum River	80	816	1,319	1,704
St. Cloud	Mississippi River	76	7,686	8,663	9,422
White Bear Lake	White Bear Lake	40	1,356	1,288	1,724
Total urban population			37,597	56,248	64,018

[a] Rinker, Cappelen, and Hazen, op. cit. [b] Locally known as Hassan River.

TYPHOID FEVER.

The relations between the principal settlements and the streams, as shown in Pl. II, counterbalance to some extent the comparatively low population per square mile and explain the prevalence of typhoid fever. Aitkin takes its domestic supply from Mud River. Brainerd, below Aitkin, uses Mississippi River water, as do also Little Falls, St. Cloud, and Minneapolis, all without filtration. Each in turn discharges sewage directly into Mississippi River without purification. In this manner each is exposed to infection from its neighbors above and subjects its neighbors below to additional danger. Epidemics of typhoid fever have visited nearly every community in the area, and the disease is always prevalent. Records at Minneapolis are as follows:

TABLE 26.—*Typhoid fever at Minneapolis.* [a]

Year.	Typhoid cases.	Typhoid deaths.	Typhoid death rate per 100,000.[b]	Ratio of deaths to cases (percent).
1891	583	93	54.7	16
1892	462	76	44.7	16
1893	1,080	134	74.4	12
1894	847	101	56.2	12
1895	740	88	48.8	12
1896	435	60	31.6	13
1897	1,534	148	77.9	9
1898	689	86	43	12
1899	537	71	35.5	13
1900	376	79	39.5	21
1901	630	121	57.6	19
1902	320	66	28.7	21
1903	720	95	39.5	13
1904	738	103	41.2	14
Averages			48.1	14

[a] Hall. Dr. P. M., Ann. Rept. Dept. of Health, Minneapolis, 1904, p. 19.
[b] Population computed from the average annual increase shown by the censuses of 1890, 1900, and 1905.

The relationship of water supply and typhoid fever at Minneapolis has been extensively investigated, and reports of the findings have been published.[a] The severest epidemic in late years occurred in 1897, when 1,534 cases were reported, a record closely approached in 1893, when there were 1,080 cases. In the first three months of 1904 there were over 450 cases, with 61 deaths. A study of the progress of the disease for several years has shown that the severest epidemics occur after the introduction of water from the two lower pumping stations,[b] while the least typhoid is reported when the supply is drawn exclusively from stations at the northern limits of

[a] Rinker, Cappelen, Hazen, Rept. of Minneapolis Water Commission, 1904; Hall, Dr. P. M., Ann. Repts. Dept. of Health of Minneapolis; Corbett, Dr. J. F., Typhoid and water supply: Ann. Rept. Minneapolis Dept. of Health, 1904, p. 27; Smith, E. G., The Mississippi River as the Source of Water Supply for the Inhabitants of the Mississippi Valley: Jour. New Eng. Waterworks Assoc., 1905, vol. 19, p. 215; Bass, F. H., An epidemic of typhoid fever in East Minneapolis: Eng. News, March 3, 1904, vol. 51, p. 208.
[b] See p. 63 for location of intakes.

the city. Continued bacteriological examinations of the water for more than 100 miles above the city have demonstrated the pollution of the river water.

At St. Cloud well-marked epidemics have occurred and the disease has seldom been absent. In twenty-one months from November 1, 1900 to August 1, 1902, 154 cases were reported, with 12 deaths. In 1901 a general spread of the disease over the city was attributed to infection of the water supply by seepage from the sewer of a hosiptal at which typhoid patients were being treated. The supply, which is taken from Mississippi River without filtration, has been repeatedly condemned by the State board of health.

The records of deaths from typhoid fever indicate that the disease is not confined to the cities, but is prevalent as well in the rural districts.

QUALITY OF WATER.

Samples of water were taken at points in the basin[a] above and below the principal settlements, and examined for the purpose of ascertaining the general characteristics of the stream water and the changes that might occur in it from place to place. Since it was not possible, on account of the expense, to make weekly or even monthly examinations of water from all stations, the samples were collected in series under conditions as nearly similar as practicable. Series I of Table 27 was taken during the late fall and early winter of 1903; Series II was collected during the early part of 1904, at a time when the waters had been icebound for more than two months; Series III, taken during May and June, 1904, represents the water during the decline following the spring floods. During the period intervening between the first and the last samples the river fluctuated comparatively little; gage readings at the Survey station above Sauk Rapids show a total fall of 1.65 feet between May 18 and June 18. Between September 2 and November 4, when Series IV was taken, there was some change in the stream discharge. Heavy rains in October caused a gradual rise of the river, which reached its maximum about the middle of the month and then declined, so that the samples taken at Anoka probably represent a greater dilution than those taken at St. Cloud. Series V was collected during the latter part of the winter in 1905. The river was frozen during this period and there was little change in the discharge.

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[a] See Pl. I for location of sampling stations.

TABLE 27.—*Quality of water in Mississippi River basin above Minnesota River.*

[Parts per million.]

SERIES I. FALL AND WINTER OF 1903.

Source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c. c.[a]	B. coli communis.[a]
Mississippi River:																		
Entrance into Lake Bemidji [b]	Dec. 15	13	0	<7	0.2	0	182	189				0.21	0.065	0.000	0.00		120	–
At Cass Lake [b]	Dec. 14	4	0	<7	.2	0	153	158				.24	.125	.000	Trace.		450	–
Above Grand Rapids [c]	Dec. 12	22		<7		0	142	140										
Above Brainerd [d]	Oct. 26				1.0			83				.28	.04	.000	Trace.		75	+
Waterworks, Brainerd [d]	do				1.0			84				.24	.06	.000	Distinct.		31	+
Above large sewer, Brainerd [d]	do				1.0			80				.30	.04	.000	Trace.		95	+
Below large sewer, Brainerd [d]	do				1.6			80				.32	.04	Trace.	Distinct.		2,200	+
Above Sauk Rapids [d]	do				1.2			116				.26	.04	.000	Trace.		70	+
Waterworks, St. Cloud [d]	do				1.0			122				.24	.03	.000	Distinct.		170	+
Below St. Cloud [d]	do				1.6			116				.09	.01	.000	Distinct.		375	+
Tributaries:																		
Hale Lake at Grand Rapids [c]	Dec. 12	40	3 e.	8		0	100	103										

SERIES II. WINTER OF 1904.

Source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c. c.[a]	B. coli communis.[a]
Mississippi River:																		
Above Schoolcraft River [b]	Jan. 28	25	4 v.	<7	0.3	0	268	178				0.16	0.191	0.000	Trace.		425	–
Entrance into Lake Bemidji [b]	do	4	0	<7	.3	0	205	130				.21	.141	Trace.	0.00		60	–
Below Lake Bemidji [b]	do	25	2 v.+2 m.	<7	.3	0	232	171				.23	.071	Trace.	Trace.		250	–
Below Cass Lake [b]	Jan. 29	18	0	<7	.3	0	162	110				.80	.275	.000	Trace.		47	–
Above Grand Rapids [b]	Jan. 30	40	2 e.	<7	.3	0	164	158				.95	.55	Trace.	Trace.			–
Above Mud River [b]	Feb. 8	74	2 v.	<7		0	139	99									140	–
Below Mud River [b]	do	81	2 v.	10	.2	0	143	166				.30	.12	.000	Trace.		300	–
Above Brainerd [b]	Feb. 10	60		10	.3	0	131	154				.31	.17	Trace.	Distinct.		110	+
Waterworks, Brainerd [b]	do	56		16	.3	0	131	166				.30	.13	Trace.	Distinct.		160	+
Below Brainerd [b]	do	60		15	.3	0	131	163				.32	.16	Trace.	Distinct.		1,700	+
Above Sauk Rapids [d]	Jan. 5				.5			212				.14	.22	.000	Distinct.			+
Waterworks, St. Cloud [d]	do				.5			229				.24	.28	.000	Distinct.		225	+
Below St. Cloud [d]	do				.8			229				.25	.28	.000	Distinct.			+
Tributaries:																		
Mud River above Aitkin [b]	Feb. 8	65	2 v.	<7	.2	0	87	89				.52	.23	Trace.	Distinct.		350	–
Mud River 200 feet above intake [d]	do				.2			89				.43	.15	.000	Distinct.		500	–
Mud River at intake [d]	do				.2			89				.45	.15	Trace.	Distinct.		300	+
Hale Lake at Grand Rapids [b]	Jan. 30	4	2 e.	0	.2	0	148	130				.975	.30	Trace.	Trace.		39	+

Mississippi River:																		
Above Schoolcraft River [b]	May 18	60	3 v.	<7	0.3	0	143	141	0			0.23	0.05	0.000	Trace.			
Above Lake Bemidji [b]	do	56	3 v.	<7	.3	.0	140	134	0			.30	.08	.000	Trace.			
Below Lake Bemidji [b]	do	25	2 v.	<7	.3	0	161	127	0			.18	.01	.000	Trace.			
Above Grand Rapids [b]	May 17	60	2 v.	10	.3	0	100	99	0			.26	.05	.000	0.00		650	–
Above Mud River [b]	May 22	116	3 v.+2 e.	20	.4	Trace.	64	74	0			.30	.07	.000	Trace.			+
Below Mud River [b]	do				.4			83				.35	.13	.000	Trace.		1,100	+
Above Brainerd [b]	May 21	121	2 M.	<7	.4	0	67	85	0			.44	.20	.000	Trace.		300	+
Waterworks, Brainerd [b]	do	121	2 M.	<7	.4	0	64	85	0			.29	.05	.000	Trace.		1,000	+
Below Brainerd [b]	do	121	2 M.	<7	.4	0	64	85	0			.41	.19	.000	Trace.		2,000	+
Above Sauk Rapids [d]	June 17				.2			110				.20	.05	.000	Trace.		1,300	+
Above St. Cloud [d]	do				1.5							.13	.07	.000	Marked.			
Waterworks, St. Cloud [d]	do				2.0							.22	.07	.000	Marked.		500	+
Above Rum River [e]	June 18	76			2.5					128		.212	.02	.000	.00		700	+
Below Rum River [e]	do	76			2.0					129		.222	.21	.000	.00		750	+
Below Minneapolis [d]	June 6				.2			130				.23	.10	.000	.00			
Tributaries:																		
Mud River above Aitkin [b]	May 22	74	3 v.+2 M	10	.4	0	64	70	0			.30	.10	Trace.	Trace.		2,800	+
Mud River 200 feet above intake, Aitkin [b]	do				.4							.42	.08	Trace.	Trace.		3,800	+
Mud River at intake, Aitkin [b]	do	74	3v.+2 M.	10	.4	0	66	87	0			.31	.23	Trace.	Trace.		1,400	+
Rum River above asylum, Anoka [e]	June 18	78			2.					153		.313	.046	.000	.03		650	+
Rum River below Anoka [e]	do	'8			2.4					146		.332	.029	.000	.03		900	–
Hale Lake at Grand Rapids [b]	June 17	10	2 v.	<7	.4	0	120	113	0			.11	.01	.000	Trace.		130	–

[a] Bacteriological examinations by Dr. E. H. Beckman.
[b] Determinations of chlorine and nitrogen by H. C. Carel, other chemical determinations by R. B. Dole.
[c] Chemical analyses by R. B. Dole.
[d] Chemical analyses by H. C. Carel.
[e] Chemical analyses by G. B. Frankforter.

TABLE 27.—*Quality of water in Mississippi River basin above Minnesota River*—Continued.

[Parts per million.]

SERIES IV. FALL OF 1904.[a]

Source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c.c.[b]	B. coli communis.
Mississippi River:																		
Above Schoolcraft River	Nov. 2	40	0	<7	0.6	Trace.	226	208	Trace.	251	16	0.160	0.012	0.000	0.03	7	1,100	−
Below Lake Bemidji	...do...	18	0	<7	1.4	0	180	160	Trace.	198	19	.234	.030	.000	.03	1.1	300	−
Above Grand Rapids	Oct. 31	56	2 v.	<7	.9	0	141	132	Trace.	178	21	.282	.034	.000	.04	8	450	−
Above Mud River	Nov. 4	160	2 v.	17	1.2	0	97	96	Trace.	153	7	.368	.046	.000	.02	4	......	+
Above Brainerd	Nov. 3	112	2 v.	13	1.1	0	96	104	1.5	147	17	.360	.030	.000	.02	6	275	+
Waterworks, Brainerd	...do...	112	2 v.	14	1.0	0	100	104	1.5	150	19	.382	.022	.000	.03	5	650	−
Below Brainerd	...do...	112	2 v.	15	1.0	0	100	104	1.5	142	14	.382	.040	.000	.03	6	850	+
Above Sauk Rapids	Sept. 4	56	0	15	.3	Trace.	137	132	Trace.	186	19	.270	.026	.000	.10	8	1,200	+
Waterworks, St. Cloud	...do...	60	2 v.+1 m.	20	.4	Trace.	156	159	Trace.	202	18	.318	.036	.000	.10	12	1,000	+
Below St. Cloud	...do...	......	......	......	......	......	......	......	......	......	......	.300	.036	......	......	......	1,100	+
Above Rum River	Oct. 20	56	2 v.+1 m.	55	.7	Trace.	130	132	Trace.	194	16	.418	.058	.000	.04	......	2,600	....
Below Rum River	...do...	56	2 v.+1 m.	55	.8	Trace.	116	121	Trace.	192	25	.422	.052	.000	.04	......	1,200	+
Tributaries:																		
Millelacs at Wealthwood	Nov. 4	18	0	<7	.2	Trace.	77	77	Trace.	112	7	.384	.012	.000	Trace.	6	95	−
Rum River at Anoka, above asylum	Oct. 20	88	2 v.	13	.9	0	76	76	0	138	13	.422	.054	.000	.00	......	2,800	+
Rum River at Anoka waterworks	...do...	88	2 v.	13	1.1	0	74	77	0	136	15	.460	.054	.000	.00	......	1,800	+
Rum River below Anoka	...do...	88	2 v.	20	1.0	0	73	77	0	125	10	.418	.060	.000	.00	......	3,400	+
Lake Latoka, Alexandria	Sept. 2	4	0	<7	.5	Trace.	156	149	0	186	19	.280	.066	.000	.00	0	300	−
Lake Carlos, Alexandria	...do...	4	1 v.	<7	1.0	Trace.	170	204	0	198	22	.280	.014	.000	.00	0	70	−
Lake Osakis, Osakis	Sept. 3	18	2 v.	11	1.0	0	148	166	0	187	22	.368	.058	.000	.00	0	130	−
Sauk River above Sauk Center	...do...	25	3 v.	10	.3	5 est.	180	173	Trace.	205	23	.428	.112	.002	.02	8	700	−
Sauk River below Sauk Center	...do...	25	2 v +1 m.	10	.3	5 est.	181	173	Trace.	221	23	.462	.136	.003	.02	12	4,600	+
Sauk River above Melrose	...do...	......	......	......	.4	5 est.	199	......	......	......	......	......	......	......	......	......	900	+
Sauk River below Melrose	...do...	25	2 v.	<7	1.0	5 est.	201	215	0	234	18	.320	.076	.000	.02	10	1,700	+
Sauk River at mouth	Sept. 4	40	0	10	.4	Trace.	187	188	Trace.	235	23	.306	.048	.001	.09	14	1,500	+
Hale Lake at Grand Rapids	Oct. 31	18	2 m.	<7	.9	5 est.	147	132	Trace.	195	14	.148	.080	.000	.00	7	65	−
Leech Lake at Walker	Nov. 3	0	0	<7	1.2	5 est.	166	174	0	190	15	.090	.038	.000	.02	4	130	−

SERIES V. WINTER OF 1905.

Mississippi River:																	
Above Schoolcraft River [a]	Feb. 27	18	2 m.	<7	1.5	0	280	......	1.0	301	18	0.100	0.370	Trace.	0.03	28	450	–
Below Lake Bemidji [a]	...do....	18	2 v.	......	1.7	0	214	......	0	240	14	.190	.034	.000	.01	10	325	–
Below Lake Winnibigoshish [a]	Feb. 26	18	0	<7	.9	0	186	172	0	209	16	.300	.054	.000	.05	10	120	–
Above Grand Rapids [a]	Feb. 25	18	0	<7	1.2	0	181	160	Trace.	217	13	.308	.066	.001	.06	9	200	–
Below Grand Rapids [a]	...do....	18	0	<7	1.2	0	181	146	Trace.	211	13	.302	.064	.001	.06	10	200	+
Above Mud River [a]	Mar. 1	40	1 v.	7	1.4	0	170	154	0.5	198	9	.234	.066	.002	.04	13	1,600	+
Above Brainerd [a]	Feb. 28	40	1 v.	10	1.0	0	160	142	.5	182	12	.230	.073	.002	.04	11	4,200	+
Waterworks, Brainerd [a]	...do....	40	1 v.	10	1.4	0	161	142	.5	185	14	.256	.051	.002	.04	11	475	–
Below Brainerd [a]	...do....	40	1 v.+1m.	10	1.8	0	162	142	.5	188	17	.300	.068	Trace.	.04	11	12,500	+
Above Rum River [a]	Mar. 14	22	2 v.	10	1.8	5 est.	163	169	.5	201	16	.220	.050	.000	.14	9	425	–
Below Rum River [a]	...do....	22	2 v.	10	2.6	5 est.	194	179	.5	234	12	.206	.205	.000	.14	11	1,000	–
Above Minneapolis [c]	Mar. 16	20	....	......	1.8	....	160	[d] 18	....	220	[e] 86	.312	.109	Trace.	Trace.	......	100	+
Tributaries: [a]																	
Mud River at waterworks, Aitkin	Mar. 1	60	1 v.	10	1.8	0	108	97	Trace.	154	21	.412	.080	Trace.	.05	11	1,800	–
Rum River above asylum at Anoka	Mar. 14	25	3 v.	<7	2.4	Trace.	145	114	Trace.	176	14	.252	.160	.000	.16	8	1,200	–
Rum River at Anoka waterworks	...do....	25	3 v.	<7	2.7	Trace.	146	120	Trace.	189	23	.250	.170	.000	.16	9	2,800	–
Rum River below Anoka	...do....	25	3 v.	<7	2.5	Trace.	146	112	Trace.	173	18	.246	.160	.000	.19	9	6,500	–
Sewage effluent at Anoka asylum	...do....	40	5 fe.	15	3.6	15 est.	196	250	1.0	393	85	.552	13.42	.010	.56	9	340,000	+
Leech Lake at Walker	Feb. 28	4	0	<7	1.5	Trace.	180	172	0	206	16	.220	.027	.000	.03	7	120	–

[a] Chemical analyses by R. B. Dole.
[b] Bacteriological examinations by Dr. E. H. Beckman.
[c] Chemical analysis by A. D. Meeds; bacteriological examination by Dr. J. F. Corbett.
[d] Temporary.
[e] Volatile.

The high nitrogen content, the vegetable odor, the color, and the fact that the albuminoid ammonia was separated with difficulty indicate that the stream contains a large amount of vegetable matter. These sanitary examinations show the futility of attempting to demonstrate the pollution of a stream of this character by chemical analysis of samples taken above and below settlements on its banks. The considerable amount of vegetable matter that is probably present completely masks the much-diluted but still dangerous sewage contributed by the towns and prevents its detection. Besides this difficulty, the tests indicate only an increase or a decrease in the amount of organic matter, without showing whether it is dangerous or harmless. Therefore the nitrogen determinations do not show the hygienic value of the stream. They do, however, demonstrate the presence of much organic matter, mostly in the undecomposed or "albuminoid" form. Free ammonia is generally about 0.05 part per million, but varies within wide limits. A small amount of nitrates is usually found; nitrites are seldom present except in winter and then only in small quantity; the greater part of the organic matter is determined as albuminoid ammonia. The water has a vegetable odor, combined sometimes with a moldy smell. It has at all times a distinct brown color, which runs as high as 160 parts per million, though its usual range is from 20 to 80. It has been suggested that the color is due to some compound of iron; but this can hardly be the case, because the small amount of this element present could not account for the high tint observed. It is probably caused by swamp drainage and resins extracted from the logs floated in the stream. The highest color is found in waters coming from swamp districts or in streams on which extensive logging operations are conducted, and the lowest in the large lakes, where opportunity is afforded for oxidation and destruction of the dissolved organic matter. The drainage of swamp lands and the decline of the lumber industry will therefore be accompanied by a progressive decrease in the color of the streams in this basin.

In mineral content the stream presents distinct characteristics. Chlorine is low, seldom exceeding 2 parts per million. A small amount of combined sulphuric acid, varying from a trace to about 5 parts per million, is present. Calcium and magnesium occur in appreciable quantities, as is shown by the alkalinity and total hardness. They are probably present as bicarbonates, since the samples examined gave no alkaline reaction with phenolphthalein in the cold. The fact that only a small percentage of the residue is soluble in alcohol shows that the water contains but a small amount of alkaline salts, though its content of alkaline-earth compounds is comparatively high. These statements are corroborated by the mineral analyses given in Table 28.

TABLE 28.—*Mineral analyses of water from upper Mississippi River basin.*[a]

[Parts per million.]

Place.	Date.	Total solids.	Suspended solids.	Organic and volatile.	Total alkalinity (as $CaCO_3$).	Oxide of iron and alumina Fe_2O_3+ (Al_2O_3).	Iron (Fe).	Aluminum (Al).
Mississippi River:								
At Brainerd[b]	Aug. —, 1884	[c] 195					2.0	2.1
At Little Falls[d]	Mar. 31, 1903		12		151	3.4		
At St. Cloud[d]	do		21		152	4.4		
Above Minneapolis[e]	Dec. 20, 1881	[f] 212		24			.4	
Below Minneapolis[e]	do	[f] 211		34			1.3	
At Minneapolis[g]	Dec. 10, 1890	215				7.5		
At Minneapolis[g]	Mar. 29, 1900	188						
Rum River at Anoka[d]	Mar. 27, 1903		10		197	1.0		
Sauk River at Sauk Center[d]	Mar. 31, 1903		8		206	Trace.		
Platte River at Royalton[d]	do		49		198	3.4		
Millelacs[e]	1881	186		42			1.7	
Lake Minnetonka[h]	May 2, 1883	[i] 110					Trace.	

Place.	Date.	Silica (SiO_2).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Chlorine (Cl).	Sulphate radicle (SO_4).	Carbonate radicle (CO_3).
Mississippi River:									
At Brainerd[b]	Aug. —, 1884	18	44	20	10	3.4	0.9	2.0	90
At Little Falls[d]	Mar. 31, 1903	4.3	43	13	8		12	9	90
At St. Cloud[d]	do	5.8	45	14	16		24	9	96
Above Minneapolis[e]	Dec. 20, 1881	13	44	15	3.3	1.4	1.6	3.2	105
Below Minneapolis[e]	do	17	42	12	2.3	1.3	1.9	3.5	94
At Minneapolis[g]	Dec. 10, 1890		50	18	6.7		4.8	3.1	124
At Minneapolis[g]	Mar. 29, 1900		40	13					98
Rum River at Anoka[d]	Mar. 27, 1903	18	50	17	7.3		12	.8	118
Sauk River at Sauk Center[d]	Mar 31, 1903	5	47	25	3.9		6	13	124
Platte River at Royalton[d]	do	9	58	14	9		6	17	118
Millelacs[e]	1881	4.3	22	16	9.6	3.2	.8	1.2	85
Lake Minnetonka[h]	May 2, 1883	4.8	28	8	1.1	2.6	.8	Trace.	64

[a] Expressed by analysts in hypothetical combinations; recomputed to ionic form at U. S. Geological Survey.
[b] Analysis by C. F. Sidener.
[c] Traces of NO_3 and PO_4.
[d] Analyses by Kennicott Water Softener Company.
[e] Analyses by J. A. Dodge.
[f] Trace of NO_3.
[g] Analyses by Chicago, Milwaukee and St. Paul Railway Company.
[h] Analysis by W. A. Noyes.
[i] Traces of lithium, phosphates, borates, and nitrates.

This portion of Mississippi River is distinctly different from the lower part, especially in its percentage of suspended matter and alkaline salts. Its use in boilers causes no serious difficulties, and it may be classed as good for steaming purposes. The calcium and magnesium compounds can be removed by using small amounts of soda ash. The water is harder than that of St. Louis River or that of St. Croix River and softer than the waters of Minnesota and Red rivers. The two latter streams also contain a higher percentage of alkaline salts than the upper Mississippi.

The bacterial content is of course extremely variable, and no average can be calculated logically from the data at hand. The amounts recorded probably indicate more nearly the actual condition of the stream than such figures usually do, because the samples were plated immediately after collection instead of after shipment to the laboratory. The water from the upper section of the system contained from 100 to 500 bacteria per cubic centimeter, while some samples from the lower river contained as high as 3,000 to 6,000 per cubic centimeter. Though this rise in the number of bacteria shows that the water is open to suspicion as a source of domestic supply, the most positive index of pollution is the fact that from almost every sample examined between Grand Rapids and Minneapolis *B. coli communis* was isolated in pure culture with 1 cubic centimeter of water. The constant presence of this intestinal organism proves that the stream is unfit for domestic consumption in its natural state. In February, 1902, a culture of *B. coli communis* that was virulent for guinea pigs in small doses in twelve hours was isolated from the St. Cloud water supply, which is raw Mississippi River water. The importance of this fact is increased when it is stated that the total number of colonies was 50 per cubic centimeter, over 90 per cent being *B. coli communis*. A series of samples taken by the Minneapolis department of health from Brainerd to Minneapolis show that large numbers of this bacillus are constantly present in the river.[a] It is especially worthy of note that the organism was frequently found in other streams of the basin while it was not isolated from samples of water taken from the large lakes.

Mud and Rum rivers carry considerably less dissolved mineral matter than Mississippi River, as is shown by their alkalinity, hardness, and total solids. Millelacs is similar to Rum River át Anoka in its mineral constituents. On the other hand, Leech, Winnibigoshish, Cass, Bemidji, Carlos, Osakis, Latoka, and Hale lakes, all lying within the limits of the Cretaceous rocks, have high mineral contents. The influence of the Cretaceous rocks may also be seen by consideration of the river analyses in series. The mineral constituents in the river above Bemidji are highest; from that point downstream the alkalinity, hardness, and total solids decrease in every series, a change that shows the effect of dilution by waters from the regions comprising Archean and Cambrian rocks. In the same journey the water increases perceptibly in turbidity and in content of organic matter.

A comparison of the analyses of the five series of samples (Table 27) shows the seasonal variation in the water. In winter the inorganic substances are all higher than at any other time of year, as may be expected, since practically all the stream flow is derived from underground water which has been in more or less intimate contact with the mineral constituents of the ground. In the main stream the alkalinity is between 130 and 280 parts per million in winter, as compared with 60 to 180 parts in the spring and fall. There is a corresponding difference in chlorine, hardness, and total residue. During the winter the color, turbidity, and nitrogenous matter decrease noticeably.

[a] Corbett, Dr. J. F., Typhoid and Water Supply: Ann. Rept. Minneapolis department of health, 1904, p. 27.

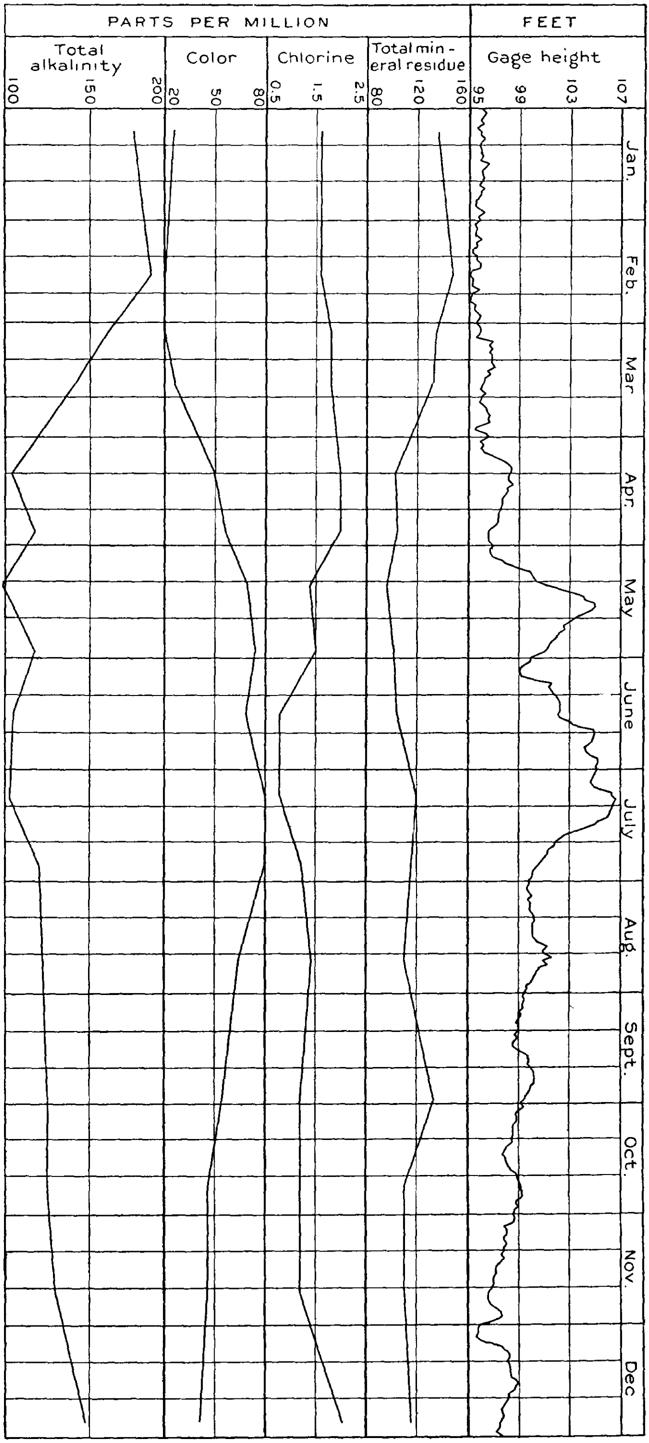


FIG. 2.—Diagram showing quality of Mississippi River water at Minneapolis, 1905, at different gage heights and seasons.

Though the number of bacteria per cubic centimeter suffers some diminution, *B. coli communis* is found as often in winter as in summer, a fact that indicates the constant presence of polluting matter. The presence of large numbers of these organisms in winter is not surprising when it is considered that the river is then practically a closed sewer from one settlement to the next, since its surface is covered with 10 to 40 inches of ice and the water is effectually protected from the purifying influences of sun and air.

TABLE 29.—*Quality of water of Mississippi River at Minneapolis, Minn., 1905.*[a]

[Parts per million.]

Date.	Total residue.	Volatile residue.	Fixed residue.	Sediment.	Color.	Chlorine.	Alkalinity.	Permanent hardness.	Oxygen consumed, 10 minutes boiling.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.
Jan. 6	231	95	136	Slight........	25	1.60	173	18	5.48	0.192	0.090	Trace.	Trace.
Feb. 15	241	95	146	.....do........	20	1.60	193	14	4.64	.169	.120	Trace.	Trace.
Mar. 3	220	86	134	.....do........	20	1.80	160	18	5.28	.312	.109	Trace.	Trace.
Mar 16	206	74	132	.....do........	25	1.80	150	19	5.52	.240	.088	Trace.	Trace.
Apr. 10	178	76	102	.....do........	50	2.00	105	18	9.80	.468	.072	Trace.	Trace.
Apr. 26	175	72	103	Heavy........	55	2.00	120	10	8.68	.298	.072	None.	Trace.
May 16	176	80	96	.....do........	70	1.40	98	16	11.00	.416	.160	Trace.	Trace.
May 29	188	86	102	.....do........	75	1.50	118	18	11.56	.420	.120	Trace.	Trace.
June 16	193	90	103	.....do........	70	.80	105	15	11.08	.480	.088	None.	Trace.
July 7	204	84	120	.....do........	80	.80	103	12	13.92	.640	.080	None.	Trace.
July 26	203	88	115	.....do........	80	1.20	120	10	14.36	.336	.080	None.	Trace.
Aug. 22	188	78	110	.....do........	65	1.40	123	6	12.08	.312	.060	None.	Trace.
Sept. 29	207	74	133	Moderate.....	55	1.20	128	14	9.92	.336	.072	None.	Trace.
Oct. 23	184	74	110	.....do........	45	1.20	128	16	7.56	.298	.080	Trace.	Trace.
Nov. 21	181	70	111	.....do........	45	1.20	133	19	6.88	.312	.038	Trace.	Trace.
Dec. 27	197	81	116	.....do........	40	2.00	150	14	7.60	.240	.072	Trace.	Trace.

[a] Analyses by A. D. Meeds, Minneapolis, Minn.

The seasonal fluctuation in the quality of the water is shown in more detail by Table 29, which gives the results of analyses of Mississippi River at Camden Park pumping station, Minneapolis, during 1905. By means of fig. 2 a comparison may be made of the color, chlorine, alkalinity, and "fixed" or mineral residue with the river level at various times of the year. Acknowledgment is made to the department of health of Minneapolis for the analytical results. The gage heights, giving the change in level of the mill pond above the dam at St. Anthony Falls, have been obtained through the courtesy of Mr. R. D. Thomas, of the Minneapolis Mill Company. Color follows the gage height closely. In winter, when the swamps and other sources of vegetable matter are icebound, the color is lowest. It increases with the spring floods and follows the decline of the water in autumn, finally returning to its winter normal when the streams close. Chlorine and alkalinity, on the other hand, vary inversely with the depth of water. They are highest in winter, when the ground flow constitutes the greater part of the run-off and decrease during the open season in proportion to the dilution caused by freshets. The relation of the total mineral solids to the discharge is not so simple, because that estimate includes both dissolved and suspended inorganic solids. Therefore the dilution of dissolved mineral matter during freshets is to some extent modified by an increase of turbidity.

The examinations noted in the preceding tables support the conclusions reached by sanitary inspection. It is evident that Mississippi River in its raw state is not a safe source of municipal supply. It is not, however, so grossly polluted as to be incapable of purification by well-operated filters. At the same time it is the most desirable source of supply for general use on account of its softness as compared with local well waters. In conclusion, the averages of 64 analyses of waters of upper Mississippi River are given in Table 30, which shows the maximum and minimum determinations made.

TABLE 30.—*Summary of quality of water of upper Mississippi River.*

[Parts per million.]

Determination.	Maximum.	Minimum.	Average.
Color	160	4	50
Odor			2 v
Turbidity	55	<7	<7
Chlorine	2.6	0.2	0.9
Sulphate radicle	[a] 5	0	Trace.
Alkalinity	280	64	151
Total hardness	229	83	136
Iron	1.5	Trace.	Trace.
Total residue	301	128	189
Soluble residue	25	7	16
Free ammonia	.370	.01	.191
Albuminoid ammonia	.95	.09	.475
Nitrates	.14	Trace.	.05
Nitrites	.002	Trace.	.000

[a] Estimated.

NOTES ON MUNICIPALITIES.

Thirty-four of the 42 settlements described below have public water supplies, 16 of which are derived from lakes or streams without purification. Twelve have sanitary sewerage systems. In all of them privies and cesspools are common and generally no particular restrictions are observed in their construction or care. Garbage is usually hauled outside the settlement limits and either burned or allowed to decay.

Aitkin, Aitkin County.—On left bank of Mississippi River at its confluence with Mud River. Water supply is taken from Mud River without filtration within the village limits. The stream is exposed to several sources of pollution and there was considerable typhoid fever in 1904. Ice supply is taken from Mud River above pumping station. Sewerage system, both storm and sanitary, enters Mississippi River. Private sewers also enter Mud River below the pumping station. Garbage is hauled away to the public dumping ground.

Akely, Hubbard County.—On Crow Wing River near its headwaters. Water for fire protection only is supplied by Red River Lumber Company. Water for domestic use is taken from shallow private wells. Ice is cut from Crow Wing Lake, 1 mile from town. There is no sewerage system, so that cesspools and privies are common. Garbage is hauled one-half mile from town and burned.

Alexandria, Douglas County.—Lakes Agnes and Winona border on the village and drain to Long Prairie River. Water supply is derived from a dug well in town, 30 feet deep by 20 feet diameter, sunk in gravel. The surroundings of the well are extremely unsanitary. Ice supply is taken from Lake Henry and Lake Latoka. A storm sewer enters Lake Agnes, as well as one or two private sewers, though there is no public sanitary sewerage. Garbage is hauled outside the city limits.

Anoka, Aitkin County.—On Mississippi River at the confluence with Rum River. Water supply is taken from Rum River without filtration; ice supply from the same source. A municipal sewerage system, both storm and sanitary, has recently been established; it discharges into Rum River just above its mouth. Garbage is hauled outside the city limits and burned. The First State Asylum for the Insane (300 inmates) is located less than 1 mile above the waterworks intake, on the west bank of the river. It has a private water supply from shallow wells and a private sewerage system with a septic tank and intermittent contact beds and sand filters discharging into Rum River above waterworks.

Bemidji, Beltrami County.—On west shore of Lake Bemidji, about 50 miles below Lake Itasca. Water supply is obtained from five 3½-inch points, driven 106 feet deep, on west side of the village at the edge of a swamp partially filled in with manure. Ice supply is taken from Lake Bemidji. Two private sewers, one from Markham Hotel and one from the hospital, enter Lake Bemidji in front of town. A public system has not yet been constructed, though a septic tank discharging into Mississippi River before its entrance into Lake Bemidji is contemplated. Garbage is hauled away and burned.

Brainerd, Crow Wing County.—On Mississippi River, 11 miles above the entrance of Crow Wing River. Water supply is derived from Mississippi River in front of the city, about 1 mile below a groundwood pulp mill. Two Jewell pressure filters are installed, but their capacity is not equal to the daily consumption and they are seldom used. The supply is subject to evident pollution from houses and industrial plants above it. Much of the drinking water consumed in town is obtained from a flowing well about 1 mile from town, the water being peddled in carts. Ice supply is obtained from Rice Lake, above city. Less than half the city is equipped with sanitary sewerage. On one of the main sewers purification has been attempted by means of a long wooden box with baffle boards at each end. No test has been made of its efficiency. The other sewers discharge raw sewage. Garbage is hauled to dumping ground outside the city limits.

Buffalo, Wright County.—On Buffalo Lake, which is connected with the north branch of Crow River. It has no waterworks or sewerage. Ice supply is obtained from Buffalo Lake. Garbage is hauled to the dumping ground and covered with dirt.

Cambridge, Isanti County.—On Rum River, 30 miles below Princeton. Water supply is derived from a well 140 feet deep by 8 inches diameter, which draws water from a sandstone struck at 115 feet. Ice supply is obtained from Lake Fanny. No sewerage. Garbage is hauled outside city limits.

Cass Lake, Cass County.—On west shore of Cass Lake, near foot of Pike Bay. Water supply is obtained from 4 wells driven 28 feet in sand to clay. They have unsanitary surroundings and show evidence of pollution. Ice supply is taken from Cass Lake. A sanitary sewerage system discharges into a creek entering Pike Bay.

Cokato, Wright County.—Drainage goes to a marsh that is ditched to Sucker Creek. No waterworks or sewerage. Ice supply obtained from Brooks Lake.

Deer River, Itasca County.—One mile north of Mississippi River on Deer River. Water supply obtained from a flowing well 96 feet deep, with a 3-inch casing, driven through sand, quicksand, and blue clay into water-bearing gravel. No sewerage.

Delano, Wright County.—On the south branch of Crow River. Water supply obtained from the river; used only for fire protection and for sprinkling, and not filtered. Ice supply cut from Lake Rebecca. Garbage burned. No sewerage.

Elk River, Sherburne County.—On Elk River at its junction with Mississippi River. No waterworks or sewerage. Drinking water is generally obtained from private artesian and driven wells; ice supply from both rivers. Garbage is burned or hauled out in the country.

Excelsior, Hennepin County.—On Lake Minnetonka. Chiefly a summer resort and has but small constant population. No waterworks or sewerage. About 5,000 tons of ice are harvested on the lake for local use and for shipment to Minneapolis. There is no public garbage disposal.

Fort Snelling, Hennepin County.—A military reservation with accommodations for about 1,500 men on west bank of Mississippi River at its confluence with Minnesota River. Water for general use is obtained from a 10-inch artesian well 636 feet deep drawing its supply from the sandstone. Separate storm and sanitary sewerage systems discharge into both rivers. The ice supply is cut on Minnesota River just above the post.

Glencoe, McLeod County.—On Buffalo Creek. Water supply obtained from one 8-inch well drilled 1,728 feet deep, drawing its supply from sand rock. Ice supply is taken from an artificial basin fed by artesian wells and connected with the creek most of the year. No sewerage. No regular garbage disposal.

Grand Rapids, Itasca County.—On Mississippi River just below Pokegama Falls. Water supply is taken without filtration from Hale Lake, which may perhaps receive surface drainage from several dwellings and farms. Ice supply is cut from Forest Lake, 1 mile west of the village. Sewerage system discharges into a small creek, thence into the river. Garbage is hauled to dumping ground.

Grove City, Meeker County.—Is connected with Crow River by a slough north of town. Water supply is obtained from an 8-inch well sunk 740 feet deep; ice supply from a small lake 3 miles north of town. No sewerage.

Hector, Renville County.—Drained by a county ditch to the south fork of Crow River. Water supply obtained from an 8-inch drilled well 420 feet deep; ice supply from an artificial pond fed by wells. Storm sewerage, but no sanitary system has been established.

Hutchinson, McLeod County.—On South Fork (locally called Hassan River) of Crow River, near Otter Lake. Water supply is obtained from an artesian well 10 inches diameter, driven 60 feet to rock, then drilled 100 feet; ice supply from Crow River above city drainage. A sanitary sewerage system empties into Crow River. Garbage is dumped into a pit outside the city limits.

Litchfield, Meeker County.—Drains to Jewett Creek, the outlet of Lake Ripley, which enters north branch of Crow River. Water supply is obtained from 2-inch wells driven 42 feet in the drift; ice supply from Lake Ripley. No sewerage. No regular garbage disposal.

Little Falls, Morrison County.—On Mississippi River, 38 miles above St. Cloud. Water supply is procured from Mississippi River without filtration; ice supply from the river opposite the city. Sanitary sewage is discharged into Mississippi River. Garbage is hauled outside city limits to dumping ground.

Long Prairie, Todd County.—On Long Prairie River. Water supply is obtained from two dug wells, one 12 feet in diameter by 20 feet deep, the other 30 feet in diameter by 40 feet deep. Ice supply is cut from Lake Charlotte, south of the village. No sewerage. Garbage is generally dumped in hollows and covered with dirt.

Melrose, Stearns County.—On Sauk River, 20 miles below Sauk Center. Water supply for fire protection only is taken from Sauk River. Drinking water is procured from private driven or dug wells; ice supply from Sauk River, above the dam. No sewerage. Garbage is hauled outside the city limits.

Milaca, Millelacs County.—On Rum River, 15 miles above Princeton. Water supply for fire protection only is obtained from Rum River; ice supply from Rum River. A combined sewerage system empties into Rum River below the village. Garbage is hauled to the village dumping ground.

Minneapolis, Hennepin County.—On both sides of Mississippi River, about 9 miles above its confluence with Minnesota River. The city water supply is taken unfiltered from Mississippi River by four intakes: (*a*) north station, at Camden Park, near the upper city limits; (*b*) northeast station, at foot of Thirty-seventh avenue NE., before the river enters the city; (*c*) east-side station, and (*d*) west-side station, in the heart of the city, below several sewers. The lower stations have been closed by the water board. The present supply has been repeatedly condemned by sanitary experts, who recommend filtration. The city ice supply, amounting to more than 150,000 tons annually, is cut from all the numerous lakes in Hennepin County, among which are lakes Amelia, Big, Calhoun, Cedar, Clearwater, Crystal, Twin, and Waconia. Storm and sanitary sewerage systems extend throughout the greater part of the city, discharging into Mississippi River by several outlets. Privies and cesspools, which must have water-tight vaults, are permitted only where there is no access to sewers. Garbage is burned at a crematory owned and operated by the city.

Monticello, Wright County.—On Mississippi River, 26 miles above the mouth of Rum River. Water supply is obtained from an artesian well 8 inches in diameter by 237 feet deep in the drift; ice supply from First Lake, west of the village, and from the river. No sewerage system or regular garbage disposal.

New London, Kandiyohi County.—On Middle Fork of Crow River. Waterworks for fire protection only. No sewerage; ice supply from lakes Green and Andrew and from the river.

Osakis, Douglas and Todd counties.—At the south end of Lake Osakis. Water supply for fire protection and for sprinkling is taken from the lake; drinking water is commonly taken from shallow driven wells. Ice supply is cut from Lake Osakis. Limited storm sewerage is established.

Park Rapids, Hubbard County.—On Fishhook River, about 2 miles below Fishhook Lake. Water supply and ice supply are both taken from the river. The village water is little used for domestic purposes. No sewerage. Garbage is hauled to the public dumping ground.

Paynesville, Stearns County.—On North Fork of Crow River. Water supply is obtained from four 3-inch wells driven 80 feet in the drift; ice supply from Lake Koronis south of town. No sewerage. Garbage is dumped on convenient vacant property.

Princeton, Millelacs County.—On Rum River about 100 miles above its mouth. Water supply is taken from one tubular well, 8 inches diameter by 187 feet deep, in the drift; ice supply from Rum River. No sewerage.

Royalton, Morrison County.—On Platte River, 7 miles above its confluence with Mississippi River. Ice is cut from the river. Garbage is carted to the village dumping ground. No waterworks or sewerage system.

St. Cloud, Benton, Sherburne, and Stearns counties.—On Mississippi River 76 miles above Minneapolis and 2 miles below the entrance of Sauk River. Water supply is taken without filtration from Mississippi River near the upper edge of the city. It is grossly polluted and has been pronounced unsafe by the State board of health. The part of the city on the west bank of the river discharges sewage into the river by 5 main sewers, both storm and sanitary. East St. Cloud is not sewered. The Minnesota State Reformatory, with about 200 inmates, is just below the city, on the east bank of the river. Its water supply is taken from 4 shallow wells in an old river bottom east of the reformatory grounds. The buildings are completely equipped with sewerage, which discharges into Mississippi River.

St. Louis Park, Hennepin County.—A suburb of Minneapolis, situated on Minnehaha Creek. The ice supply is cut from the creek and from Lake Calhoun. No waterworks, sewerage, or systematic garbage disposal.

Sauk Center, Stearns County.—On Sauk River. Water supply is derived from Sauk River just above the mill dam, opposite the city, without filtration. It is little used for domestic purposes. The ice supply is taken from the river above the city. Sanitary sewerage discharging into Sauk River is established. Garbage is hauled outside the city limits and dumped.

Sauk Rapids, Benton County.—On Mississippi River, opposite the confluence of Sauk River, 2 miles above St. Cloud. Ice is cut from Mississippi River. No waterworks or sewerage. Garbage is generally hauled away by farmers.

Staples, Todd County.—Connected by a small creek with Crow Wing River. The ice supply is from Dower Lake, 2 miles west of the village. Garbage is taken to high sandy ground 2 miles east of town. No waterworks or sewerage.

Wadena, Wadena County.—On Union Creek 2 miles south of Leaf River. Water supply is obtained from a well, 22 feet deep by 20 feet in diameter, in the center of the village. Ice supply is cut from Union Creek and from Leaf River. No sewerage. Garbage is hauled to the public dumping ground.

Walker, Cass County.—On the west shore of Leech Lake. Water and ice supplies are taken from the lake in front of the town. The water is not filtered. No sewerage is established. Garbage is burned.

West Minneapolis (Hopkins), Hennepin County.—A short distance southwest of Minneapolis. Drains to Minnehaha Creek. Water for fire protection only is furnished by the Minneapolis Threshing Machine Company from an 8-inch well 600 feet deep. Ice is cut on Shady Oak Lake. No sewerage. Garbage is usually hauled away by market gardeners.

White Bear Lake, Ramsey County.—On the west shore of White Bear Lake, which discharges through a chain of lakes and Rice Creek into Mississippi River. It is a summer resort with a comparatively small permanent population. A 10-inch well for a village supply has been recently put down. No sewerage. Garbage is hauled outside the village limits and dumped.

MINNESOTA RIVER BASIN.

GENERAL DESCRIPTION.

Boundaries.—The basin lies across the southern third of Minnesota and includes also small portions of Iowa and South Dakota. It is bounded on the north by upper Mississippi and Red River drainage areas; on the east by lower Mississippi area and the basin of Cedar River; on the south by Des Moines River basin, and on the west by several small streams tributary to Missouri River. (Pl. III.)

Course and slope of Minnesota River.—Minnesota River rises on the eastern slope of the Dakota foothills (Coteau des Prâiries), in the northeastern part of Marshall County, S. Dak., about 30 miles west of Lake Traverse, at an approximate elevation of 1,896 feet above sea level (Nicollet). It flows southeastward to the State border, where it falls rapidly to the level of Bigstone Lake. The stream is a mere mountain torrent in this upper section, where the bed is often entirely dry. Bigstone Lake is about 30 miles long and 1 to 2 miles wide. Its east and west shores are well defined by gravel bluffs that rise abruptly 150 feet to the level of the surrounding prairies. The lake is narrow and shallow, exceeding 15 feet in depth at only a few places. Pleasure craft and other small steamers ply on the lake, and there is regular water communication between Ortonville and Browns Valley during the open season. At its upper or northern end, where Minnesota River enters, a marshy strip, not over 20 feet high, stretches northward 5 miles to the equally swampy southern extremity of Lake Traverse, the headwaters of Bois de Sioux River. At Ortonville the Minnesota River emerges from the southern extremity of Bigstone Lake and, after uniting with Whetstone River, which enters from the south, flows southeastward to Mankato, a distance of 150 miles. Though there are some stretches of still water between Ortonville and Mankato, the river riffles over granitic rocks at several places and is not navigable. Blue Earth River enters from the south just above Mankato, where the main stream turns abruptly and pursues a northeasterly course to its mouth. The lower portion, which has an average width of 300 feet, is navigable by light-draft vessels for 37 miles from its mouth to Little Rapids.

In the first 40 miles of its course the stream falls 900 feet, having an average slope of 25.4 feet per mile. (See fig. 3.) After passing 24 miles through Bigstone Lake it drops, by series of rapids alternating with reaches of still water, to Little Rapids, with an average slope of 1.25 feet per mile. Excluding the principal drop of 50 feet in 5 miles at

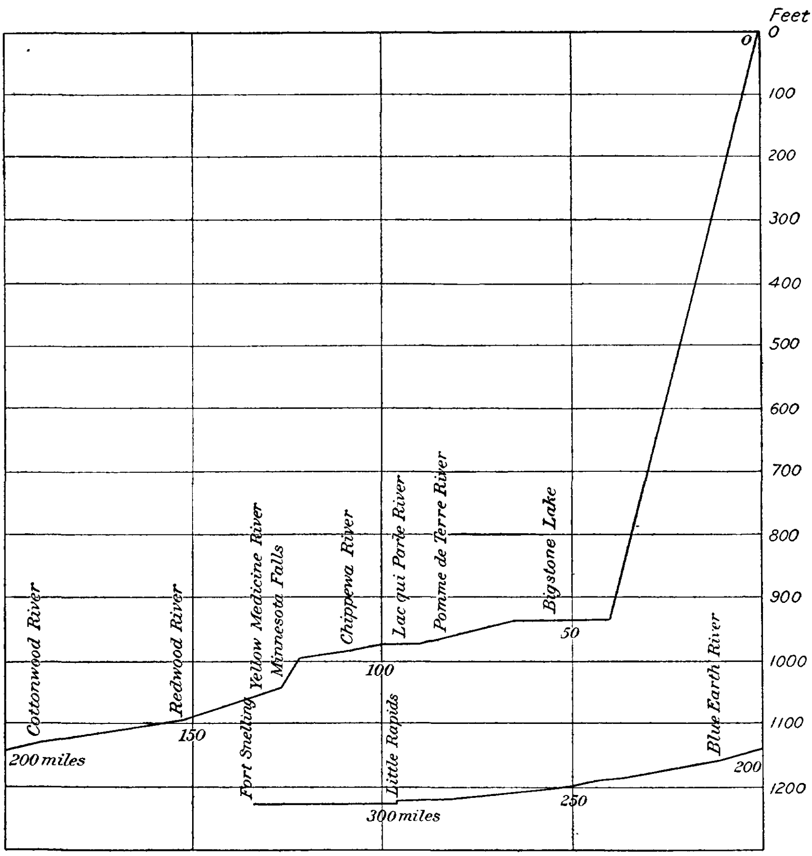


FIG. 3.—Profile of Minnesota River.

Granite Falls, this section has a grade of 1.06 feet per mile. Below Little Falls, after an abrupt descent of 2 feet, the slope is less than 0.1 foot per mile. If the small stream above Bigstone Lake is excluded, the mean slope of Minnesota River is considerably less than that of upper Mississippi River.

Tributaries of Minnesota River.—The principal affluents of the Minnesota are Pomme de Terre River, Chippewa River, and Hawk Creek

MAP OF MINNESOTA RIVER BASIN.

from the north, and Whetstone, Lac qui Parle, Redwood, Cottonwood, and Blue Earth rivers from the south, all of which enter above Mankato. (See Pl. III.) The largest tributary is Blue Earth River, which rises in Kossuth County, Iowa, and flows northward as a meandering prairie stream. It is about 60 feet wide at its mouth and 2 to 3 feet deep during ordinary stages. Below the mouth of Blue Earth River near Mankato the Minnesota drains a comparatively narrow area, its tributaries being small and insignificant. Around the headwaters of Pomme de Terre and Chippewa rivers there are many lakes, and throughout the entire valley there are small bodies of water that lie in shallow depressions of the drift and are fast being eliminated by silting, artificial drainage, and other factors.

Topography.—The Coteau des Prairies, in the southeastern part of the area, slopes rather steeply and evenly to the plain forming the valley of the Minnesota. Except for this feature the entire region is a rolling prairie crossed by the deep, wide bed of the river. Formerly some lumbering was done in the extreme northern part, but now the forests are gone. On account of the absence of woods and of large lakes capable of retaining flood waters, the streams rise rapidly after rains or thaws and become very turbid, for they easily disintegrate the unprotected clayey gravels along their banks.

Geology.—Gneisses, schists, and granites are exposed along the deeply eroded valley of the river from New Ulm to Lac qui Parle. Red quartzite is found in the southern part of the valley, through Cottonwood, Watonwan, and Jackson counties. Limestones, shales, and sandstones of Cambrian and Ordovician age reach as far west as the valley of Blue Earth River and occupy the eastern part of Minnesota Valley. The most widespread deposits, however, are the Cretaceous rocks, which extend eastward from the Dakotas and cover about two-thirds of the basin, including all of its western part except some small areas, in which there are exposures of earlier rocks. These extensive deposits and the many scattered Cretaceous beds found in the eastern section of the valley have undoubtedly a modifying influence on the composition of the drift and consequently on the drainage. The more or less stratified materials of the Pleistocene overlie the earlier rocks throughout the entire region.

When Lake Agassiz, a glacial lake, occupied the valley of Red River its outlet, to which the name Warren River has been given, extended through the valley in which Traverse and Big Stone lakes and Minnesota River are now situated. This river cut a channel 150 to 200 feet deep and from 1 to 2 miles wide across the valley. Before Lake Agassiz was formed a body of water gathered in this basin at the margin of the receding ice sheet, extending from Big Stone Lake to Waseca and comprising an area of more than 3,000 square miles. This great lake, which has been called Lake Minnesota, found an outlet southward through Blue Earth River to Des Moines River.[a] Lacustrine gravels, sands, and clays, having a thickness of more than 100 feet in some places in the central part of the valley, testify to the existence of this prehistoric lake.

Soil and subsoil.—The top layers of the drift in this region differ distinctly from those of upper Mississippi Valley in their content of certain mineral constituents. The following table gives the average composition of soils in Minnesota Valley as computed from analyses made by the Minnesota agricultural experiment station:

TABLE 31.—*Chemical composition of soil and subsoil in Minnesota.*

	Surface soil.		Subsoil.	
	Minnesota River basin.	Entire State.[a]	Minnesota River basin.	Entire State.[a]
Insoluble in HCl	76.65	79.92	76.77	82.41
Volatile	9.75	8.98	6.10	5.33
Potassium oxide (K_2O)	.39	.43	.38	.40
Sodium oxide (Na_2O)	.25	.45	.30	.32
Calcium oxide (CaO)	1.43	1.29	6.64	1.78
Magnesium oxide (MgO)	.80	.61	.55	.80
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	7.87	7.20	8.89	8.32
Phosphoric anhydride (P_2O_5)	.22	.20	.20	.17
Sulphuric anhydride (SO_3)	.13	.10	.08	.06
Carbonic anhydride (CO_2)	.75	.62	1.36	.93

[a] Snyder, H., Characteristic features of Minnesota soils: Bull. 65, Agr. Exp. Sta., University of Minnesota, Chem. Div., Nov., 1899, p. 69.

The amount of sand is not excessive, the insoluble matter being lower than in the average soil in the rest of the State. Nearly all of the soluble constituents are present in larger amounts than the average, and the high percentage of these is in line with the high percentage of inorganic matter found generally in the water of Minnesota River. In their content of alkaline ingredients the soils lie midway between those of upper Mississippi Valley and those of Red River basin. The influence of the Cretaceous deposits and the difference in rainfall may cause this difference between the soils of these regions.

INDUSTRIAL POLLUTION.

The following list gives the number of establishments in this area having wastes of deleterious nature:

TABLE 32.—*Industrial establishments causing stream pollution in Minnesota River basin.*

Breweries	23
Creameries	45
Gas works	2
Sawmills	6
Woolen mill	1

[a] Upham, Warren, The Glacial Lake Agassiz: Mon. U. S. Geol. Survey, vol. 25, p. 264.

Four breweries are located at New Ulm and two at Mankato, the total output of all these amounting to about 6,000 barrels per month. Most of these establishments do their own malting. Their wastes, consisting of washings from floors, barrels, vats, etc., and of slop, after the brewer's "grains" have been screened out, are run into Minnesota River either directly or through sewers. The other establishments noted in the list above are all small and their wastes are not likely to be troublesome in the streams. Corn and wheat raising are the principal industries of the district. Drainage from the cultivated lands contains generally more suspended and dissolved matter than that from the other lands, because the tilled soils are less compact and therefore more easily disintegrated. In regions where manure is used more or less organic matter reaches the streams from the fields, especially during freshets.

MUNICIPAL POLLUTION.

POPULATION.

Table 33 shows the population by counties for three successive censuses in Minnesota River drainage area. There are 26 inhabitants per square mile, about the average density of the State (see Table 34). Since this region is essentially a farming country the population is chiefly in the rural districts and is evenly distributed over the entire area, except possibly a small part above Ortonville, which is not now open for settlement. This portion of the State was first to be developed and, on account of its remarkable fertility, rose quickly to its present population. It is probable that there will not be a great increase in the future but only the gradual growth incident to a rural region.

TABLE 33.—*Population in Minnesota River basin.*

County.	U. S. census, 1890.	U. S. census, 1900.	State census, 1905.
Bigstone	5,214	7,875	8,442
Blue Earth	29,210	32,263	31,228
Brookings, S. Dak	800	1,000	*a* 1,200
Brown	15,817	19,787	20,523
Carver	11,758	12,418	12,504
Chippewa	8,555	12,499	13,356
Codington, S. Dak	700	800	*a* 900
Cottonwood	5,012	7,835	8,286
Dakota	2,872	2,885	3,172
Deuel, S. Dak	2,200	3,300	*a* 4,000
Douglas	6,008	7,234	7,382
Faribault	16,708	22,055	20,448
Freeborn	4,885	5,779	5,592
Grant	3,438	4,468	4,826
Hennepin	1,728	1,912	2,087
Jackson	820	1,304	1,306
Kandiyohi	7,911	10,913	11,826
Lac qui Parle	10,382	14,289	15,182
Lesueur	15,667	16,462	16,479
Lincoln	4,552	7,173	7,990
Lyon	9,501	14,591	16,171

TABLE 33.—*Population in Minnesota River basin*—Continued.

County.	U. S. census, 1890.	U. S. census, 1900.	State census, 1905.
Martin	7,761	14,157	14,661
McLeod	2,432	2,800	2,759
Grant, S. Dak	6,814	9,103	[a] 11,000
Murray	631	1,103	1,088
Nicollet	13,382	14,774	14,994
Ottertail	3,878	4,946	5,210
Pipestone	100	323	323
Pope	8,151	10,288	11,035
Redwood	9,386	17,261	19,034
Renville	12,993	18,281	18,336
Rice	182	249	304
Roberts, S. Dak	1,200	8,000	[a] 11,000
Scott	13,831	15,147	15,094
Sibley	15,199	16.862	16,354
Steele	1,411	1,602	1,609
Stevens	4,454	7,366	7,773
Swift	10,161	13,503	13,575
Traverse	498	721	902
Waseca	11,663	13,027	12,085
Watonwan	7,746	11,496	11,494
Yellow Medicine	9,854	14,602	15,899
Kossuth, Iowa	2,763	4,952	4,729
Winnebago, Iowa	2,143	3,655	3,460
Total	310,371	411,060	425,568

[a] Estimated.

TABLE 34.—*Density of population in Minnesota River basin.*

	Drainage area.	Inhabitants per square mile.		
		1890.	1900.	1905.
	Sq. miles.			
Above Ortonville	[a] 1,232	2.9	8.1	8.7
Above Mankato:				
Entire area	[b] 13,400	16.6	23.6	24.8
Excluding chief settlements		14.3	19.6	20.8
Above Mississippi River:				
Entire area	[c] 16,350	19.0	25.1	26.0
Excluding chief settlements		15.7	20.4	21.4

[a] Ann. Rept. Chief of Engineers, U. S. Army, 1898, p. 1838.
[b] Water-Sup. and Irr. Paper No. 130, U. S. Geol. Survey, 1905, p. 53.
[c] Ann. Rept. Chief of Engineers, U. S. Army, 1894, pt. 3, p. 1704.

CONDITIONS ON THE MINNESOTA.

General conditions.—The drainage and general hydrography of the valley are exhibited in Pl. III, which shows also the location and the relation of all settlements having a population exceeding 1,000 according to the census of 1900. A vertical bar within the population circle indicates that a municipality has a public sewerage system. Unlike those of the upper Mississippi Valley, many of the centers of population are remote from running water. It does not follow from this‘ however, that the streams thus escape pollution. The general distribution of both city and rural population all over the area is sufficient to render any surface water within it unsafe.

Conditions at Ortonville.—Around the headwaters of the river above Ortonville the population is less dense than in any other part of the basin. Sisseton and Browns Valley, the only settlements in this district, are both small. There is little pollution in this region.

Conditions at Mankato.—Over three-fourths of the Minnesota basin lies above Mankato. It is farming land, on which wheat and corn are the principal crops. One of the most noticeable features of this region is the number of small settlements distributed over it. New Ulm, the second city in size, is located on the river, a little over 20 miles above Mankato. The presence of this large place is sufficient to condemn the water of Minnesota River for domestic use at Mankato without filtration. The stream is often so muddy after heavy rains and thaws that the use of the raw water at such times is undesirable. The chief sources of stream pollution are given in the following table:

TABLE 35.—*Principal settlements in Minnesota River basin above Mankato.*

Name.	Stream.	Distance above Mankato.[a]	Population.		
			1890.	1900.	1905.
		Miles.			
Appleton	Pomme de Terre River	133	994	1,184	1,321
Benson	Chippewa River	138	877	1,525	1,766
Blue Earth	Blue Earth River	71	1,569	2,900	2,364
Canby	Canby Creek	161	470	1,100	1,505
Fairmont	Lake George	86	1,205	3,040	2,955
Glenwood	Lake Minnewaska	178	627	1,116	1,718
Granite Falls	Minnesota River	87	....	1,214	1,340
Janesville	Lake Elysian	45	921	1,254	1,205
Lake Crystal	Crystal Lake	15	824	1,215	1,231
Madelia	Watonwan River	30	852	1,272	1,290
Madison	....	146	625	1,336	1,604
Mapleton	Little Cob River	27	607	1,008	938
Marshall	Redwood River	106	1,203	2,088	2,243
Milbank, S. Dak	Whetstone River	161	1,207	1,426	....
Montevideo	Chippewa River	103	1,437	2,146	2,595
Morris	....	168	1,266	1,934	2,003
New Ulm	Minnesota River	22	3,741	5,403	5,720
Ortonville	....do	149	768	1,247	1,612
Redwood Falls	Redwood River	63	1,238	1,661	1,806
Renville	Sacred Heart Creek	81	413	1,075	1,229
St. James	St. James Lake	43	939	2,607	2,320
Sleepy Eye	Sleepy Eye Creek	38	1,513	2,046	2,312
Springfield	Cottonwood River	116	716	1,511	1,546
Tracy	Branch of Cottonwood River	92	1,400	1,911	2,015
Waseca	Clear Lake	51	2,482	3,103	2,838
Wells	....	51	1,208	2,017	1,814
Willmar	Hawk Creek	131	1,825	3,409	4,040
Winnebago	....	66	1,108	1,816	1,553
Total urban population	....	....	32,035	53,564	54,883

[a] Mankato is 119 miles from the mouth of the river.

Conditions at mouth of river.—Minnesota River below Mankato is not used for any purposes other than navigation and ice harvesting. The following list of settlements in its basin gives their distances above the mouth of the river and their population. Many of these places have reached their maximum size, and some of them are even now on a decline, due to the inevitable reaction caused by a rush of pioneers to cheaper lands. This decline will probably be followed by a slower and more permanent growth, as has been the case with similar towns in the older Central States.

TABLE 36.—*Principal settlements in Minnesota River basin above Mississippi River.*

Name.	Stream.	Distance above mouth.	Population.		
			1890.	1900.	1905.
		Miles.			
Settlements above Mankato (see Table 35, p. 71)			32,035	53,564	54,883
Belle Plaine	Minnesota River	52	814	1,121	1,301
Chaska	.....do	30	2,210	2,165	2,085
Jordan	Sand Creek	40	1,233	1,270	1,311
Le Sueur	Minnesota River	82	1,763	1,937	1,842
Mankato	.....do	119	8,838	10,599	10,996
New Prague		55	955	1,228	1,419
St. Peter	Minnesota River	97	3,671	4,302	4,514
Shakopee	.....do	26	1,757	2,047	2,069
Total			53,276	78,233	80,420

TYPHOID FEVER.

Though typhoid fever is prevalent in Minnesota River Valley, no regular report of it has been made, so that detailed statistics can not be given. Mankato, New Ulm, Montevideo, and Ortonville all have had undesirable records of typhoid fever. Although there have been no extensive outbreaks, a number of cases are distributed over the area every year. Surface water is not extensively used for domestic supply, so that the spread of the fever is probably not due to infected streams. Many cases of the disease have been traced to the use of water from infected wells. Since modern improvements have not been adopted with extreme thoroughness, large sections of the principal cities are still unconnected with sewers, and the inhabitants have a general disinclination to abandon their private wells for municipal supplies. Consequently many driven or dug drift wells in close proximity to cesspools, privy vaults, and other foci of pollution are still in existence, and the use of water from these wells no doubt propagates this preventable disease. Typhoid fever will be eradicated only when the people generally are convinced that shallow wells in cities are as a rule unsafe sources of drinking water and offer much chance for the dissemination of specific diseases.

QUALITY OF WATER.

At the beginning of the work points were selected for the collection of samples above and below the principal settlements on the main stream and on Redwood River. Series I in Table 37 was collected during January and February, 1904, when the river was completely frozen and fluctuated little in its discharge. Series II was collected during the next winter under similar circumstances. Series III was collected when the ice was going out and, unfortunately, shows the stream under varied conditions at different points. The sample from Big Stone Lake was taken through the ice, just before the spring thaw. The samples at Granite Falls, New Ulm, and Redwood Falls were taken while the ice was breaking up and probably show considerable dilution of the characteristic run-off. When the samples at Mankato were taken the river was in decided flood condition, standing somewhat over 4 feet above its winter level, and rapidly rising. The sample from Fort Snelling was also taken near the crest of a flood after the ice had left the lower river.

The stream carries a noticeable quantity of organic matter, as evinced by the nitrogen determinations. Albuminoid ammonia almost invariably exceeds 0.3 parts per million and free ammonia is likewise high. Nitrates are found in measurable quantity and nitrites are present, especially during flood time. The water has generally a slight vegetable odor, which during freshets is accompanied or overshadowed by an earthy or a musty smell. Though the water has some color, which is, as may be expected, highest during floods, it is not so high as that of surface water from regions where swamps and forest are more abundant.

In mineral content the waters of this region are distinctly different from those of upper Mississippi Valley. Chlorine is considerably higher, generally 3 to 10 parts per million, and often exceeds the latter amount. Sulphates vary from 70 to 450 parts per million and are also present in considerable quantity in other waters of the basin, as shown by Table 38, which gives the results of inorganic analyses of surface waters from divers sources. The total residue is high and the amount soluble in alcohol indicates the presence of considerable sodium and potassium. The inorganic determinations in these tables prove that there is an essential difference between the prairie stream Minnesota River and the woodland drainage of upper Mississippi Valley. The greatest distinction is in the amounts of sodium, potassium, and sulphuric acid. Though the surface waters are softer than those furnished by wells in the region, they still carry much mineral matter and prove troublesome when used in boilers in their raw state. The river is not so strongly mineralized as Red River, though it is similar to it in many respects.

The samples examined bacteriologically contained excessive numbers of bacteria. *B. coli communis* was isolated in pure culture from a majority of the samples, a fact indicating the unfitness of the water for domestic use without filtration. The waters of the tributaries, so far as they have been examined, are similar to the water of Minnesota River, as might have been expected, since they drain regions that are similar in geologic and economic conditions. The influence of the Cretaceous rocks is shown to some extent by a difference between the mineral content of the waters in the upper valley and that of Minnesota River at Fort Snelling, though the dilution is not so marked as in other rivers in the State.

TABLE 37.—*Quality of water in Minnesota River basin.*

[Parts per million.]

SERIES I, WINTER OF 1904.[a]

Source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c. c.	B. coli communis.
Minnesota River:																		
Bigstone Lake at Ortonville	Feb. 17				17.5		105	708				0.54	0.08	0.000	Trace.		225	−
Below Ortonville	...do...				17.0		112	666				.70	.09	.000	Trace.		65	−
Below Chippewa River	...do...				15.0		192	706				.79	.28	Trace.	Trace.		850	+
Above Granite Falls	Feb. 18				13.7		185	994				.55	.50	Trace.	Distinct.		550	−
Below Granite Falls	...do...				14.0		186	986				.71	.36	Trace.	Distinct.		475	−
Above New Ulm	Feb. 19				8.5		155	688				.41	.45	Trace.	Distinct.		550	
Below New Ulm	...do...				9.0		155	703				.45	.38	Trace.	Distinct.		1,400	+
Above Mankato	Jan. 7				4.2			620				.33	.30	Distinct.	Trace.		10,500	+
Below Mankato	...do...				4.8			606				.35	.308	Distinct.	Distinct.			
Tributaries:																		
Chippewa River above Montevideo	Feb. 17				4.0		195	708				.43	.445	Trace.	Distinct.			
Redwood River above Redwood Falls	Feb. 18				6.0		185	891				.23	1.06	Distinct.	Distinct.		100	−
Redwood River below Redwood Falls	...do...				6.0		185	898				.31	.73	Distinct.	Distinct.		850	+
Blue Earth River at mouth	Jan. 7							408				.18	.308	Distinct.	Distinct.		([b])	+

SERIES II, WINTER OF 1904–5.[c]

Source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c. c.	B. coli communis.
Minnesota River:																		
Bigstone Lake at Browns Valley	Dec. 4	4		15	12.4	457	223	584	0	933	365	0.530	0.156	Trace.	0.025	7	100	−
Minnesota River above Granite Falls	Dec. 5	25		<7	4.3	188	326	473	Trace.	618	89	.396	.122	0.000	.04	13	2,000	+
Minnesota River below Granite Falls	...do...	25		<7	5.0	201	321	473	Trace.	623	88	.480	.136	.000	.04	13	3,200	+
Minnesota River above New Ulm	Dec. 7	25		30	4.9	259	320	529	1.0	659	179	.490	.062	.000	.04	10	400	−
Minnesota River above Mankato	Dec. 8	18		19	4.5	207	322	529	1.0	619	172	.380	.070	.000	.04	13	300	−
Minnesota River above Mankato	Jan. 4	25	2 v.	15	4.5	207	380	640	1.0	728	184	.100	.220	Trace.	.09	18	600	−
Minnesota River below Mankato	Dec. 8	18		20	4.7	207	330	473	1.0	618	222	.400	.296	.000	.04	18	4,100	+
Minnesota River below Mankato	Jan. 4																4,200	+
Tributaries:																		
Redwood River below Marshall	Dec. 7	18		20	10.0	514	335	640	0	1,176	335	.340	1.40	.025	.18	19	3,100	+
Blue Earth River at mouth	Jan. 4	4	1 v.	<7	3.5	71	311	473	Trace.	457	92	.352	.420	.000	.02	20	400	−

SERIES III, SPRING OF 1905.[c]

Minnesota River:																		
Bigstone Lake at Browns Valley	Mar. 19	29	2 v.	9	7.6	276	152	290	0	524	118	0.350	0.024	0.000	0.04	15	950	−
Minnesota River above Granite Falls	Mar. 20	29	3 v.+1 m.	<7	4.6	153	193	304	Trace.	428	167	.440	.158	Trace.	.08	10	1,900	−
Minnesota River below Granite Falls	....do...	29	3 v.+1 m.	<7	4.6	153	192	304	Trace.	429	138	.440	.158	Trace.	.08	7	3,800	+
Minnesota River above New Ulm	Mar. 21	.....	2 v.+2 e.	30	4.6	173	192	275	Trace.	429	131	.280	.172	.01	.11	.....	5,200	−
Minnesota River above Mankato	Mar. 22	81	3 v.+2 e.	150	3.6	173	159	230	0.5	442	107	.490	.180	.03	.32	.....	8,500	+
Minnesota River below Mankato	....do...	40	2 M.+2 e.	350	3.3	76	121	157	0.5	603	55	.710	.240	.05	.75	.....	40,000	+
Minnesota River just above mouth	Mar. 14	74	2 v.+1 M.	95	3.0	106	138	197	Trace.	364	74	.440	.326	.005	.24	9	4,500	−
Tributaries:																		
Redwood River above Redwood Falls	Mar. 21	.....	3 M.	<7	0.4	46	51	124	Trace.	153	39	.370	.260	.004	.31	5	1,100	−
Redwood River below Redwood Falls	....do...	.....	3 M.	20	4.0	334	114	382	Trace.	643	172	.412	.146	.002	.31	11	1,700	−
Blue Earth River at mouth	Mar. 22	114	2 v.+2 e.	350	3.6	59	113	130	0.5	844	37	.600	.204	.05	.75	.....	30,000	+

[a] Chemical analyses by H. C. Carel; bacteriological examinations by Dr. E. H. Beckman.
[b] Overgrown.
[c] Chemical analyses by R. B. Dole; bacteriological examination by E. H. Beckman.

TABLE 38.—*Mineral analyses of water in Minnesota River basin.*

[Parts per million.]

Source.	Date.	Oxide of iron and alumina (Al_2O_3+Fe_2O_3).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Silica (SiO_2).	Chlorine (Cl).	Sulphate radicle (SO_4).	Carbonate radicle (CO_3).	Total solids.
Bigstone Lake at Ortonville[a]	1883.	1.5	44	48	37	5.6	106	9.2	220	112	553
Minnesota River at Granite Falls[b]	July —, 1891	5.0	92	19	43		....	3.8	212	108	484
Chippewa River at Montevideo[b]	Jan. 17, 1891	28	223	66	28		....	4.1	122	305	676
Chippewa River at Montevideo[b]	Nov. 17, 1895	8.6	88	53	51		....	17	234	234	582
Chippewa River at Montevideo[b]	Jan. 24, 1902	....	122	71	39		....	13	163	295	704
Pomme de Terre River at Appleton[b]	Jan. 11, 1891	11	130	56	40		....	2.7	258	221	719
Pomme de Terre River at Appleton[b]	Dec. 24, 1901	....	100	70	26		....	5.5	219	214	634
Redwood River at Florence[c]	Aug. 21, 1903	1.5	65	16	26		10	9.1	100	102	(d)
Redwood River at Marshall[c]	....do....	2.0	92	32	11		18	12	140	134	(e)
Lake at Alden[c]	Oct. 27, 1892	4.4	32	19	22		....	23	6.5	99	208
Prior Lake at Prior Lake[c]	Nov. 15, 1888	4.1	32	9.9	1.0		....	1.4	Trace.	71	119
Temperance Lake at Sherburne[e]	Oct. 12, 1892	9.9	34	22	20		....	3.1	27	113	230
George Lake at Fairmont[c]	Mar. 27, 1894	4.4	34	14	6.7		....	2.7	Trace.	94	156
Budd Lake at Fairmont[c]	June 27, 1898	1.2	27	15	13		....	4.6	8.7	84	153
Budd Lake at Fairmont[c]	Feb. 6, 1899	1.5	41	21	11		....	7.5	13	113	208
Budd Lake at Fairmont[c]	Sept. 18, 1901	.8	18	17	7.2		....	4.6	9.1	68	124
Sulphur Creek at Ortonville[c]	Sept. 3, 1888	8.6	256	61	110		....	3.8	700	237	1,377

[a] Analysis by C. T. Sidener; trace of phosphates.
[b] Analyses furnished by Chicago, Milwaukee and St. Paul Railway.
[c] Analyses furnished by Kennicott Water Softener Company.
[d] Suspended solids, 5.0.
[e] Suspended solids, 63.

TABLE 39.—*Analyses of waters of Minnesota and Blue Earth rivers.*

[Parts per million.]

MINNESOTA RIVER ABOVE MOUTH OF BLUE EARTH RIVER.

Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron as Fe.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per c. c.[a]	B. coli communis.[a]
Aug. 27, 1903[b]	0	0	....	3	....	200	170	0	520	....	0.7	Trace.	Trace.	Trace.	....	650	—
Jan. 7, 1904[c]	....	....	....	4.2	....	....	620	....	....	....	.33	.30	Distinct.	Trace.	....	10,500	+
May 3, 1904[c]	....	....	....	1.0	....	....	....	....	....	....	....	....	.000	Trace.	....	1,100	+
Dec. 4, 1904[d]	18	....	19	4.5	207	322	529	1.0	619	172	.380	.070	.000	.04	13	300	
Jan. 4, 1905[d]	25	2 v.	15	4.5	207	380	640	1.0	728	184	.100	.220	Trace.	.09	18	600	-
Mar. 22, 1905[d]	81	3 v.+2 e.	150	3.6	173	159	230	0.5	442	107	.490	.180	.03	.32	....	8,500	+

MINNESOTA RIVER BELOW MANKATO, MINN.

Aug. 27, 1905 c	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,500	—
Jan. 7, 1905 c	...	...	...	4.8	...	...	606	...	...	...	0.35	0.308	Distinct.	Distinct.	...	(e)	+
May 3, 1904 c	...	...	...	...	...	...	...	...	...	...	.50	.31	.000	Trace.	...	2,500	+
Dec. 8, 1904 d	18	...	20	4.7	207	330	473	1.0	618	222	.400	.296	.000	.04	18	4,100	+
Jan. 4, 1905 d	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4,200	+
Mar. 22, 1905 d	40	2 M.+2 e.	350	3.3	76	121	157	0.5	603	55	.710	.240	.05	.75	...	40,000	+

BLUE EARTH RIVER AT MOUTH, MANKATO, MINN.

Aug. 27, 1903 b	...	...	...	2.5	...	...	315	0	...	...	0.52	0.047	0	0	...	2,000	—
Jan. 7, 1904 c	...	...	...	...	...	...	408	...	...	...	.18	.308	Distinct.	Distinct.	...	(e)	+
May 3, 1904 c	...	...	...	...	...	...	...	...	...	...	.55	.41	.000	Trace.	...	1,200	—
Jan. 4, 1905 d	4	1 v.	<7	3.5	71	311	473	Trace.	457	92	.352	.420	.000	.02	20	400	—
Mar. 22, 1905 d	114	2 v.+2 e.	350	3.6	59	113	130	0.5	844	37	.600	.204	.05	.75	...	30,500	+

MINNESOTA RIVER AT MOUTH, FORT SNELLING, MINN.

June 6, 1904 c	...	...	...	...	...	...	...	...	...	...	0.32	0.30	0.000	Trace.	...	3,900	+
Oct. 23, 1904 d	40	1 v.+1 M.	80	8.5	...	244	243	Trace.	411	107	.502	.130	Trace.	.03	...	1,800	+
Mar. 14, 1905 d	74	2 v.+1 M.	95	3.0	106	138	197	Trace.	364	74	.440	.326	.005	.24	9	4,500	—
June 12, 1905 d	81	2 e.+2 v.	55	4.3	123	236	...	Trace.	473	...	.40	.054	Trace.	.04	...	10,000	+

a Bacteriological examination by Dr. E. H. Beckman.
b Chemical analysis by E. H. Beckman.
c Chemical analysis by H. C. Carel.
d Chemical analysis by R. B. Dole.
e Overgrown.

From Table 39, giving analyses made of water of Minnesota and Blue Earth rivers at Mankato and Fort Snelling, an idea may be had of the variation in the quality of the water between winter and summer. The inorganic substances are higher during the season when the river is frozen and are supplied mainly by its underground flow. In the spring the water exhibits at once its highest color and turbidity and its lowest mineral content. Bacteriological examinations of samples taken at Mankato prove the frequent presence of *B. coli communis* in Minnesota River above the mouth of Blue Earth River, both in summer and in winter. This is probably due to the fact that New Ulm, a short distance above Mankato, discharges its sewage and the effluent from four large breweries into the river. Fig. 4 is a graphic representation of daily turbidity determinations made at Mankato below the mouth of Blue Earth River, extending over a period of seventeen months. The gage heights at the same point are also given for comparison. These curves show an almost exact coincidence between the rise and fall of turbidity and gage height. Ordinarily the river carries suspended matter equivalent to 10 to 40 parts per million of turbidity, but during the spring freshets this amount is often increased to 600 or 800 parts per million.

It is evident that the water of Minnesota River without filtration is not safe for municipal supply. Its purification, however, would not be very difficult, and the water is more desirable for general use than that obtained from deep wells, on account of its comparative softness. The following table shows the average of 24 analyses of Minnesota River, together with the maximum and minimum observations:

TABLE 40.—*Summary of quality of water of Minnesota River.*

[Parts per million.]

Determination.	Maximum.	Minimum.	Average.
Color	81	0	30
Odor			
Turbidity	350	<7	70
Chlorine	17.5	1.0	6.4
Sulphate radicle	383	76	178
Alkalinity	380	105	220
Total hardness	994	157	470
Iron	1.0	Trace.	Trace.
Total residue	933	364	556
Soluble residue	365	55	143
Free ammonia	.326	.024	.193
Albuminoid ammonia	.710	.100	.454
Nitrates	.75	.025	.16
Nitrites	.05	Trace.	.009

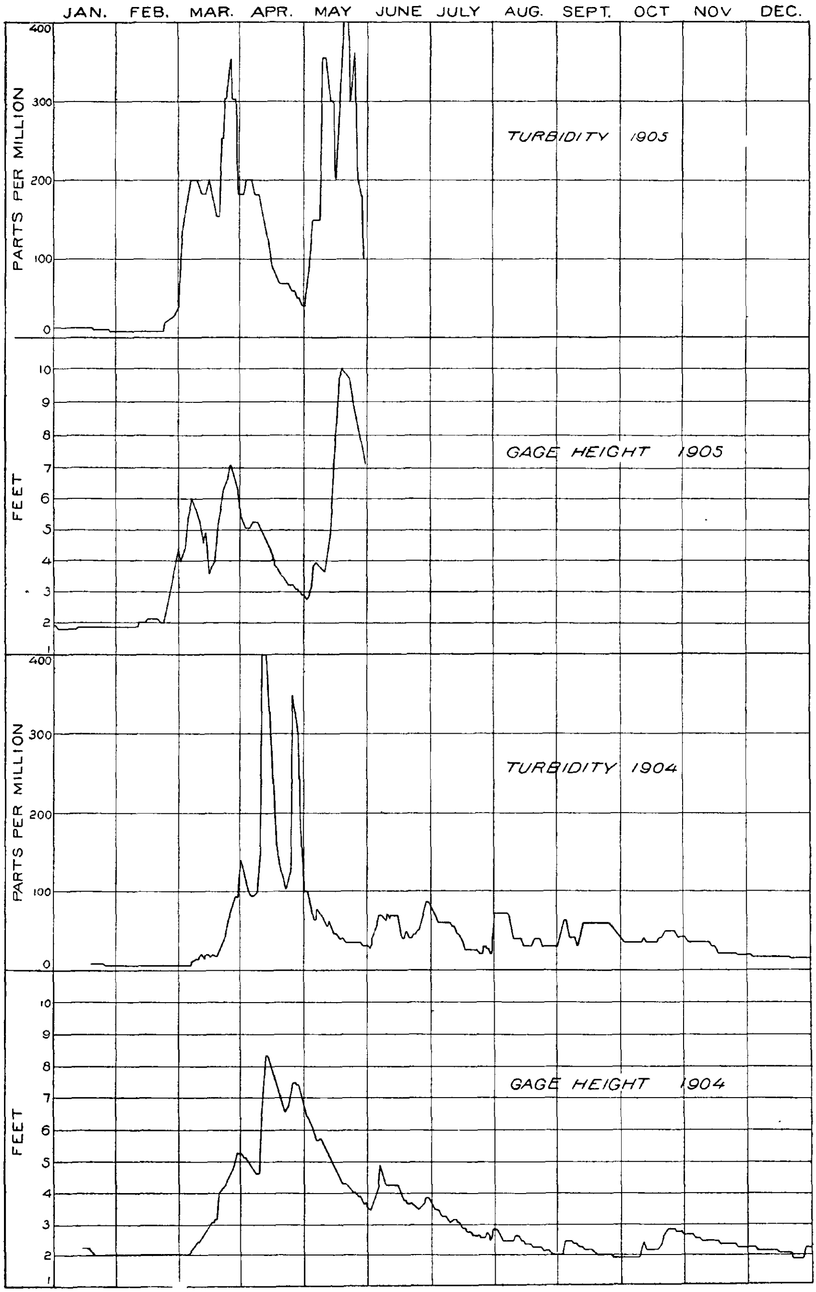


FIG. 4.—Diagram showing relation of turbidity to gage height on Minnesota River at Mankato.

NOTES ON MUNICIPALITIES.

Forty-four of the fifty-two settlements described below have underground water supplies, while only two report stream or lake water as their supply. Sixteen towns, less than one-third, report the installation of sanitary sewage systems. One city reports that a sewage-disposal plant is in operation. Privies and cesspools are common in all of these places, even where sewers have been constructed.

Alden, Faribault County.—On a small creek that enters Walnut Lake. Walnut Lake drains to the east fork of Blue Earth River. The village water supply is derived from a deep well. No sewerage.

Appleton, Swift County.—On Pomme de Terre River, 3 miles above its entrance into Minnesota River. Water supply ordinarily taken from a well, but there is also connection with Pomme de Terre River for use in emergencies. Ice supply from Pomme de Terre River above the village. No sewerage. Garbage is hauled to a dumping ground outside the village.

Belle Plaine, Scott County.—On Minnesota River 52 miles above its mouth. Water supply is obtained from a well in the center of the town, ice supply from small lakes near the borough. No sewerage. Garbage is hauled away to the dumping ground.

Benson, Swift County.—On Chippewa River 40 miles above its confluence with Minnesota River. Water supply is taken from two wells in the village, ice supply from Chippewa River above village. A combined sewerage system discharges into Chippewa River. Garbage is dumped on the prairie 2 miles east of the village.

Bird Island, Renville County.—Drained by a county ditch to Minnesota River. Water supply is derived from an 8-inch tubular well 285 feet deep. No sewerage. No systematic garbage disposal.

Blue Earth, Faribault County.—On Blue Earth River, 20 miles above Winnebago City. Water supply is obtained from two wells, one 6 inches by 375 feet, supplied from the St. Peter sandstone, the other 8 inches by 672 feet, drawing from the "Jordan" sandstone. Ice supply is cut from Browns Lake and from Blue Earth River. Sanitary sewerage, discharging into Blue Earth River, is installed. Garbage is hauled to the public dumping ground.

Browns Valley, Traverse County.—On the low divide between Lakes Traverse and Big Stone. Drainage goes to Big Stone Lake. Water supply is obtained from springs on the east side of the bluffs; ice supply from Lake Traverse. No sewerage. Garbage is hauled out of town and dumped at several points.

Canby, Yellow Medicine County.—On Canby Creek 46 miles above the mouth of Lac qui Parle River. Has a public water service for fire protection only. Ice supply is cut from Canby Creek east of the city. No sewerage. Garbage is taken to the city dumping ground and burned.

Chaska, Carver County.—On Chaska Creek at its entrance into Minnesota River. Water supply, used chiefly for fire protection, is obtained from an 8-inch artesian well 640 feet deep; ice supply from Minnesota River above the city. No sewerage. Garbage is hauled out of town.

Elmore, Faribault County.—Drains to Blue Earth River. Water supply is obtained from a 6-inch drilled well 300 feet deep; ice supply from a small lake and from the river. No sewerage. Garbage is hauled one-half mile out of town to a dumping ground.

Fairmont, Martin County.—Lakes George and Sisseton, which drain by Center Creek to Blue Earth River, receive the surface drainage of the city. Water supply is taken from Lake Budd, a short distance south of the city; ice supply from Lakes George and Budd. No sewerage. Garbage is hauled to the city dumping ground.

Glenwood, Pope County.—On north shore of Lake Minnewaska, from which the ice supply is taken. Water supply is obtained from springs, which flow into a large concrete basin properly protected against pollution. A sanitary sewerage system, equipped with a septic tank, is installed, discharging its effluent into the lake. Garbage is commonly dumped on low ground and covered with earth.

Granite Falls, Yellow Medicine County.—On Minnesota River 16 miles below the mouth of Chippewa River. The only considerable water power on the stream is located at this point. Water supply is taken from Minnesota River. The water goes by a canal from above the dam to the waterworks plant, where it is passed through a bed of coarse gravel and sand into a well. Since the well is at the base of a high gravel bluff there is probably a large ground flow to the well. Ice supply is cut from Minnesota River above the dam. No sewerage. Garbage is hauled to a dumping ground outside the city limits.

Henderson, Sibley County.—On Minnesota River 73 miles above its mouth. Ice supply is taken from a small lake near the city. No systematic garbage disposal. No report on waterworks or sewerage.

Janesville, Waseca County.—At south end and near the outlet of Lake Elysian, which drains by Lesueur River into Blue Earth River. Water supply is obtained from a 3-inch tubular well 75 feet deep. It passes through 61 feet of clay into sand and gravel. No sewerage. Ice supply is cut from Lake Elysian 2 miles above its outlet. There is no public garbage disposal, but each resident takes care of his own household waste.

Jordan, Scott County.—On Sand Creek, about 7 miles above its entrance into Minnesota River. Ice supply is cut from Sand Creek above the dam. Garbage is hauled to the village dumping ground. No report on waterworks or sewerage.

Lake Benton, Lincoln County.—At south end of Lake Benton on the divide. Water supply is procured from a well; ice supply from

Lake Benton, northeast of town. No sewerage. Garbage is hauled outside the village to the regular dumping ground.

Lake Crystal, Blue Earth County.—On shore of Crystal Lake. Water supply, for fire purposes only, is obtained from an 8-inch well, 775 feet deep, drawing water from the rock. Ice supply is cut from Crystal Lake. No sewerage. Garbage is removed to the village dumping ground and covered with earth.

Le Sueur, Lesueur County.—On Minnesota River, 82 miles above its mouth. Water supply is obtained from one 8-inch well, 668 feet deep in the rock; ice supply from Minnesota River. Sanitary sewerage discharges into Minnesota River. Garbage is hauled to the village dumping ground and burned.

Madelia, Watonwan County.—Near Watonwan River, just below the junction of North and South forks. Water supply is procured from two 6-inch wells, each 206 feet deep; ice supply from three lakes near the village. Sanitary sewerage discharges into Watonwan River. Garbage is hauled to a dumping ground near Watonwan River.

Madison, Lac qui Parle County.—Five miles from Lac qui Parle River. Water supply, for fire protection only, is derived from cisterns in the city. Ice supply is cut from Lac qui Parle River and some small lakes. No sewerage. Garbage is removed to the city dumping ground, where it is sometimes burned.

Mankato, Blue Earth County.—On Minnesota River, just below the entrance of Blue Earth River. Water supply is obtained from two artesian wells, 650 feet deep in the rock. Ice supply is cut from Minnesota River, above the city. Sanitary and storm sewerage discharges into Minnesota River. Garbage is commonly hauled outside the city limits and dumped. The Second State Normal School and St. Joseph's Hospital are situated in this city.

Mapleton, Blue Earth County.—Drainage to Blue Earth River by way of Little Cobb Branch and Lesueur River. Water supply is obtained from a deep well. A combined system of sewerage discharges into Little Cobb River. Ice supply is cut from an artificial lake supplied by wells. Garbage is hauled to the village dumping ground.

Marshall, Lyon County.—On Redwood River, 45 miles above its mouth. Water supply is procured from an artesian well, 410 feet deep in the rock, and a dug well, 40 feet deep by 12 feet in diameter, with two driven pipes in the bottom, 4 inches by 70 feet and 9 inches by 90 feet, respectively. An 8-inch well, 250 feet deep, is used for the boiler supply and there is also an emergency pipe to Redwood River. Ice supply is cut from Redwood River on the outskirts of the village. A sanitary and storm sewerage system discharges into Redwood River. Garbage is hauled outside the city.

Milbank, Grant County, S. Dak.—On Whetstone River, 12 miles above its entrance into Minnesota River. Water supply is obtained from deep wells in the town; ice supply from Whetstone River above the city. A combined system of sewerage is in process of construction. Garbage is hauled outside the city and burned or covered with dirt.

Minneota, Lyon County.—On south branch of Yellow Medicine River. Water supply is obtained from a 6-inch tubular well, 105 feet deep, drawing from the sandstone; ice supply from Yellow Medicine River. A combined sewerage system discharges into the river. Garbage is collected and burned regularly, except during the winter.

Montevideo, Chippewa County.—On Chippewa River, 1 mile above its entrance into Minnesota River. Water supply is taken from collecting galleries sunk in an uninhabited gully 3 miles north of town; ice supply from Chippewa and Minnesota rivers. A combined sewerage system discharges into Chippewa River. Garbage is hauled to the village dumping ground.

Montgomery, Lesueur County.—Drained by a county ditch to a neighboring lake, which connects with Minnesota River. Water supply is procured from a 10-inch well 238 feet deep; ice supply from Lake Pepin, north of the city. No sewerage. No systematic garbage disposal.

Morris, Stevens County.—Drained to Pomme de Terre River, 2 miles east of town. Water supply is taken from five 8-inch wells 78 feet deep, one mile east of the city; ice supply from Pomme de Terre River. No sewerage. A United States Indian School situated near the city is supplied with city water and discharges its sewage into the river after it has passed through a septic tank. Garbage is hauled to dumping grounds outside the city limits.

Morton, Renville County.—On Minnesota River about 6 miles below the entrance of Redwood River. Water supply is procured from springs in a gravel bluff above the village level; ice supply from Minnesota River. No sewerage. Garbage is removed to a dumping ground outside the village limits.

Mountain Lake, Cottonwood County.—Between the North and South forks of Watonwan River. Water supply is obtained from a well in the village, 10 feet deep, provided with a stone curbing. Ice supply is cut from a creek near the village. No sewerage. Garbage is removed to the public dumping grounds.

New Prague, Scott and Lesueur counties.—Water supply is procured from an 8-inch well 300 feet deep; ice supply from an artificial lake in the city. No sewerage. No systematic garbage disposal.

New Ulm, Brown County.—On Minnesota River, 22 miles above Mankato. Water supply is obtained from wells in the city, about 200 feet deep, two with 6-inch, three with 8-inch, and one with 10-inch casing.

They are said to go through 145 feet of clay and 20 feet of sandstone to granite. Ice supply is cut from Minnesota River. A combined sewerage system discharges into Minnesota River. Garbage is hauled to the city dumping ground and buried.

Olivia, Renville County.—Drains to Minnesota River by way of the east fork of Beaver Creek. Ice is commonly not cut in the vicinity, but is shipped in from Granite Falls. Garbage is hauled into the country. No report on waterworks or sewerage.

Ortonville, Bigstone County.—At the foot of Big Stone Lake on Minnesota River. Water supply is procured from a dug well, 45 feet deep by 26 feet in diameter; ice supply from Big Stone Lake, 1 mile from the city. No sewerage. There is no systematic garbage disposal.

Ottawa, Lesueur County.—On Minnesota River, 90 miles above its mouth. No waterworks or sewerage. Ice supply is cut from Minnesota River.

Redwood Falls, Redwood County.—On Redwood River, just above its entrance into Minnesota River. Water supply is obtained from a dug well in the outskirts of the village, 12 feet in diameter by 20 feet in depth. There is also a connection with Redwood River for use in emergencies. Ice supply is cut from Redwood River above the dam. A sanitary sewerage system discharges into Redwood River below the dam.

Renville, Renville County.—Connected with Minnesota River by Sacred Heart Creek. Water supply is obtained from an 8-inch well, 230 feet deep, passing through about 180 feet of clay into water-bearing sand. Ice supply is obtained from Granite Falls. No sewerage. Garbage is removed to the village dumping grounds.

St. James, Watonwan County.—Drains to Watonwan River by St. James Creek. Water supply is obtained from one well 8 inches by 185 feet; one well 10 inches by 385 feet, for domestic use; and one dug well 40 feet deep, for boiler use. Ice supply is cut from St. James Lake, west of the city. A sanitary sewerage system discharges into St. James Creek. Garbage is hauled to the dumping grounds below the city.

St. Peter, Nicollet County.—On Minnesota River, 97 miles above its mouth. Water supply is obtained from an 8-inch well 350 feet deep; ice supply from a small lake at the foot of the bluffs. A storm sewerage system discharges into Minnesota River. Garbage is commonly hauled to the city dumping ground. Gustavus Adolphus College, with about 350 students, and the First State Hospital for the Insane, with 1,000 to 1,200 inmates, are located at this place. The water supply for the hospital is procured from two 6-inch wells, 260 feet deep, in water-bearing sandstone. A sanitary sewerage system from the hospital empties into Minnesota River.

Shakopee, Scott County.—On Minnesota River, 26 miles above its mouth. No waterworks or sewerage. Ice supply is cut from Minnesota River. Garbage is hauled to the village dumping ground.

Sherburne, Martin County.—Near Temperance Lake. Water supply is obtained from an artesian well; ice supply from Fox Lake, 2 miles north of Sherburne. Sewerage not reported. Garbage is removed to the city dumping ground.

Sleepy Eye, Brown County.—Drains to Big Cottonwood River by way of Sleepy Eye Creek. Water supply is procured from a dug well in the center of town, 20 feet in diameter and about 20 feet deep. In the bottom of this pit a casing is driven to rock. Ice supply is cut from Sleepy Eye Lake and Cottonwood River. No sanitary sewerage. Garbage is regularly removed to the city dumping ground.

Springfield, Brown County.—On Big Cottonwood River. Water supply, for fire protection and sprinkling only, is obtained from a 6-inch well 28 feet deep, in the village. Ice supply is cut from Big Cottonwood River above the dam. No sewerage. Garbage is occasionally hauled outside the village.

Tracy, Monroe Township, Lyon County.—Water supply is obtained from a 10-inch drilled well, 500 feet deep; ice supply from Lake Sigel. No sewerage. Garbage is hauled to the village dumping ground.

Waconia, Carver County.—On south shore of Clearwater (Waconia) Lake. No public water supply. Ice supply is cut from Clearwater Lake. Storm sewerage has been installed, but no sanitary system. Garbage is hauled to the village dumping ground.

Waseca, Waseca County.—A short distance from Clear Lake. Water supply is procured from two artesian wells, 10 inches by 400 feet and 10 inches by 1,000 feet, respectively. Ice supply is cut from Clear Lake. No sewerage. No regular garbage disposal.

Wells, Clark Township, Faribault County.—Water supply is obtained from a 12-inch artesian well and an 8-inch well, 200 feet deep. Ice supply is cut from an artificial lake, which is filled with water from the public supply. A combined sewerage system is installed, the outlet of which is not reported.

Westbrook, Cottonwood County.—Near Double Lake, which discharges into Cottonwood River. The village is equipped with water service for fire protection only. No sewerage.

Willmar, Kandiyohi County.—Near Foot Lake, which discharges by way of Hawk Creek into Minnesota River. Water supply is obtained from wells 240 feet deep; ice supply from Eagle Lake, 5 miles northeast of the city. The city has storm and sanitary sewerage.[a]

Winnebago, Faribault County.—One and one-half miles east of Blue Earth River. Water supply is obtained from an 8-inch well, 283 feet

[a] Baker, M. N., Manual American Waterworks, 1897, p. 454.

deep, ice supply from Blue Earth River. No sewerage. Garbage is hauled to the village dumping ground.

Winthrop, Sibley County.—Near the North Branch of Rush River, to which its surface drainage goes. Water supply is procured from a 10-inch drilled well, 239 feet deep, which passes through about 200 feet of blue clay into water-bearing gravel and sand. Ice supply is cut from Sand Lake, 3 miles from the village. No sewerage. Garbage is hauled to a dumping ground 2 miles from the village.

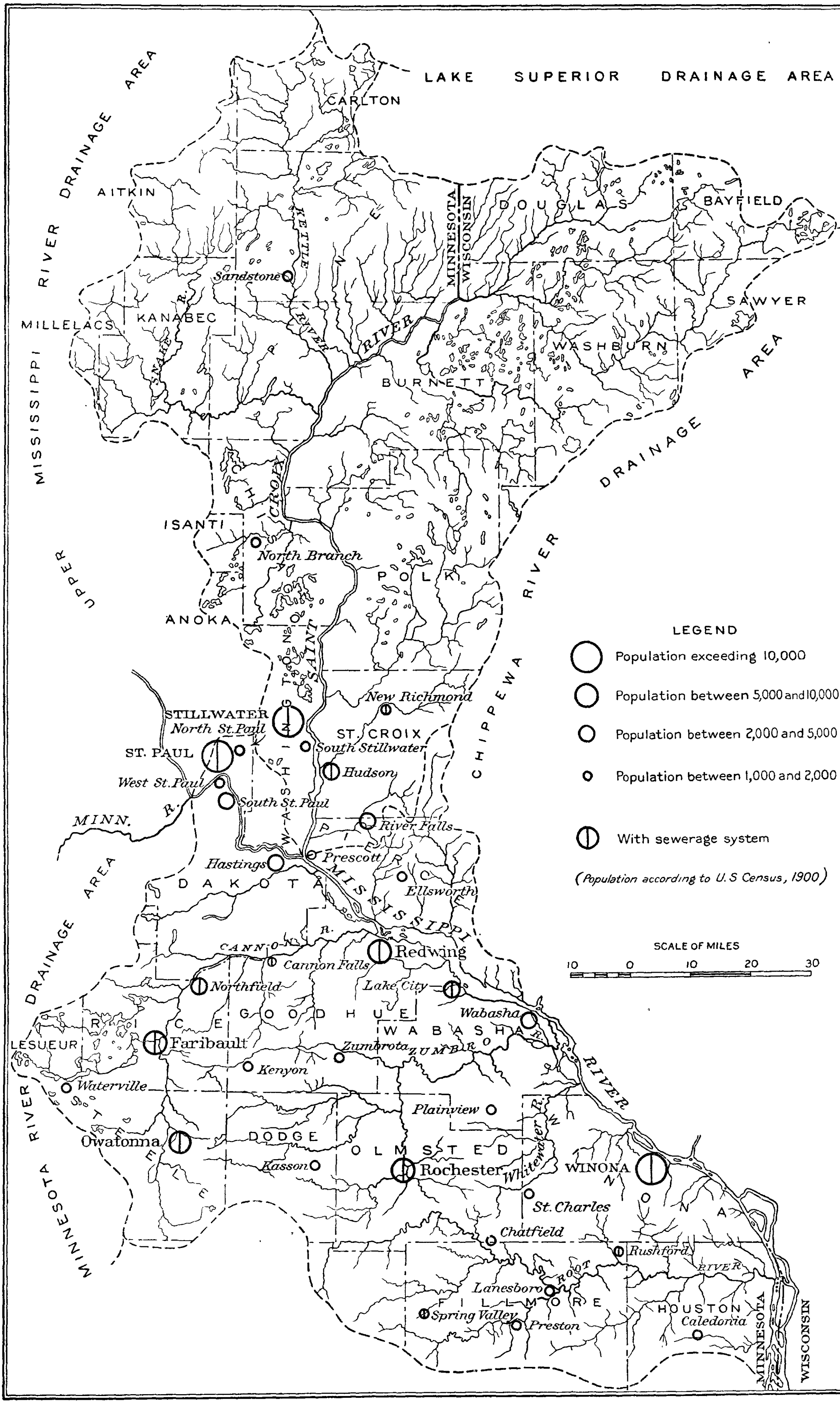
ST. CROIX RIVER BASIN.

GENERAL DESCRIPTION.

Boundaries.—The St. Croix basin is bounded on the east by Chippewa River drainage area, on the west by upper Mississippi River drainage area, and on the north by drainage areas of streams tributary to Lake Superior. It forms part of the boundary between Minnesota and Wisconsin. (Pl. IV.)

Character and slope of St. Croix River.—St. Croix River has its head in Upper St. Croix Lake, a body of water in Township 45 N., R 11 W., Douglas County, Wis., about 25 miles east of the Minnesota-Wisconsin boundary. This lake, which is 4 miles long and one-half mile wide, is fed by many springs from its sandy bed and along its banks. After emerging from this lake, the river flows generally southwestward for 70 miles to the mouth of Kettle River, and thence pursues a more southerly direction to its confluence with the Mississippi. Its watershed comprises many forests of pine and hard wood, dotted by cedar or tamarack swamps. The major part of the territory was formerly covered with timber, but steady encroachments have been made upon it from the south until much of it has been converted into farms. The river is navigable for light-draft vessels from its mouth to The Dalles of the St. Croix at Taylors Falls. At St. Croix Boom, one mile above Stillwater, the river spreads out to form a lake one-half mile to 1 mile wide, which continues to Prescott. This sheet of water, 25 miles long and 6 to 15 feet deep, has a barely perceptible current, except during flood times. At its lower end it narrows abruptly to a channel about 100 feet wide, which connects with Mississippi River 3 miles below Hastings. St. Croix River flows for the most part between high bluffs of gravel or of rock. It is extensively used for logging purposes. Numerous lakes lie within its drainage area, especially in the upper part of the valley, though none of them are of large size.

In the first 20 miles of its course, including Upper St. Croix Lake, the river falls but little. (Pl. V.) It then enters upon a series of



MAP OF ST. CROIX AND LOWER MISSISSIPPI RIVER BASINS IN MINNESOTA.

rapids which extend to the mouth of Yellow River, 28 miles, and in which the average slope is 4.2 feet per mile. The stream then continues with a slope of 1.6 feet per mile to the head of Kettle River Rapids. A section of rapid descent extends thence to the head of navigation at Taylors Falls, in which the river falls about 3.5 feet per mile. Below this point the grade is slight, so that from Stillwater to Prescott there is hardly any fall at all. In the last 50 miles of the river's course, the navigable portion, there is a grade of 0.3 foot per mile. The principal falls are Kettle River Rapids, at the mouth of Kettle River, and St. Croix Falls, just above Taylors Falls village. In the 170 miles from the mouth of the river to the head of Upper St. Croix Lake there is a total fall of 345 feet, or an average of 2 feet per mile.

Tributaries of St. Croix River.—Many short streams enter St. Croix River. (See Pl. IV.) Kettle River, its largest tributary, rises in Township 49 N., R. 14 W., Carlton County, Minn., and flows in a southerly direction across the open, sandy lands of Carlton and Pine counties to its entrance into St. Croix River. It has several falls, especially in its lower course, where it drops 185 feet in 25 miles. Namekagon River, the tributary second in size, is the outlet of Namekagon Lake, which is located in the central part of Buffalo County, Wis. The river flows southwestward, then westward, entering St. Croix River 133 miles above its mouth. It is a forest stream, much used for logging purposes. The following list gives the chief tributaries of St. Croix River, with the area drained by each and the distance from its mouth to Prescott:

TABLE 41.—*Principal tributaries of St. Croix River.*

Tributary.	Drainage area.[a]	Distance of mouth above Prescott.
	Sq. miles.	*Miles.*
Apple	427	30
Clam	416	108
Kettle	1,093	95
Namekagon	1,025	133
Snake	937	92
Yellow	310	122

[a] Water powers of the United States, Tenth Census U. S., pt. 2, sec. 2, p. 77.

Geology.—The formations which, in other sections of the State, especially in its western half, make drainage water hard or alkaline are absent from St. Croix Valley. Drift generally covers the area to a depth of 75 to 100 feet, except in the deeper valleys, so that outcrops of rock are infrequent and limited in extent. Trap appears in the valleys of Pine County and at Taylors Falls in Chisago County, where precipitous walls of it extend along the river for some distance. In Kanabec County the limited exposures are coarse-grained syenite, granite, and schist. Sandstone is seen along Kettle River and is found extensively in the southern part of the main valley. Limestone, which underlies most of Washington County, is in sight at Stillwater.[a] Cretaceous formations apparently do not lie in this basin. The most important geologic feature from a hydro-economic view is the apparent absence of calcareous rocks in the upper part of the valley around the headwaters of the principal streams.

Soil and subsoil.—The transported Pleistocene materials are derived mainly from areas of early rocks around Lake Superior and were deposited as bowlder clay or till, in which water-bearing beds of sand and gravel are found. There are many areas of stratified gravels and sands of the modified drift. Alluvium similar to that in lower Mississippi Valley occurs along St. Croix River bottom as far north as Taylors Falls. Throughout Chisago and Isanti counties a yellow gravel and sand subsoil is found and sandy soils occur in many parts of the area. The following table gives averages of analyses of soil from different parts of St. Croix Valley made by the Minnesota Agricultural Experiment Station:

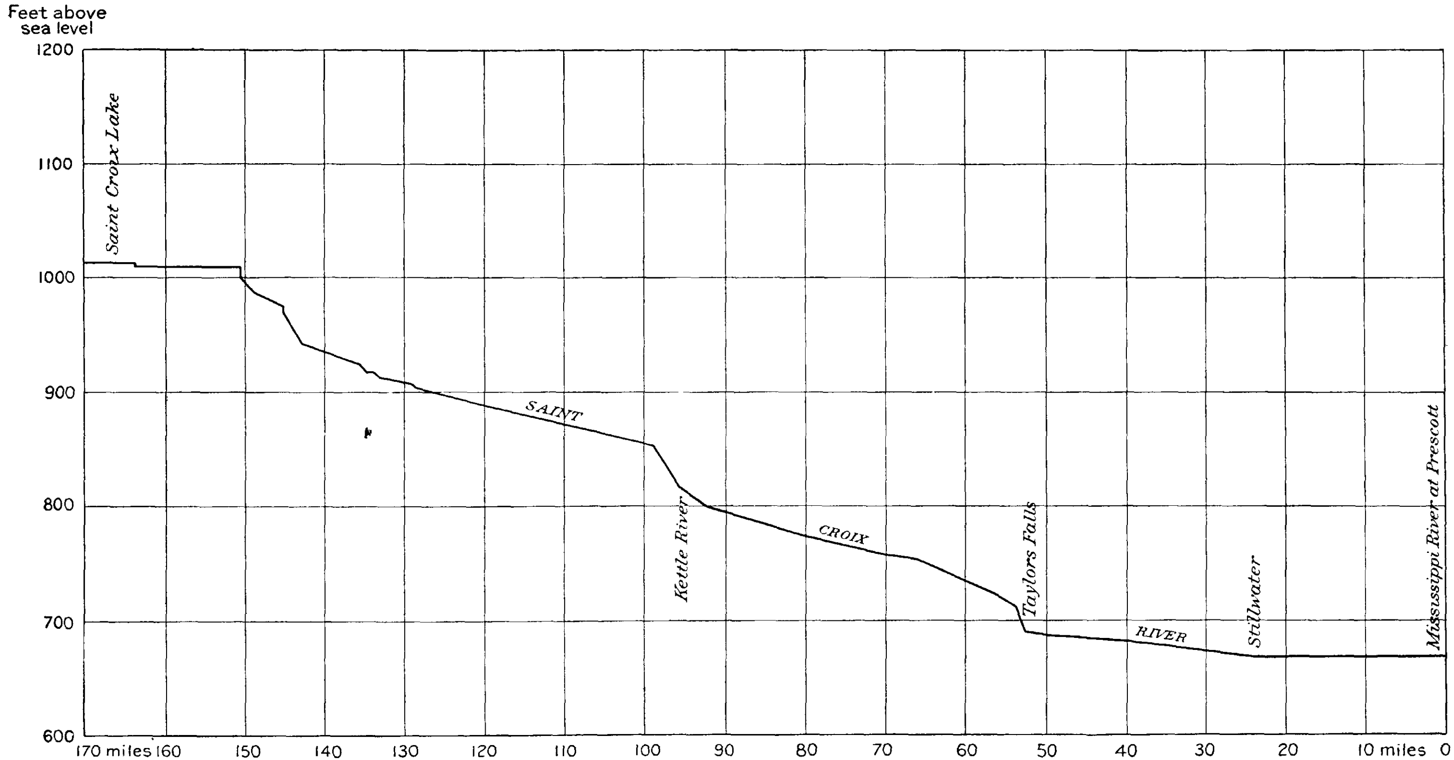
TABLE 42.—*Chemical composition of soil and subsoil in St. Croix River basin.*

	Surface soil.		Subsoil.	
	St. Croix River basin.	Entire State.[a]	St. Croix River basin.	Entire State.[a]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Insoluble in HCl	86.64	79.92	86.97	82.41
Volatile	3.65	8.98	3.91	5.33
Potassium oxide (K_2O)	.19	.43	.23	.40
Sodium oxide (Na_2O)	.19	.45	27	.32
Calcium oxide (CaO)	.48	1.29	.36	1.78
Magnesium oxide (MgO)	.28	.61	.32	.80
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	5.70	7.20	6.57	8.32
Phosphoric anhydride (P_2O_5)	.41	.20	.42	.17
Sulphuric anhydride (SO_3)	.07	.10	.06	.06
Carbonic anhydride (CO_2)	.09	.62	.09	.93

[a] Snyder, H., Characteristic features of Minnesota soils: Bull. 65, Agr. Exp. Sta., University of Minnesota, Chem. Div., Nov., 1899, p. 69.

These averages show characteristics pertaining to sandy soils. Siliceous matter is high, while all other constituents are low, both soil and subsoil containing about half as much as the State in general of those ingredients known as incrustants. Calcium, magnesium, and sulphuric and carbonic acids are small in amount and there is little sodium or potassium. As a result of this composition of the upper drift layers the water of St. Croix River is one of the softest in the State.

[a] Minn. Geol. and Nat. Hist. Survey, Final Rept., vol. 2, Geology of Washington, Isanti, Kanabec, Chisago, and Pine counties.



PROFILE OF ST. CROIX RIVER.

Reproduced from Exhibit Q, Lake Superior and Mississippi Canal, H. Doc. 330, Fifty-fourth Congress, first session.

INDUSTRIAL POLLUTION.

Twenty-three[a] establishments in St. Croix basin were reported as likely to furnish wastes of deleterious character.

TABLE 43.—*Industrial establishments causing stream pollution in St. Croix River basin.*

Breweries	5
Gas works	1
Sawmills	13
Starch factories	4

The breweries are small and their effluents are not large in amount.

Lumbering.—Lumbering is still the principal industry, and the industrial pollution from this source is important. Nine large sawmills are located at Stillwater and South Stillwater on Lake St. Croix. The logs are boomed and stored on the lake. After the lumber is sawed much of it is rafted down the river. Doubtless a large amount of the color in St. Croix River is due to dissolved resins and other extractives from the logs floated in the water and from the sawdust, bark, and other kinds of refuse that reach the stream. During the past ten years from 300,000,000 to 350,000,000 feet of logs have been run annually on St. Croix River above Stillwater.[b] The waste from this industry is not, however, specifically dangerous or likely to become noxious during putrefaction. It is undesirable because it increases the color and the organic content of the water and provides foci for the growth of bacteria.

Starch making.—Complaint was made in 1900 that Goose Creek, in Chisago County, was being polluted by a starch factory at Harris.[c] Inspection showed that the stream for 2 or 3 miles below the factory was full of potato gratings in an advanced state of putrefaction, and it was claimed that fish in the creek were killed by the waste. This condition is typical where the effluent from these factories is permitted to enter streams without previous purification. In the usual method for manufacturing starch from potatoes the tubers are first washed free from adhering dirt and sand by agitation in a revolving drum with brushes so placed as to scrub the potatoes. The waste water from this process contains the coloring matter of the skins, some particles of the peelings, and a large amount of dirt. The potatoes are then rasped or ground to a soft pulp, which is passed through a series of shaking sieves or revolving wire-gauze cylinders where the starch is washed out with water. After the suspended starch is removed from this liquid by levigation it still contains the soluble part of the potato, considerable potash, phosphoric acid, albumin, and other

[a] One sawmill in Ellsworth, Wis.; 1 in New Richmond, Wis.; 1 sawmill and 2 breweries in Hudson, Wis., and 1 starch factory in River Falls, Wis., are included in this number.

[b] Ann. Rept. Chief of Engineers, U. S. Army, 1901. p. 2332.

[c] Biennial Rept. State board of health of Minnesota for 1899–1900, p. 111.

nitrogenous matters, which rapidly become offensive by putrefactive fermentation.[a] These waste liquids can be used to irrigate land, while the pulp remaining after the starch is extracted can be pressed and dried for sale as a low-grade cattle food. There is no excuse for discharging this waste into streams, for with a small amount of care valuable materials which now create a nuisance could be economically recovered.

MUNICIPAL POLLUTION.

Population and pollution.—Stillwater and Taylors Falls, on the main stream, are two of the oldest places in the State. Pioneers attracted by the seemingly inexhaustible timber resources of the area built up a vast lumber industry, with its headquarters at Stillwater. Settlers seeking farms followed the lumbermen in their progress northward and are now turning the former forest lands into wheat farms. Up to the present time few large villages have been established in the drainage area, and the population, except the large percentage of it concentrated at Stillwater, is composed of farming communities and of inhabitants of lumber camps. The following table shows the distribution by counties of the total population in St. Croix Valley for three successive censuses. (See also Pl. IV.)

TABLE 44.—*Population in St. Croix River basin.*

County.	U. S. Census, 1890.	U. S. Census, 1900.	State Census, 1905.
Aitkin	200	388	686
Anoka	205	374	440
Bayfield, Wis	407	747	1,900
Burnett, Wis	4,393	7,478	9,261
Carlton	1,096	2,778	13,678
Chisago	10,359	13,248	14,341
Douglas, Wis	272	924	1,220
Isanti	235	372	452
Kanabec	1,579	4,614	6,194
Millelacs	200	300	400
Pierce, Wis	4,928	5,723	5,594
Pine	4,052	11,546	14,869
Polk, Wis	12,968	17,801	20,885
Sawyer, Wis	988	3,157	4,172
St. Croix, Wis	16,857	19,518	19,492
Washburn, Wis	2,761	4,991	2,439
Washington	23,308	24,996	25,908
Total population	84,718	118,955	141,931

TABLE 45.—*Density of population in St. Croix River basin.*

	Drainage area.	Inhabitants per square mile. 1890.	1900.	1905.
Above Stillwater:	*Sq. miles.*			
Entire area	[b] 7,000	5.7	9.8	13.0
Excluding chief settlements		5.6	9.6	12.8
Above Mississippi River:				
Entire area	[c] 7,655	11.1	15.5	18.5
Excluding chief settlements		8.4	12.4	15.2

[a] Thorp, F. H., Outlines of Industrial Chemistry, 1901, p. 360.
[b] Measured from best available maps.
[c] Gannett, H., Twelfth U. S. Census, Bulletin 1.

The number of inhabitants per square mile in the valley is considerably less than the average for the entire State. The distribution of both rural and urban populations is similar to that of the Mississippi area above Minneapolis. In the upper part of the basin the population is scant, only two villages, North Branch and Sandstone, having had more than 1,000 inhabitants in 1900. The lower part is more thickly inhabited and contains several important settlements, the largest of which, Stillwater, with a population of 12,435, is one of the industrial and commercial centers of the State. The growth of 10 per cent in these cities and villages during the last 15 years is small as compared with the rapid increase of villages in other parts of the State. During the same period an increase of 60 per cent in the total population of the area indicates an important occupation of territory by farmers and homesteaders. Within the last decade and a half the number of inhabitants per square mile in the area above Stillwater has more than doubled, and the part of the valley that was developed earlier has shown a decided increase. The population is not yet so dense as that of Minnesota Valley and there is still prospect of growth.

The portion of St. Croix Valley above Stillwater includes over 90 per cent of the basin, but is occupied by a little over 60 per cent of the population. The density of population is considerably less than in the St. Croix Valley as a whole. North Branch and Sandstone are the largest villages. Mora, Taylors Falls, St. Croix, and Pine City are other places of minor importance. None of these towns have sanitary sewerage, and the pollution of St. Croix River by them is not large.

The principal cities and villages of the valley of St. Croix River are situated a short distance above the confluence of this stream with the Mississippi.

TABLE 46.—*Principal settlements in St. Croix River basin.*

Place.	Distance above Mississippi River.	Population.		
		1890.	1900.	1905.
	Miles.			
Hudson, Wis	15	2,885	3,259	3,220
New Richmond, Wis	30	1,408	1,631	1,824
North Branch[a]	79	1,141	1,211	1,375
Prescott, Wis	0	911	1,002	889
River Falls, Wis	12	1,783	2,008	2,300
Sandstone	120	1,054	1,189	1,589
South Stillwater	20	1,453	1,422	1,572
Stillwater	23	12,004	12,318	12,435
Total urban population		22,639	24,040	25,204

[a] Including Branch Township.

Three of the six cities below and including Stillwater, having a population of 17,000, are equipped with sanitary sewerage. The larger two (see Table 46), Stillwater and Hudson, discharge their sewage without purification into the sedimentation basin of the lower river, called Lake St. Croix. It is probable that a great part of the sewage is rendered innocuous before it reaches Mississippi River. While the discharge of raw sewage into this part of the river can not be commended, the volume of pollution from these sources is insignificant when compared with the discharge of sewage into Mississippi River at Minneapolis and St. Paul.

Typhoid fever.—Comparatively few cases of typhoid fever occur in this region, doubtless because it is not thickly settled. Stillwater, the chief commercial center and the largest city in the area, has naturally the most typhoid fever. The use of Lake McKusick as a partial source of supply subjected the city to constant danger, because there was no provision against infection from houses and other buildings on the banks of the lake. Fortunately, no cases of typhoid fever were cared for in that immediate locality while the lake water was used, and this source of domestic supply has now been abandoned.

QUALITY OF WATER.

Two series of samples from St. Croix River were examined.[a] The first was taken in the fall of 1904, while the river was open and at an ordinary stage. The second was collected when the river was covered with ice about 30 inches thick and is fairly representative of winter condition. Examinations of Lake McKusick and Browns Creek at Stillwater were made during the summer and fall of 1904.

TABLE 47.—*Quality of water in St. Croix River basin.*[b]

[Parts per million.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron.
St. Croix River—									
Above Taylors Falls	Oct. 22, 1904	120	2 v.	35	0.8	0	45	49	0
Below Taylors Falls	do	162	2 v.	30	.8	0	45	49	0
Above Stillwater	Oct. 21, 1904	162	2 v.	17	1.0	0	58	63	0
Below Stillwater	do	148	2 v.	15	1.5	0	58	63	0
Above Prescott	Oct. 14, 1904	29	2 v.	9	.3	0	87	90	0
Above Taylors Falls	Mar. 15, 1905	18	2 v.	10	1.2	Trace.	91	84	1.0
Below Taylors Falls	do	22	2 v.	10	1.4	Trace.	72	67	1.0
Above Stillwater	Mar. 16, 1905	18	2 v.	9	1.4	Trace.	95	90	1.0
Above Prescott	Feb. 11, 1905	25	1 v.	<7	1.1	[c]5	108	111	Trace.
Lake McKusick at Stillwater, average of five analyses	Aug. 15, 1904	40	3 v.	<7	1.1	....	139	135	....
Browns Creek at Stillwater	Oct. 1, 1904	25	2 v.	<7	.7	....	182	188	....

[a] See Pl. I for location of sampling stations.
[b] Chemical analyses by R. B. Dole. Bacteriological examinations by Dr. E. H. Beckman.
[c] Estimated.

TABLE 47.—*Quality of water in St. Croix River basin*—Continued.

[Parts per million.]

Locality and source.	Date.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Bacteria per c. c.	B. coli communis.
St. Croix River—									
Above Taylors Falls	Oct. 22, 1904	115	9	0.192	0.098	0.000	0.04	3,500	+
Below Taylors Falls	.....do.......	120	10	.192	.092	.000	.04	4,800	+
Above Stillwater	Oct. 21, 1904	127	8	.420	.052	.000	.04	2,400	+
Below Stillwater	.....do.......	112	9	.408	.046	.000	.04	1,300	+
Above Prescott	Oct. 14, 1904	118	8	.210	.054	.000	.05	670	+
Above Taylors Falls	Mar. 15, 1905	129	9	.162	.024	.000	.05	750	−
Below Taylors Falls	.....do.......	110	10	.402	.180	Trace.	.05	1,100	−
Above Stillwater	Mar. 16, 1905	133	8	.140	.022	.000	.05	400	+
Above Prescott	Feb. 11, 1905	132	7	.194	.014	.000	.10	64	−
Lake McKusick at Stillwater, average of five analyses	Aug. 15, 1904	183	15	240	.434	.12	.19	1,400	+
Browns Creek at Stillwater.	Oct. 1, 1904	208	11	.078	.024	.007	.45	1,700	+

The characteristic effect of woodland drainage is seen in the high albuminoid ammonia, color, and odor. On the other hand the mineral content is low. There is practically no sulphuric acid present and very little chlorine or iron. The turbidity is low for the samples examined, and the amount of suspended matter is never excessive. The low hardening constituents, which are principally bicarbonates of calcium and magnesium, indicate that the stream is excellent for boiler use.

B. coli communis was isolated in pure culture from every sample taken in the fall, while in the winter it was found only above Stillwater. The number of bacteria per cubic centimeter was found to be considerably lower in winter than in fall. It is especially significant that both examinations at Prescott show a diminution in the number of bacteria present. Two other examinations of water from the river at Prescott also gave very small numbers of bacteria; on August 29, 1903, 45 colonies were counted, and on June 8, 1904, there were 130, while *B. coli communis* was not isolated in either case.

The effect of sedimentation is further shown by the reduction in color, odor, turbidity, albuminoid ammonia, and free ammonia, and the increase in nitrates. At the same time there is an increase in alkalinity, hardness, and total residue, probably due to the introduction of ground water from the limestone region along the shores of Lake St. Croix. The same changes were noted between summer and winter conditions as in other streams; the nitrogens, color, and bacterial content decrease, while all amounts representing mineral matter are increased, showing the effect of a change in the percentage of underground flow to the river. The principal features to be noted in regard to the quality of this water are that it drains from a wooded, swamp, and farming country, not very thickly settled; that there are no serious industrial pollutions in the area; that it is softer than that of the other two great tributaries of Mississippi River in Minnesota; that the small amount of municipal pollution is largely eliminated by sedimentation and oxidation in Lake St. Croix.

In conclusion a table is given showing the average of nine analyses of the river water, with the maximum and minimum determinations. The water is likely to vary considerably from these figures because they do not represent examinations made over a long period.

TABLE 48.—*Summary of quality of water of St. Croix River.*

[Parts per million.]

Determination.	Maximum.	Minimum.	Average.
Color	162	18	70
Odor	2 v.	1 v.	2 v.
Turbidity	35	<7	14
Chlorine	1.5	0.3	1.0
Sulphate radicle	[a] 5	0	Trace.
Alkalinity	108	45	89
Total hardness	111	49	89
Iron	1.0	0	Trace.
Total residue	133	110	135
Soluble residue	10	7	9
Free ammonia	.180	.014	.094
Albuminoid ammonia	.420	.140	.239
Nitrates	.10	.04	.05
Nitrites	Trace.	.000	.000

[a] Estimated.

NOTES ON MUNICIPALITIES.

Of the 8 Minnesota settlements mentioned below wells are reported as public water supplies from 5. Sanitary sewerage has been installed at only one place.

Hudson, St. Croix County, Wisconsin.—On St. Croix River at the mouth of Willow River. Water supply is taken from two 8-inch artesian wells, 250 and 500 feet deep, respectively, which enter sandstone at 15 feet and are supplied from it. Ice supply is procured from Willow River and from St. Croix River, which is at this point known as Lake St. Croix. A sanitary sewerage system discharges into St. Croix River.

Mora, Kanabec County.—On Snake River 30 miles above St. Croix River. Water supply is procured from one 10-inch driven well, 210 feet deep; ice supply from Lake Mora. No sewerage. Garbage is hauled to the public dumping ground.

New Richmond, St. Croix County, Wisconsin.—On Willow River 15 miles above its mouth. Water supply is obtained from a 6-inch well, drilled 185 feet deep; ice supply from Willow River above the dam. A combined sanitary and storm sewerage discharges into Willow River. Garbage is hauled to the village dump.

North Branch, Chisago County.—On North Branch River 8 miles above St. Croix River. No waterworks, sewerage, or public garbage disposal. Ice supply is cut from two small lakes near the village.

Pine City, Pine County.—On Snake River at the outlet of Cross Lake. No waterworks or sewerage. Ice supply is cut from Snake River. Garbage is buried or burned at the village dumping ground. A private sanitarium for the treatment of tuberculosis is situated above the town.

Prescott, Pierce County, Wisconsin.—At confluence of St. Croix and Mississippi rivers. No waterworks or sewerage. Ice supply is cut from Lake St. Croix. Garbage is carted outside the village limits and burned.

River Falls, St. Croix and Pierce counties, Wisconsin.—On Kinnickinnic River, 12 miles above Prescott. Water supply is obtained from artesian wells 550 feet deep. There is no public sewerage. Ice supply is cut from the mill pond on Kinnickinnic River. Garbage is hauled outside the city limits.

Rush City, Chisago County.—On Rush Creek. Water supply, for fire protection only, is obtained from shallow wells. Ice supply is cut from Rush Lake. No sewerage. Garbage is hauled outside the village limits.

Sandstone, Pine County.—On Kettle River, about 25 miles above St. Croix River. Water supply is derived from two wells drilled in sandstone, 12 inches by 750 feet and 10 inches by 150 feet, respectively. Ice supply is cut from Miller and Wolf lakes. No sewerage. Garbage is hauled to the village dumping ground, where all putrescible matter is burned.

South Stillwater. Washington County.—On St. Croix River, 20 miles above its mouth. Water supply, for fire protection only, is procured from a dug well 25 feet deep by 20 feet diameter, on the bank of a brook, with which there is also an emergency connection. Ice supply is cut from St. Croix River. No sewerage. Garbage is hauled to the public dumping grounds.

Stillwater, Washington County.—On St. Croix River 23 miles above its confluence with Mississippi River. Has two distinct water systems. One, for drinking and domestic use only, is supplied by a spring in the sand rock and a deep well, both located in the central part of the city. The deep well, drilled 2,640 feet deep and 8 inches in diameter, was cased 650 feet and afterward plugged at 750 feet,[a] so that the water is probably derived from the "Potsdam" sandstone. The other water system, for fire protection and boiler use, is supplied by Lake McKusick, a small shallow body of water on the outskirts of the city. The ice supply is taken from Lily Lake, within the city limits, and from St. Croix River in front of the city. The sewerage discharges by two main outlets into St. Croix River near the bridge. The Minnesota State prison is situated near St. Croix River, in the

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[a] The Stillwater deep well; review of paper by A. D. Meeds, read before the Minnesota Academy of Natural Sciences: Am. Geol., vol. 3, 1889, p. 342; Science, vol. 13, No. 329, p. 401.

northern part of Stillwater. Its sewage is discharged into St. Croix River.

Taylors Falls, Chisago County.—On St. Croix River 52 miles above its mouth. No waterworks or sewerage. Ice supply is cut from Thaxter Lake, Wisconsin. Garbage is commonly hauled outside the village limits.

MISSISSIPPI RIVER BASIN BETWEEN MINNESOTA RIVER AND THE IOWA LINE.

GENERAL DESCRIPTION.

Area discussed.—Above the southern border of Minnesota the Mississippi River basin extends over nearly one-half of Minnesota and Wisconsin, including the area drained by Minnesota, St. Croix, Chippewa, and Black rivers. The area considered under this heading includes the portions of Minnesota that are drained by Mississippi River below Minnesota River except the St. Croix basin (Pl. IV), which is described under a separate heading. Examinations of the main stream were, however, made only as far south as the foot of Lake Pepin, just above the entrance of Chippewa River, near Wabasha, Minn. Consequently, the discussion of the quality of water in this lower section is confined to that part of the basin that lies above the mouth of Chippewa River. The consideration of municipal pollution above that point must necessarily have reference to settlements on the upper portion of the Mississippi, on the Minnesota, and on the St. Croix. In addition there is presented a brief summary of conditions in settlements of the Minnesota portion of the area.

Character and slope of Mississippi River.—After passing Minneapolis, the Mississippi assumes the appearance that characterizes its lower sections. From a swift running, highly colored stream it becomes sluggish, receives considerable suspended matter from its tributaries, and spreads out over a wide alluvial bottom cut by sloughs and dotted with islands. Its slope is greatest from St. Anthony Falls to the mouth of Minnesota River, a stretch in which the stream passes through a deep, wide gorge which it has excavated during the gradual recession of the falls. After it is joined by Minnesota River it commences to occupy a broad valley, through which it runs in a tortuous course. St. Croix River enters from the north 32 miles below Minnesota River. The Mississippi then pursues a southeasterly course to the State border. Its valley is from 2 to 3 miles wide and 50 to 200 feet deep, with sandstone and lime rock frequently exposed along its banks. The river follows several channels, commonly called "sloughs," and its bed is sand, gravel, and fine silt. Twenty-five miles below the entrance of St. Croix River it broadens in a body of water called Lake Pepin, about 23 miles long and 3 miles wide, through which there is a gentle current at all times. Below

Lake Pepin it again assumes its character as a stream of many chanels. It is joined immediately by Chippewa River from the east, and a few miles farther down by Zumbro River from the west.

In the 172 miles from the mouth of Minnesota River to the Iowa boundary, Mississippi River falls a little over 72 feet, making an average slope of 0.42 foot per mile (see fig. 1). Lake Pepin, through which there is practically no fall, is seemingly an excellent place for the sedimentation and destruction of polluting matter received from the large cities upon its banks. At flood times, however, the water passes along swiftly and probably gets little purification between St. Paul and La Crosse.

Tributaries of Mississippi River.—The three larger tributaries on the west side below Minnesota River are Cannon, Zumbro, and Root rivers. The first, having its source in the northwestern part of Rice County, after performing a semicircle through Lesueur County, flows northeastward to Mississippi River near Red Wing. Straight River, its chief tributary, rises in the southern part of Steele County and, flowing northward, joins Cannon River at Faribault. Cannon River below this point is 80 to 85 feet wide and flows in a series of rapids and reaches of smooth water. Ten miles below Cannon Falls the stream becomes narrow, deep, and tortuous as it sinks to the alluvial plain bordering the main stream. Zumbro River is formed by the junction of three small branches in Wabasha County. In its upper part there are many rapids and shoals, but as it emerges from the high bluffs bordering Mississippi River the rapids become fewer and the stream deepens and grows winding, like the other tributaries. Root River rises in Mower County in two branches, which unite in Olmsted County, after which the river pursues an easterly course across Fillmore and Houston counties to its confluence with Mississippi River, a few miles above the State border. Chippewa and Black rivers are important streams that drain a large part of Wisconsin below Lake Pepin.

Topography.—The southeastern part of Minnesota is rolling prairie, bounded on the east by the wide, deeply eroded valley of Mississippi River, which is intersected at different points by large trenches bearing tributary streams. The area is now devoted to the cultivation of corn and wheat. The number of lakes in this section is small as compared with those in other parts of the State.

Geology.—The Archean and the Algonkian rocks, so common in other parts of the State, are not exposed below Minneapolis. Conspicuous formations throughout the counties in this part of the State are the sandstones and limestones of the Ordovician and the Cambrian. The "St. Croix" sandstone appears along the valley of Mississippi River. The coarse, friable St. Peter sandstone outcrops here and, gently dipping southward, becomes an important aquifer in the artesian basin of Iowa. Rocks of Trenton age, mainly limestones, occur all over the region, particularly in the southern counties. Occasional deposits belonging to the Cretaceous period appear in the western part of the basin, and Devonian rocks are found in the southern part of Mower and Fillmore counties. Drift of varying thickness covers all except about 3,000 square miles in the southeast corner of the State, which unites with similar country in Wisconsin, Iowa, and Illinois to form the "Driftless Area." The drift is thickest in the western part, where it is similar in character to that found in Minnesota Valley, being mainly blue till. Toward the east it becomes thinner and gradually blends with the red till. In the deep river bottoms stratified alluvial deposits of sand and gravel are found.

Soil and subsoil.—The soil and subsoil are similar to those of Minnesota River basin in chemical composition. They show a fair percentage of alkaline and alkaline-earth ingredients, though true "alkali" soils are not found. Toward the east they gradually lose this characteristic and contain less and less soluble ingredients.

INDUSTRIAL POLLUTION.

From lower Mississippi Valley there have been reported as likely to furnish effluents of undesirable character the following establishments:

TABLE 49.—*Industrial establishments causing stream pollution in lower Mississippi River basin in Minnesota.*

Breweries	20
Gas works	5
Sawmills	17
Tanneries	4
Woolen mills	3

Several large breweries are included in this list, and their effluents are all discharged into Mississippi River and its tributaries either directly or through the city sewers. This waste contains considerable nitrogenous matter that is capable of offensive putrefaction. The gas-works wastes vary according to the character of the process used and the care with which valuable ingredients are recovered. By-products in the manufacture of coal gas are coke, ammonia, and tar. The latter two, in liquid form, are sometimes discharged into streams, though this procedure is wasteful and is not countenanced by progressive establishments. The larger sawmills along Mississippi River use considerably less lumber than those on the upper tributaries. The tannery wastes are spent bark liquors, vat sludges, lime, and wash waters containing bits of flesh, hair, and other putrescible matter. Although there has been no complaint on this account, the same kind of pollution has caused a great deal of trouble in other parts of the United States and is likely to become a public nuisance if the establishments increase in size. The three woolen mills noted are small, and the wastes that reach the streams are wool scourings, soapy water, and waste dye liquors. The abattoirs, packing houses, rendering works, and stockyards of the slaughtering establishments at St. Paul discharge a great deal of objectionable material through private sewerage systems into Mississippi River. The pollution consists, mainly, of foul, bloody, wash water, yard drainage, and putrescent scraps of animal matter that pass through the skimming tanks. If Minneapolis, just above St. Paul, is included, the manufacturing establishments in this region exceed in number, size, and value of output all those in the rest of the State.

MUNICIPAL POLLUTION.

Population and sources of pollution.—Lower Mississippi Valley in Minnesota was the first part of the State to be settled and is now the most densely populated. Twenty-six towns (see Pl. IV) exceeding 1,000 population are situated in the valley, and the country surrounding them is well occupied by homesteads. The following table shows the distribution of population by counties:

TABLE 50.—*Population of Mississippi River basin in Minnesota below the mouth of Minnesota River, excluding St. Croix River basin.*[a]

County.	U. S. census of 1890.	U. S. census of 1900.	State census of 1905.
Dakota	17,368	18,848	20,299
Dodge	8,890	10,896	10,415
Fillmore	25,996	28,238	27,216
Goodhue	28,806	31,137	31,628
Houston	14,653	15,400	15,092
Lesueur	3,390	3,772	3,796
Mower	4,706	5,620	5,286
Olmsted	19,806	23,119	22,409
Ramsey	136,476	166,809	201,676
Rice	23,786	25,831	25,943
Steele	11,821	14,922	14,984
Wabasha	16,972	18,924	18,710
Washington	2,684	2,812	2,976
Waseca	1,650	1,733	1,608
Winona	33,797	35,686	35,836
Total population	350,771	403,747	437,874

[a] The statistics of population in St. Croix River basin are given in Table 44, p. 90.

TABLE 51.—*Density of population in Mississippi River basin in Minnesota.*

	Drainage area.	Inhabitants per square mile.		
		1890.	1900.	1905.
	Sq. miles.			
Mississippi River basin above Minnesota River	[a] 19,731	19.8	26.9	32.1
Minnesota River basin	[a] 16,350	15.7	25.1	26.0
St. Croix River basin	[b] 7,655	11.1	15.5	18.5
Mississippi River basin above foot of Lake Pepin:				
Entire area	[c] 46,586	21.9	28.5	32.3
Excluding chief settlements		12.2	16.4	17.9
Lower Mississippi basin in Minnesota:				
Entire area	[d] 6,260	56.0	64.5	69.9
Excluding chief settlements		23.9	25.3	24.6

[a] Ann. Rept. Chief of Engineers, U. S. Army, 1894, pt. 3, p. 1704.
[b] Gannett, Henry, Bull. 1, Twelfth Census U. S.
[c] Measured from best available maps.
[d] Hall, C. W., Geography and Geology of Minnesota, vol. 1, p. 151.

Mississippi River above the foot of Lake Pepin is the most heavily polluted stream in Minnesota, as is shown by the following table, which gives the names of the principal settlements above this point, the distance of each above the foot of the lake, and the population for three successive censuses.

TABLE 52.—*Principal settlements in Mississippi River basin above the foot of Lake Pepin.*

Locality.	Stream.	Distance above foot of Lake Pepin.	Population.		
			1890.	1900.	1905.
		Miles.			
Belle Plaine	Minnesota River	132	814	1,121	1,301
Cannon Falls	Cannon River	46	1,078	1,239	1,460
Chaska	Minnesota River	110	2,210	2,165	2,085
Faribault	Cannon River	73	6,520	7,868	8,279
Ellsworth, Wis		39	670	1,052	1,066
Hastings	Mississippi River	51	3,705	3,811	3,810
Hudson, Wis	St. Croix River	63	2,885	3,259	3,220
Jordan	Sand Creek	120	1,233	1,270	1,311
Lake City	Mississippi River	10	2,128	2,744	2,877
Minneapolis	do	89	164,738	202,718	261,974
New Richmond, Wis	Willow River	78	1,408	1,631	1,824
Northfield	Cannon River	62	2,659	3,210	3,438
North St. Paul		83	1,099	1,110	1,400
Owatonna	Straight River	93	3,849	5,561	5,651
Prescott, Wis	St. Croix River	48	911	1,002	889
Red Wing	Mississippi River	26	6,294	7,525	8,149
River Falls, Wis	Kinnickinnic Creek	60	1,783	2,008	2,300
St. Paul	Mississippi River	77	133,156	163,065	197,023
Shakopee	Minnesota River	106	1,757	2,047	2,069
South St. Paul	Mississippi River	73	2,242	2,322	3,458
Stillwater	St. Croix River	71	12,004	12,318	12,435
South Stillwater	do	68	1,453	1,422	1,572
Waterville	Cannon River	93	937	1,260	1,383
West St. Paul	Mississippi River	77	1,596	1,830	2,100
Total			357,129	433,558	531,068

By reference to this list and to Table 51[a] the position of pollution foci on the three great streams which unite to form lower Mississippi River and the relative danger from human habitations on this watershed can be seen. Upper Mississippi Valley is the largest area and has also the greatest density of population. Minneapolis in that basin is the chief pollution center. St. Croix drainage area, the smallest basin, has the smallest number of inhabitants per square mile. The number of inhabitants per square mile above Lake Pepin for the entire area is 32.3; in the same basin, excluding the chief settlements, it is 17.9. This means that nearly one-half of the population above Lake Pepin is concentrated in sewered cities. With a population of over 450,000 in two cities 60 miles above the head of the lake, there is no need for analysis of the water to establish its pollution and the necessity for artificial purification before it is used for domestic supply. Practical experiments at the price of human lives have demonstrated that the so-called self-purifying power of streams is too precarious a safeguard against water-borne disease. There can be no doubt that sewage discharged into Mississippi River at St. Paul or at Minneapolis has time

[a] See also Pls. II, III, and IV.

to reach Lake Pepin before the death of pathogenic organisms in it. There is, therefore, a flow of highly polluted water into the lake. In its comparatively slow journey of 23 miles through this broad body of water considerable organic matter is destroyed during ordinary water stages. When the spring freshets are in progress and the current is accelerated, Lake Pepin is no longer a sedimentation basin and the water passes through it in its worst sanitary condition, with practically no purification.

In lower Mississippi basin in Minnesota there are 26 settlements having a population exceeding 1,000, and among these are some of the largest cities in the State. These cities and villages are given in the following list:

TABLE 53.—*Settlements in Mississippi River basin in Minnesota, below Minnesota River.*

Locality.	Stream.	Distance above State line.	Population.		
			1890	1900.	1905.
		Miles.			
Caledonia	Crooked Creek	22	927	1,175	1,405
Cannon Falls	Cannon River	138	1,078	1,239	1,460
Chatfield	Mill Creek	100	1,335	1,426	1,300
Faribault	Cannon River	165	6,520	7,868	8,279
Hastings	Mississippi River	145	3,705	3,811	3,810
Kasson	Branch of Zumbro River	150	992	1,112	1,049
Kenyon	do	115	666	1,202	1,252
Lake City	Mississippi River	100	2,128	2,744	2,877
Lanesboro	Root River	65	898	1,102	1,041
Northfield	Cannon River	154	2,659	3,210	3,438
North St. Paul		180	1,099	1,110	1,405
Owatonna	Straight River	185	3,849	5,561	5,651
Plainview		45		1,038	1,140
Preston	Root River	80		1,278	1,320
Red Wing	Mississippi River	118	6,294	7,525	8,149
Rochester	Zumbro River	145	5,321	6,843	7,233
Rushford	Root River	50	968	1,062	1,133
St. Charles	White River	45	1,178	1,304	1,238
St. Paul	Mississippi River	170	133,156	163,065	197,023
South St. Paul	do	165	2,242	2,322	3,458
Spring Valley	Spring Valley Creek	100	1,381	1,770	1,573
Wabasha	Mississippi River	90	2,487	2,528	2,619
Waterville	Cannon River	185	937	1,260	1,383
West St. Paul	Mississippi River	170	1,596	1,830	2,100
Winona	do	51	18,208	19,714	20,334
Zumbrota	Zumbro River	135	867	1,119	1,129
Total			200,491	242,792	495,933

With 70 inhabitants per square mile this is the most densely populated district of the State, and over one-half of this number are in cities, one of which, St. Paul, is the city second in size in Minnesota. Most of the settlements are old; some have reached their maximum development and are now decreasing in size. In general they do not show such advance in sanitary matters as do similar communities elsewhere in the State, for of the 32 principal settlements 7 have no public waterworks, 2 have waterworks for fire protection only, and only 13 have public sewerage.

Typhoid fever.—Records of typhoid fever are extremely fragmentary, and do not adequately represent its true prevalence. The disease is frequently found both in the cities and in the country.

Although some cases are imported, the spread of the disease and its general continuation is probably due to unsanitary conditions in the small villages and to the lack of proper sewage disposal, on account of which the shallow wells used as sources of supply become infected.

QUALITY OF WATER.

The Mississippi unites with the Minnesota just above St. Paul. Thirty-two miles farther downstream the St. Croix enters the Mississippi from the north. Both tributaries are large and the water from each of them constitutes an appreciable percentage of the flow of the main stream. As a result, therefore, the water of the lower Mississippi River shows a quality that is less representative of the regions immediately bordering its banks than of the three great areas from which its headwaters are derived. The dissolved and suspended ingredients not only have this composite nature but the amount of each constituent varies measurably with the rise and fall of the tributary that introduces it. A sudden rainfall in upper Mississippi basin causes a flood and a resultant increase of flow at Winona; the percentage of water from upper Mississippi drainage area is relatively increased and the mineral constituents that are most abundant in that region will be found to increase in Mississippi River at Winona. A freshet on Minnesota River causes a similar fluctuation in the ingredients peculiar to that locality. Table 54 gives general averages for the various estimates made on the waters of the three tributaries, together with the size of each drainage area.

TABLE 54.—*Quality of water of chief confluents of lower Mississippi River.*

[Parts per million.]

Determination.	Upper Mississippi River (drainage area 19,731 square miles).	Minnesota River (drainage area 16,350 square miles).	St. Croix River (drainage area 7,655 square miles).
Color	50	30	70
Odor	2 v.		2 v.
Turbidity	<7	70	14
Chlorine	.9	6.4	1.0
Sulphuric acid	Trace.	178	Trace.
Alkalinity	151	220	89
Total hardness	136	470	89
Iron	Trace.	Trace.	Trace.
Total residue	189	556	135
Soluble residue	16	143	9
Free ammonia	.191	.193	.094
Albuminoid ammonia	.475	.454	.239
Nitrates	.05	.16	.05
Nitrites	.000	.009	.000

By comparison of the figures it is seen that:

1. Upper Mississippi and Minnesota basins are nearly equal in size while St. Croix basin is less than half as large as either of the other two. This comparison gives some idea of the relative amount of discharge from each stream.

2. The water of St. Croix River is higher in color and generally lower than that of the other two streams in all other amounts estimated. The difference is especially noticeable in alkalinity, total hardness, and residues.

3. The water of upper Mississippi River is higher than that of St. Croix River but much lower than that of Minnesota River in alkalinity, total hardness, and residues.

4. Minnesota River water has the lowest color, the greatest amount of suspended matter, and the highest mineral solids.

It is to be expected, therefore, that increased discharge from Minnesota River will increase the mineral content of the lower Mississippi and will cause especially a rise in turbidity and alkalinity. An increased discharge from St. Croix River, on the other hand, will cause an increase in color but will lower the percentage of mineral matter.

The average quality of upper Mississippi River water, as shown in Table 54, is determined from analyses made above Minneapolis and consequently above the pollution introduced from that place. It is probable, therefore, that the nitrogen determinations made do not represent the quality of the water just above the mouth of Minnesota River. In other constituents, however, the averages are representative. In Table 55, giving the results of analyses of water in Lower Mississippi Valley at different points,[a] there may be found assays of Mississippi River at Hastings. Since this sampling station lies between the mouths of Minnesota and St. Croix rivers, it represents the condition of the stream after its confluence with Minnesota River and shows the effect of that stream. The turbidity, chlorine, sulphuric acid, alkalinity, total hardness, total residue, and soluble residue are all greater than in the Mississippi above Minneapolis, and the water has a different appearance. Beside the entrance of strongly mineralized water from Minnesota River it has received gross pollution, which appears as decomposing sewage and other refuse, from a population of over 450,000 at Minneapolis and St. Paul. The examinations made at Red Wing show the quality of the water just above the head of Lake Pepin and below the mouth of St. Croix River. Comparison with examinations made at Hastings shows that sulphuric acid, chlorine, total alkalinity, total hardness, and total residue are decreased by the introduction of the soft water of St. Croix River. The examinations at Wabasha do not reveal a greater change in mineral content than might be expected by reason of the introduction of water from small tributaries.

[a] See Pl. I for location of sampling stations.

TABLE 55.—*Quality of water in lower Mississippi River basin.*

[Parts per million.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Bacteria per cc.[a]	B. coli communis.[a]
Mississippi River:																	
At Hastings	Aug. 29, 1903															3,000	+
Above Wabasha[b]	do	0	0		3				0	210		0.44	0.48	0.00	0.5	200	+
At Hastings[c]	June 8, 1904							168				.27	.08	.00	Distinct.	10,500	+
At Hastings[d]	Oct. 14, 1904	44	3 v	19	2.2	e 15	140	160	0	209	24	.312	.138	.000	.05	3,800	+
Below Red Wing[d]	Oct. 13, 1904	40	2 v	15	1.3	e 10	124	132	0	169	20	.264	.092	.000	.05	3,000	+
Above Wabasha[d]	do	25	2 v	15	2.4	e 15	141	160	0	192	20	.260	.080	Trace.	.05	200	+
At Hastings[d]	Feb. 10, 1905	29	2 M	12	5.3	25	228	233	Trace.	297	32	.328	.360	.010	.23	4,000	+
Below Red Wing[d]	Feb. 11, 1905	29	2 M	10	4.6	e 20	190	194	Trace.	238	30	.282	.320	.009	.23	2,200	+
Above Wabasha[d]	do	29	0	e 10	3.3	e 15	175	174	Trace.	224	16	.238	.196	Trace.	.25	60	−
Zumbro River:																	
Above Rochester[b]	Aug. 28, 1903	0	0		7				0	200		.8	Trace.	Trace.	.5	6,100	−
Above mouth[b]	Aug. 29, 1903	0	0		10		130		0	220		.4	.35	Trace.	1.0	1,300	−
Above Rochester[c]	May 4, 1904				1.7									Trace.	Distinct.	700	+
Below Rochester[c]	do				3.5									Distinct.	Distinct.	7,000	+
Above Rochester[c]	July 15, 1904				2.1							.18	.22	Trace.	Distinct.	1,000	+
Below Rochester[c]	do				5.2							.24	.36	Distinct.	Distinct.	5,500	+
Above Rochester[d]	Aug. 17, 1904	18	2 v	e 10	2.6		221	187		271		.200	.290	.00	.05	1,600	+
Below Rochester[d]	do	18	2 M	e 20	7.3		226	187		272		.262	.480	.05	5.0		+
At mouth[d]	Oct. 14, 1904	18	2 e + 1 v	60	2.2	15	214	230	0	279	28	.206	.102	.015	.12	2,800	+
At mouth[d]	Feb. 11, 1905	4	0	<7	2.0	e 10	250	230	Trace.	278	46					450	−
Bear Creek at Rochester[c]	May 4, 1904													Distinct.	Distinct.	650	+
Bear Creek at Rochester	Aug. 17, 1904	4	3 M	e 15	2.6		209	215		265		.148	.170	.025	8.4	4,200	+
Pool at mouth of sewer Owatonna[d]	Nov. 29, 1904	44			18.2	e 15	416	529	0.5	497	139	2.30	15.7	.073		120,000	+
Straight River above Owatonna[d]	do	4			2.6	d 5	306	418	Trace.	340	24	.186	.034	.000	.02	3,000	+
Straight River below Owatonna[d]	do	24			6.8	d 5	318	418	Trace.	390	37	.316	.270	.008	0.9	11,000	+

[a] Bacteriological examinations by Dr. E. H. Beckman.
[b] Analysis by Dr. E. H. Beckman.
[c] Analysis by H. C. Carel.
[d] Analysis by R. B. Dole.
[e] Estimated.

The condition of the organic matter in the lower stream is distinctly different from that in the river above Minneapolis. Though the river has received an enormous amount of sewage, the albuminoid ammonia averages less than in upper Mississippi River. Free ammonia is, however, higher, and nitrites are usually found, and both ammonias vary considerably from time to time. In winter nitrites are generally found. The evidence of fecal pollution is more positive from the bacteriological examinations, which show enormous numbers of bacteria in nearly every sample examined. *B. coli communis* was isolated in pure culture from all but three of the bacteriological samples taken in lower Mississippi basin, and this fact indicates a general presence of pollution. It is unfortunate that more detailed data could not be obtained regarding the possible purification of the water during its passage through Lake Pepin. In October, 1904, Mississippi River was about 5 feet above its normal level at Wabasha, and the water passed swiftly through Lake Pepin. The samples taken at that time show no appreciable decrease in the amount of organic matter nor a great change in its condition. Water from the foot of the lake revealed a trace of nitrites, which did not appear at the head, and the number of bacteria per cubic centimeter was lower The presence of *B. coli communis*, however, was established. In February, 1905, samples taken at the same points did show an apparent oxidation of organic matter by a reduction of the albuminoid ammonia, free ammonia, and nitrites, and a slight increase in nitrates. The number of bacteria was reduced, and *B. coli communis* was not isolated. It should be remarked in this connection, however, that only 1 cubic centimeter of water was examined for this bacillus, and it is possible that it might have been found if larger amounts of water had been used.

Examinations were made of Zumbro River at Rochester and above its mouth, near Wabasha. Since this stream drains prairie country, its quality fluctuates greatly with the season and the amount of local precipitation. Heavy rains cause sudden floods in it, which are accompanied by great increase of turbidity and organic matter, due to the scouring effect of the current on its easily disintegrated banks and bed. In winter the water of the stream was found to be clear and sparkling and to contain a considerable amount of mineral matter, as is shown by the alkalinity and total residue. In the fall it was in flood, and the estimates show flood conditions. There is an increase of mineral matter during its course to the Mississippi. All examinations showed large numbers of bacteria, and *B. coli communis* was isolated in every case but one. Straight River was examined during the latter part of November, 1904, when the stream was frozen. It has a high mineral content, and its bacterial condition indicates pollution. There is an increase of organic matter at Owatonna.

In 1882 considerable excitement was caused at Waterville by the existence of supposed poisonous algæ in Lake Tetonka and other ponds in that vicinity. Samples of the organisms were examined microscopically by Prof. J. C. Arthur, who has fully reported the incident.[a] The death of several cattle was attributed to this plant without any experimental basis for the popular belief, which was not concurred in by the above-mentioned author.

Mississippi River below Red Wing may be said to vary in its quality according to the fluctuations of St. Croix, Minnesota, and upper Mississippi rivers. If examinations were extended from that point to the State border, the river would doubtless be found to increase in mineral content on account of drainage from the limestone formations in its area. The river is grossly polluted, and the sewage introduced has not disappeared by the time the water reaches Wabasha. It would be decidedly dangerous for domestic consumption without purification. The following table gives a summary of the examinations made.

TABLE 56.—*Summary of quality of water of lower Mississippi River.*

[Parts per million.]

Determination.	Maximum.	Average.	Minimum.
Color	44	28	25
Odor	2 M	2 v+1 M	0
Turbidity	19	13	10
Chlorine	5.3	3.1	1.3
Sulphate radicle	25	16	10
Alkalinity	228	166	124
Total hardness	233	174	132
Iron	Trace.	Trace.	0
Total residue	297	219	169
Soluble residue	32	23	16
Free ammonia	0.48	0.218	0.08
Albuminoid ammonia	0.44	0.311	0.238
Nitrates	0.25	0.13	0.05
Nitrites	0.010	Trace.	0.00

NOTES ON MUNICIPALITIES.

Twenty-two of the thirty-two settlements in the basin use ground water, one is supplied with river water, and one is supplied with both well and lake water. Eleven cities and villages are equipped with sanitary sewerage.

Caledonia, Houston County.—On a small creek entering Mississippi River. Water supply is obtained from an 8-inch well, 318 feet deep, passing through clay, 40 feet; hard sandstone, 30 feet; limestone, 130 feet; soft sand rock, 118 feet. Ice supply is cut from Crooked Creek and from one of the sloughs connected with Mississippi River. No sewerage system. Garbage is taken outside the city.

[a] Arthur, J. C., Some algæ of Minnesota supposed to be poisonous: Bull. Minn. Acad. Nat. Sci., 1880-82, vol. 2, Bull. 4, Appendix 1. Also A supposed poisonous seaweed in the lakes of Minnesota: Proc. Am. Assoc. Adv. Sci., 1883, vol. 32, p. 305.

Cannon Falls, Goodhue County.—On Cannon River, 20 miles above Mississippi River, at the mouth of Little Cannon River. Water supply is obtained from an 8-inch artesian well, 400 feet deep; ice supply from Cannon River. A sanitary sewerage system discharges into Little Cannon River. Garbage is hauled to the public dumping ground outside the city.

Chatfield, Fillmore County.—On Mill Creek just above the north branch of Root River. Water supply is procured from a 6-inch well, 200 feet deep, drilled through sand rock and limestone; ice supply from Root River above the city drainage. No sewerage. Offensive garbage is hauled outside the city and buried.

Claremont, Dodge County.—Near a branch of Zumbro River, to which it drains. No waterworks. Ice supply is cut from Zumbro River and Rice Lake. Storm sewerage is installed.

Dakota City, Winona County.—On Mississippi River, 18 miles below Winona. No waterworks or sewerage.

Dodge Center, Dodge County.—A short distance from the south middle branch of Zumbro River. No waterworks. Ice supply taken from Zumbro River. No sewerage. Garbage and night-soil commonly used on adjacent farms.

Faribault, Rice County.—On Cannon River at its confluence with Straight River, 27 miles above Cannon Falls. Water supply is obtained from two artesian wells 800 and 700 feet deep, respectively, and from two surface wells with uncemented brick walls 20 feet deep. Ice supply is cut from Cannon and Straight rivers. Sanitary sewerage discharges into Cannon River. Garbage is hauled to a dumping ground on the outskirts of the city. Shattuck School for Boys, 200 pupils; St. Mary's Hall for Girls, 100 pupils; Bethlehem Academy for Girls, 70 pupils; State School for the Deaf, 300 pupils; State School for the Blind, 100 pupils; State School for the Feeble-minded, 1,000 pupils, are all located within or near the city. These institutions are supplied with city water and connected with the city sewerage.[a]

Farmington, Dakota County.—On Vermilion Creek, about 20 miles above its entrance into Mississippi River. No waterworks or sewerage. Ice supply is cut from Vermilion Creek. Garbage is removed to a dumping ground just outside the village limits.

Hastings, Dakota County.—On Mississippi River, 3 miles above its confluence with St. Croix River. No waterworks or sewerage. Ice supply is cut from Mississippi River, Lake St. Croix, and Lake Rebecca. Garbage is hauled to the dumping ground outside the city. The Second State Asylum for the Insane is located about 2 miles from Hastings. It has a private water supply, derived from a deep well, and a sanitary sewerage system discharging into Mississippi River.

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[a] Biennial Rept. Minnesota State Board of Health, 1901–02, p. 284.

Kasson, Dodge County.—On a small creek about 3 miles above its entrance into the south middle branch of Zumbro River. Water supply is obtained from an 8-inch well, 200 feet deep, drilled into the rock; ice supply from small branches of Zumbro River. Storm sewerage, but no sanitary sewerage has been installed.

Kenyon, Goodhue County.—On north branch of Zumbro River, 20 miles above Zumbrota. Water supply is taken from a well 25 feet deep; ice supply from Zumbro River. No sewerage. Garbage is hauled to a public dumping ground east of the city.

Lake City, Wabasha County.—On the shore of Lake Pepin, 20 miles below Red Wing. Water supply is obtained from a dug well in the village. There is also an emergency connection with Lake Pepin. Ice supply is cut from Lake Pepin. A combined sewerage system discharges into Lake Pepin.

Lanesboro, Fillmore County.—On Root River, 45 miles above its confluence with Mississippi River. Water supply is procured from a spring near the village; ice supply from south branch of Root River above the mill-pond dam. No sewerage. Garbage is dumped on a lot outside the corporation limits.

Northfield, Rice County.—On Cannon River, 6 miles above Cannon Falls. Water supply is obtained from an 8-inch artesian well, 640 feet deep, drilled through the following strata:

Log of well at Northfield.

	Feet.
Lime rock	265
Sand rock	50
Shale	225
Sand rock	20
Shale	3
Sand rock	15
Shale	9
Sand rock	35
Lime rock	25

Ice supply is cut from Cannon River. A sanitary sewerage system discharges into Cannon River. Garbage is hauled to a dumping ground outside the city.

North St. Paul, Ramsey County.—Near the city of St. Paul. Water supply is obtained from an 8-inch well, 300 feet deep. There is also an emergency connection with an adjacent lake. Ice supply is cut from a lake south of town. No sewerage. There is no regular garbage disposal; it is usually burned by individual householders.

Owatonna, Steele County.—On Straight River, 20 miles above Faribault. Water supply is procured from five drilled wells—three 8-inch wells, 120 feet deep; one 5-inch well, 90 feet deep; and one 8-inch well, 650 feet deep, all entering rock at 40 feet. The 120-foot wells are driven in the bottom of a dug well 20 feet by 27 feet. Ice supply is cut from Straight River, above the mill dam. A sewerage system discharges into Straight River. Garbage is removed to the public dumping ground. The State School for Dependent and Neglected Children, with 250 pupils, is located at Owatonna. Its water supply is taken from two 6-inch wells, 260 feet deep, and it has also a private sewerage system entering the river.

Plainview, Wabasha County.—Water supply is procured from two deep wells, 4¾ inches by 335 feet and 5¾ inches by 700 feet, respectively. They penetrate 60 feet of clay and are then drilled through limestone and sandstone. No sewerage.

Preston, Fillmore County.—On South Branch of Root River, 60 miles above its entrance into Mississippi River. Water supply is obtained from a spring near the village, inclosed with rock and cement, and covered. Ice supply is cut from Root River. No sewerage. Garbage is hauled to a public dumping ground 1 mile below the town.

Red Wing, Goodhue County.—On Mississippi River, just above the head of Lake Pepin. Water supply for fire protection only is taken from Mississippi River; ice supply from Mississippi River. Sewerage discharges into Mississippi River. Garbage is removed by a public scavenger and buried at the city dumping grounds. The Red Wing Seminary, 130 pupils; Lutheran Ladies Seminary, 200 pupils, and the State Training School, with about 400 inmates, are located in or near Red Wing. The water supply for the training school is taken from a surface well 15 feet in diameter, sunk in the sand near the river, and a sewerage system discharges into Mississippi River.[a]

Rochester, Olmsted County.—On Zumbro River, at its confluence with Bear Creek. Water supply is obtained from driven points and a bricked well 30 feet in diameter by 30 feet deep on the banks of Bear Creek, near its confluence with Zumbro River. There is also an emergency connection to Bear Creek. Sewerage discharges into Zumbro River. The Second State Hospital for the Insane (about 1,300 inmates) is situated 1¼ miles east from the center of the town, near a small creek. The water supply is obtained from four 8-inch wells. The private sewerage system is equipped with a disposal plant designed to purify the sewage by precipitation and intermittent filtration.[b]

Rushford, Fillmore County.—On Root River, at the entrance of Rush Creek. Water supply is procured from a 6-inch flowing well, 565 feet deep, in limestone and sandstone; ice supply from Root River. A sanitary sewerage system is installed, discharging into Rush Creek. Garbage is commonly thrown into the river.

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[a] Biennial Rept. Minn. State Board of Health, 1901-2, p. 280.

[b] Rafter and Baker, Sewage Disposal in the United States, second edition, p. 500; Biennial Rept. Minn. State Board Health, 1901-2, p. 277; Engineering and Building Rec., vol. 23, p. 72.

St. Charles, Winona County.—On Whitewater River, 25 miles above Mississippi River. Water supply is obtained from a 10-inch well, 942 feet deep, in sandstone. No sewerage. Garbage is hauled to a dumping ground 1 mile from the city.

St. Paul, Ramsey County.—On Mississippi River, just below the entrance of Minnesota River. The city water supply is both surface and ground water, though the greater part is from lakes. The wells, 37 in all, with depths varying from 63 to 85 feet, are put down on the shore of Vadnais and Centerville lakes. The surface supply is taken from 22 small lakes, 5 to 20 miles away from the city, principally from Phalen, Vadnais, and Pleasant lakes. [a] Ice supply is cut from Minnetonka, White Bear, Phalen, Bass, McCarrons, and Long lakes, and from Minnesota River, just above Fort Snelling. Sanitary and storm sewerage discharges into Mississippi River. Part of the city garbage is dumped into Mississippi River, but most of it is sold to farmers for fertilizer.

South St. Paul, Dakota County.—On Mississippi River, just below St. Paul. Water for the public supply is furnished from private artesian wells at Swift & Co.'s packing house. Ice supply is cut from small lakes in the vicinity. No sewerage. Garbage is hauled to the stock yards and dumped near the river.

Spring Valley, Fillmore County.—On Spring Valley Creek, which enters the middle branch of Root River. Water supply is procured from a spring a short distance from the pumping station; ice supply from Deer Creek, 3 miles north of the city. A combined sewerage system discharges into Spring Valley Creek. Garbage is removed to a dumping ground, where it is buried at intervals.

Stewartville, Olmsted County.—On Root River. Water supply is obtained from an 8-inch well drilled 62 feet in the rock; ice supply from the river. No sewerage. Garbage is hauled to the village dumping ground.

Wabasha, Wabasha County.—On Mississippi River, just below the foot of Lake Pepin. No water supply or sewerage. Ice supply is cut from Mississippi River above the town. Garbage is generally burned, though some is dumped into the river.

Waterville, Lesueur County.—Between Lakes Tetonka and Sakata, through which Cannon River flows. Water supply is procured from an 8-inch drilled well, 185 feet deep; ice supply from Lake Sakata. No sewerage. Garbage is removed to a public dumping ground, where animal matter is usually burned and other refuse buried.

West Concord, Dodge County.—On north middle branch of Zumbro River. Water supply for fire protection. No sewerage.

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[a] Fanning, M. G., Observations on the algæ of the St. Paul city water: Minnesota Botanical Studies, second series, pt. 5, July 20, 1901, p. 609.

West St. Paul, Dakota County.—On Mississippi River, opposite St. Paul. No waterworks or sewerage; ice supply from Thompson and Sunfish lakes. No regular garbage disposal.

Winona, Winona County.—On Mississippi River, 51 miles above the southern State boundary. Water supply is obtained from two shallow wells in Riverside Park near the river. There is an emergency connection from Mississippi River to the north shallow well. Ice supply is cut from Mississippi River and Lake Winona. Separate storm and sanitary sewerage equipped with Shone automatic ejectors discharge into Mississippi River. There is no public garbage disposal.

Zumbrota, Goodhue County.—On Zumbro River, 50 miles above its entrance into Mississippi River. Water supply is obtained from a well drilled 210 feet deep into limestone;[a] ice supply from Zumbro River. No sewerage. Garbage is hauled to the public dumping ground.

ST. LOUIS RIVER BASIN.

GENERAL DESCRIPTION.

Boundaries.—This area includes a small but important section in the northeastern part of the State, north and west of Lake Superior. It is bounded on the north by Rainy River drainage area, from which it is separated by the highest elevations in the State. It is bounded on the west and the south by Mississippi basin. On the east are the basins of the minor tributaries of Lake Superior. (Pl. VI.)

Character and slope of St. Louis River.—The streams are in general short and tumultuous. They rise on the slopes of the Mesabi and Sawteeth ranges, and there are many rapids and cataracts in their courses. The largest stream, St. Louis River, has its source in the west-central part of Lake County and flows southwestward across St. Louis County, nearly to its southwest corner, where at its confluence with Floodwood River it turns abruptly and flows southeastward for about 40 miles, then eastward, in which general course it continues to its entrance into Lake Superior at Duluth. Throughout its entire course it is a typical woodland stream, traversing regions in which the pine timber is now standing or from which it has been removed but recently. In most of its course it is swift, broad, and moderately deep, and it receives practically the whole drainage of the Mesabi Range.

Comparatively little data have been published regarding surveys on this stream, so that a proper profile can not be presented. Though it is rather sluggish in its upper section, it has considerable fall in its

[a] Biennial Rep. Minn. St. Bd. Health, 1901-2, p. 327.

lower part, below the points of entrance of the principal tributaries. A survey made by the Corps of Engineers of the United States Army shows the slope of the river from Floodwood to its mouth.[a] Below the entrance of Floodwood River it falls about 40 feet in 6 miles; thence to Cloquet Rapids the stream has little descent, but at these rapids there is a natural fall of 5 feet in less than one-quarter of a mile. A short distance below, at Grand Rapids, the river falls 75 feet in 5 miles. At Knife Falls it drops 20 feet in a very short distance and has a total fall of 154 feet in less than 5 miles. This power has been partly utilized at Cloquet. Between these falls and Fond du Lac lie the rapids of the St. Louis, in the course of which the river descends about 460 feet. Fond du Lac, appropriately so named because it is situated at the head of navigation on St. Louis River, is 18 miles above Lake Superior. From this town to Minnesota Point the river widens out into a placid shallow bay, with a barely perceptible current.

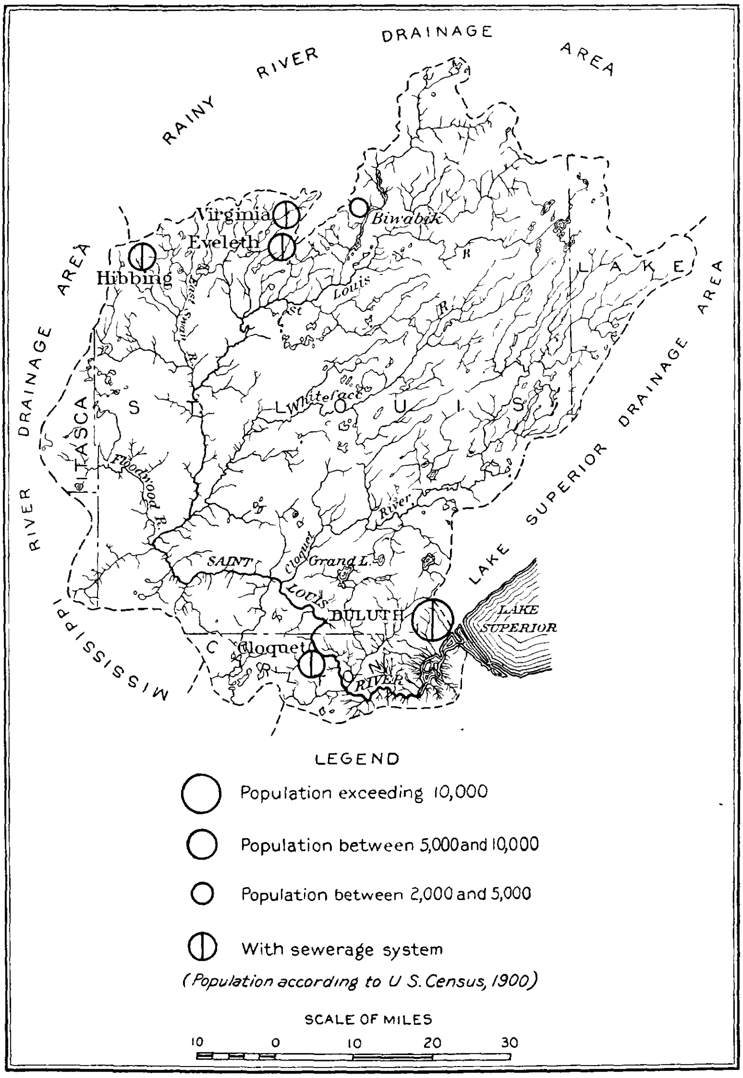
Tributaries of St. Louis River.—The longest tributary of St. Louis River is Cloquet River, which rises in Lake County and, flowing southwestward across St. Louis County, enters the main stream near Cloquet Rapids, a few miles above the village of Cloquet. (See Pl. VI.) The stream is rapid in its upper portion, but becomes less swift after entering the level parts of St. Louis County. Its drainage area is 675 square miles.[b] Whiteface River lies between Cloquet and St. Louis rivers and follows the same general direction across St. Louis County, joining the St. Louis near Floodwood. Its drainage area is 534 square miles.[b] East Swan River has its headwaters in the Mesabi Range, near Hibbing, and flows southward to St. Louis River. Floodwood River is also a western tributary running southward from Itasca County into St. Louis River near Floodwood. Its drainage area is 257 square miles.[b] Embarrass River is a smaller tributary, which has its source in the central part of St. Louis County and flows southward, crossing the Mesabi Range, passing through several long narrow lakes, and entering St. Louis River above East Swan River. Many smaller streams of similar character enter St. Louis River. Woodland lakes are distributed all over the basin. They are of moderate depth and are highly colored by the dissolved vegetable matter that reaches them.

Geology.—The geological features of St. Louis Valley and the rest of the Lake Superior region have been elsewhere discussed in much detail.[c] A prominent feature is the line of hills comprising the Sawteeth and Mesabi ranges, which form the northern boundary of the

[a] Lake Superior and Mississippi Canal, Exhibit F, H. R. Doc. 330, 54th Cong., 1st sess.

[b] Water Powers of the United States, pt. 2, Tenth Census U. S., p. 72.

[c] Winchell and Grant, Geol. and Nat. Hist. Survey of Minnesota, Final Report. vol. 4, pp. 212–58; Leith, C. K., The Mesabi Iron-bearing District of Minnesota; Mon., U. S. Geol. Survey, vol. 43.



MAP OF ST. LOUIS RIVER BASIN.

basin and separate its waters from those of the Rainy River system. The rocks of the range are old, belonging almost entirely to the Archean and Algonkian systems. Though generally modified by glacial action, bed rock is widely exposed in these hills and the drift is thin in many places. South of these elevations there is in St. Louis County a broad expanse of level, often swampy land, heavily covered with drift underlain to some extent by Cretaceous formations. Bordering Lake Superior below this plain there is another rugged section exhibiting early rocks of hard, durable character, which cause waterfalls and rapids in the streams that cross them. The most important formations from an economic standpoint are the iron-ore deposits in the Mesabi district, the hydro-economic influences of which are discussed elsewhere.[a] Along the lake shore lava is seen at many places. Granite, micaceous schists, gneisses, and slates are the prevailing rocks all over the area; there is little material to render the drainage water hard and chemical analyses in general show amounts of incrustants so small that the streams of this basin may be ranked with those of the St. Croix as the softest in the State.

INDUSTRIAL POLLUTION.

Little manufacturing is done in the Lake Superior region and few establishments exist which would be likely to pollute the streams.

TABLE 57.—*Industrial establishments causing stream pollution in Lake Superior basin.*

Breweries	2
Gas works	1
Paper mills	1
Sawmills	15
Tanneries	2
Woolen mills	1

Many of these establishments are located at Duluth and their effluents are discharged into Lake Superior. There are five sawmills at Cloquet and there is another large one a short distance below, at Scanlon. These are situated along the banks of St. Louis River and much of their waste goes into that stream. A paper mill and two pulp mills, operated by the Northwest Paper Company, are also located at Cloquet. The ground-wood process is used without chemicals and the capacity of this establishment is about 86,000 pounds a day of news, manila, and hanging paper.[b]

[a] See pp. 25, 115, 116–117.
[b] Post's Paper Mill Directory, 1895–6, p. 191.

TABLE 58.—*Quality of underground waters in the Mesabi Range.*[a]

[Parts per millon.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Alkalinity.	Total hardness.	Iron.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Free CO_2.	Bacteria per cc.	B. coli communis.
Biwabik:																		
Public well	Nov. 29, 1903	0	0	0		0	165	171									17	–
Do.[b]	Feb. 4, 1904	0	2e	0	0.3	Trace.	182	185				0.02	0.015	Absent.	Trace.		6	–
Do.[b]	May 11, 1904	0	0	0	.30	c10	182	226	c0.5			.02	.01	Absent.	Trace.		44	–
Do	Sept. 19, 1904	0	0	0	1.9	c10	202	216	Trace.	254	32	.028	.008	.000	.057	21	74	–
Open-pit mine	Nov. 29, 1903	0	2e	0		Trace.	88	103										
Eveleth:																		
Adams mine[b]	Nov. 27, 1903	3	2e	0	1.25	0	121	'171				.01	.01	Absent.	Distinct.		400	+
Do.[b]	Feb. 3, 1904	4	3e+2M	10	0.30		105					.10	.07	Trace.	Distinct.		200	–
Do	May 13, 1904	0	2e	c5	.45	Trace.	112	155	0			.01	.08	Trace.	Distinct.		100	+
Spruce mine	Sept. 21, 1904	0	0	0	1.5	Trace.	111	132	0	137	10	.016	.010	.000	.00	26	41	+
Shallow well near Lake Ely	Sept. 12, 1904	0	0	0	4.8	Trace.	78	90	Trace.	109	12	.026	.004	.000	1.20	21		
Do	Sept. 20, 1904	0	0	0	4.8	Trace.	69	90	Trace.	122	26	.014	.004	.000	1.25	22	30	–
Hibbing:																		
Old prospecting shaft, public supply	Nov. 25, 1903	4	0	0		0	57	103									170	–
Do.[b]	Feb. 1, 1904	0	0	0	.40	0	67	110				.02	.018	Absent.	Distinct.		20	–
Do	May 14, 1904	0	0	0	.35	0	69	86	0			.006	.006	Absent.	Distinct.		12	–
Do	Sept. 19, 1904	0	0	0	1.5	Trace.	77	83	0	107	9	Trace.	Trace.	.000	.080		90	–

[a] Analyses by R. B. Dole. Bacteriological examinations by Dr. E. H. Beckman.
[b] Nitrogen and chlorine determinations by H. C. Carel.
[c] Estimated.

Lumbering and mining are the chief industries in the region. Logging was the first attraction for explorers, but that business has been far outranked by iron mining in the Mesabi district. Statistics regarding the extent of this industry are given on page 25, and the hygienic condition of the water in the ore is discussed under the heading "Municipal pollution," on pages 116–117, so that it is here necessary only to speak of the probable effect of the mine drainage on the mineral constituents of the streams. Since the mineral content of natural water is determined by the character of the geologic formations it traverses, the drainage from ore deposits will contain compounds similar to those that are most prominent and most soluble in the ore itself. Analysis of many representative ore samples from the Mesabi district[a] shows that the ores contain from 50 to 60 per cent of iron, 2 or 3 per cent of silica, less than one per cent of calcium and magnesium and small percentages of manganese and aluminum, while the phosphorus and sulphur together seldom exceed 1 per cent. The mine drainage does not therefore seriously affect the quality of the waters for boiler use. Chemical analyses of samples of mine waters corroborate these conclusions. (See Table 58.)

MUNICIPAL POLLUTION.

Lake Superior basin in Minnesota outside of St. Louis County is very thinly settled, so that pollution from human habitations in that region is not yet important. Two Harbors is the only large settlement in Lake County, and the country east of that village is generally wild and uninhabited. Duluth, the chief center of population in St. Louis Valley, owes its growth to its strategic commercial position. The remarkable growth of population in the drainage area north of Duluth during the last twenty-five years has been caused almost entirely by the discovery and the development of the Mesabi iron-bearing district. All of the cities in this area have been established since 1890, and their location and their increase or decrease in population have been coincident with the development of mining properties. The statistics presented in Tables 59–62 indicate the enormous rate at which settlement has taken place.

TABLE 59.—*Population in the Lake Superior basin of Minnesota.*

Area.	U. S. census, 1890.	U. S. census, 1900.	State census, 1905.
St. Louis basin	45,157	78,920	116,875
Cook County	98	810	1,462
Lake County	1,299	4,654	6,275
Pigeon River Indian Reservation	(b)	(b)	362
Total	46,554	84,384	124,974

a Leith, C. K., The Mesabi iron-bearing district of Minnesota: Mon. U. S. Geol. Survey, vol. 43.
b Included in the population of Cook County.

TABLE 60.—*Population in St. Louis River basin.*

Area.	1890.	1900.	1905.
Carlton County	4,174	7,239	12,069
St. Louis County	39,983	71,681	103,920
Fond du Lac Indian Reservation	(a)	(a)	886
Total	45,157	78,920	116,875

[a] Included in the population of Carlton County.

TABLE 61.—*Density of population in Lake Superior basin in Minnesota.*

Area.	Drainage area in square miles.	Inhabitants per square mile.		
		1890.	1900.	1905.
Lake Superior basin:				
Entire basin	[a]7,175	6.5	11.8	17.3
Excluding chief settlements		1.3	2.2	4.1
St. Louis basin:				
Entire basin	[b]3,700	12.2	21.3	31.6
Excluding chief settlements		2.5	3.6	7.3
Excluding Duluth		3.3	7.0	14.0

[a] Hall, C. W., Geography and Geology of Minnesota, vol. 1, p. 151.
[b] Measured from the best available maps.

TABLE 62.—*Principal settlements above Duluth.*

Locality.	Stream.	Distance above Duluth.	Population.		
			1890.[a]	1900.	1905.
		Miles.			
Biwabik	Embarrass Lake	125	....	1,299	946
Cloquet	St. Louis River	30	2,530	3,072	6,117
Eveleth	Small creek	100	....	2,752	5,332
Hibbing	Penobscot Creek	110	....	2,481	6,566
Virginia	Silver Lake	120	....	2,962	6,056
				12,566	25,017

[a] Information regarding population is incomplete.

The Mesabi district, a strip across St. Louis County on the northern border of St. Louis drainage, is the chief mining district of the State and, since mining is the reason for its population, the inhabitants are collected into small villages at the "locations," while the lands around the mines are generally uncultivated and uninhabited. The principal mining towns are Biwabik, Chisholm, Eveleth, Fayal, Hibbing, McKinley, Missabe Mountain, Mountain Iron, Sparta, and Virginia. In some of these places, particularly in Eveleth, the mine water has undoubtedly been the cause of considerable typhoid fever. The porous ore body contains more or less water, which must be removed for successful operation. From the standpoint of the hydraulic engineer it is economical to utilize this water for domestic purposes, but from the sanitarian's standpoint it is dangerous. The mines are inhabited by large numbers of men, one or two of whom are always likely to have an infectious disease. The miners commonly urinate and defecate in the mines, the drainage from which reaches the sumps, whence the water is pumped to the surface. When this infected water is used for a public supply, serious epidemics usually result. Whether the water from unused shafts is dangerous is a debatable matter, but it should always be regarded with suspicion until a thorough inspection has demonstrated that the shaft which is being utilized is not connected by seams or faults or artificial passageways with a mine in operation. In considering the probable pollution of underground water by the dejecta of miners, it may be noted that *B. coli communis* was isolated in three out of four examinations of the town supply of Eveleth, which was taken from a shaft mine, and was not found in that of Biwabik village, the supply for which is taken from a deep shaft dug for water supply, nor in the supply of Hibbing, which comes from an old prospecting shaft. The cities of Hibbing, Eveleth, and Virginia are equipped with sewerage systems, which discharge into tributaries of St. Louis River. The other towns have no public sewerage as yet, and the use of privies and cesspools is general.

The St. Louis basin, between the Mesabi district and Cloquet, is now but slightly populated and contains much forest and swamp land. Floodwood and Swan River are small villages.

Between Cloquet and Duluth the river basin is more thickly populated on account of the gradual extension of the city suburbs and the development of water powers on the river. Scanlon, Carlton, and Fond du Lac are small villages in this section. The figures given in Table 61, showing the density of population in the basin excluding the chief settlements, do not adequately represent the condition, because it was impossible to learn the population of many of the small villages. As a matter of fact, the population of St. Louis basin is concentrated in Duluth, two or three large sawmill towns, and the mining locations of the Mesabi district. Except these, the region contains only a few scattered farms in its southern part, and the county in general is unsettled.

QUALITY OF WATER.

The first series of samples collected in St. Louis basin was taken in the early winter of 1903, just after the lakes and streams had become icebound. The second series was taken during February, 1904, under similar conditions. The third series was taken in the spring of 1904, just after the ice had gone out, when the stream showed flood conditions at many places. The fourth series was taken in the fall of the same year, while the streams were open. The fifth series was taken at Cloquet during the winter of 1905, while the river was icebound.

TABLE 63.—*Quality of water in St. Louis River basin.*

[Parts per million.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Bacteria per c. c. [c]	B. coli communis. [c]
Silver Lake at Virginia [a]	Nov. 27, 1903	324	3 v.	10	......	Trace.	31	62	......	......	......	......	......	......	......	......	......
Do.	Feb. 2, 1904	176	4 v.	10	0.5	[d]10	59	89	......	......	......	0.28	0.206	0.00	Distinct.	700	+
Do.	May 14, 1904	120	3 M.	50	.3	......	44	50	Trace.	......	......	.35	.46	Trace.	Trace.	......	+
Do.[b]	Sept. 21, 1904	86	2 M.	15	3.0	0	80	90	0	135	26	.250	.152	Trace.	Trace.	1,300	+
Virginia Lake at Virginia [a]	May 14, 1904	138	3 M.	50	.3	Trace.	42	50	Trace.	......	......	.32	.55	Trace.	Distinct.	6,900	+
Ely Lake at Sparta [a]	Nov. 28, 1903	20		9	.3	0	48	75								80	−
Do.	Feb. 3, 1904	18	0	0	.3	Trace.	56	89	......	......	......	.21	.07	Trace.	Distinct.	10	−
Do.	May 11, 1904	18	......	0	.3	0	49	78	0	......	......	.27	.08	.00	Trace.	250	−
Do.[b]	Sept. 20, 1904	18	2 v.	<7	1.8	Trace.	58	62	Trace.	92	14	.212	.036	.000	.015	20	−
Silver Lake at Eveleth [a]	May 12, 1904	18	0	0	.3	0	46	50	0	......	......	.17	.05	.000	Trace.	600	−
Do.[b]	Sept. 12, 1904	25	2 v.	<7	2.0	Trace.	64	62	Trace.	101	16	.204	.016	.000	.014	......	......
Do.[b]	....do......	25	2 v.	<7	2.1	Trace.	61	62	Trace.	82	......	.216	.014	.000	.014	......	......
Do.[b]	Sept. 20, 1904	25	2 v.	<7	1.8	Trace.	57	62	Trace.	85	29	.206	.026	.000	.015	{30 {25	− +
St. Marys Lake at Eveleth [a]	Feb. 3, 1904	25	0	<7	.3	Trace.	16	34	......		......	.35	.085	.000	Trace.	2	−
Do.	May 12, 1904	29	0	<7	.3	0	12	17	0	......	......	.25	.05	.000	Trace.	21	−
Do.[b]	Sept. 12, 1904	18	1 v.	<7	.5	Trace.	26	21	0	58	12	.252	.014	.000	.010	......	......
Do.[b]	....do......	18	1 v.	<7	.5	Trace.	22	21	0	64	......	.252	.016	.000	.010	......	......
Do.[b]	Sept. 20, 1904	4	1 v.	<7	.5	Trace.	19	21	0	43	16	.410	.032	.000	010	{35 {55	− −
Longyear Lake at Chisholm [a]	Nov. 26, 1903	324	2 v.	10	2.0	0	<10	49	......	......	......	......	......	......	......	......	−
Do.	Feb. 1, 1904	324	4 v.	<7	2.0	0	8	29	......	......	......	.45	.74	.000	.00	1,000	+
Do.	May 13, 1904	224	2 v.	<7	.4	0	13	14	0	......	......	.60	.22	.000	Trace.	......	+
Do.[b]	Sept. 19, 1904	224	2 v.	12	1.8	0	20	21	Trace.	87	30	.670	.130	.000	Trace.	250	−
Embarrass Lake at Biwabik [a]	Nov. 29, 1903	296	2 v.+1 M.	10	1.3	0	<6	32	......	......	......	.22	.13	.000	.00	50	−
Do.	Feb. 4, 1904	324	2 v.+2 M.	0	.3	0	24	48	......	......	......	.60	.23	.000	Trace.	0	−
Do.	May 11, 1904	224	3 v.	10	.4	0	26	36	0	......	......	.50	.09	.000	Trace.	550	−
Do.[b]	Sept. 19, 1904	176	3 v.	11	.6	0	27	28	0	95	3	.250	.034	.000	Trace.	50	−
St. Louis River above Cloquet [a]	Dec. 11, 1903	160	......	10	1.0	0	46	62	......	......	......	.26	.10	.000	Trace.	350	+
Do.	Jan. 31, 1904	112	......	<7	.3	Trace.	80	123	......	......	......	.225	.081	.000	Trace.	......	−
Do.	May 16, 1904	240	3 v.	20	.3	0	23	28	0	......	......	.33	.02	.000	.00	550	−
Do.[b]	Oct. 31, 1904	292	2 v.	17	1.6	0	34	35	1.5	121	13	.502	.036	.000	.04	1,000	−
Do.[b]	Feb. 25, 1905	112	2 v.	<7	1.2	0	104	100	1.0	151	23	.322	.152	Trace.	.08	250	−
St. Louis River below Cloquet [a]	Jan. 31, 1904	112	......	......	.3	Trace.	82	94	......	......	......	.262	.056	.000	Trace.	400	+
Do.	May 16, 1904	260	2 v.+2 M.	20	.4	0	23	28	0	......	......	.26	.02	.000	.00	900	+
Do.[b]	Oct. 31, 1904	324	2 v.	20	1.8	0	33	35	3.0	128	21	.504	.026	.000	.04	900	+
Do.[b]	Feb. 25, 1905	112	2 v.	<7	1.4	0	96	96	1.0	146	13	.312	.072	Trace.	.08	600	+
St. Louis River at Scanlon [b]	Oct. 31, 1904	324	3 v.	19	1.8	0	31	35	3.0	121	16	.504	.036	.000	.04	1,200	+
Do.	Feb. 25, 1905	112	2 v.	<7	1.8	0	98	97	1.0	156	22	.302	.032	Trace.	.08	500	−
St. Louis River average of 11 samples	....	196	2 v.	13	1.0	Trace.	59	66	1.3	137	18	.343	.057	Trace.	.04	......	......

[a] Determinations of chlorine and nitrogens by H. C. Carel; other tests by R. B. Dole.
[b] Analyses by R. B. Dole.
[c] Bacteriological examinations by Dr. E. H. Beckman.
[d] Estimated.

Most of the samples examined were collected from small lakes adjacent to the mining towns in the iron range. (See Pl. VI and Table 63.) Silver Lake, at Virginia, is a small, shallow body of water, which is connected at its upper end immediately with Virginia Lake and discharges by a small brook to Threemile Lake. Neither Silver Lake nor Virginia Lake exceeds one-half mile in diameter or 20 feet in depth, and both receive much infiltration from the city. They are used for log storage. They show high color and low chlorine, sulphuric acid, alkalinity, and total hardness. The albuminoid ammonia is fairly high and nitrites are generally present. *B. coli communis* was isolated in pure culture from every sample taken from these lakes. Samples were collected from Ely Lake at Sparta and at Eveleth. This body of water is considerably larger than either Silver or Virginia Lake. Though possibly as much lumber is floated in it, the effect of the logging operations is different because the volume of water is greater and the timber is stored for shorter periods. In this water the color and all of the dissolved constituents, including the nitrogenous matter, are low. *B. coli communis* was isolated in only one sample, though it might have been found if amounts larger than 1 cubic centimeter had been examined. St. Marys (or Virgin) Lake, about 3 miles from Eveleth, is a small deep body of water surrounded by woods. At the time samples were taken from this lake logging operations were not in progress on its shores and there were no logs in the water. As compared with the other lakes it is lower in color and in organic constituents, especially albuminoid ammonia. The water is very soft, has practically no turbidity, but sometimes has a slight vegetable odor. Its bacterial content is extremely low and *B. coli communis* was not isolated. Longyear Lake lies on the eastern border of Chisholm village. A sawmill is located on its eastern shore and the water is continually used for log storage. It has very high color and odor. It is low in mineral and other contents and is probably the softest water that was examined. *B. coli communis* was isolated from two samples. Embarrass Lake is an enlargement of Embarrass River, long, narrow, and shallow. It lies about three-quarters of a mile east of Biwabik, and is separated from it by a high ridge. Logs are driven on Embarrass River, and the lake generally contains a large number. The water is high in color and the albuminoid ammonia is usually excessive. It is soft and contains practically no sulphates, chlorine, or suspended matter. Its bacterial content is not particularly high and *B. coli communis* was not found.

St. Louis River was sampled (*a*) above all sources of pollution at Cloquet, (*b*) just above the paper mill below the village and (*c*) at Scanlon, 3 miles by river below Cloquet. Comparison of the three samples of each set shows almost identical organic content, and the slight variations are quite as likely to be due to refuse from the sawmills at Cloquet or to normal fluctuations in the water as to pollution from the village. Five large sawmills stand along the river between the points at which the first and second samples were taken, but since the water is full of logs, which probably cause its high color, it is not possible to determine from the examinations whether the mills increase its organic content. *B. coli communis* was isolated once from water taken above Cloquet and in every sample but one taken below the village.

The waters of this basin are, in general, extremely soft. The dissolved minerals are principally small amounts of bicarbonates of calcium and magnesium. Sulphates and chlorides are present only in very small amounts. Table 63 gives an average of 11 examinations of St. Louis River near Cloquet, which shows the general quality of the discharge. It is especially noteworthy that Silver, Virginia, Longyear, and Embarrass lakes and St. Louis River at Cloquet, all of which contain great numbers of logs, show high color, and a vegetable odor; while, on the other hand, Ely and St. Marys lakes, which are not so much used by lumbering firms, show comparatively low color. It is possible that log extract is not the only source of the color, but it is fair to infer from the data at hand that it is the chief source. It should be mentioned in this connection that St. Louis basin below the Mesabi Range is largely swamp land, and the drainage from this area may be in part a cause of the color. Iron was found only in very small amounts. The test for iron was made by thoroughly oxidizing the sample with nitric acid and developing the potassio-ferric sulphocyanide. A qualitative examination of the sample taken from St. Louis River above Cloquet on October 31, 1904, was made to determine the nature of the coloring matter. Twenty-five hundred cubic centimeters of the sample were evaporated to dryness on the water bath and the residue was tested with various reagents. It consisted almost entirely of organic matter of vegetable origin, and the color of the dissolved residue was affected by change in the reaction from acid to alkaline or vice versa. It was apparently a solution of tannin and vegetable extractives.

St. Louis River at Cloquet shows the same seasonal variations that are exhibited by other rivers in the State. In winter the color, the turbidity, and the organic content are decreased, while the total residue, total hardness, and alkalinity are increased.

NOTES ON MUNICIPALITIES.

Four of the thirteen places in this basin have well-water supplies and four have lake-water supplies. Six municipalities report sanitary sewerage.

Biwabik, St. Louis County.—Near Embarrass Lake, which is connected with St. Louis River by Embarrass River. Water supply is obtained from a well in the village, dug and timbered 9 feet by 9 feet square, extending through 100 feet of clay and 75 feet of sand and gravel. Ice supply is procured from Ely Lake at Sparta. No sewerage. Garbage is hauled to a public dump 1 mile from the village and burned as thoroughly as possible.

Carlton, Carlton County.—Near St. Louis River and below Cloquet. No waterworks or sewerage. Ice supply is cut from a mill pond on Otter Creek and from Chub Lake. Garbage is hauled to the village dumping ground and burned.

Chisholm, St. Louis County.—On Longyear Lake. A public water supply is installed; source of water not reported. Garbage is buried at the public dumping grounds.

Cloquet, Carlton County.—On St. Louis River a few miles below its confluence with Cloquet River. No public waterworks. Ice supply is cut from St. Louis River above the village. Sanitary sewerage discharges into St. Louis River. Garbage is hauled to dumping grounds away from the village and burned.

Duluth, St. Louis County.—At confluence of St. Louis Bay, the lower part of St. Louis River, with Lake Superior. Water supply is obtained unfiltered from Lake Superior, 8 miles east of the center of the city, by an intake which extends 1,500 feet into the lake and is 65 feet under water. Ice supply is obtained from Spirit Lake and from Lake Superior. Separate sanitary and storm sewerage systems discharge into Lake Superior. Garbage was formerly dumped on the bay front, but a modern crematory is now being installed. A State Normal School and large hospitals are located at Duluth.

Eveleth, St. Louis County.—On a small creek that enters Swan River, a tributary of the St. Louis. Water supply is taken unfiltered from Lake St. Marys (Virgin Lake), about 3 miles from the city. Ice supply is cut from Lakes Ely and St. Marys. A sanitary sewerage system discharges into the creek west of town, near Spruce Location. Garbage is regularly collected and hauled outside the city limits.

Hibbing, St. Louis County.—Drainage is carried by small creeks to Little Swan River. Water supply is obtained from an old prospecting shaft, 215 feet deep, passing through the following strata:

Log of well at Hibbing, St. Louis County.

	Feet.
Surface soil and gravel	6
Blue-clay hardpan	55
Quicksand	10
Hardpan	7
"Paint rock" and iron ore	127

Ice is shipped in from Lake Ely at Sparta. Sanitary sewerage discharges into Penobscot Creek 2 miles south of the city. Garbage is taken to a dumping ground outside of the city and burned.

McKinley, St. Louis County.—On the shore of a small lake connected with St. Louis River. Water supply is derived from driven wells, 5 inches in diameter by 40 feet deep, on the shore of the lake, passing through blue clay 9 feet and the rest in quicksand. The water is filtered through a chamber containing crushed rock, and provision is made for the use of alum coagulant if necessary. Ice supply is taken from the lake. No sewerage. Garbage is hauled to the village dumping ground.

Proctorknott (Proctor post-office), St. Louis County.—On Kingsbury Creek, which enters St. Louis Bay. No waterworks or sewerage. Ice supply cut from Kingsbury Creek.

Scanlon, Carlton County.—Three miles below Cloquet, on St. Louis River. No waterworks or sewerage. Ice is shipped in from Cloquet. Garbage is collected at regular intervals and deposited outside the village limits.

Sparta, St. Louis County.—On west shore of Lake Ely. Water supply is taken, unfiltered, from Lake Ely, which is at times, especially in the spring, exposed to local pollution. Ice supply is cut from Lake Ely. Considerable ice is sent from Sparta to neighboring cities and villages. No sewerage.

Two Harbors, Lake County.—On north shore of Lake Superior, 27 miles east of Duluth. Water supply is taken from Lake Superior, without filtration, by a 20-inch intake pipe extending 620 feet into the lake, with inlet 56 feet under water. Ice supply is cut from Lake Superior. A combined storm and sanitary sewerage discharges into Agate Bay. Garbage is regularly removed to the public dumping grounds.

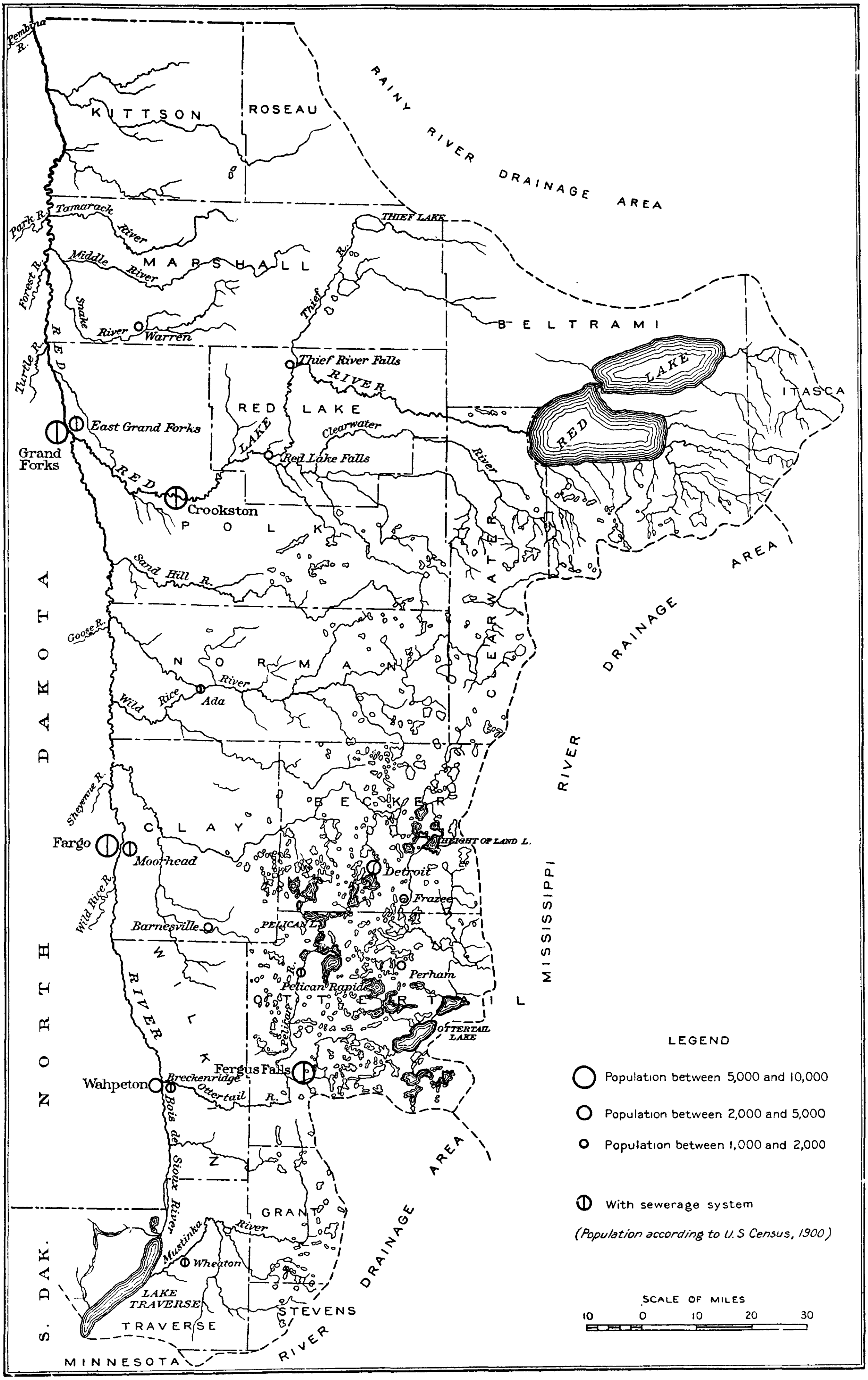
Virginia, St. Louis County.—On the shores of Virginia and Silver lakes. Water supply is obtained from a well on the shore of Silver Lake, with an emergency connection to Silver Lake. Consumers' ice is cut on St. Marys Lake. Ice for cold-storage purposes is cut on Silver Lake. Sewerage discharges into Threemile, or Mashkenoda, Lake.

RED RIVER BASIN.

GENERAL DESCRIPTION.

Boundaries.—Red River drainage area in Minnesota is bounded on the east by Rainy River area and by Mississippi basin, on the south by Minnesota River drainage area, on the west by the Dakotas, and on the north by Canada and minor tributaries of Red River. The river forms the boundary between North Dakota and Minnesota. (Pl. VII.)

This section treats essentially of that part of Red River drainage area which lies in Minnesota, but comprises also descriptions of the three principal North Dakota cities on Red River and a few inor-


KITTSON
ROSEAU
RAINY RIVER DRAINAGE AREA
MARSHALL
BELTRAMI
RED LAKE
ITASCA
POLK
NORMAN
CLEARWATER
BECKER
CLAY
WILKIN
OTTERTAIL
GRANT
STEVENS
TRAVERSE
MISSISSIPPI RIVER DRAINAGE AREA
NORTH DAKOTA
S. DAK.
MINNESOTA
Pembina R.
Park R.
Tamarack River
Middle River
Snake River
Forest R.
Turtle R.
Thief R.
Thief Lake
Red Lake
Red River
Clearwater River
Sand Hill R.
Goose R.
Wild Rice River
Sheyenne R.
Wild Rice R.
Otter tail R.
Bois de Sioux River
Mustinka River
Lake Traverse
Pelican R.
Pelican L.
Height of Land L.
Ottertail Lake
Warren
Thief River Falls
East Grand Forks
Grand Forks
Red Lake Falls
Crookston
Ada
Fargo
Moorhead
Detroit
Frazee
Barnesville
Perham
Pelican Rapids
Fergus Falls
Wahpeton
Breckenridge
Wheaton
LEGEND
Population between 5,000 and 10,000
Population between 2,000 and 5,000
Population between 1,000 and 2,000
With sewerage system
(Population according to U.S Census, 1900)
SCALE OF MILES
10 0 10 20 30

ganic analyses of water from western tributaries, procured from divers sources. Laboratory examinations were made of samples in Red River Valley as far north as Grand Forks, N. Dak., where Red Lake River joins the main stream. No samples were collected from tributaries in North Dakota and no field work was done in that State; consequently the conditions in the western half of the drainage area can be only briefly mentioned.

Character and slope of Red River.—Red River is formed[a] by the confluence of Ottertail and Bois de Sioux rivers at Breckenridge, whence it flows northward in an extremely tortuous course between North Dakota and Minnesota, through the province of Manitoba, into Lake Winnipeg. Its total length from Breckenridge to the Canadian boundary is 395.5[b] miles, though the distance between these points in a straight line is only about half that number of miles. Although the river is very crooked, it does not meander more than 4 or 5 miles to the right or left, but has many short ox-bow curves in its windings. It is a true prairie stream, having all the characteristics of rivers of that type. From Grand Forks to the border it is navigated by flatboats and scows carrying grain and other produce. Red Lake River, the chief tributary, is navigable from Thief River Falls to and across Red Lake. With these exceptions, the streams of this region are not generally used for shipping, either on account of shallow water or the presence of rapids.

Red River is extremely sluggish, its slope rarely exceeding 6 inches per mile.[c] From Breckenridge to Moorhead, which are 41 miles apart in a direct line, the stream runs 97 miles and has a total fall of 74 feet, 34 feet of which occur in a stretch of 21 miles, leaving the average slope of the remainder only 0.5 foot per mile. From Moorhead to Grand Forks, 155 miles, there is generally a slight slope, except at Goose Rapids, where a fall of 13 feet occurs in a little over 13 miles. In the 143.5 miles from Grand Forks to the Canadian border the river has an average slope of about 0.24 foot per mile. From Breckenridge to the international boundary its total fall is 180 feet, and its average slope in the United States is 0.46 foot per mile.

Tributaries of Red River.—Of the two streams that unite to form Red River the Ottertail furnishes 90 per cent of the stream flow. It rises in the southwest part of Clearwater County on the western slope of the Leaf Hills and flows southward to Fergus Falls, passing through or uniting with a great number of lakes scattered over Becker and Ottertail counties, the principal of which are Height of Land, Pine,

[a] Decision of the United States Geographic Board.

[b] Ann. Rept. Chief of Engineers, U. S. Army, for 1904, pt. 1, p. 427.

[c] Ann. Rept. Chief of Engineers, U. S. Army, for 1875, pt. 1, p. 370.
Ibid. for 1904, pt. 1, p. 427.
Gannett, Henry, Profiles of rivers in the United States: Water-Sup. and Irr. Paper No. 44, U. S. Geol. Survey.

Rush, and Ottertail lakes. After its confluence with the chief tributary, Pelican River, 4 miles below Fergus Falls, it follows a westerly course to its mouth. From Ottertail Lake to Breckenridge its total fall is 368 feet, nearly all of which occurs in the hilly country above or near Fergus Falls, the river in its lower portion being sluggish and flowing in a tortuous course. Bois de Sioux River is a small, meandering stream, nearly dry in summer, forming part of the boundary between the Dakotas and Minnesota; Lake Traverse, its headwaters, is a long, narrow body similar to Big Stone Lake, which lies south of it and from the basin of which it is separated by a low, narrow strip of land. Lake Traverse is 1 to 1½ miles wide and 15 miles long, and its average depth is 10 feet. It stretches northeast and southwest in a deep valley, which it fills from bluff to bluff. At its marshy northern extremity the high banks gradually recede and Bois de Sioux River flows from it 35 miles northward to Breckenridge. The river has a total fall of 21 feet. Red Lake River is the outlet of Red Lake,[a] in the central part of Beltrami County. This body of water, the largest lake that is included entirely within the State, is divided into two parts by a long cape extending from the east side. The southwestern portion is slightly larger than the other and is the source of the river. The lake is shallow and is surrounded by marshy woodland. From Red Lake the river runs westward 50 miles to its junction with Thief River at Thief River Falls. This upper portion of the stream is navigable, and regular water communication is maintained during the open season between Thief River Falls and the small settlements on Red Lake. In its southwestern course to Crookston the river traverses several falls and rapids, so that it is not there navigable. Below Crookston it winds westward again as a sluggish prairie stream to its confluence with Red River at Grand Forks, N. Dak. Its total fall from Red Lake to Grand Forks is probably not less than 400 feet.[b] Other smaller tributaries of Red River are Wild Rice, Sand Hill, Snake, and Two Rivers in Minnesota, and Pembina, Cheyenne, and Wild Rice rivers in North Dakota.

Topography.—The basin consists of two sections—a central, rolling prairie and a surrounding hilly country, which is also prairie land but rather more undulating than the lower part. The eastern or hilly part of the basin is forested and contains many lakes; the lower or prairie portion along the main stream comprises many swamps, as well as sites of swamps that have been drained by ditches.

Geology.—Since the entire basin of Red River in Minnesota is covered with thick glacial deposits, nearly all information regarding the

[a] Though Red Lake is commonly regarded as the source of Red Lake River, that name is also applied to the largest tributary of Red Lake, which rises in Lake Julia, in Nebish township, Beltrami County, about 20 miles south of Red Lake.

[b] Water Powers of the United States, pt. 2, sec. 1, p. 90, Tenth Census U. S.

underlying rocks must be derived from an examination of well borings. Fortunately a large number of deep wells have been bored all over the area, and from the records of these borings considerable data concerning the geology of the section have been obtained. The older formations throughout the greater part of the basin are covered by Cretaceous rocks, upon which rests a heavy mantle of Pleistocene deposits. The older rocks have, however, practically no influence on the quality of surface waters in the valley of Red River. The Cretaceous rocks, on the other hand, through their alkaline contents, have an important influence. The stratified materials of this system in Red River Valley have been described in full by Prof. Warren Upham.[a] The earliest deposits, termed the Dakota formation, consist of yellow, red, and white sandstone, with occasional shales and impure lignites. They furnish a strong artesian flow in many parts of the area. Next in order of time are the beds of the Benton formation, consisting of shales and clays, alternating in some places with layers of soft limestone. Above these lie the calcareous marls of the Niobrara and the darker colored shales and clays of the Pierre. The latter three are extensive and generally encountered by well borings sunk throughout the valley. All of these rocks are strongly impregnated with alkaline and alkaline-earth compounds.

The unmodified drift, from 100 to 200 feet thick, consists mainly of hard blue till, which becomes softer and has a yellow color near the surface. Since all this material is largely derived from the disintegration of the Cretaceous deposits, it is, like them, strong in hardening constituents, and on account of its comparatively loose packing is more easily dissolved by the waters with which it comes in contact. Water drawn from wells in the old drift is strongly alkaline and often brackish and unpalatable.

In the latter part of the Pleistocene epoch Lake Agassiz covered the greater part of Red River basin. This immense lake found outlet southward, through the valley now occupied by Traverse and Big Stone lakes and Minnesota River. The traces of its existence consist of the beaches it left in its gradual recession, the broad, deep valley that formed its outlet, and the fine, lacustrine silts which make Red River Valley one of the most fertile regions in the world.

Soil and subsoil.—The characteristic influence of the Cretaceous rocks on the upper layers ot the drift is demonstrated by an examination of Table 64, which gives the average composition of the soil and subsoil in Red River Valley and in the entire State. This table shows how greatly the soil here differs from the soils in other parts of the State, and especially from the nonsoluble soils of the St. Croix Valley.

[a] The Glacial Lake Agassiz: Mon. U. S. Geol. Survey, vol. 25, pp. 81-107.

TABLE 64.—*Chemical composition of soil and subsoil in Red River basin.*

Constituent.	Surface soil.		Subsoil.		Surface soil.			
	Red River basin.	Entire State.[a]	Red River basin.	Entire State.[a]	Marsh.	Swamp.	Peat.	Alkali.
Insoluble in HCl	70.52	79.92	65.93	82.41	19.70	14.33	12.60	67.05
Volatile	10.43	8.98	5.51	5.33	27.72	27.72	52.60	6.57
Potassium oxide (K_2O)	.55	.43	.45	.40	.44	.44	.40	.46
Sodium oxide (Na_2O)	.49	.45	.37	.32	.30	.30	.21	2.56
Calcium oxide (CaO)	2.18	1.29	5.67	1.78	23.27	23.31	12.20	7.48
Magnesium oxide (MgO)	.89	.61	1.52	.80	.80	.80	.64	.16
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	10.59	7.20	10.41	8.32	3.25	3.25	2.02	9.04
Phosphoric anhydride (P_2O_5)	.26	.20	.18	.17	.30	.30	.21	.27
Sulphuric anhydride (SO_3)	.27	.10	.08	.06	.75	.75	.22	1.00
Carbonic anhydride (CO_2)	1.78	.62	5.72	.93	23.00	23.00	12.60	4.84

[a] Snyder, H., Characteristic features of Minnesota soils and conservation of fertility: Bull. 65, Agr. Exp. Sta., University of Minnesota, Chem. Div., Nov., 1899, p. 69.

The amount of soluble material is much greater than the average for the State, while the quantity of volatile matter is slightly less. All other constituents are much higher, especially calcium, magnesium, sodium, and potassium. It is evident that there are considerable amounts of alkaline carbonates, which produce a corresponding hardness in the drainage waters. The analyses given in the last four columns show the characteristic composition of different types of surface soil. The marshes are found to be very high in volatile and soluble constituents, especially in calcium, possibly on account of marl deposits. The peaty soils contain over 50 per cent of volatile matter, and, they too, indicate the presence of much calcium carbonate. True alkali soils are found in many places where the surface of the ground is covered with a white efflorescence due to the deposition of alkaline salts by evaporation. Such soils are naturally high in soluble matter, particularly sodium. Just as the Cretaceous formations have influenced the chemical constitution of the drift, the drift has in turn produced an alkaline soil, which imparts its essential qualities to the lakes and streams that stand or flow over it. The waters examined in this valley show a far greater percentage of dissolved minerals than those in any other part of the State.

INDUSTRIAL POLLUTION.

Only a few manufacturing establishments are located in Red River basin, and these furnish little waste of undesirable character. They are tabulated below.

TABLE 65.—*Industrial establishments causing stream pollution in Red River basin.*

Breweries	4
Sawmills	9
Tanneries	2
Woolen mills	3

Nearly all of the sawmills are on Red Lake River at or above Crookston. The color of the stream may be, to some extent, affected by the logging operations or the wastes from the mills.

MUNICIPAL POLLUTION.

Since Red River basin is devoted principally to lumbering and to wheat raising it is thinly populated, and the size of its towns or cities is determined not by the development of manufacturing interests, but by the necessity for trading centers. The following tables show the distribution of population for three successive censuses:

TABLE 66.—*Population in Red River basin in Minnesota.*

County.	1890.	1900.	1905.
Becker	6,771	10,603	13,425
Beltrami	100	2,949	3,504
Bigstone	508	856	1,032
Clay	11,517	17,942	19,457
Clearwater	(a)	(a)	4,830
Grant	3,437	4,467	4,826
Itasca	100	753	2,795
Kittson	5,387	7,889	9,878
Marshall	9,130	15,689	17,737
Norman	10,618	15,045	18,176
Ottertail	20,661	28,071	29,994
Polk	30,192	35,429	37,212
Red Lake	(b)	12,195	15,955
Roseau	(c)	5,596	8,952
Stevens	797	1,355	1,442
Traverse	4,018	6,852	7,083
Red Lake Indian Reservation	(d)	(d)	1,327
White Earth Indian Reservation	(d)	(d)	4,968
Total population	107,382	173,771	211,872

[a] Formed from part of Beltrami County in 1903.
[b] Formed from part of Polk County in 1897.
[c] No population given for 1890.
[d] Included in county population.

TABLE 67.—*Density of population in Red River basin.*

Area considered.	Drainage area in square miles.	Population per square mile.		
		1890.	1900.	1905.
Red Lake River basin, above Crookston:				
Entire area	[a] 5,525	1.9	4.3	6.7
Excluding chief settlements		1.8	3.6	5.8
Red Lake River basin, above mouth:				
Entire area	[a] 6,100	3.8	7.8	10.2
Excluding chief settlements		2.0	6.3	8.2
Ottertail River basin, above Fergus Falls:				
Entire area	[a] 1,311	10.5	14.7	16.6
Excluding chief settlements		10.0	13.1	14.6
Ottertail River basin, above mouth:				
Entire area	[a] 2,300	11.1	15.7	17.3
Excluding chief settlements		8.4	10.8	11.9
Red River basin in Minnesota, above Moorhead:				
Entire area	[a] 3,800	10.2	15.2	18.0
Excluding chief settlements		6.6	11.6	13.9
Red River basin in Minnesota, above Red Lake:				
Entire area	[a] 7,800	9.3	13.9	16.6
Excluding chief settlements		7.8	11.3	13.6
Red River basin in Minnesota:				
Entire area	[b] 18,365	5.9	9.4	11.5
Excluding chief settlements		4.9	7.7	9.4

[a] Measured from best available maps.
[b] Hall, C. W., Geography and Geology of Minnesota, vol. I, p. 151, Minneapolis, 1903.

The population of the basin is less than half as dense as the average for the State as a whole. Though statistics show that the population is rapidly increasing, it is doubtful whether Red River Valley will ever become as thickly settled as some regions of the State where manufacturing interests are more predominant, for this is essentially a farming and lumbering district. Its most thickly settled part lies between Moorhead and Lake Traverse, particularly in the basin of Ottertail River. The population is most sparse in Red Lake River basin above Crookston. The low population per square mile is counterbalanced, however, so far as stream pollution is concerned, by the fact that the cities and villages are situated directly on the banks of streams into which they discharge sewage and other refuse. Since a great many of these settlements are supplied with unfiltered surface water for general municipal consumption, it is particularly important to consider in detail the chance of river pollution from farms and villages on the watershed. (See Pl. VII.)

TABLE 68.—*Chief settlements in Red River basin, above Breckenridge.*

Locality.	Distance above Breckenridge, in miles.	Population.		
		1890.	1900.	1905.
Detroit	90	1,510	2,060	2,149
Fergus Falls	40	3,772	6,072	6,692
Frazee	110	....	1,000	1,146
Pelican Rapids	60	624	1,033	1,095
Perham	90	761	1,182	1,366
Total	....	6,667	11,347	12,448

TABLE 69.—*Chief settlements in Red River basin, above Moorhead.*

Locality.	Distance above Moorhead, in miles.	Population.		
		1890.	1900.	1905.
Settlements above Breckenridge (see Table 68)	....	6,667	11,347	12,448
Wahpeton, N. Dak	97	1,510	2,228	*a* 2,500
Wheaton	150	383	1,132	1,346
Total	....	9,215	15,989	18,144

TABLE 70.—*Chief settlements in Red River basin, above Grand Forks.*

Locality.	Distance above Grand Forks, in miles.	Population.		
		1890.	1900.	1905.
Settlements above Moorhead (see Table 69)	....	9,215	15,989	18,144
Ada	100	622	1,253	1,515
Barnesville	170	1,069	1,326	1,566
Fargo, N. Dak	155	5,664	9,589	*a* 12,000
Moorhead	155	2,088	3,730	4,794
Total	....	18,658	31,887	38,019

a Estimated.

Table 67 gives the number of inhabitants per square mile above each of the principal cities. Tables 68 to 70 give the principal sources of municipal pollution. In view of the fact that the lesser drainage basins have the same characteristics with a few exceptions, observations on one may be applied as well to the others. The statistics show sources of pollution above every city that uses raw stream water as a public supply. It is also evident from a consideration of gage heights that at certain periods of the year much objectionable, if not dangerous, matter is in the streams, and is transported by them to the vicinity of all the waterworks intakes. Above Fergus Falls, on Ottertail River, there is considerable rural population and immediately above the city intake there are several likely sources of contamination. Fergus Falls itself furnishes too much pollution from its sewers and from the State insane asylum, near by, to permit the use of unfiltered river water at Breckenridge. Fargo and Moorhead, on Red River, are using a water that is objectionable on account of its turbidity, and is besides liable to sewagic pollution not only by settlements above but by the suburbs of the cities themselves. Much of the territory above Crookston, in Red Lake River basin, is timbered and the reservations have not yet been entirely opened for settlement; consequently the population per square mile is low. Three sawmill villages—Thief River Falls, Red Lake Falls, and St. Hilaire—are located on the river above Crookston. The principal source of pollution of Red Lake River above East Grand Forks is Crookston, which discharges sewage into the river. The supply of Grand Forks, N. Dak., is taken from Red Lake at its entrance into Red River. There can be no doubt that Red River, receiving as it does the sewage of Fargo, Moorhead, and Breckenridge, is the more seriously polluted stream of the two. It is also evident that the water of Red Lake River in its unfiltered condition is not safe for drinking or for general domestic use. Whether the sewage from the above-mentioned cities always reaches Grand Forks is a debatable question, not to be decided by a consideration of the distance traveled alone, but by a determination whether the pathogenic bacteria perish during the time consumed in the voyage. Unfortunately, the average stream velocities can not be determined by the data at hand. Ordinarily Red River is sluggish, shallow, and winding. During flood times it is subject to rapid and extreme rises, which sweep the bed free from accumulated organic matter and greatly increase the velocity of the current. Red River carries at all times an amount of suspended matter that would make it undesirable for use without filtration.

The Red River system drains about half of North Dakota along the broad prairie in that part of the State bordering Minnesota east of the Dakota foothills. The valley is devoted almost exclusively to wheat raising, containing within its borders some of the largest farms in the world. The population is sparse, and there are few large cities. Three of the largest—Grand Forks, Fargo, and Wahpeton—are on the banks of Red River. (See Pl. V.) The North Dakota tributaries of Red River are generally small, meandering, and sluggish. Many of them are dry in summer.

QUALITY OF WATER.

The location of sampling stations in Red River basin is shown in Pl. I. They were selected above and below the principal settlements with the view (*a*) of determining how much evidence of pollution from infiltration or from direct discharge of sewage could be gained by laboratory examinations; (*b*) of estimating by rapid and approximate methods the amount of mineral matter ordinarily carried by the streams; and (*c*) of finding the seasonal variation in the chemical and bacteriological conditions of the water. Two complete sets of samples were taken, one late in the fall of 1904, just before the streams closed, the other in the latter part of March, 1905, while the ice was going out and the streams were rising in flood. In addition some miscellaneous samples were taken at Crookston and at Grand Forks. Table 71 gives the results of analyses.

It is commonly believed that the entrance of sewage into water may be detected in analyses by changes in the figures representing certain arbitrary estimates. The amounts of chlorine, free ammonia, and albuminoid ammonia are supposed to increase; nitrites, representing organic matter in an unstable condition of oxidation, are regarded as indicating pollution; the amount of nitrates is considered to represent the completeness of the destruction of the organic material; finally, an increase in bacterial count is expected, together with the presence of *B. coli communis*, an intestinal organism always present in fresh feces. The chemical analyses made fail to reveal positive evidence that any of the unquestionable sources of dangerous pollution damage the stream waters, either because the contaminating substances were much diluted or because the samples did not happen to strike currents of pollution in the rivers. The points for analysis were, however, chosen with the definite object of getting representative samples both above and below each city, and the stations were such as would generally be selected by chemists engaged in similar work. Though some of the analyses indicate slight increases in the figures representing organic matter, yet the changes noted were only such as might be due to normal fluctuations in quality, independent of the introduction of sewage. From this point of view the chemical results are unsatisfactory.

TABLE 71.—*Quality of water in Red River basin.*

[Parts per million.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Bacteria per c. c.[a]	B. coli communis.[a]
Red Lake River:																	
Above Crookston[b]	Dec. 16, 1903				6.4			173				0.42	0.21	0.00	Trace.	500	+
Below Crookston[b]	do			12		0	153									1,000	+
Above Crookston[b]	Jan. 27, 1904	25	0	<7	.3			206				.37	.085	.00	Trace.	350	+
Below Crookston[b]	do	25	0	12	.4	Trace.	164	164				.41	.09	.00	Trace.	900	+
Above Thief River[c]	Nov. 22, 1904	18	0	17	.3	Trace.	144	166	Trace.	210	14	.740	.034	Trace.	.03	800	−
Below Thief River[c]	do	18	0	17	.5	Trace.	146	166	Trace.	220	15	.770	.036	Trace.	.03	1,300	−
Above Crookston[c]	do	12	0	25	.4	Trace.	149	166	Trace.	232	18	.550	.044	.000	.03	1,400	+
Below Crookston[c]	do	12	0	25	.4	Trace.	141	166	Trace.	231	16	.650	.044	.000	.03	2,100	+
At mouth[c]	Nov. 21, 1904	18		40	.9	[d]5	185	251	2.0	280	58	.530	.062	.000	.02	1,600	+
Above Thief River[c]	Mar. 31, 1905	18	2 v.	9	1.0	[d]5	131	129	Trace.			.460	.062	.000	.04	4,100	−
Below Thief River[c]	do	18	2 v.	10	1.2	[d]5	132	129	Trace.			.460	.066	.000	.04	2,700	+
Above Crookston[c]	do	25	2 v.	15	1.7	[d]10	139	149	Trace.			.476	.058	.000		4,700	+
Below Crookston[c]	do	25	1 v.	30	1.7	[d]10	142	142	Trace.			.476	.072	.000		10,500	+
At mouth[c]	do	25	3 v.	50	1.7	[d]20	145	136	1.5	235	54	.488	.042	Trace.	.06	7,700	+
At mouth[c]	May 25, 1905	60	3 v.	250	1.1	[d]15	178	199	Trace.			.570	.134	.000	.04	1,100	+
Ottertail River:																	
Above Fergus Falls[c]	Nov. 18, 1904	4	0	<7	1.0	Trace.	182	209	0	214	8	.248	.020	.000	.02	500	−
Below Fergus Falls[e]	do	4	1M.	<7	1.8	Trace.	181	209	0	213	9	.260	.026	.000	.02	1,500	+
At Breckenridge[c]	Nov. 19, 1904	4		20	1.6	[d]5	197	209	2.5	343	26	.414	.060	.000		1,100	+
Above Fergus Falls[c]	Mar. 28, 1905	4	0	<7	1.9	[d]5	196	183	.5	222	25	.330	.058	.000	.08	375	−
Below Fergus Falls[c]	do	4	1 m.	<7	2.2	[d]5	193	180	.5	219	24	.350	.110	.000	.08	2,600	+
At Breckenridge[c]	Mar. 29, 1905	4	2 e.	100	2.2	[d]5	194	183	2.6	518	32	.660	.172	.002	.07	3,300	+
Traverse Lake at Browns Valley[c]	Dec. 4, 1904	0		10	26.0	432	216	696	Trace.	1,477	517	.860	.182	.004	.04	4,700	−
Bois de Sioux River at Breckenridge[c]	Nov. 19, 1904	60		<7	2.2	442	314	640	Trace.	1,181	340	1.20	.074	.000	.05	2,900	+
Sand Hill River at Beltrami[c]	Nov. 23, 1904	4	0	15	.3	[d]5	278	304		315	17	.270	.150	Trace.	.05	1,300	+
State Ditch at Ada[c]	do	18	2 e.	50	.8	[d]15	247	277	1.0	324	20	.320	.028	.000	.01	1,300	−
Traverse Lake at Browns Valley[c]	Mar. 19, 1905	4	2 v+1 m.	11	13.0	359	112	382	1.5	686	229	.492	.042	.000	.04	4,700	−
Bois de Sioux River at Breckenridge[c]	Mar. 29, 1905	29	3 m.	<7	8.2	185	121	245	Trace.	428	137	.502	.182	.000	.02	1,900	−
Red River:																	
Above Moorhead[c]	Nov. 20, 1904	12		26	7.7	35	209	333	1.0	309	36	.410	.070	Trace.	.00	650	+
Above Red Lake River[c]	Nov. 21, 1904	12		50	9.2	50	242	333	1.0	419	65	.284	.046	.000	.00	800	+
Below Red Lake River[c]	do	18		50	7.2	29	217	333	1.5	341	47	.368	.052	.000	Trace.	3,200	+
At Breckenridge[e]	Mar. 29, 1905	4	2 e.	90	2.6	[d]5	192	186	Trace.	406	20	.522	.158	.002	.07	2,300	+
Above Moorhead[c]	do	4	3 e.	70	2.8	[d]10	172	177	Trace.	291	54	.356	.046	.002	.05	3,700	+
Above Red Lake River[c]	Mar. 30, 1905	4	3 e.	65	9.5	47	200	208	2.0	358	88	.376	.038	Trace.	.07	5,800	−
Below Red Lake River[c]	do	18	3 e+1 M.	60	7.5	37	195	182	Trace.	302	74	.396	.056	Trace.	.07	11,000	+
Above Red Lake River[c]	May 25, 1905	60	2 v+2 M.	550	5.9	81	202	268	Trace.			.570	.060	Trace.	.05	1,600	+
Below Red Lake River[c]	do	60	2 v+2 M.	400	4.8	50	194	243	Trace.			.570	.060	Trace.	.05	2,200	+

[a] Bacteriological examinations by Dr. E. H. Beckman.
[b] Determinations of chlorine and nitrogens by H. C. Carel; other determinations by R. B. Dole.
[c] Analyses by R. B. Dole.
[d] Estimated.

The bacteriological examinations yield much more satisfactory evidences of pollution. Water taken from Red Lake River above Thief River, after flowing through a practically uninhabited country, does not show the presence of *B. coli communis*. In all other samples of water from Red Lake River the organism was found. It is worthy of note that it was isolated from 1 cubic centimeter amounts of every sample taken above the intake of the Crookston waterworks. It was not found in samples of Ottertail River taken above Fergus Falls, but, except in one or two other samples, it was found in the waters of all the rivers of the area.

Red River and most of its tributaries show higher mineral content than the other streams in the State, due to solution of the alkaline materials constantly present in the soil and subsoil. The water of Lake Traverse, at the head of Bois de Sioux River, shows the highest percentage of total and soluble solids, total hardness, sulphuric acid, and chlorine, indicating that it is very strongly charged with alkaline salts. This alkalinity is probably caused by the inflow of springs that have percolated through the calcareous alkaline strata of the bluffs that rise abruptly on both shores. The stream that forms its outlet, Bois de Sioux River, is similarly mineralized. Ottertail River, at Fergus Falls, is low in chlorine, sulphuric acid, turbidity, and color, but has considerable alkalinity and total hardness. The percentage of solids soluble in alcohol is noticeable here, as in general throughout the Red River basin, indicating the probable presence of alkaline salts. There is little change in these constituents at Breckenridge except the increase in turbidity, which causes a corresponding change in total solids. In its northward course from Breckenridge Red River is joined by a large number of short streams that drain swamps or the alkaline soils of the valley near the main river, and the effect of this added drainage is shown by comparison of analyses of the water of Red River at Breckenridge, Moorhead, and above Red Lake River at Grand Forks. The comparatively high chlorine in Red River is undoubtedly due to soluble chlorides derived from the soils and not to sewagic pollution. Therefore this figure gives no index of the sanitary condition of the water. The turbidity is generally high and the color low. The odor is extremely variable. The amount of sulphuric acid is high as compared with that in Mississippi River. The water of Red River is similar in many respects to that of Minnesota River. Iron is always found. The total residue in the water of Red River is higher than that found in any other stream examined, and the percentage of solids soluble in alcohol is noticeable.

TABLE 72.—*Mineral analyses of surface water in Red River basin.*

[Parts per million.]

Locality.	Source.	Date.	Suspended matter.	Silica (SiO_2).	Oxides of iron and aluminum (Fe_2O_3 + Al_2O_3).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Chlorine (Cl).	Sulphate radicle (SO_4).	Carbonate radicle (CO_3).	Total solids.
Bathgate, N. Dak	Tongue River	Mar. 5, 1904 [a]	6.8	29	3.4	100	25	23	12	31	212	....
Crookston, Minn	Red Lake River	Mar. 31, 1903 [a]	18	4.4	2.5	56	17	2.3	5.9	15	111	....
Drayton, N. Dak	Red River	....do	31	14	1	56	20	11	18	26	118	....
Eastedge, N. Dak	Sheyenne River	Mar. 26, 1903 [a]	....	18	Trace.	70	29	43	18	141	130	....
East Grand Forks, Minn	Red Lake River	Mar. 31, 1903 [a]	18	3.7	3.9	50	14	1.3	4.2	12	103	....
Fargo, N. Dak	Red River	Feb. 12, 1903 [a]	....	....	11	82	18	22	2.8	29	175	....
Do	....do	Jan. 15, 1891 [b]	....	8.9	2.5	67	37	1.9	6.1	26	158	341
Fergus Falls, Minn	Ottertail River	Apr. 14, 1903 [a]	3.9	9.9	Trace.	35	23	13	6	5	118.1	....
Do	....do	June, 1882 [c]	....	14	1.2	40	20	4	1.3	1.2	117	[d] 202
Forest River, N. Dak	Forest River	Mar. 31, 1903 [a]	3.7	11	16	116	35	25	12	118	208	....
Graceville, Minn	Lake	Nov 14, 1888 [b]	....	....	49	57	59	58	8.5	186	185	605
Hannaford, N. Dak	Hill Creek	Feb. 24, 1903 [a]	4.9	21	Trace.	128	38	37	18	188	203	....
Jessie, N. Dak	Pond	....do	8	17	10	54	80	339	115	381	383	....
Leeds, N. Dak	....do	Mar. 26, 1903 [a]	12	27	20	82	30	76	18	45	254	....
Lisbon, N. Dak	Sheyenne River	Feb. 12, 1903 [a]	2	14	3.4	103	56	124	36	295	237	....
Magnolia, N. Dak	Pond	Feb. 24, 1903 [a]	11	15	3.	108	75	77	12	354	214	....
Mapleton, N. Dak	Maple River	Feb. 12, 1903 [a]	12	27	5.9	233	114	124	73	547	390	....
Mekinock, N. Dak	Turtle River	Mar. 31, 1903 [a]	....	28	2.	120	34	46	42	158	186	....
Pembina, N. Dak	Pembina River	....do	8.9	7	1.5	60	20	21	18	36	130	....
Ralph, Minn	Brook	Aug. 29, 1901 [b]	....	....	1.5	38	14	8.7	1.3	4.8	100	171
Stockwood, Minn	Buffalo River	Mar. 31, 1903 [a]	9.9	24	2	88	36	17	12	68	192	....
St. Vincent, Minn	Red River	June 10, 1882 [c]	....	13	1.	49	24	16	14	46	117	[e] 284
Wahpeton, N. Dak	Ottertail River	Apr 17, 1903 [a]	2	20	Trace.	34	25	11	6	14	113	....
Wheaton, Minn	Mustinka River	Aug. 13, 1903 [b]	....	....	....	95	60	52	4	328	148	688
Wild Rice, N. Dak	Wild Rice River	Oct. 17, 1888 [b]	....	....	10	78	42	117	41	219	203	712
Winnipeg, Minn	Buffalo River	Apr. 31, 1903 [a]	5.9	12	Trace.	71	33	5.4	6	51	157	....
Valley City, N. Dak	Sheyenne River	Feb. 12, 1903 [a]	....	16	7.5	91	52.3	105	30	188	259	....

[a] Analysis furnished by Kennicott Water Softener Company.
[b] Analysis furnished by Chicago, Milwaukee and St. Paul Railway.
[c] Analysis by W. A. Noyes.
[d] Traces of nitrates, nitrites, bromides, and lithium; potassium=2.4.
[e] Traces of nitrites and bromides. Nitrites=0.83; phosphate radicle=0.49; lithium=0.11; potassium=3.9

The water of Red Lake River resembles in many respects that of upper Mississippi River. It is low in turbidity and sulphuric acid and has moderate alkalinity, total hardness, and total residue, while it carries some color and generally has a vegetable odor. It is somewhat similar to that of Ottertail River above Fergus Falls. The differences between the waters of upper Red Lake and Ottertail rivers and that of Red River lead to the inference that forest lands have considerable influence on the quality of stream water, perhaps because forest soils are less easily disintegrated and not subject to the excessive leaching that occurs in prairie regions. It is at any rate worthy of note that the waters of Red River basin that come from forested areas are softer and apparently contain less alkali than those that come from the prairies.

Red River and Red Lake River unite at Grand Forks. A comparison of the three samples taken in that vicinity, namely, above and below Red Lake River on Red River, and above Red River on Red Lake River, show the effect of diluting Red River with a softer water. The turbidity, chlorine, sulphuric acid, alkalinity, total hardness, and total residue are decreased, while the color is often increased. The organic content of Red Lake River at this point, as shown by the nitrogen determinations, is higher than that of Red River.

In conclusion, a table is given showing the average condition of Red River as compared with upper Mississippi and Minnesota rivers. It is distinctly different from the former and conforms in quality in many respects with the latter.

TABLE 73.—*Summary of quality of water.*

[Parts per million.]

Determination.	Red River.	Minnesota River.	Upper Mississippi River.
Color	21	30	50
Odor			2 v.
Turbidity	151	70	<7
Chlorine	6.3	6.4	.9
Sulphate radicle	38	178	Trace.
Total alkalinity	202	220	151
Total hardness	251	470	136
Iron	Trace.	Trace.	Trace.
Total residue	346	556	189
Soluble residue	54	143	16
Albuminoid ammonia	0.428	0.454	0.475
Free ammonia	0.065	0.193	0.191
Nitrites	Trace.	0.009	0.000
Nitrates	0.03	0.16	0.05

NOTES ON MUNICIPALITIES.

Twenty-five Minnesota settlements are reported in Red River basin. Eleven are supplied with ground water, five with surface water, and six are equipped with sanitary sewerage.

Ada, Norman County.—On Marsh River, which is at this point connected with Wild Rice River by a ditch. Water supply is obtained from two 2-inch tubular wells, 265 feet deep, driven through clay to water-bearing sand. Sewerage system discharges into Marsh River. Ice supply is cut from "Long Lake," a part of the ditch joining the two rivers. Garbage is hauled to a dumping ground outside the village.

Argyle, Marshall County.—On Middle River, 10 miles above its entrance into Snake River. No waterworks or sewerage. Ice supply is cut from Middle River. Some garbage is fed to hogs and the remainder is taken to the village dumping grounds.

Audubon, Becker County.—On Audubon Lake. No waterworks or sewerage. Ice supply is cut from Audubon Lake and other small lakes in the vicinity.

Barnesville, Clay County.—On south branch of Buffalo River. No waterworks or sewerage system. Ice supply is cut from a pond formed by damming a neighboring creek. Garbage is burned or hauled away at intervals.

Black Duck, Beltrami County.—On Black Duck River at the outlet of Black Duck Lake. Water supply for fire protection is taken from two 4-inch wells about 90 feet deep in the drift. Ice supply is cut from a small lake near the village. No sewerage. Garbage is hauled to the village dumping ground.

Breckenridge, Wilkin County.—At point where Ottertail and Bois de Sioux rivers unite to form Red River. Water supply is taken without filtration from Ottertail River near the upper edge of the town. Ice supply is cut from Ottertail River. A combined sewerage system discharges into Ottertail River. Garbage is carted to the village dump.

Crookston, Polk County.—On Red Lake River 50 miles above its entrance into Red River. Water supply is taken unfiltered from Red Lake River 1 mile above the center of the city. Deep-well water is also furnished by a separate system over a limited area. Ice supply is cut from Red Lake River. A combined storm and sanitary sewerage discharges into Red Lake River below the city. Garbage is removed to the village dumping ground and burned.

Detroit, Becker County.—On Pelican River near Detroit Lake. Water supply is obtained from a shallow well dug in sand. Ice supply is cut from Detroit Lake. No sewerage. Garbage is removed to the municipal dumping ground.

East Grand Forks, Polk County.—On Red Lake River at its confluence with Red River opposite Grand Forks, N. Dak. A system of waterworks is under construction. Part of the village is at present supplied from the public system of Grand Forks. Ice supply is cut from Red River, from Red Lake River, and from Maple Lake. Garbage is irregularly hauled outside the village limits.

Fargo, Cass County, N. Dak.—Opposite Moorhead, on Red River. Water supply is taken from Red River without filtration. Ice supply is cut from Red River. The combined sewerage system empties into the same body of water.

Fergus Falls, Ottertail County.—On Ottertail River 40 miles above its confluence with Bois de Sioux River. Water supply is taken unfiltered from Ottertail River at a point 1 mile above the center of the city. Ice supply is cut from Ottertail River. A combined sewerage system discharges into Ottertail River. Some garbage is hauled from the city and some is used for grading. The Third State Hospital for the Insane, 1,500 inmates, is situated about 1 mile north of the center of the city. The hospital is at present supplied with city water and is connected with the city sewers.

Fertile, Polk County.—On Sand Hill River 30 miles below Fosston. Water supply is obtained from a 6-inch well 250 feet deep, passing through sand 10 feet, clay 30 feet, gravel 210 feet. Ice supply is cut from Sand Hill River. No sewerage. Garbage is hauled to the village dumping ground and buried.

Fosston, Polk County.—On Sand Hill River, 30 miles above Fertile. Water supply is obtained from a dug well, 40 feet deep by 20 feet in diameter. Ice supply is taken from lakes near the village. No sewerage. No regular garbage disposal.

Frazee, Becker County.—On Ottertail River, 60 miles above Fergus Falls. No waterworks. Ice supply is cut from Carow Lake, 1 mile east of the village. Garbage is commonly removed to the village dumping ground.

Graceville, Bigstone County.—Water supply is obtained from a deep well. No report on sewerage. Ice supply is cut from Bigstone Lake. Garbage is burned or hauled outside the village limits.

Grand Forks, Grand Forks County, North Dakota.—On Red River, at its confluence with Red Lake River. Water supply is taken from Red Lake River at its entrance into Red River. The water is purified by a slow sand-filtration plant having a capacity of 1,000,000 gallons a day. Ice supply is cut from Maple Lake and Red River. A combined sewerage system empties into Red River. The University of North Dakota and Wesleyan University are located near the city.

Hallock, Kittson County.—On Two Rivers about 10 miles in a direct line above its entrance into Red River. Water supply is taken from the river unfiltered. Ice supply is cut from Two Rivers. No sewerage. Garbage is hauled to the village dumping grounds.

Herman, Grant County.—A short distance north of the South Fork of Mustinka River. Water supply is obtained from a 6-inch tubular well, 122 feet deep, penetrating the following strata:

Log of well at Herman, Grant County.

	Feet.
Black loam	2
Yellow clay	17
Blue clay containing small bowlders	40
Hardpan	1
Blue clay and quicksand	60
Water-bearing gravel	2

The village has no public sewerage.

Lake Park, Becker County.—On Lake Flora, which is connected with Buffalo River. Water supply is obtained from an 8-inch well, 350 feet deep, which passes through the following strata:

Log of well at Lake Park, Becker County.

	Feet.
Loam	3
Yellow clay	130
Blue clay	60
Hardpan	10
Gravel	20
Hardpan	118
Quicksand	6
Gravel	3

Ice supply is cut from Lakes Labella and Boyer, near the village. No sewerage.

Moorhead, Clay County.—On Red River 97 miles below its head. Water supply is taken from Red River unfiltered; ice supply from Red River and Detroit Lake. A combined sewerage system discharges into Red River. Garbage is commonly hauled to the city dumping grounds. A State normal school, 500 pupils, and Concordia College, 400 pupils, are situated in Moorhead.

Pelican Rapids, Ottertail County.—On Pelican River. No waterworks; storm sewerage; ice supply from Pelican River.

Perham, Ottertail County.—Near Ottertail River. Ice supply is cut from Little Pine Lake and Ottertail River. Water supply for fire protection is taken from one large well. No sewerage.

Red Lake Falls, Red Lake County.—On Red Lake River at its confluence with Clearwater River. No waterworks or sewerage. Ice supply is cut from Red Lake River. Garbage is hauled to the public dumping ground and buried.

St. Hilaire, Red Lake County.—On Red Lake River 50 miles above Red Lake Falls. No waterworks or sewerage. Ice supply is cut from Red Lake River. Garbage is hauled to the village dumping ground.

Thief River Falls, Red Lake County.—On Red Lake River about 50 miles below Red Lake. No waterworks or sewerage. Ice supply is taken from Red Lake River below the entrance of Thief River. Garbage is regularly removed during the summer.

Wahpeton, Richland County, North Dakota.—Opposite Breckenridge at confluence of Ottertail and Bois de Sioux rivers. Water and ice supply from Ottertail River. No report on sewerage. Garbage hauled outside the city limits.

Warren, Marshall County.—On Snake River. Water supply is taken from an 8-inch artesian well, 200 feet deep, sunk through clay, hardpan, and sand. Ice supply is cut from Snake River above the dam. No sewerage. Garbage is regularly removed to the village dumping ground and buried during the summer months.

Wheaton, Traverse County.—On Mustinka River. Water supply is obtained from two wells, one 8 feet square by 150 feet deep, curbed with plank, the other 4 inches in diameter by 180 feet deep, with an iron casing. Ice supply is taken from a small creek entering Mustinka River. Garbage is burned at the village dumping ground. A combined sewerage system discharges into Mustinka River.

RAINY RIVER BASIN.

GENERAL DESCRIPTION.

The Rainy River basin, lying along the northern boundary, is more thinly settled and less fully explored than any other part of the State. A chain of lakes forms the international boundary from North Lake, in the northeastern part of Cook County, to Rainy Lake. Rainy River runs westward along the border to Lake of the Woods, which is connected with Hudson Bay by Nelson River. The area is bounded on the north by the Dominion of Canada, on the east by the Laurentian basin, on the south by Mississippi Valley, and on the west by Red River drainage area. It includes the northern parts of Cook, Lake, St. Louis, Itasca, and Beltrami counties, comprising an area of 9,675 square miles.[a] It is in large part covered with pine forests, but contains many large swamps, which by artificial drainage will become productive lands. The principal tributary of the Rainy River system is Vermilion River, which rises in Vermilion Lake, a large body of water of very irregular form, not very deep, situated in the north-central part of St. Louis County, on the western edge of the Vermilion iron-bearing district, at an elevation of about 1,330 feet above sea level. From a northern arm of this lake Vermilion River runs northward, with numerous falls and rapids, to Crane Lake, and empties into one of the chain of lakes forming the northern boundary. Other important tributaries are Bowstring River, which enters Rainy River about 15 miles below Rainy Lake and drains much of Itasca County, and Little Fork River, which enters Rainy River a short distance above Bowstring River.

[a] Hall, C. W., Geography and geology of Minnesota, vol. 1, p. 151, Minneapolis, Minn., 1903.

INDUSTRIAL POLLUTION.

At present there is in this area practically no pollution of rivers from industries. One brewery and two sawmills are located at Tower, on the shore of Tower Bay, an arm of Vermilion Lake. Koochiching, now a frontier village at International Falls, near the outlet of Rainy Lake, is likely to become a manufacturing center and may sometime be the site of important industries. Near Tower and at Ely there are large shaft mines from which considerable water is pumped. This drainage is unimportant and will probably never cause any trouble.

MUNICIPAL POLLUTION.

As previously stated, Rainy River basin is the most thinly settled area in the State. The following table shows the distribution of population:

TABLE 74.—*Population of Rainy River basin in Minnesota.*

County.	Population. U. S. census, 1890.	U. S. census, 1900.	State census, 1905.
Beltrami		2,949	3,504
Itasca	100	886	1,985
St. Louis	4,879	11,251	13,593
Roseau		1,398	238
Bois Fort Indian Reservation	(a)	(a)	762
	4,979	16,484	22,082

a Given in county population.

TABLE 75.—*Density of population in Rainy River basin in Minnesota.*

[Drainage area, 9,675 square miles.]

Area considered.	Inhabitants per square mile. 1890.	1900.	1905.
Entire basin in Minnesota	0.5	1.7	2.3
Excluding chief settlements	.3	1.2	1.7

More than half the inhabitants of this basin live in the Vermilion district of St. Louis County, and most of them are concentrated at Ely and Tower. The pollution from population is therefore inappreciable, except, possibly, in the vicinity of these two places. Ely, a city of 4,045 inhabitants, is on Long Lake, to which its sewage goes. Tower, with 1,340 inhabitants, is on a bay connected with Vermilion Lake. The rapid growth of population in this section and the advantages it presents to settlers indicate that it will soon be as thickly inhabited as any farming section of the State.

QUALITY OF WATER.

Very few chemical or bacteriological examinations of the water in this basin have been made, and not much is known regarding its quality. Since the rocks of this region are hard and insoluble, and the drift is largely derived from granite, schists, and slates, it is fair to presume that the waters will not be extremely hard. Samples were collected from Tower Bay and Vermilion Lake, outside Tower Bay, near Tower, as well as from the head and the foot of Long Lake and from over the waterworks intake at Ely. Analyses of these are given in Table 76.

The water of Tower Bay shows a higher color than that of the main lake, but in other respects it is much the same. *B. coli communis* was isolated once from the water of Tower Bay. This was in the spring, when flood conditions prevailed, after the ice had gone out. The bacterial count was generally low. The water of Long Lake at Ely is soft. It contains little matter that could be called incrusting, but its color makes the use of a coagulant desirable in its purification.

NOTES ON MUNICIPALITIES.

Ely, St. Louis County.—On south shore of Long Lake. Water supply is taken from Long Lake and purified by a Continental Jewell filter, with alum coagulant supplemented by a large sedimentation tank. Ice supply is cut from Long Lake. Sewerage discharges into Long Lake. Garbage is regularly removed to the village dumping ground and burned.

Soudan, St. Louis County.—Near Tower. No waterworks or sewerage. Ice supply is cut from a small pond. Garbage is hauled outside the village limits.

Tower, St. Louis County.—On shore of Tower Bay, an arm of Vermilion Lake. Water supply for fire protection is taken from a small creek running through town. Ice supply is cut from East Two Rivers. No sewerage. Garbage is hauled to the village dumping ground.

MISSOURI RIVER BASIN.

GENERAL DESCRIPTION.

In the southwest corner of the State, parts of Pipestone, Rock, Murray, Jackson, Lincoln, and Nobles counties are drained by streams tributary to Missouri River, principally by Rock River. This stream has its source in Etna Township, Pipestone County, flows southward, and enters Big Sioux River near Calliope, Iowa. Little Sioux River has its source near Lakefield, Jackson County, flows southwestward across Iowa, and discharges into Missouri River near River, Iowa.

TABLE 76.—*Quality of water in Rainy River basin.*

[Parts per million.]

Locality and source.	Date.	Color.	Odor.	Turbidity.	Chlorine.	Sulphate radicle.	Total alkalinity.	Total hardness.	Iron.	Total residue.	Soluble residue.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Bacteria per c.c.[a]	B. coli communis.[a]
Tower Bay:																	
At Tower[b]	Nov. 30, 1903	324	3v	13	1.3	0	16	34	....	......	......	0.25	0.13	0.000	0.00	200	—
Do.[b]	Feb. 5, 1904	......	......	<7	.3	0	24	51	....	......	......	.32	.42	Trace.	.00	......	—
Do.[b]	May 10, 1904	148	2v	12	.3	0	18	36	0	......	......	.52	.19	.000	Trace.	104	+
Vermilion Lake:																	
At Tower[b]	Feb. 5, 1904	60	......	<7	.2	0	23	41	....	......	......	.28	.07	.000	Trace.	18	......
Do.[b]	May 10, 1904	74	2v	<7	.3	0	22	36	0.5	......	......	.26	.09	.000	Trace.	10	—
Do.[c]	Sept. 17, 1904	56	0	11	.7	0	26	35	0	70	23	.470	.056	.000	Trace.	70	—
Long Lake at Ely:																	
Upper end[b]	Feb. 6, 1904	40	0	<7	.2	Trace.	29	44	....	......	......	.37	.21	Trace.	Trace.	......	—
Do.[b]	May 9, 1904	50	2v	<7	.3	0	15	36	Trace.	......	......	.28	.08	.000	Trace.	250	+
Do.[c]	Sept. 18, 1904	40	2v	11	.4	0	26	26	0	43	11	.202	.022	.000	.00	250	—
At intake[b]	Feb. 6, 1904	44	0	<7	.2	Trace.	26	37	....	......	......	.225	.085	Trace.	Trace.	......	—
Do.[b]	May 9, 1904	56	0	<7	.3	......	......	29	....	......	......	.30	.04	.00	Trace.	110	—
Do.[b]	June 5, 1904	......	......	......	......	......	......	......	....	......	......	.18	.10	.00	.00	50	—
Do.[c]	Aug. 15, 1904	44	1v	<7	.9	......	25	28	....	83	......	.262	.070	.00	.00	75	+
Lower end[b]	Dec. 1, 1963	15	......	<7	......	0	27	34	....	......	......	......	......	......	......	33	—
Do.[b]	Feb. 6, 1904	40	0	<7	.2	Trace.	25	34	....	......	......	.22	.09	.00	Trace.	20	—
Do.[b]	May 9, 1904	44	0	<7	.3	0	26	42	Trace.	......	......	.26	.07	.00	Trace.	......	......
Do.[c]	Sept. 18, 1904	40	2M	11	1.2	0	27	28	0	65	8	.380	.032	.000	.00	100	+

[a] Bacteriological examinations by Dr. E. H. Beckman.
[b] Nitrogen and chlorine determinations by H. C. Carel; other determinations by R. B. Dole.
[c] Analyses by R. B. Dole.

MUNICIPAL POLLUTION.

This is in general a farming area, with only small trading centers. The population is shown in Table 77.

TABLE 77.—*Population in Missouri River basin in Minnesota.*

County.	Population.		
	1890.	1900.	1905.
Pipestone	5,132	8,941	9,339
Lincoln	1,139	1,793	1,998
Rock	6,817	9,668	9,729
Murray	631	1,103	1,648
Nobles	3,979	7,466	7,528
Jackson	820	1,304	1,306
	24,518	30,195	31,348

TABLE 78.—*Density of population in Missouri River basin in Minnesota.*

[Drainage area, 1,550 square miles.[a]]

	Population per square mile.		
	1890.	1900.	1905.
Entire basin	15.8	19.5	20.2
Excluding chief settlements	13.6	15.6	16.1

[a] Hall, C. W., op. cit., p. 151.

NOTES ON MUNICIPALITIES.

Adrian, Nobles County.—On Kanaranzi Creek, 15 miles above its entrance into Rock River. Water supply is obtained from a large well, ice supply from Kanaranzi Creek. No sewerage. Manure is hauled to adjacent farms; other combustible rubbish is usually burned.

Lakefield, Jackson County.—On Little Sioux River [a] near its head. Water supply is derived from an 8-inch tubular well, 185 feet deep, passing through black loam 2 feet, yellow clay 42 feet, sand 2 feet, blue clay hardpan 130 feet, sand 9 feet. Ice supply is cut from Heron Lake. No sewerage. Manure is regularly hauled to the village dumping ground. House garbage is privately collected and fed to hogs.

Luverne, Rock County.—On Rock River. Water supply is taken from a well in the river bottom, 22 feet deep by 20 feet in diameter, stoned and cemented and covered by a wooden roof. It passes through top soil 2 feet, clay 5 feet, gravel 6 feet, quicksand 7 feet. Ice supply is cut from Rock River above the city. Sanitary sewerage discharges into Rock River. Garbage is hauled to the village dumping ground below the city.

Pipestone, Pipestone County.—Near Pipestone Creek, which flows southward into Sioux River. Water supply is obtained from two

[a] Geol. Nat. Hist. Survey Minnesota, Final Rept., vol. 6, Pl. XIX.

wells in the city; one 6 inches in diameter by 200 feet deep, entering rock at 30 feet; the other 8 inches in diameter by 365 feet deep, entering rock at about the same depth. Ice supply is cut from a small lake on the neighboring Indian reservation and from Pipestone Creek. Garbage is hauled to the village dumping ground.

DES MOINES RIVER BASIN.

GENERAL DESCRIPTION.

Des Moines River basin in Minnesota is situated near the southern border of the State. The river has its source in two branches, which flow southward, uniting near Humboldt, Iowa; thence it flows southeastward across Iowa to Mississippi River near Keokuk. The east fork rises in Jay Township, Martin County, and flows through Tuttle Lake into Iowa. The west fork, which is much larger and longer, has its source in Rainy Township, Pipestone County, on the east slope of the Dakota foothills, and flows thence generally southeastward into Iowa, draining parts of Murray, Nobles, Cottonwood, and Jackson counties. It is a fairly swift stream about 100 feet wide and 5 to 6 feet deep.

MUNICIPAL POLLUTION.

Des Moines River basin in Minnesota is a well-settled portion of the State, comprising general farming districts and a few manufacturing and trading centers.

TABLE 79.—*Population of Des Moines River basin in Minnesota.*

County.	U. S. Census, 1890.	U. S. Census, 1900.	State census, 1905.
Cottonwood	2,400	4,234	4,290
Jackson	8,104	13,489	13,572
Martin	1,642	2,779	2,926
Murray	6,061	10,808	10,069
Nobles	3,979	7,466	7,528
Total	22,186	38,776	38,383

TABLE 80.—*Density of population in Des Moines River basin in Minnesota.*

[Drainage area, 1,847 square miles.[a]]

	Population per square mile.		
	1890.	1900.	1905.
Entire basin in Minnesota	12.0	21.0	20.8
Excluding chief settlements	10.5	17.7	17.5

[a] Hall, C. W., op. cit., p. 151.

TABLE 81.—*Chief settlements in Des Moines River basin in Minnesota.*

Locality.	Population.		
	1890.	1900.	1905.
Jackson	720	1,756	1,776
Windom	835	944	1,884
Worthington	1,164	2,386	2,276
Total	2,719	6,086	5,936

NOTES ON MUNICIPALITIES.

Fulda, Murray County.—Near Sevenmile Lake, now usually called Fulda Lake. Water supply is obtained from a well 230 feet deep, entering rock. Ice supply is cut from Sevenmile Lake. No sewerage. Garbage is irregularly hauled outside the village.

Heron Lake, Jackson County.—Near north end of Heron Lake, which is connected by a small lake with Des Moines River. No waterworks or sewerage. Ice supply is cut from Heron Lake. Garbage is dumped on the ground about 1 mile from the village.

Jackson, Jackson County.—On Des Moines River. Water supply is obtained from a well dug in gravel, 20 feet square by 20 feet deep, and walled with brick. There is also an emergency connection with Des Moines River. Garbage is removed to the village dumping ground. A combined sewerage system discharges into Des Moines River.

Slayton, Murray County.—On Beaver Creek. Water supply is obtained from one 8-inch well, 205 feet deep, sunk through hardpan, clay, and gravel. Ice supply is cut from Badger Lake. The village is equipped with storm and sanitary sewerage. Garbage is removed to a dumping ground outside the village.

Windom, Cottonwood County.—On Des Moines River. Water supply is procured from wells. One is an 8-inch well, 280 feet deep. There is also a shallow dug well, 20 feet deep, in the bottom of which about thirteen 3-inch points have been driven to a depth of 60 feet in the gravel. Ice supply is cut from Des Moines River above the dam. No sewerage. Garbage is commonly hauled to adjacent farms.

Worthington, Nobles County.—On Lake Okabena. Water supply is obtained from four driven wells 60 feet deep, three of which are 10 inches and one 8 inches in diameter. At the time of an investigation of the city supply in 1905 a connection existed between the reservoir, into which the well water was discharged, and a cistern that held water coming from a trench or collecting gallery on the shore of Lake Okabena. Ice supply is cut from Lake Okabena. A combined sewerage system discharges into a small creek that runs northward from the city. No systematic garbage disposal.

CEDAR RIVER BASIN.

GENERAL DESCRIPTION.

Cedar River rises in Hayfield Township, Dodge County, and flows southward across Mower County into Iowa; then, turning slightly to the east, it flows across that State to Mississippi River. It drains parts of Dodge, Mower, and Freeborn counties.

MUNICIPAL POLLUTION.

TABLE 82.—*Population of Cedar River basin in Minnesota.*

County.	Population.		
	1890.	1900.	1905.
Dodge	1,974	2,444	2,342
Freeborn	13,077	16,059	16,843
Mower	13,313	16,715	21,385
Total	28,364	35,228	40,570

TABLE 83.—*Density of population in Cedar River basin in Minnesota.*

[Drainage area, 1,165 square miles.[a]]

	Inhabitants per square mile.		
	1890.	1900.	1905.
Entire basin	24.3	30.2	34.8
Excluding chief settlements	18.2	21.7	24.4

[a] Hall, C. W., op. cit., p. 151.

Austin, one of the important cities of the State, situated on Cedar River, about 20 miles above the Iowa boundary, discharges its sewage directly into the stream. Albert Lea, in Freeborn County, on Shellrock River, a tributary of Cedar River, also discharges its sewage into the stream. No analyses of surface waters were made in Cedar River basin during the cooperative work.

NOTES ON MUNICIPALITIES.

Albert Lea, Freeborn County.—Near the upper end of Lake Albert Lea, which is drained by Shell Rock River. Water supply is procured from an artesian well 650 feet deep.[a] Ice supply from Fountain Lake above the city. No report on sewerage.

[a] Bien. Rept. Minnesota State Bd. Health, 1899-1900, p. 172.

Austin, Mower County.—On Cedar River. Water supply is obtained from five drilled wells—one 150 feet, one 400 feet, and three 600 feet deep—passing through the following strata:

Log of well at Austin, Mower County.

	Feet.
Drift	35
Limestone	132
Shale	2
Limestone	306
Shale	25
Sandstone	100

The supply of the deeper wells is probably derived from the "St. Peter" sandstone. There is also an emergency connection with Cedar River. Ice supply is cut from Cedar River. Separate storm and sanitary sewerage discharge into Cedar River. Garbage is removed to the public dumping ground. The Southern Minnesota Normal College and School of Commerce, with 100 to 700 pupils, is situated at Austin.

Blooming Prairie, Steele County.—Near the west fork of Cedar River. Water supply is procured from a 10-inch tubular well, 244 feet deep, which is sunk about 100 feet in the rock. Ice supply is cut from Cedar River. Public sewerage. Part of the garbage is carted outside the village limits.

Glenville, Freeborn County.—On Shell Rock River. No waterworks or sewerage. Ice supply is taken from Shell Rock River.

MUNICIPAL WATER SUPPLIES.

EXTENT OF PUBLIC SUPPLIES.

In order to ascertain the extent to which surface waters are used for public supplies in Minnesota, inquiries were made in over 200 of the principal settlements of the State. Nearly 50 per cent of this information was obtained by visits to the municipalities. The remainder was derived from statements signed by the city or village clerk and by the superintendent of waterworks where there is one. It is believed that fairly accurate information has thus been gained concerning the condition of the water supplies before July, 1905. The results of the inquiry are summarized in the accompanying tables. Table 84 comprises towns supplied with ground water. In the last column it is noted whether there is an emergency connection with an adjacent surface supply. Table 85 gives the names of places having surface supplies, the source of the water, and, under "Remarks," pertinent observations regarding some supplies. Table 86 gives the names of settlements that were reported to be without public waterworks at the close of the inquiry (July, 1905). Henderson, Jordan, and Olivia are the only important settlements that failed to report on waterworks. Table 87 comprises places that have public supplies whose source is not reported.

TABLE 84.—*Places having ground-water supplies.*

Locality.	Source of supply.	Depth.	Diameter of well.	Remarks.
Ada	2 tubular wells through clay to sand.	265 feet	2 inches	Auxiliary supply from State ditch.
Adrian	1 large well	47 feet [a]	12 feet [a]	
Albert Lea	Artesian wells in rock			
Alden	1 deep well	100 feet [a]		
Alexandria	Dug well	30 feet	20 feet	
Appleton	1 well			Connection with Pomme de Terre River.
Austin	5 wells drilled in sandstone	One 150 feet; One 400 feet; Three 600 feet	One 7½ inches; Four 11⅞ inches	
Belle Plaine	1 well			
Bemidji	5 driven wells in swamp	106 feet	3½ inches	
Benson	2 wells			
Bird Island	1 tubular well	285 feet	8 inches	
Biwabik	Dug well through clay into gravel.	175 feet	9 feet square	
Black Duck	2 driven wells	90 feet	4 inches	
Blooming Prairie	1 tubular well in the rock	244 feet	10 inches	
Blue Earth	2 drilled wells; supply from sandstone.	375 feet; 672 feet	6 inches; 8 inches	
Browns Valley	Springs in side of bluff			
Caledonia	1 drilled well; supply from sandstone.	318 feet	8 inches	
Cambridge	1 drilled well in sandstone	140 feet	do	
Cannon Falls	1 drilled well	400 feet	do	
Cass Lake	4 driven wells in sand	28 feet		
Chaska	1 drilled well	640 feet	8 inches	Chiefly used for fire protection.
Chatfield	1 drilled well; supply from rock.	200 feet	6 inches	
Deer River	1 flowing well through clay into gravel.	96 feet	3 inches	
Detroit	Shallow dug well			
Elmore	1 well	300 feet	6 inches	
Faribault	2 artesian wells; 2 surface wells	800 feet; 700 feet; 20 feet		
Fertile	1 well through clay into gravel.	250 feet	6 inches	
Fort Snelling	Artesian well; supply from sandstone.	636 feet	10 inches	
Fosston	1 dug well through clay into sand.	40 feet	20 feet	
Fulda	1 well entering rock	230 feet		
Glencoe	1 drilled well; supply from sandstone.	1,728 feet	8 inches	
Glenwood	Springs			
Graceville	Deep well			
Grove City	1 deep well	740 feet	8 inches	
Hector	do	420 feet	do	
Herman	1 tubular well through clay into gravel.	122 feet	6 inches	
Hibbing	Dug well; old prospecting shaft.	215 feet		
Hutchinson	1 drilled well	160 feet	10 inches	
Jackson	1 dug well in alluvial gravel	20 feet	20 feet square.	Connection with Des Moines River.
Janesville	1 well; supply from gravel	75 feet	3 inches	
Kasson	1 well drilled in rock	200 feet	8 inches	
Kenyon	1 shallow well	25 feet		
Lake Benton	1 well			
Lake City	1 dug well in sand			Emergency connection with Lake Pepin.
Lake Crystal	1 well drilled in rock	775 feet	8 inches	For fire purposes only.
Lakefield	1 tubular well	185 feet	8 inches	Supply from sand.
Lake Park	1 well; supply from gravel	350 feet	8 inches	
Lanesboro	A spring in side of bluff	3 feet	30 feet square.	

[a] Bien. Rept. Minnesota State Bd. Health, 1899-1900, pp. 168-204.

TABLE 84.—*Places having ground-water supplies*—Continued.

Locality.	Source of supply.	Depth	Diameter of well.	Remarks.
Le Sueur	1 drilled well	668 feet	8 inches	
Litchfield	Driven wells in gravel	42 feet	2 inches	
Long Prairie	2 dug wells; masonry lining	20 feet 40 feet	12 feet 30 feet	
Luverne	1 well dug in quicksand	22 feet	20 feet	
McKinley	Driven points in gravel on shore of lake.	45 feet	5 inches	See p. 122.
Madelia	2 wells	206 feet	6 inches	
Madison	Dug wells			For fire protection only.
Mankato	2 artesian wells in rock	650 feet		
Mapleton	1 deep well	265 feet [a]		
Marshall	1 artesian well in rock, 1 deep well, 1 dug well 40 feet deep by 12 feet in diameter with 2 driven points in it.	410 feet 250 feet 70 feet 90 feet	 8 inches 4 inches 9 inches	
Minneota	1 tubular well; supply from sandstone.	105 feet	6 inches	
Montevideo	Collecting galleries in a gully north of town.			Emergency connection to Chippewa River.
Montgomery	1 well through blue clay	238 feet	10 inches	
Monticello	1 drilled well	237 feet	8 inches	
Mora	1 driven well	210 feet	10 inches	
Morris	5 driven wells in sand and gravel.	78 feet	8 inches	
Morton	Springs in gravel bluff			
Mountain Lake	1 dug well; stone curbing	10 feet		
New Prague	1 well	300 feet	8 inches	
New Ulm	6 drilled wells; supply from sandstone.	200 feet	Three 8 inches, two 6 inches, one 10 inches.	
Northfield	1 drilled well; supply from sandstone.	640 feet	8 inches	Iron collects in mains.
North St. Paul	1 well	300 feet	8 inches	Emergency connection with a lake.
Ortonville	1 dug well	45 feet	26 feet	
Owatonna	5 drilled wells in rock; 1 dug well 20 feet by 27 feet.	One 650 feet, one 90 feet, three 120 feet.	8 inches 5 inches 8 inches	120-foot wells in bottom of dug well.
Paynesville	4 tubular wells	80 feet	3 inches	
Perham	1 large well			For fire protection only.
Pipestone	2 wells entering rock at 30 feet.	200 feet 365 feet	6 inches 8 inches	
Plainview	2 drilled wells; supply from sandstone.	335 feet 700 feet	4¾ inches 5¼ inches	
Preston	1 spring			Inclosed with rock and covered.
Princeton	1 tubular well in gravel	187 feet	8 inches	
Redwood Falls	1 dug well	20 feet	12 feet	Connection with Redwood River.
Renville	1 well through clay into sand.	230 feet	8 inches	
Rochester	Bricked well in gravel and driven points (large well).	30 feet	30 feet	Emergency connection with Bear Creek.
Rush City	Shallow wells			Fire protection only.
Rushford	1 drilled well; supply from sandstone.	565 feet	6 inches	Objectionable odor.
St. Charles	1 well; supply from sandstone.	942 feet	10 inches	
St. James	2 drilled wells	185 feet 385 feet	8 inches 10 inches	Dug well for boiler use only.
St. Peter	1 dug well 1 drilled well in the rock	40 feet 350 feet	 8 inches	
Sandstone	2 wells drilled in sandstone	150 feet 750 feet	10 inches 12 inches	
Sherburne	1 artesian well	200 feet [a]		
Slayton	1 tubular well	205 feet	8 inches	Supply from sand and gravel.
Sleepy Eye	Dug well with casing in bottom driven to rock.	20 feet	20 feet	
South St. Paul	Artesian wells			
South Stillwater	Dug and stoned well connected with a brook.	25 feet	20 feet	For fire protection only.

[a] Bien. Rept. Minnesota State Bd. Health, 1899-1900, pp. 168-204.

TABLE 84.—*Places having ground-water supplies*—Continued.

Locality.	Source of supply.	Depth.	Diameter of well.	Remarks.
Springfield	1 well	28 feet	6 inches	
Spring Valley	1 spring			
Stewartville	1 well drilled in rock	62 feet	8 inches	
Stillwater	Spring and a deep well	750 feet	8 inches	Auxiliary supply from Lake McKusick. See p. 95.
Tracy	1 drilled well	500 feet	10 inches	
Virginia	Driven well			Emergency connection with Silver Lake.
Wadena	1 dug well in gravel	22 feet	20 feet	
Warren	1 well through hardpan to sand.	200 feet	8 inches	
Waseca	2 drilled wells	400 feet 1,000 feet	10 inches	
Waterville	1 drilled well	185 feet	8 inches	
Wells	2 wells	200 feet	8 inches 12 inches	
West Minneapolis	1 drilled well	600 feet	8 inches	For fire protection only.
Wheaton	2 wells	150 feet 180 feet	8 feet by 8 feet 4 inches	
White Bear Lake	1 deep well		10 inches	
Willmar	Wells	240 feet		
Windom	1 dug, 1 drilled, and 13 driven wells.	One 20 feet One 280 feet Thirteen 60 feet	14 feet 8 inches 3 inches	Points driven in bottom of shallow well.
Winnebago City	1 well	283 feet	8 inches	
Winona	2 wells in alluvium	35 feet	50 feet	Connection with Mississippi River.
Winthrop	1 tubular well; supply from gravel and sand.	239 feet	10 inches	
Worthington	4 driven wells	60 feet	Three 10 inches, one 8 inches.	
Zumbrota[a]	1 well drilled into limestone	210 feet		

[a] Bien. Rept. Minnesota State Bd. Health, 1901-2, p. 327.

TABLE 85.—*Places having surface water supplies.*

Locality.	Source of supply.	Filtered.	Remarks.
Aitkin	Mud River	No	
Anoka	Rum River	No	
Brainerd	Mississippi River		Filtering capacity inadequate.
Breckenridge	Ottertail River	No	
Crookston	Red Lake River	No	
Delano	Crow River	No	For fire protection only.
Duluth	Lake Superior	No	
Ely	Long Lake	Yes	
Eveleth	St. Marys Lake	No	
Fairmont	Lake Budd	No	
Fergus Falls	Ottertail River	No	
Grand Rapids	Hale Lake	No	
Granite Falls	Minnesota River	No	So-called filter of no practical value.
Hallock	Two Rivers	No	
Little Falls	Mississippi River	No	
Melrose	Sauk River	No	For fire protection only.
Milaca	Rum River	No	Do.
Minneapolis	Mississippi River	No	
Moorhead	Red River	No	
Osakis	Osakis Lake	No	Do.
Park Rapids	Fishhook River	No	Little used for domestic purposes.
Red Wing	Mississippi River	No	For fire protection only.
St. Cloud	do	No	
St. Paul	Small lakes	No	Auxiliary supply from artesian wells. See p. 110.
Sauk Center	Sauk River	No	Little used for domestic purposes.
Sparta	Ely Lake	No	
Tower	Creek	No	For fire protection only.
Two Harbors	Lake Superior	No	
Walker	Leech Lake	No	

TABLE 86.—*Settlements having no public water supply.*

Argyle.	Farmington.	Sauk Rapids.
Audubon.	Frazee.	Scanlon.
Buffalo.	Glenville.	Shakopee.
Carlton.	Hastings.	Soudan.
Claremont.	Heron Lake.	St. Hilaire.
Cloquet.	North Branch.	St. Louis Park.
Cokato.	Ottawa.	Staples.
Dakota City.	Pelican Rapids.	Taylors Falls.
Dodge Center.	Pine City.	Thief River Falls.
East Grand Forks.	Proctorknott.	Waconia.
Elk River.	Red Lake Falls.	Wabasha.
Excelsior.	Royalton.	West St. Paul.

TABLE 87.—*Places whose source of supply is not reported.*

Akely.	Chisholm.	Westbrook.
Canby.	New London.	West Concord.

Several interesting facts are revealed by these tables. Possibly the most striking one is that only 15 settlements, with a population exceeding 1,000, according to the census of 1900, are without public water supplies. The next is that less than 25 per cent of the supplies are surface waters; while correlative with this seeming preponderance of ground supplies is the fact that St. Paul, Minneapolis, and Duluth, the three largest cities in the State, use surface water, except that the St. Paul system is provided with auxiliary wells. Among cities of moderate size those in the southern or older part of the State are generally supplied from wells, and those in the northern, or more recently settled part, are generally supplied from lakes or streams.

DEVELOPMENT OF WATERWORKS.

In the natural development of communities water supply is now one of the first public utilities to be considered. Many things which were once looked upon as luxuries are to-day necessities, and water available for use in the house and in the streets ranks high in this list. When, therefore, a newly established village is obliged to install waterworks in order to obtain reasonable insurance rates, an adjacent river or lake is seized upon as the most convenient source of supply for fire protection. When, subsequently, the householder desires to have running water in his dwelling, he discovers that the water of the river or lake is colored, turbid, or so polluted that it is undesirable. Since color and turbidity are the most obvious troubles they are avoided by the use of shallow wells in the line of seepage to the lake or stream. The householder then finds that the water from these shallow wells is invariably harder than the surface water; that it takes an enormous amount of soap to wash with it; that steam boilers are corroded or scaled by it; and that frequently it contains so much iron that clothing washed in it is rusted and stained. The next move is to explore the deeper aquifers for more suitable water, and in regions where it is possible to obtain supplies in this manner deep wells are generally used as a source of public water. The wells, however, fail to meet the increasing demand and connection with the river is made for use in emergencies. The supply is then worse than ever from a hygienic point of view, for it is never known when the polluted surface water is in use or when after its use the pollution introduced into the system of pipes has disappeared. By increased consumption of the surface water, due to continued growth of urban population, the deep wells in turn become the auxiliary supply and are frequently abandoned altogether. Finally, the ultimate step of filtering the surface water is taken and the city has an abundance of safe, soft water. All settlements do not pass consecutively through every one of these stages. Some places, profiting by the experience of their neighbors, jump at once to the final solution of the problem, and some never progress beyond the first condition. Cities affording examples of all the different stages of development in water supply are found in Minnesota.

COMPARATIVE VALUE OF SURFACE AND GROUND WATERS.

Many factors other than the age of the settlement have, however, influenced a choice between surface and ground supplies. The quantity of water always has been, and doubtless always will be, the chief controlling condition. The supply and the demand, present and prospective, can be accurately estimated by mechanical contrivances, and the results of these measurements, reduced to gallons per day, can be comprehended by a majority of the consumers. There must be at all times sufficient amount of water and sufficient pressure to afford adequate protection in case of fire; sanitary appliances require fixed supplies for their proper performance of duty; sprinklers, hydraulic elevators, and steam boilers also demand a never-failing quantity; therefore the quality of the water is regularly subordinated to the quantity. In recent years, however, the quality has been receiving more and more attention. It has been demonstrated that certain diseases are transmissible by water. It has been shown by experience that water acceptable from a hygienic point of view will not be drunk if it is muddy, highly colored, or odoriferous. With increased scrutiny of the cost of production in industries, the removal of the hardening constituents of water is receiving more careful attention.

As has been noted in previous pages, very few surface water supplies in Minnesota are well protected against pollution, and many of them are therefore likely to become the vehicles for the transportation of pathogenic bacteria. Without engaging in a lengthy discussion of the problem it may be said that many of the shallow wells used for public service are also exposed to danger of infection and that the users of them depend too much on the overtaxed filtration power of the surrounding soil or gravel. On the other hand, the deep wells, especially those in southern Minnesota, can probably be considered safe from a hygienic standpoint if they are carefully cased. Nearly all of the deep driven or drilled wells go through impervious strata, which effectually cut off surface drainage and protect the underlying water-bearing beds. Deep-well water is usually more satisfactory in "esthetic" qualities than raw surface water. In the northern or forested portion of the State many of the streams are frequently so highly colored that their water is undesirable for domestic use in its raw condition, and requires careful filtration before it can be made suitable for many industries. In the southern or prairie section of Minnesota floods scour the easily disintegrated banks of the streams, and the resultant muddy water is objectionable. Some of the deep-well waters develop growths of micro-organisms that impart to them disagreeable odors or tastes and cause troublesome flocculent deposits in pipes. The surface waters are much softer than the ground waters. The deep-well waters carry more mineral matter than those of the lakes and streams in the same region for many reasons. They remain longer and more intimately in contact with the limestones and other rocks containing soluble minerals in the strata through which they pass. Their solvent action on the minerals with which they come in contact is greater than that of surface waters, because of their greater content of carbon dioxide, greater pressure, and other differences in physical conditions. In addition they are not so immediately subject to dilution by soft running water or by rains. Since the underground waters carry a large amount of scale-forming and corrosive ingredients, the task of procuring good water for use in locomotives and for other steaming purposes is difficult in some parts of southern Minnesota. The general employment of deep-well waters in laundries and for domestic purposes is not economical, for they must be artificially softened before they can be used. The reports of waterworks superintendents throughout the State show that in the majority of towns supplied with well waters it is necessary to use preheaters and boiler compounds to make the water suitable for steaming purposes. Soda ash, trisodium phosphate, oils, vegetable mixtures, and all kinds of proprietary boiler compounds are commonly employed. In the smaller cities such trouble as this is not so serious as absolutely to prohibit the use of hard well water, but in the large cities it has been found necessary to provide a soft surface water for steaming purposes, because the cost of softening the well water would economically prohibit its use. At present the solutions of the problem seem to be, on one hand, the filtration of the unprotected surface supplies, or, on the other, the adoption of two separate systems, with deep-well water for general domestic use and with raw lake or stream water for fire protection and industrial use. The latter is costly to install and affords a menace to health, since, if available, it might lead to the use of an unsafe supply for drinking and other domestic purposes.

METHODS OF ANALYSIS.

CHEMICAL EXAMINATIONS.

Field assays.—Color, turbidity, iron, chlorine, sulphates, alkalinity, and total hardness were determined according to the methods outlined in Water-Supply Paper 151, entitled "Field Assay of Water." Odor was determined cold and expressed as outlined in Tables 92 and 93. The field analyses were all made under cover, either in a hotel room or in the office of the local health officer. The determinations of color, odor, iron, and turbidity are comparable in accuracy with laboratory results obtained by the same procedures. The determination of chlorine is probably least accurate on account of its relatively low percentage in the waters as compared with the strength of silver nitrate tablet used. The high color of some samples, error in measuring the amount of water used, and the variation in the strength of tablet may all be sources of error in the determination of alkalinity. These factors may cause a probable error of 5 to 10 parts per million. In case total sulphates were too low for determination by the turbidimeter, the amount was estimated by the cloudiness of the precipitated fluid when held up to the light. Total hardness was so low in nearly all cases that the results are comparable with laboratory figures obtained by using soap solution. When turbidity was less than 7 on the graduated turbidity rod the expression "<7" has been used.

Laboratory analyses before August, 1904.—Samples were collected in 2-quart cork-stoppered or 1-gallon glass-stoppered bottles and shipped in locked wooden boxes to the laboratory, where they were submitted to chemical examination. A few analyses were made by Prof. G. B. Frankforter, dean of the chemical department, University of Minnesota, or by Dr. E. H. Beckman, assistant bacteriologist, Minnesota State board of health. Standard methods were used in the work, and the results are comparable with any laboratory analyses. The greater part of the chemical laboratory work done during this period was performed by H. C. Carel, assistant professor of medical chemistry, University of Minnesota, who was employed by the State board of health to make chemical examinations of water. He determined quantitatively chlorine, ammonias, and total hardness according to current methods.

Laboratory examinations after August, 1904.—The chemical analyses made between August 1, 1904, and July 1, 1905, were performed by R. B. Dole, assistant hydrographer, United States Geological Survey. Color, turbidity, iron, and sulphates were determined according to the methods outlined in Water-Supply Paper 151 and circular 9 of the hydrographic branch. Since it was believed that the importance of the determination of sulphates did not warrant the more laborious gravimetric method, the Jackson electric turbidimeter was used in nearly all cases. In the determination of iron the samples were boiled vigorously with nitric acid in order to insure complete change of the iron to the ferric form.

Chlorine, free and albuminoid ammonia, and nitrates were determined according to the methods described by Mason[a] with some exceptions. If the chlorine content was less than 5 parts per million, 250 cubic centimeters of the sample were concentrated on the water bath with 1 drop of strong sodium carbonate solution before titration. Albuminoid ammonia was determined on the residue after the free ammonia estimate by distilling five 50 cubic centimeter tubes after adding a freshly-boiled alkaline permanganate solution. Many of the samples were highly colored and were decomposed very slowly by the oxidizing agents employed.

Nitrites were determined by the Ilosvay modification of the Greiss method: 0.5 gram sulphanilic acid was dissolved in 150 cubic centimeters acetic acid (specific gravity 1.04); 0.1 gram naphthylamine hydrochloride was boiled in 20 cubic centimeters of water, filtered through a plug of absorbent cotton, diluted to 200 cubic centimeters with acetic acid (specific gravity 1.04), and mixed with the sulphanilic acid solution. Five cubic centimeters of this reagent was added to 100 cubic centimeter amounts of the waters under examination in beakers and coincidently to appropriate dilutions of a standard nitrite solution. By comparison of the colors at the end of twenty minutes the amount of nitrites was estimated. Both nitrites and nitrates are reported as nitrogen.

Alkalinity was estimated by titrating with N/50 sulphuric acid, using methyl orange indicator. Free carbon dioxide was found by titrating with N/10 sodium carbonate, using phenolphthalein indicator.

For total solids 100 cubic centimeters of the sample was evaporated to dryness on the water bath in a tared platinum dish, dried at 110° C. for two hours, cooled, and weighed. For "soluble solids" the total residue was extracted for ten-minute periods with three successive portions of 20 cubic centimeters each, of 65 per cent alcohol; after each digestion the alcohol was carefully decanted; finally, the residue

[a] Mason, W. P., Chemical examination of water, 1902.

was dried at 110° C. for one-half hour, cooled, and weighed. This process is believed approximately to separate the incrustants from the nonincrustants,[a] for silica, ferric oxide, calcium carbonate, calcium sulphate, and magnesium carbonate are practically insoluble in 65 per cent alcohol. Therefore the difference between the total solids and the soluble solids represents approximately the incrustants in the sample.

Total hardness was determined by titrating 50 cubic centimeters of the properly diluted sample with standard soap solution as described by Richards.[b] The mineral content of most of the waters tested is so high that the figure representing the so-called "total hardness" is practically valueless and frequently does not bear proper relation to the other inorganic estimates.

The analytical data are expressed in parts per million. Odor is reported as outlined in circular 8 of the hydrographic branch of the Survey according to the following tables:

TABLE 88.—*Description of odor.*

v. vegetable.	s. sweetish.	f. fishy.
g. grassy.	o. oily.	d. disagreeable.
m. moldy.	a. aromatic.	p. peaty.
M. musty.	e. earthy.	H_2S. hydrogen sulphide.

TABLE 89.—*Intensity of odor.*

Numerical value.	Term.	Approximate definition.
0	None	No odor perceptible.
1	Very faint	An odor that would not be ordinarily detected by the average consumer, but that could be detected in the laboratory by an experienced observer.
2	Faint	An odor that the consumer might detect if his attention were called to it, but that would not otherwise attract attention.
3	Distinct	An odor that would be readily detected and that might cause the water to be regarded with disfavor.
4	Decided	An odor that would force itself upon the attention and that might make the water unpalatable.
5	Very strong	An odor of such intensity that the water would be absolutely unfit to drink; a term to be used only in extreme cases.

BACTERIOLOGICAL EXAMINATIONS.[c]

Collection of samples.—All samples were collected in glass-stoppered bottles having a capacity of 300 cubic centimeters. After the bottles had been thoroughly washed the stoppers were placed in them, a piece of twine was inserted between the stopper and the neck of the bottles to prevent the stopper from sticking, a clean cloth

[a] This procedure has been extensively investigated and employed by the Kennicott Water Softener Company, of Chicago, and by Dr. C. B. Dudley, chief chemist, Pennsylvania Lines.

[b] Richards, E. H., Air, water, and food analysis.

[c] See also Wesbrook, F. F., Laboratory methods and devices: Proc. Am. Pub. Health Assoc., vol. 30, pt. 2, pp. 321-324.

reaching well down on the neck of the bottles was put over the stopper and firmly tied to the neck with twine. The bottles thus prepared were sterilized by dry heat at a temperature of 160° C. for at least an hour. After the samples were collected the stopper was replaced, the cloth tied in position, and the sample labeled and taken to a hotel or some suitable place for making the plates. All plates were made within two hours of the time of collection.

Method of pouring plates.—All Petri dishes were wrapped in filter paper and sterilized by the same method and for the same length of time as the bottles previously mentioned. With a sterile pipette the desired amount of water was taken from the above-mentioned bottle after thorough shaking and placed in a sterile Petri dish. Tubes of plain agar and litmus lactose agar containing about 10 cubic centimeters of the media were melted in a portable water bath and allowed to cool nearly to the point of solidification (about 45° C. to 50° C.). The cotton plugs of these tubes were burned off in the open flame, the plug was removed, the mouth of the tube placed in the flame for a few seconds, and the contents of the tubes poured into the Petri dish containing the measured quantity of water. The cover of the Petri dish was immediately replaced and the contents of the dish were thoroughly mixed and evenly distributed in the usual manner. After the media had solidified, the Petri dish was labeled, replaced in the sterile filter paper, and shipped to the laboratory.

Quantity of water used.—Usually plain agar plates were made with 0.5 cubic centimeter and 0.1 cubic centimeter of water and litmus lactose plates with 0.5 cubic centimeter of water. These amounts were varied as circumstances demanded.

Estimation of average number of colonies.—The plain agar plates were used as a basis for all colony counts. These plates were incubated at a temperature of 22° C. for forty-eight hours after reaching the laboratory. Whenever it was possible the total number of colonies on each plate was counted. Otherwise a definite fraction was counted and the total number estimated from this count. In computing the average number of colonies from two or more plates containing different amounts of water the following method was used: The total number of colonies per cubic centimeter for each plate was multiplied by the number of tenths of a cubic centimeter used in making that plate; these amounts were then added and the sum was divided by the number of tenths of a cubic centimeter contained in all the plates. For example, suppose there were two plates made using 0.5 cubic centimeter and 0.1 cubic centimeter of water. The total number of colonies per cubic centimeter on the plate containing 0.5 cubic centimeter of water was multiplied by 5. To this amount was added the total number of colonies per cubic centimeter on the plate containing 0.1 cubic centimeter of water and this sum divided by 6—that is, the number of tenths of a cubic centimeter used in making both plates; the result was taken as the average total number of colonies per cubic centimeter for this sample of water. Insignificant figures were rejected, according to the recommendations of the committee of the American Public Health Association on standard methods of water analysis.[a]

Method of determining the presence of B. coli communis.—To tubes containing about 1 cubic centimeter of double-strength plain agar melted in the water bath and allowed to cool to about the point of solidification, there was added 1 cubic centimeter of the water by means of a sterile pipette. The tube was then shaken, the mass allowed to solidify, and the tube labeled and shipped with the plates to the laboratory. Immediately upon its receipt at the laboratory the solidified mass was broken up into fine particles with a heavy sterile platinum needle and a tube of plain broth added. The mixture was then placed in the incubator. The litmus lactose agar plates made from each sample were incubated at 37° C. for twenty-four hours after reaching the laboratory and the total number of colonies as well as the acid colonies counted. If there were colon-like colonies on this plate, they were picked and streaked upon litmus lactose agar. If at the end of twenty-four hours this growth taken from individual colonies appeared to be pure, resembled *B. coli communis* under the microscope, and acidified the litmus lactose agar, it was further tested. If there were no colonies on the litmus lactose agar plate which resembled colon, the tube of plain agar which had been incubated for twenty-four hours, was sown into fermentation tubes, to which 0.1 per cent phenol had been added, and incubated for twenty-four hours longer. If gas formed in this tube, sowings were made from it, so that the colon-like organisms could be obtained in purity and tested. If no gas formed in the fermentation tube and no colon-like colonies appeared on the litmus lactose plate, it was reported that *B. coli communis* was not found in 1 cubic centimeter samples. Suspected organisms obtained in pure culture were sown in plain broth, Dunham's peptone solution, litmus milk, fermentation tubes containing 1 per cent dextrose broth, Löffler's blood serum, plain agar, dextrose, maltose, saccharose, and lactose litmus agars and potato. Indol was tested at the end of forty-eight hours and the gas reaction after the same length of time. In all instances where colon was found present its morphological appearance under the microscope and its motility were also determined.

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[a] Proc. Am. Pub. Health Assoc., vol. 30, pt. 2, 1905, p. 84.

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C.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 193.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress, for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the nineteenth in Series L, the complete list of which follows. (WS=Water-Supply Paper.)

SERIES L, QUALITY OF WATER.

WS 3. Sewage irrigation, by G. W. Rafter. 1897. 100 pp., 4 pls. (Out of stock.)
WS 22. Sewage irrigation, Pt. II, by G. W. Rafter. 1899. 100 pp., 7 pls. (Out of stock.)
WS 72. Sewage pollution near New York City, by M. O. Leighton. 1902. 75 pp., 8 pls.
WS 76. Flow of rivers near New York City, by H. A. Pressey. 1903. 108 pp., 13 pls.
WS 79. Normal and polluted waters in northeastern United States, by M. O. Leighton. 1903. 192 pp., 15 pls.
WS 103. Review of the laws forbidding pollution of inland waters in the United States, by E. B. Goodell. 1904. 120 pp.
WS 108. Quality of water in the Susquehanna River drainage basin, by M. O. Leighton, with an introductory chapter on physiographic features, by G. B. Hollister. 1904. 76 pp., 4 pls.
WS 113. The disposal of strawboard and oil-well wastes, by R. L. Sackett and Isaiah Bowman. 1905. 52 pp., 4 pls.
WS 121. Preliminary report on the pollution of Lake Champlain, by M. O. Leighton. 1905. 119 pp., 13 pls.
WS 144. The normal distribution of chlorine in the natural waters of New York and New England, by D. D. Jackson. 1905. 31 pp., 5 pls.
WS 151. Field assay of water, by M. O. Leighton. 1905. 77 pp., 4 pls. (Out of stock.)
WS 152. A review of the laws forbidding pollution of inland waters in the United States, second edition, by E. B. Goodell. 1905. 149 pp.
WS 161. Quality of water in upper Ohio River basin and at Erie, Pa., by S. J. Lewis. 1906. 114 pp., 6 pls.

WS 179. Prevention of stream pollution by distillery refuse, based on investigations at Lynchburg, Ohio, by Herman Stabler. 1906. 34 pp., 1 pl.

WS 185. Investigations on the purification of Boston sewage, by C.-E. A. Winslow and Earle B. Phelps. 1906. 163 pp.

WS 186. Stream pollution by acid-iron wastes, a report based on investigations made at Shelby, Ohio, by Herman Stabler. 1906. 36 pp., 1 pl.

WS 189. The prevention of stream pollution by strawboard waste, by Earle Bernard Phelps. 1906. 29 pp., 2 pls.

WS 192. The Potomac River basin: Geographic history—rainfall and stream flow—pollution, typhoid fever, and character of water—relation of soils and forest cover to quality and quantity of surface water—effect of industrial wastes on fishes, by H. N. Parker, Bailey Willis, R. H. Bolster, W. W. Ashe, and M. C. Marsh. 1907. 364 pp., 10 pls.

WS 193. Quality of surface waters in Minnesota, by R. B. Dole and F. F. Wesbrook. 1907. 171 pp., 7 pls.

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THE DIRECTOR,

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WASHINGTON, D. C.

APRIL, 1907.

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