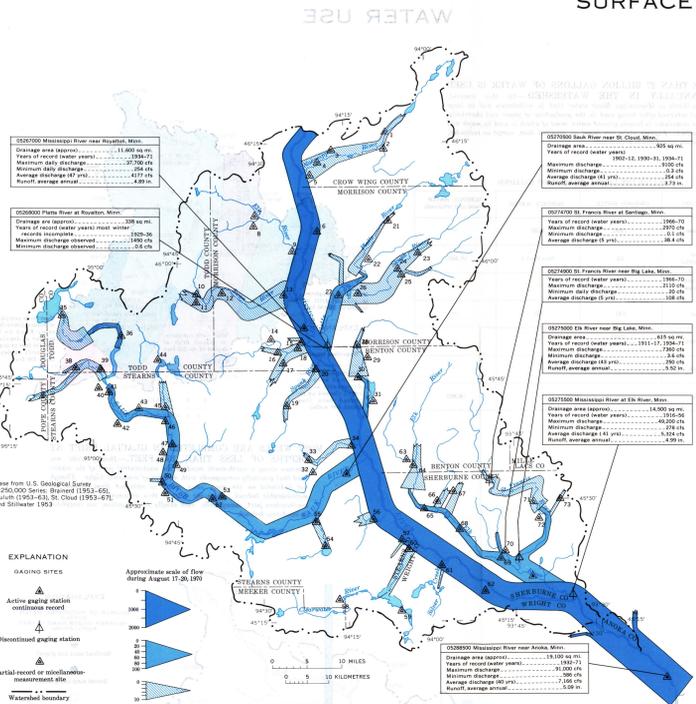
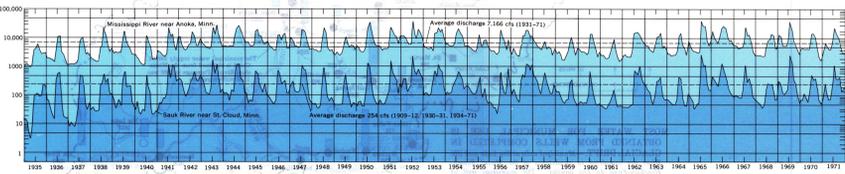


SURFACE WATER



THE FLOW DIAGRAM SHOWS THE DISTRIBUTION OF STREAMFLOW IN THE WATERSHED DURING THE BASE-FLOW PERIOD, AUGUST 17-20, 1950

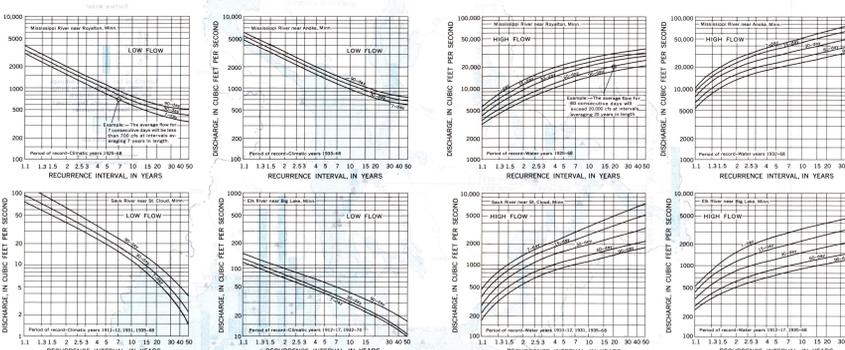
During this time, a series of streamflow measurements was made to determine base-flow yields from various parts of the basin. There was rain in the basin on August 11-12 and during the night of August 11. Total rainfall ranged from 0.6 to 0.8 inch at most stations. The precipitation caused increased runoff in flow at several gauging stations in the watershed, but by August 17, the streams were generally near normal, as discharge measured showed represent base flow. The flow at gauging station 0270500, Sauk River near St. Cloud, and 0272000, Elk River near Big Lake, were at the 60 and 80 percent, respectively, on the flow-duration curve, and 1.1 and 1.2 gpcw recurrence intervals on the 7-day low-flow frequency curve.



THE HYDROGRAPHS OF MONTHLY MEAN DISCHARGES SHOW THE LONGTERM TRENDS IN FLOW FOR TWO STREAMS IN THE WATERSHED

The flow of the Mississippi River near Anoka is affected by regulation from Wheeling, Lock, Polk, and Gull Lakes, and by flow from the Minnesota and Sauk Rivers watershed. The reservoir system was constructed near the headwaters to store flood runoff for release during periods of low flow to benefit navigation on the Mississippi River below Minneapolis, about 10 miles downstream from the Anoka gage.

The maximum annual runoff for the period of the hydrograph, 1952-71, occurred at both gauging stations in the 1952 water year. The 1952 yearly mean discharge was 13,500 cfs for the Mississippi River near Anoka and 62.6 cfs for the Sauk River near St. Cloud. The minimum annual runoff for the Mississippi River near Anoka was in 1963, when the yearly mean discharge was 14,600 cfs. The minimum for the Sauk River near St. Cloud was in 1961, when the yearly mean discharge was 62.2 cfs.



LOW FLOWS IN STREAMS ARE SUSTAINED PRIMARILY BY DISCHARGE FROM GROUND-WATER SOURCES—The slope and shape of the low-flow curves at the higher recurrence intervals reveal how well streams are sustained by groundwater discharge. Comparison of the flow-duration curves for the Elk River near Big Lake and Sauk River near St. Cloud shows that base flows in the Elk River are much larger at the higher recurrence intervals than the base flows of the Sauk River. The difference in the base flows on the Mississippi River is caused by regulation from the six upstream reservoirs during periods of low flow.

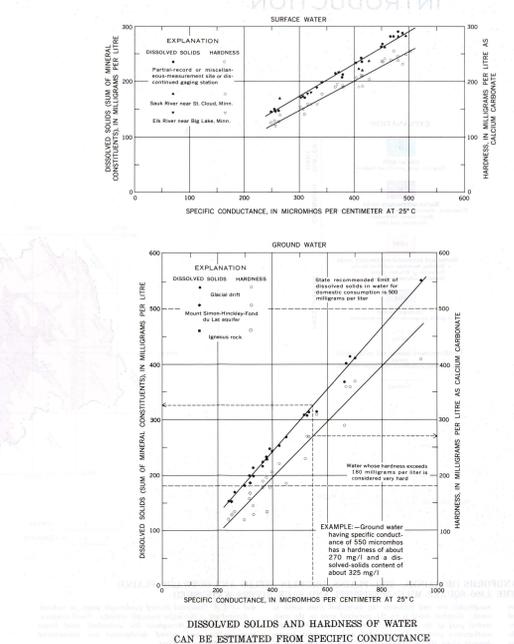
The most extended periods of low flow generally are during the winter, when little or no surface runoff occurs. On the Elk River, for example, during the 22 years of record, the smallest annual monthly flow occurred in December, January, or February.

Number	Station Number	Gauging station partial record of streamflow discharge measurement site	Apparent area (sq. mi.)	Base flow period (Aug. 17-20, 1950)	Base-flow period (Aug. 17-20, 1950)	7-day low-flow recurrence interval (cfs)	7-day low-flow recurrence interval (cfs)
				Discharge (cfs)	Specific discharge (cfs/sq. mi.)	Discharge (cfs)	Yield (cfs/sq. mi.)
1	0261331	Mississippi River near Eden	78	10.2	220	2.81	0.037
2	0261444	Big Lake near Crow Wing	22	137	265	13.1	0.61
3	0261513	Little Rapids near Fort Rouse	23	—	—	—	—
4	0262000	Little Rapids near Fort Rouse	23	—	—	—	—
5	—	Elk River at Randall	43	—	—	—	—
6	—	Elk River at Randall	43	—	—	—	—
7	—	Elk River at Randall	43	—	—	—	—
8	—	Elk River at Randall	43	—	—	—	—
9	—	Elk River at Randall	43	—	—	—	—
10	—	Sauk River at Pillsbury	4	4.80	420	14	0.01
11	—	North Branch Two Rivers near Bowles	11	2.43	202	2.18	—
12	—	North Branch Two Rivers near Bowles	11	—	—	—	—
13	0261500	Sauk River near Hartburg	14	11.0	395	6.57	0.46
14	0261500	Sauk River near Hartburg	14	—	—	—	—
15	0261500	Sauk River near Little Falls	14	—	—	—	—
16	0261700	Mississippi River near Royton	11,600	2380	206	180	0.60
17	—	North Branch Two Rivers near Bowles	11	—	—	—	—
18	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
19	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
20	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
21	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
22	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
23	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
24	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
25	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
26	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
27	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
28	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
29	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
30	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
31	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
32	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
33	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
34	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
35	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
36	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
37	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
38	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
39	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
40	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
41	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
42	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
43	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
44	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
45	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
46	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
47	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
48	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
49	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
50	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
51	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
52	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
53	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
54	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
55	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
56	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
57	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
58	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
59	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
60	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
61	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
62	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
63	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
64	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
65	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
66	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
67	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
68	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
69	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
70	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
71	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
72	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
73	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
74	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
75	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
76	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
77	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
78	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
79	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—
80	0261700	North Branch Two Rivers near Bowles	11	—	—	—	—

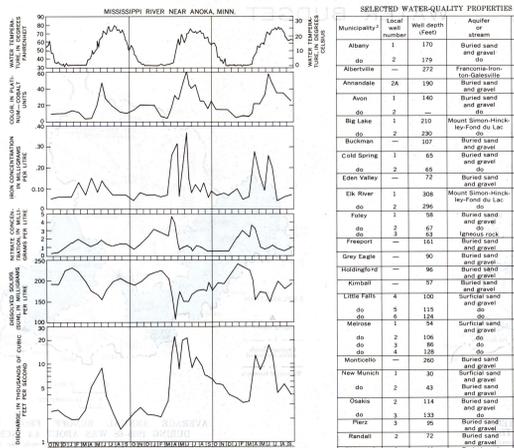
BASEIN CHARACTERISTICS OF STREAMS IN THE WATERSHED ARE REFLECTED BY THE SHAPE OF THEIR FLOW-DURATION CURVES.—The flow-duration curves for the gauging stations on the watersheds of the Mississippi River are typical of large rivers. They all have mild, uniform slopes and are more or less parallel throughout their entire length. Flows at these stations are purely regulated by six reservoirs that have a total available capacity of 1,614,800 acre-feet.

The flow-duration curves for the Elk River near Big Lake and Sauk River near St. Cloud show considerable contrast. The Sauk River station has a drainage area of 322 square miles compared with 412 square miles for the Elk River station, yet the regulated flow indicated by the lower end of the duration curve is much higher in the smaller basin. Part of this difference in flow characteristics can be attributed to the surface geology in the two basins. Surficial sand and gravel, having relatively high water-yielding capability, occur 60 percent of the Elk River basin and only 40 percent of the Sauk River basin.

WATER QUALITY



DISSOLVED SOLIDS AND HARDNESS OF WATER CAN BE ESTIMATED FROM SPECIFIC CONDUCTANCE



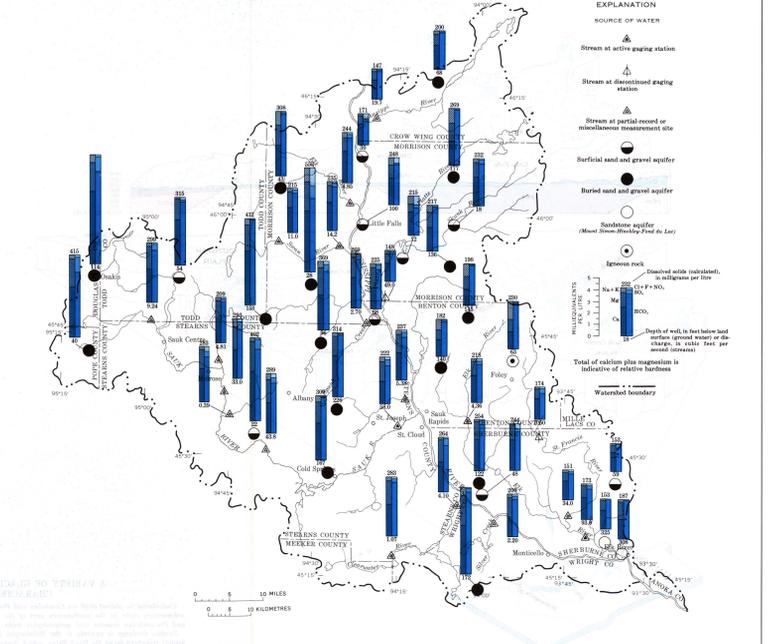
THE DAILY DURATION HYDROGRAPH SHOWS HOW THE MEAN DISCHARGE FOR ANY GIVEN DAY OF THE YEAR VARIED DURING OCTOBER 1959 THROUGH SEPTEMBER 1965.

SOME WATER-QUALITY PARAMETERS ARE CLOSELY RELATED TO DISCHARGE, AS SHOWN BY COMPOSITE DISCHARGE-WEIGHTED ANALYSES OF WATER FROM THE MISSISSIPPI RIVER NEAR ANOKA, MINN.—The inverse relationship between dissolved solids and discharge is the result of dilution by overbank runoff. Some constituents increase in concentration with increasing discharge, because in situ concentration is probably due to the flushing of natural waste and fertilizer into streams by snowmelt or rainfall. Increases in color can be attributed to organic compounds leached from decaying vegetation in soil and stream.

Decaying organic matter, by giving off carbon dioxide, also makes water acid, thereby increasing dissolved iron.

As indicated by a statistical analysis of samples collected at two gauging stations (table right), changes in overall water quality are not significant in the watersheds of the Mississippi River at the water source through the water shed. The largest increases occur in concentrations of nitrate, sulfate, and chloride.

WATER QUALITY



DISSOLVED SOLIDS CONTENT OF GROUND WATER IN GLACIAL DRIFT DECREASES GENERALLY FROM SOUTH-WEST TO NORTHEAST ACROSS THE WATERSHED.

WATER IN GLACIAL DRIFT IS TYPICALLY HARD (121-180 MILLIGRAMS PER LITER) OR VERY HARD (GREATER THAN 180 MILLIGRAMS PER LITER)—Calcium gray drift in the southwestern part of the watershed contains the hardest water because of large concentrations of calcium and magnesium. Water in surficial outwash and in red drift in the northeastern part generally has the lowest hardness.

WATER IN GLACIAL DRIFT CONTAINS IRON AND MANGANESE IN CONCENTRATIONS THAT ARE COMMONLY OBJECTIONABLE FOR SOME USES.—Concentrations that exceed the recommended limits/Minnesota Water Pollution Control Commission 1967) of these constituents (0.30 mg/l for iron and 0.05 mg/l for manganese) are reported color and taste in water. Interference of iron and manganese in certain processes, higher concentrations of iron and manganese, although iron, manganese, and hardness are commonly excessive, particularly in ground water.

Selected analyses of water from different sources (map and table above) indicate variations in individual constituents and properties. Mineralization is generally higher in water in hard aquifers than in surficial aquifers or streams. Nitrate and chloride concentrations, indicators of organic pollution, are commonly highest in surface water and in surficial aquifers because these sources of water are more susceptible. Based on two analyses, dissolved-solids (total) and hardness of water in the Anoka-Stemmed-Flood de Lac aquifer are lower than most water in drift aquifers. Both surface water and ground water are chemically suitable for most purposes.

Calcium magnesium bicarbonate type water is found throughout the watershed. Selected analyses of water from different sources (map and table above) indicate variations in individual constituents and properties. Mineralization is generally higher in water in hard aquifers than in surficial aquifers or streams. Nitrate and chloride concentrations, indicators of organic pollution, are commonly highest in surface water and in surficial aquifers because these sources of water are more susceptible. Based on two analyses, dissolved-solids (total) and hardness of water in the Anoka-Stemmed-Flood de Lac aquifer are lower than most water in drift aquifers. Both surface water and ground water are chemically suitable for most purposes.

Station number	Station name and date of collection	Discharge (cfs)	Chemical constituents and hardness, in milligrams per liter, laboratory pH, and color										Total hardness (calculated as CaCO ₃)	pH	Color			
			Dissolved Solids	Total Solids	Calcium	Magnesium	Sulfate	Chloride	Fluoride	Nitrate	Nitrite	Ammonia				Dissolved Iron	Dissolved Manganese	
1	Mississippi River near Eden	10.2	10.2	220	2.81	0.037	—	—	—	—	—	—	—	—	—	—	—	—
2	Big Lake near Crow Wing	22	137	265	13.1	0.61	—	—	—	—	—	—	—	—	—	—	—	—
3	Little Rapids near Fort Rouse	23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	Little Rapids near Fort Rouse	23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	Elk River at Randall	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	Elk River at Randall	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	Elk River at Randall	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	Elk River at Randall	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	Elk River at Randall	43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	Sauk River at Pillsbury	4	4.80	420	14	0.01	—	—	—	—	—	—	—	—	—	—	—	—
11	North Branch Two Rivers near Bowles	11	2.43	202	2.18	—	—	—	—	—	—	—	—	—	—	—	—	—
12	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	North Branch Two Rivers near Bowles	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	North Branch Two Rivers near Bowles	11	—	—	—	—	—											