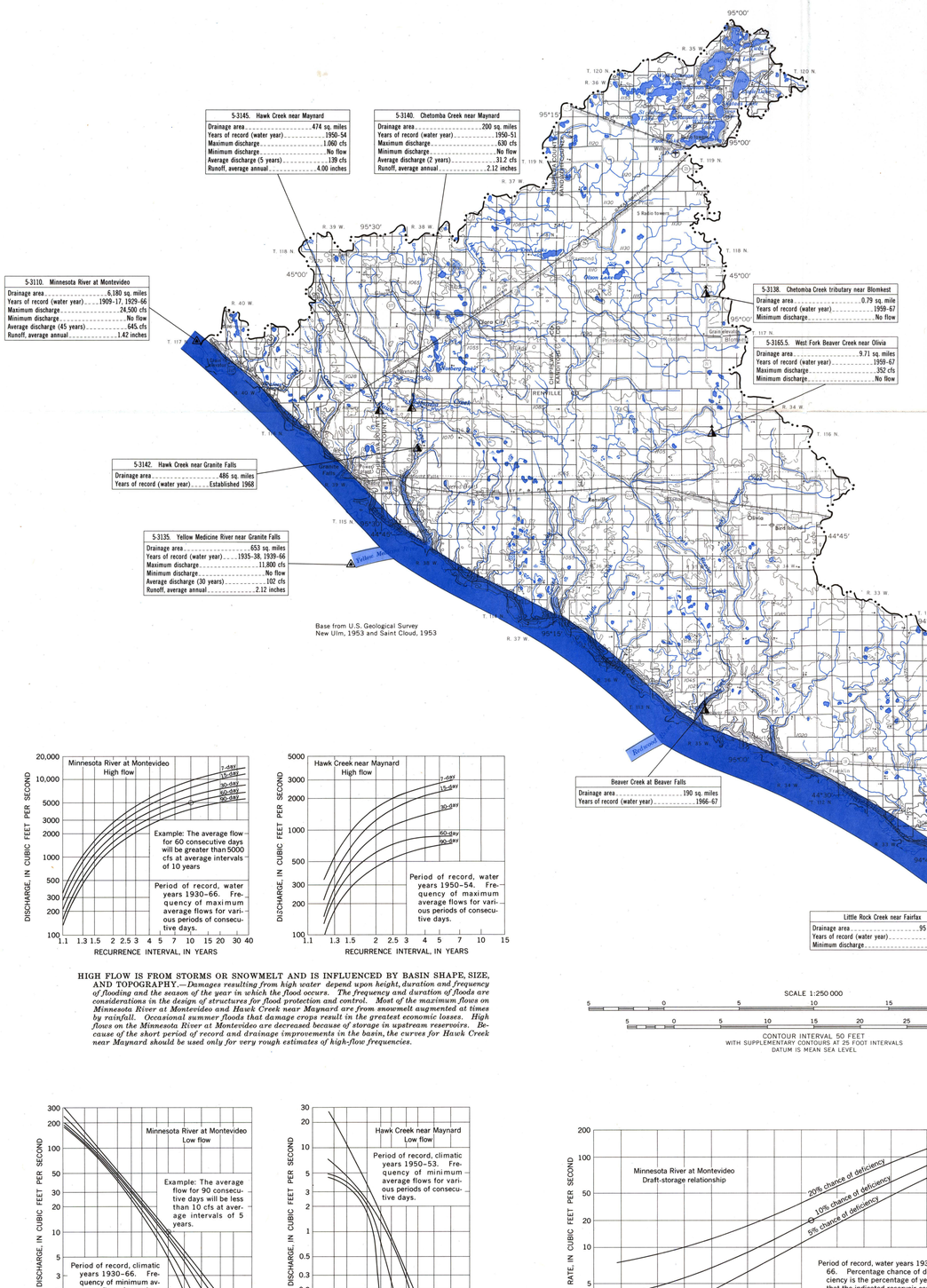
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

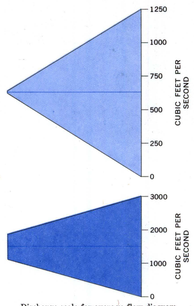
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-391 (SHEET 3 OF 3)

SURFACE WATER



EXPLANATION



Discharge scale for average flow diagram (water years 1942-66)

Automatic recording gage

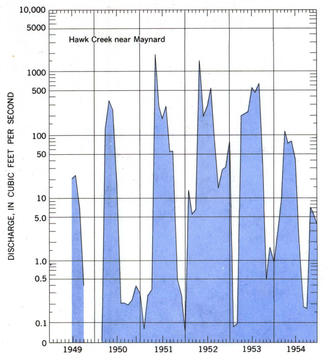
Discontinued daily nonrecording gage

Periodic nonrecording low-flow gage

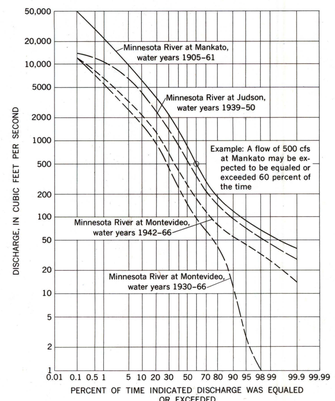
Periodic nonrecording peak-flow gage

Partial record continuous nonrecording gage

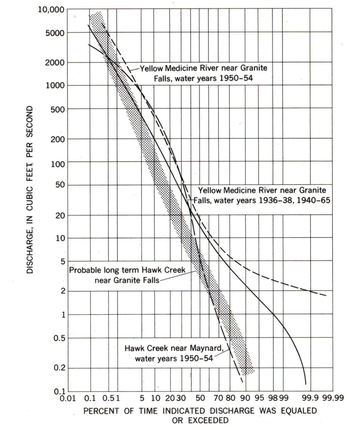
Watershed boundary



STREAMFLOW IS AFFECTED BY SEASONAL VARIATION OF TEMPERATURE AND PRECIPITATION.—*Average flows of consecutive months may vary more than 1,000 cubic feet per second. Large increases in flow usually occur in the spring and are the result of snowmelt runoff accompanied in some years by rainfall.*



COMPARISON OF THE DURATION CURVES FOR THE MINNESOTA RIVER MAIN-STEM STATIONS INDICATES THE SIMILARITY OF FLOW CHARACTERISTICS BETWEEN STATIONS.—*The different shapes of the curves for Minnesota River at Montevideo for different periods are the result of the drought years of the 1930's and the storage in upstream reservoirs beginning in 1937. The difference in the shape of the upper end of the curve for Minnesota River near Judson is the result of the shorter period of record.*



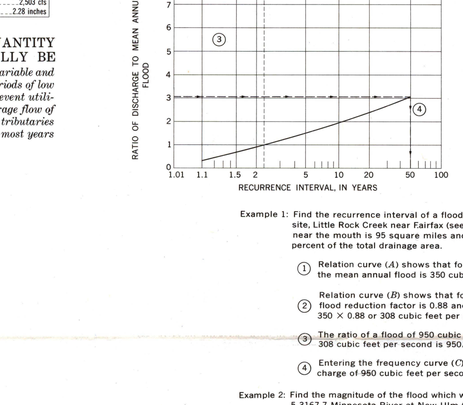
FLOW DURATION IS AFFECTED BY BASIN CHARACTERISTICS.—*Flows which occurred less than 5 percent of the time in Hawk Creek near Maynard have been diminished since about 1960 by flow through an overflow channel above the station. The probable long term curve for Hawk Creek near Granite Falls was estimated based on the duration curves for the Yellow Medicine River and Hawk Creek near Maynard. Drainage improvement projects in the headwaters of the Chetomba Creek and Hawk Creek basins since 1954 should provide flows in the 0.1 to 5 cubic feet per second range for a greater percentage of time than have occurred in the past.*

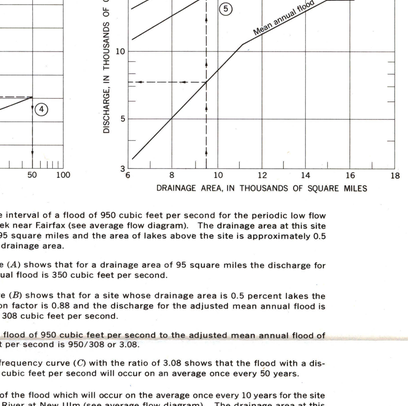
HIGH FLOW IS FROM STORMS OR SNOWMELT AND IS INFLUENCED BY BASIN SHAPE, SIZE, AND TOPOGRAPHY.—*Damages resulting from high water depend upon height, duration and frequency of flooding and the season of the year in which the flood occurs. The frequency and duration of floods are considerations in the design of structures for flood protection and control. Most of the maximum flows on Minnesota River at Montevideo and Hawk Creek near Maynard are from snowmelt augmented at times by rainfall. Occasional summer floods that damage crops result in the greatest economic losses. High flows on the Minnesota River at Montevideo are decreased because of storage in upstream reservoirs. Because of the short period of record and drainage improvements in the basin, the curves for Hawk Creek near Maynard should be used only for very rough estimates of high-flow frequencies.*

LOW FLOWS IN THE MINNESOTA RIVER ARE AUGMENTED BY DISCHARGE FROM UPSTREAM RESERVOIRS AND FROM GROUND-WATER STORAGE.—*The steepness at the low end of the curves is a result of the drought years, 1931-36. The steep slope on the lower end of the Hawk Creek near Maynard curves indicates very little contribution to base flow from the surrounding ground-water reservoir system. Because of the short period of record and subsequent drainage improvements in the basin, the curves for Hawk Creek near Maynard should be used only for very rough estimates of low-flow frequencies.*

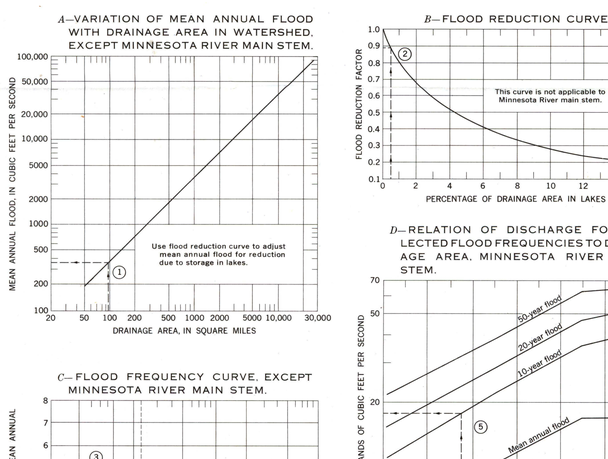
STORAGE OF STREAMFLOW IS REQUIRED TO MAINTAIN SPECIFIED DRAFT RATES WITH A SELECTED CHANCE OF DEFICIENCY.—*Low streamflow would be augmented by use of water stored during periods of high flow. Example: With a 10 percent chance of deficiency, a draft rate of 20 cubic feet per second would require a storage capacity of 2,800 acre-feet.*

THE AVERAGE FLOW DIAGRAM SHOWS THE MAXIMUM QUANTITY OF WATER IN STREAMS THAT COULD THEORETICALLY BE DEVELOPED FOR WATER SUPPLIES.—*Natural streamflow is variable and provision for a constant supply requires storage of high flow for use during periods of low flow. Evaporation, seepage losses, and lack of suitable reservoir sites can prevent utilization of the maximum quantity of water available in the stream. The average flow of the Minnesota River is not increased a significant amount by the flow from the tributaries in the watershed. The tributary flows in the watershed are intermittent in most years and could not economically be developed for municipal supplies.*





STORAGE AND ARTIFICIAL REGULATION OF STREAMFLOW OF THE MINNESOTA RIVER UPSTREAM FROM MONTEVIDEO RESULTS IN A MORE UNIFORM FLOW THROUGHOUT THE YEAR AT MONTEVIDEO THAN OCCURS AT MANKATO.—*This difference, as shown on the hydrographs by the smaller spread between the extremes and limits of mean daily discharges at Montevideo and a larger spread at Mankato, is due to the unregulated tributaries which enter the Minnesota River between Montevideo and Mankato.*



Example 1: Find the recurrence interval of a flood of 950 cubic feet per second for the periodic low flow site, Little Rock Creek near Fairfax (see average flow diagram). The drainage area at this site near the mouth is 95 square miles and the area of lakes above the site is approximately 0.5 percent of the total drainage area.

(1) Relation curve (*A*) shows that for a drainage area of 95 square miles the discharge for the mean annual flood is 350 cubic feet per second.

(2) Relation curve (*B*) shows that for a site whose drainage area is 0.5 percent lakes the flood reduction factor is 0.88 and the discharge for the adjusted mean annual flood is 350 × 0.88 or 308 cubic feet per second.

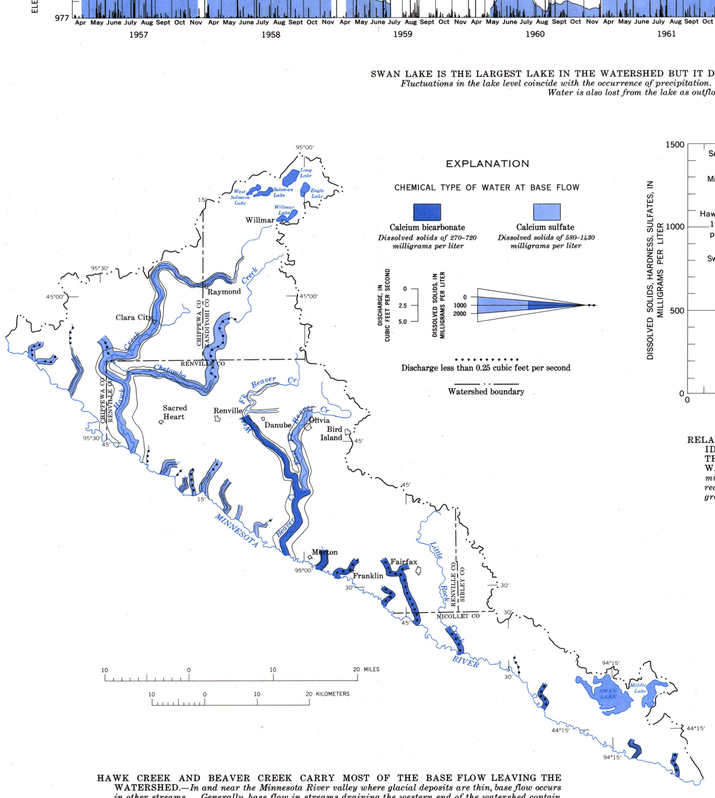
(3) The ratio of a flood of 950 cubic feet per second to the adjusted mean annual flood of 308 cubic feet per second is 950/308 or 3.08.

(4) Entering the frequency curve (*C*) with the ratio of 3.08 shows that the flood with a discharge of 950 cubic feet per second will occur on an average once every 50 years.

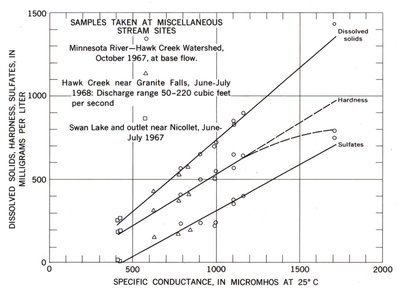
Example 2: Find the magnitude of the flood which will occur on the average once every 10 years for the site 5-3167.7 Minnesota River at New Ulm (see average flow diagram). The drainage area at this site is 9,536 square miles.

(5) Relation curve (*D*) shows that the magnitude of the 10-year flood for a site on the Minnesota River main stem is 19,000 cubic feet per second. The mean annual flood at this same site is 7,200 cubic feet per second from relation curve (*D*).

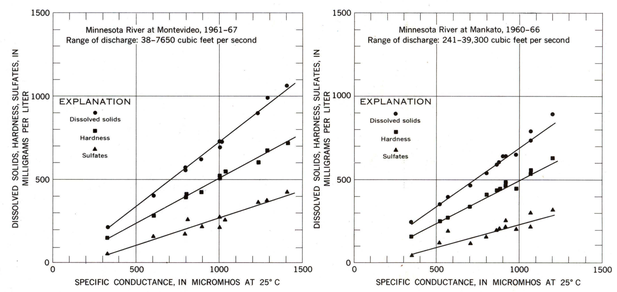
FREQUENCY AND MAGNITUDE OF FLOODING IS RELATED TO DRAINAGE AREA AND PERCENTAGE OF BASIN IN LAKES.—*Small drainage basins with little surface storage allow rapid runoff, resulting in relatively high peak flows of short duration. Larger basins with greater storage provided by lakes and swamps retard surface runoff, resulting in peak flows of lower magnitude and longer duration. The magnitude and frequency of floods can be determined from the above relation curves (Patterson and Gamble, 1963). Curves A, B, and C refer to streams within the watershed, and curve D refers to the Minnesota River between Montevideo and Mankato.*



HAWK CREEK AND BEAVER CREEK CARRY MOST OF THE BASE FLOW LEAVING THE WATERSHED.—*In and near the Minnesota River valley where glacial deposits are thin, base flow occurs in other streams. Generally, base flow in streams draining the western end of the watershed contain slightly higher dissolved-solids and sulfate concentrations. Base flow in streams in the east generally contain lower dissolved-solids and higher bicarbonate concentrations.*



RELATIONSHIPS OF SPECIFIC CONDUCTANCE TO DISSOLVED SOLIDS, HARDNESS, AND SULFATES SHOW THE VARIATIONS OF THESE THREE CONSTITUENTS IN STREAMFLOW WITHIN THE WATERSHED AND IN SWAN LAKE.—*Swan Lake contains lower mineral concentrations than any streamflow in the watershed because it receives its water from precipitation and runoff rather than from the ground-water system.*

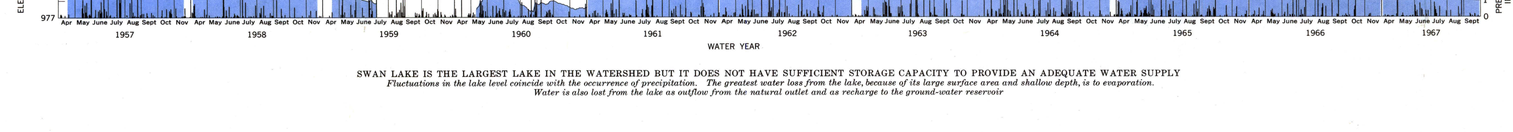


RELATIONSHIPS BETWEEN SPECIFIC CONDUCTANCE AND DISSOLVED SOLIDS, HARDNESS, AND SULFATES ARE CHARACTERISTIC OF MAJOR CHEMICAL CONSTITUENTS IN SOLUTION.—*Small differences in slope between relationships at Montevideo and Mankato are probably indicative of slight changes of water type. At Montevideo, equivalents of sulfates exceed those of bicarbonates during the same period that equivalents of bicarbonates exceed those of sulfates at Mankato. Graphs provide an easy method to estimate concentrations of constituents plotted on the vertical axis, by measuring specific conductance at either location.*

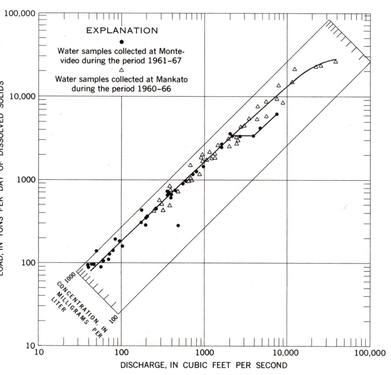
DIFFERENCES IN WATER QUALITY AND DISCHARGE IN THE MINNESOTA RIVER AT MONTEVIDEO AND AT MANKATO REFLECT CHANGES IN ENVIRONMENT.—*Water at Montevideo contains larger dissolved solids and sulfate concentrations while water at Mankato contains slightly higher concentrations of bicarbonates. This change brought about by the Blue Earth and Cottonwood Rivers larger flow components, probably indicates similar changes in surficial geology of these basins to that occurring in the eastern part of Minnesota River—Hawk Creek Basin. Although dissolved solids, color, and some individual constituents exceed recommended limits at times, standard procedures for water treatment will render the water suitable for most uses.*

[Chemical constituents in milligrams per liter, pH, and color found in 47 water samples from Minnesota River at Montevideo, 1962-1967, and 43 samples from Minnesota River at Mankato, 1960-1966]

Source		Boron	Calcium	Iron	Magnesium	Manganese	Potassium	Sodium	Bicarbonate	Chloride	Fluoride	Nitrate	Phosphate	Silica	Sulfate	Color	Hardness	Total dissolved solids	Laboratory pH
Minnesota River at Montevideo.	Maximum	0.28	141	0.44	94	0.95	13	58	473	27	0.6	10	0.98	32	418	50	710	1,060	8.4
	Median	.14	89	.04	52	.06	7.6	26	292	9.0	.3	2.2	.32	18	232	12	445	622	7.6
	Minimum	.06	33	.01	16	.00	4.7	7.8	118	2.8	.1	.1	.00	18	60	3	148	227	6.8
Minnesota River at Mankato.	Maximum	.22	145	.12	99	.72	9.0	44	487	25	.5	22	.87	26	319	50	626	880	8.4
	Median	.10	93	.04	44	.07	5.7	22	308	12	.3	7.9	.19	18	183	10	410	554	7.6
	Minimum	.00	30	.01	10	.00	3.1	4.7	142	3.7	.2	.0	.00	8.8	37	3	162	245	7.1
Recommended limits (Minnesota Water Pollution Control Commission, 1967).		.....	.....	.30	.....	.05	.....	.....	.....	250	1.5	45	.....	.....	250	15	.....	500-1,000	.....



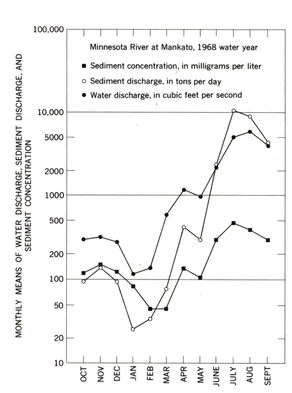
SWAN LAKE IS THE LARGEST LAKE IN THE WATERSHED BUT IT DOES NOT HAVE SUFFICIENT STORAGE CAPACITY TO PROVIDE AN ADEQUATE WATER SUPPLY
Fluctuations in the lake level coincide with the occurrence of precipitation. The greatest water loss from the lake, because of its large surface area and shallow depth, is to evaporation. Water is also lost from the lake as outflow from the natural outlet and as recharge to the ground-water reservoir



DISSOLVED-SOLIDS DISCHARGE IN THE MINNESOTA RIVER ABOVE MANKATO SHOWS A DIRECT BUT NONUNIFORM RELATION TO STREAM DISCHARGE.—*Long-term average (daily and annual) dissolved-solids discharge is calculated by relating daily dissolved-solids discharge to long-term flow duration (45 years at Montevideo and 57 years at Mankato).*

Minnesota River	Long-term average dissolved-solids discharge (tons)		Average dissolved-solids concentration (milligrams per liter)
	Daily	Annual	
at Mankato	3,270	1,195,000	485
at Montevideo	1,090	397,000	625

Long-term average dissolved-solids concentration at Mankato is less than at Montevideo indicating dilution effects from greater runoff between Montevideo and Mankato (long-term average, 154 acre-feet per square mile) than in the drainage area above Montevideo (long-term average, 75.8 acre-feet per square mile). Leaching effects may be greater above Montevideo than between Montevideo and Mankato. Dilution effects at the downstream station and at higher discharges at both stations are shown in the above illustration.



SEDIMENT DISCHARGE AND CONCENTRATION IN THE MINNESOTA RIVER VARY ACCORDING TO STREAM DISCHARGE AND SEASONAL CONDITIONS.—*Low sediment discharge occurs during winter months when there is little sediment available to the stream because of the snow cover and frozen ground. After summer storms, large increases in stream discharge are accompanied by high sediment concentrations and increased sediment discharge. The approximate sediment yield of the Minnesota River basin above Mankato for the 1968 water year was 830,000 tons. Assuming each unit of area contributed an equal amount of sediment, the annual yield was about 56 tons per square mile. The 1968 water year is marked by low spring runoff and high summer runoff.*

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WATER RESOURCES OF THE MINNESOTA RIVER–HAWK CREEK WATERSHED, SOUTHWESTERN MINNESOTA

By
W. A. Van Voast, W. L. Broussard, and D. E. Wheat

1972