STREAMFLOW ESTIMATES IN SELECTED WISCONSIN STREAMS

Open-File Report 79-1282

Prepared in cooperation with the

Wisconsin Department of Natural Resources

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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ABSTRACT

The Wisconsin Department of Natural Resources needs streamflow information in lake basins where lake-rehabilitation programs are implemented but where long-term stream-gaging stations are not justified. The U.S. Geological Survey provided streamflow estimates for 24 streams in Wisconsin. The estimates were made by the use of (1) midmonthly measurements, (2) basin characteristics, and (3) drainage-area-discharge relations. The midmonthly measurement technique probably provides the best estimates of streamflow in streams that may be affected by storage in lakes. However, it is costly, it requires 1 year of measurements, and its results cannot be obtained until streamflow data from gaging stations in the area have been processed. The basin-characteristics technique is quicker and provides good estimates, but defining the basin parameters is difficult. The drainage-area-discharge technique also provides good streamflow estimates, and it is quick, convenient, and inexpensive. However, the streamflow estimates obtained from drainage-area-discharge relations may be biased because the technique is based on gaging-station records for large streams that do not have the variability of smaller streams and that typically do not reflect the influence of lake storage.

STREAMFLOW ESTIMATES

Streamflow estimates have been made for 24 stream sites in Wisconsin (fig. 1). This study was made in cooperation with the Wisconsin Department of Natural Resources (DNR) to provide estimated long-term mean monthly and mean annual streamflow at selected sites in lake basins where DNR is making lake rehabilitation feasibility studies. DNR personnel selected the sites. The streamflow estimates were determined by one or more of three techniques: (1) midmonthly measurements, (2) basin characteristics, and (3) drainage-area discharge.

In this report the accepted U.S. Geological Survey terms relating to mean streamflows are used. "Monthly mean" flow is the mean for a particular month, such as May 1978. "Mean monthly" flow is the mean of all Mays in the period of record, or a long-term mean for May. In the same manner, "annual mean" is the mean for 1 year (1978) and "mean annual" is the long-term mean of all years in the period of record.

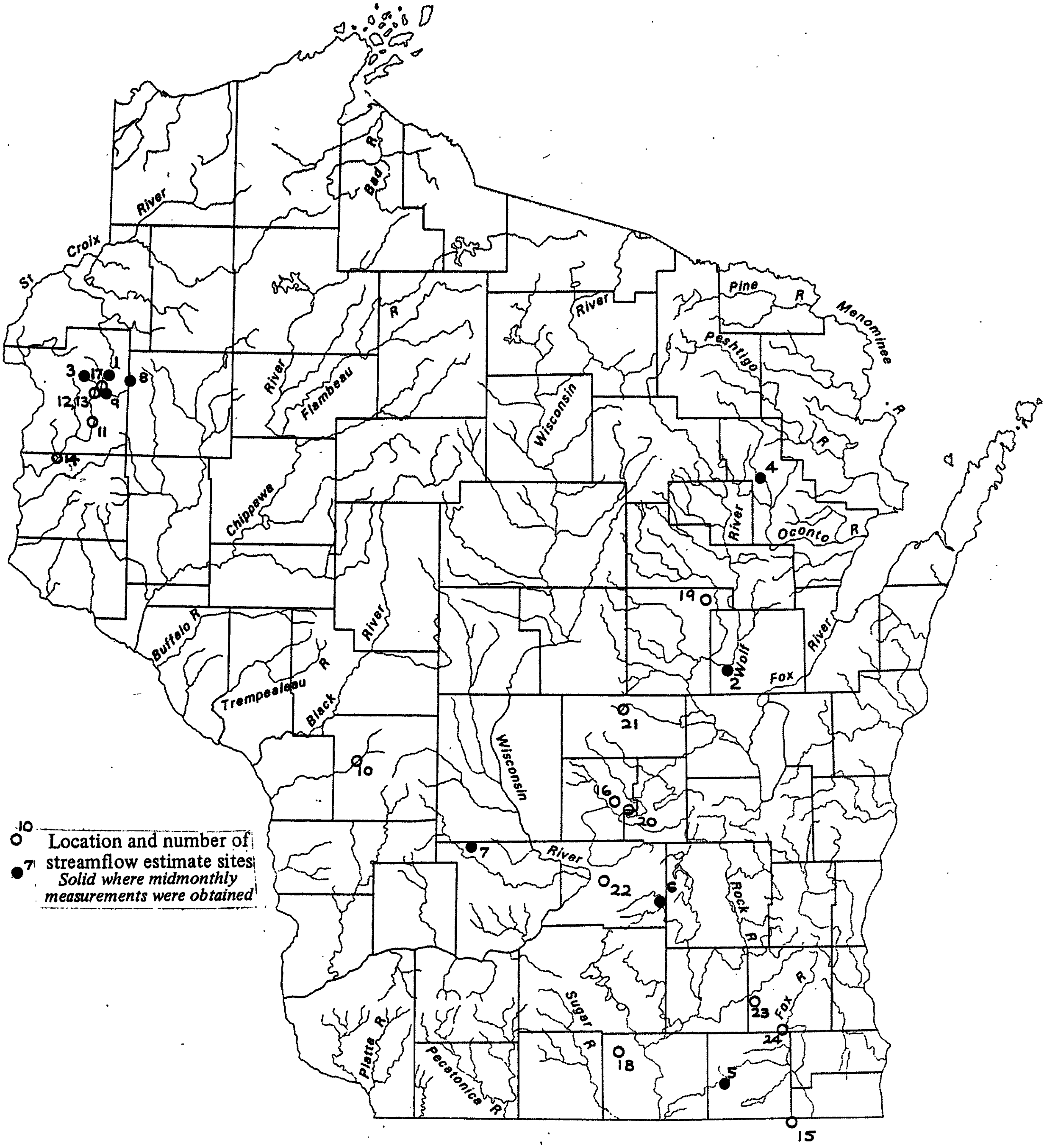

Figure 1. Location of streamflow estimate sites.

Midmonthly Measurements

Of the three estimation techniques used in this report, midmonthly streamflow measurements probably provide the best long-term streamflow estimates in streams that may be affected by storage in lakes. This technique assumes that the ratio of concurrent daily mean flows of two streams near the middle of the month equals the ratio of their means for that month (Riggs, 1969, p. 97). Riggs used this technique to estimate the annual mean flow for the year measurements were made. He then used the ratio of the annual mean to long-term mean annual flows at several nearby gaging stations to estimate the long-term mean annual flow at the estimate site (Riggs, 1969, p. 107-108). In this study, we have assumed that we can estimate the long-term mean <u>monthly</u> flow in the same manner that Riggs estimated the long-term mean <u>annual</u> flow.

First, the mean flow for each month during the study is estimated from the midmonthly measurements. Discharge measured on or near the 15th of each month at the streamflow-estimate site is plotted on log paper against the discharge for that day recorded at a nearby gaging station (fig. 2). A 45-degree line is drawn through the plotted point. The monthly mean discharge for the gaging station is transferred through the line to estimate the mean discharge at the estimate site. Estimates for the other months are obtained similarly. Riggs (1969, p. 97) suggests that during the period of high runoff, estimates are improved if two measurements are obtained each month, on the 1st and 15th, and then the 45-degree relation line is located halfway between the plotted points, providing estimates for 15-day periods. The annual mean flow is estimated by summing the monthly means and dividing by 12.

The long-term mean flows are then obtained from the estimated monthly flows. Several stream-gaging stations are selected near each streamflow estimate site. For each month, the monthly mean flows at the gaging stations are plotted against their long-term mean monthly flows on log paper (fig. 3) and a straight line fitted to the data points. The estimated monthly mean flow at the streamflow estimate site is transferred through the relation line to estimate the long-term mean monthly flow. In this example the 1978 May mean is very near the long-term mean for May.

The estimated long-term mean monthly flows for nine sites are shown in table 1. These estimates are based on midmonthly measurements from January through December 1978 (table 2).

The seasonal distribution of streamflow in Wisconsin in 1978 varied considerably. This variability affected the estimated individual mean monthly flows based on midmonthly measurements. However, the effect on estimated mean annual flows should be less pronounced. For comparative purposes, at five of the midmonthly measurement sites long-term mean monthly streamflow estimates were also provided by the other techniques. The drainage-area-discharge technique was used at three sites, and both the drainage-area-discharge and basin-characteristics techniques were used at two sites. These methods are described subsequently. These additional

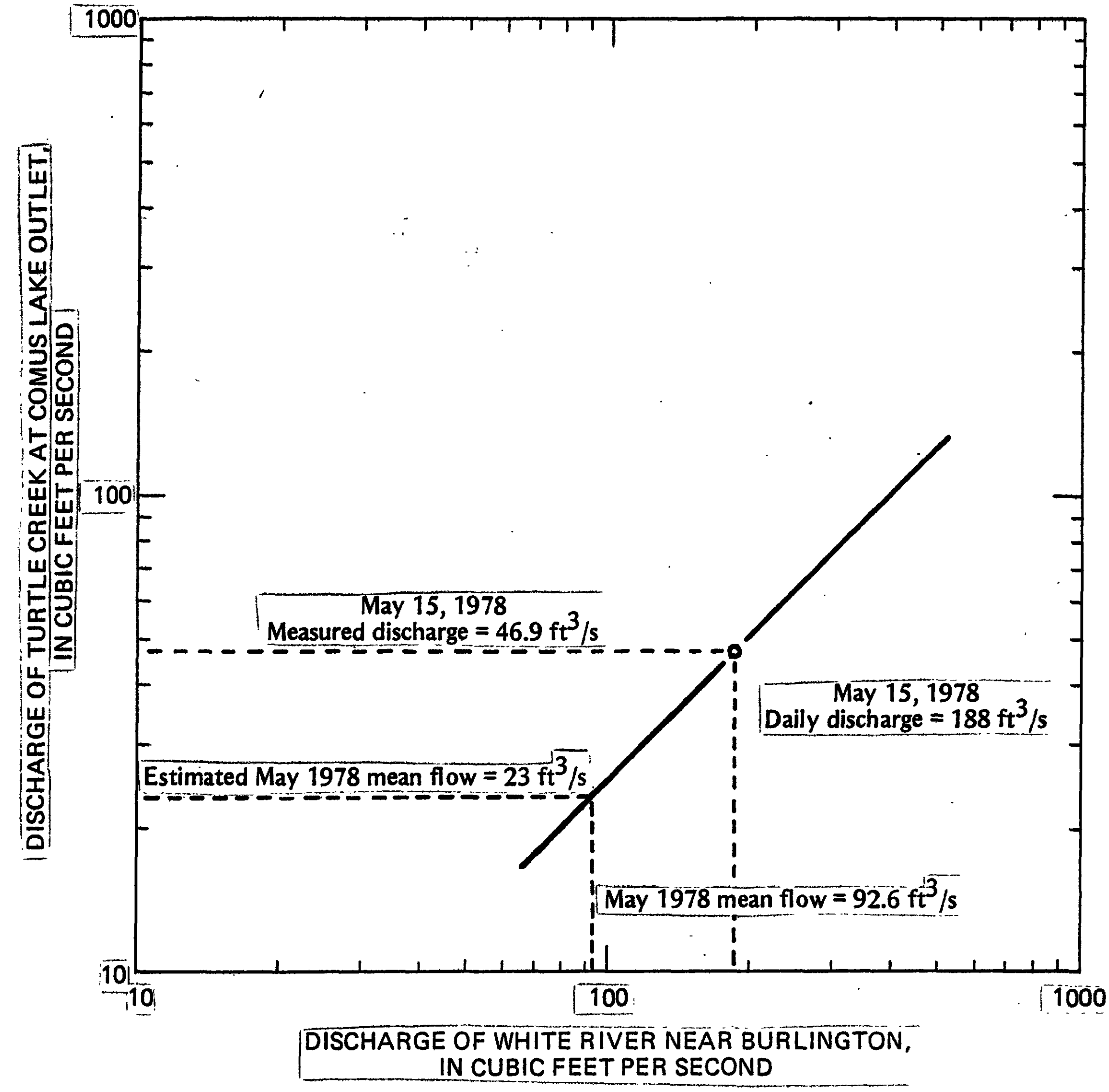

Figure 2. Example for determining monthly mean flow at a streamflow estimate site (Turtle Creek) from concurrent daily discharges.

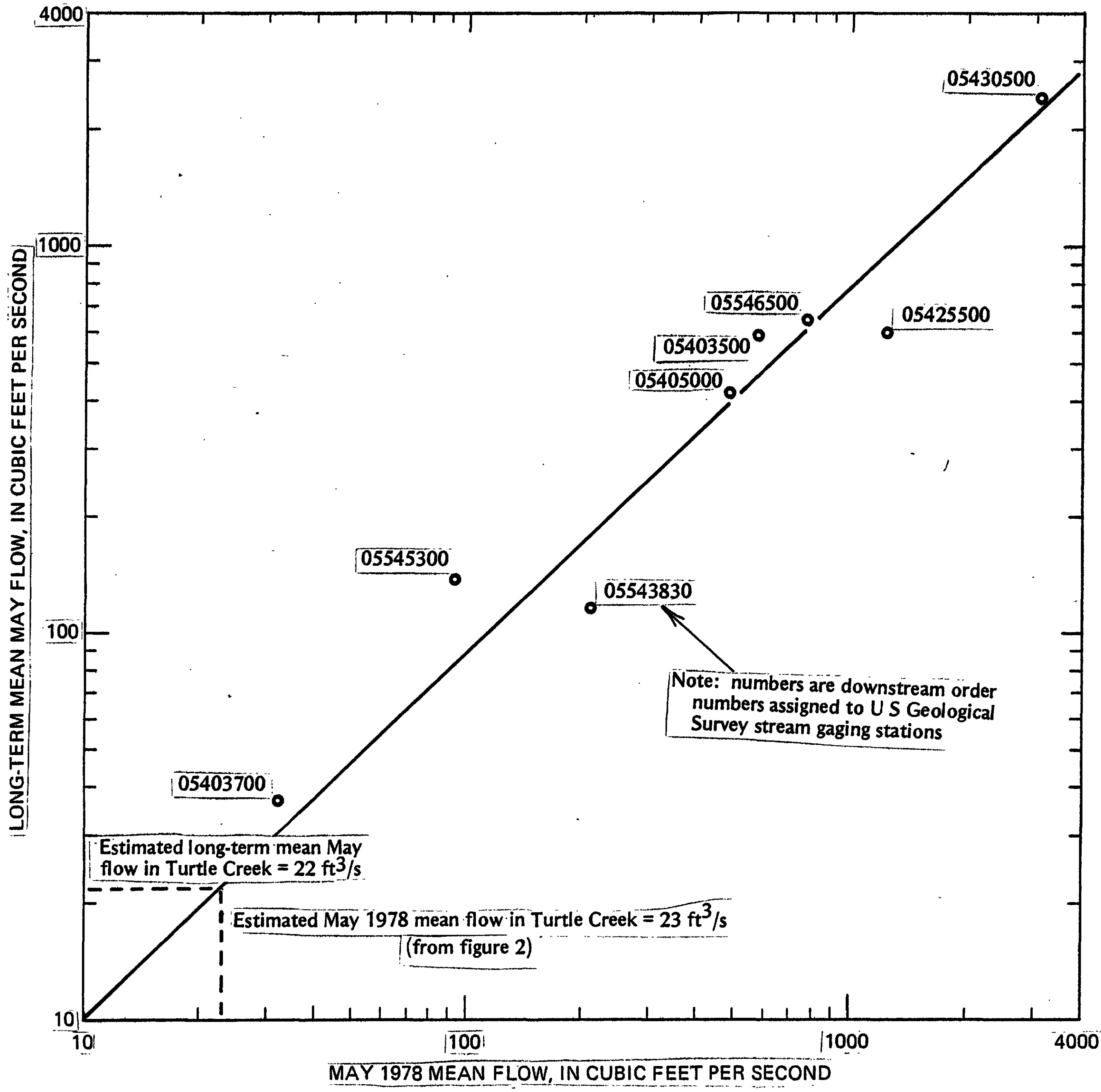

Figure 3. Example for determing long-term mean monthly flow from the relation of one monthly mean (May 1978) to the mean monthly (mean of all May flows in the period of record) at gaging stations near the estimate site (Turtle Creek).

values are also shown in table 1. Estimates for Turtle Creek (at the outlet of Comus Lake) and for the Apple River (at the outlet of White Ash Lake) by all three techniques compare favorably, although the estimates provided by midmonthly measurements show greater variability. Estimates determined from drainage-area-discharge relations for Black Otter Creek (at the outlet of Black Otter Lake), Fox Creek (at the outlet of Bone Lake), and for the outlet stream from Lazy Lake differ significantly from those determined by midmonthly measurements. Although it is assumed that the midmonthly measurement technique provides better estimates, it is beyond the scope of this report to show this conclusively.

Basin Characteristics

The basin-characteristics technique uses regression equations developed by Campbell and Dreher (1970) to predict long-term streamflow for each month and for the year. These equations are based on an analysis in which 13 different basin characteristics were considered (drainage area, main channel slope, main channel length, basin storage, mean basin elevation, forest cover, mean annual precipitation, maximum 24-hour rainfall, mean minimum January temperature, mean annual snowfall, soil index, average frost depth, and average snow depth). Eleven of the 13 basin characteristics were found significant in equations for mean monthly streamflow. An equation for each month (and one for the year) contains from five to eight of these basin characteristics with differing coefficients. For example:

$$\text{Mean June flow} = 0.00193A^{1.04}E^{0.44}F^{0.22}P^{0.68}SI^{0.22}$$

where:
- A = drainage area,
- E = mean basin elevation,
- F = forest cover,
- P = mean annual precipitation, and
- SI = soil index.

This technique is applicable only for basins larger than 50 mi^2 and requires quantification of the 11 basin characteristics. Mean monthly and mean annual streamflow was estimated by this technique at eight sites; two are shown in table 1 and six in table 3.

Drainage-Area Discharge

The drainage-area-discharge technique uses relations defined by nearby long-term gaging stations. A relation line is developed for each month and one for the year. For each monthly relation, the long-term mean monthly streamflow for each station is plotted against the station's drainage area on log paper and a straight line fitted to the data points (fig. 4). Transferring the drainage area of the estimate sites through the relation line provides the estimated long-term mean monthly discharge at the site. This technique assumes that there are several long-term gaging stations nearby and that the basins are similar, so that streamflow differences among basins are caused solely by differences in drainage basin size. It

Table 1.--Estimated long-term mean monthly and mean annual streamflow, in cubic feet per second, at selected sites based on (1) midmonthly measurements, (2) basin characteristics, or (3) drainage-area discharge

	Stream	Lake	Method	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1.	Straight River	Big Round (outlet)	1	26	20	53	53	9	11	5	25	6	20	17	21	22
2.	Black Otter Creek	Black Otter (outlet)	1	1.4	2.0	1.8	23	24	2	.3	.1	13	5	18	4	8
			3	12	10	18	23	21	18	13	11	14	14	14	12	15
3.	Fox Creek	Bone (outlet)	1	18	11	33	34	7	6	7	21	4	10	6.5	10	14
			3	3	4	11	20	6	10	5	4	4	4	4	4	5
4.	North Branch Oconto River	Chute Pond (outlet)	1	110	110	170	300	260	190	100	90	140	280	400	390	210
5.	Turtle Creek	Comus (outlet)	1	8	10	23	37	22	20	13	26	12.5	14	18	11	18
			2	11	14	33	34	25	20	13	10	10	13	16	13	20
			3	11	16	28	23	20	17	11	9	11	13	14	13	16
6.	Lazy Lake outlet	Lazy (outlet)	1	7	7	10	42	72	14	4	23	27	19	37	38	25
			3	39	40	85	88	69	55	40	36	43	44	44	39	53
7.	Big Creek	Redstone (outlet)	1	6	8	10	47	62	5	11	4	13	11	18	12	17
8.	Staples Creek	Staples (inlet)	1	.3	<.1	3	2	<.1	<.1	<.1	13	2	<.1	<.1	<.1	2
9.	Apple River	White Ash (outlet)	1	34	32	75	200	25	13	25	49	32	33	32	27	46
			2	25	22	53	220	75	69	48	37	43	44	35	35	51
			3	28	30	60	103	50	62	41	35	39	34	35	32	39

Table 2.--Discharge, in cubic feet per second, measured near midmonth at streamflow estimate sites

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Straight River at Big Round Lake outlet	20.4	18.4	20.2	46.4	20.3	21.7	39.2	31.4	27.6	19.0	19.8	21.5
2. Black Otter Creek at Black Otter Lake outlet	1.61	.814	1.02	23.7	26.8	2.04	.509	.072	49.4	4.41	9.88	3.23
3. Fox Creek at Bone Lake outlet	13.6	10.8	11.4	28.2	17.2	12.0	20.4	17.6	18.6	9.91	6.95	10.0
4. North Branch Oconto River at Chute Pond outlet	99.3	92.5	92.0	286	271	151	130	95	357	178	159	128
5. Turtle Creek at Comus Lake outlet	8.49	7.45	10.6	32.7	46.9	8.10	20.5	12.0	14.0	12.5	16.6	12.3
6. Lazy Lake outlet	5.47	4.47	5.57	43.0	757	7.07	15.1	5.56	147	17.0	31.5	16.3
7. Big Creek at Redstone Lake outlet	6.25	5.04	6.84	35.6	72.2	3.55	17.8	4.92	21.4	6.66	13.7	8.50
8. Staples Creek inlet to Staples Lake	0	0	0 [1]21	0	0	0	.35	10.2	9.85	0	0	0
9. Apple River at White Ash Lake outlet	27.8	29.7	28.3	165	45.6	25.0	59.1	46.0	136	33.6	35.4	28.0

[1]Discharge measured by Wisconsin Department of Natural Resources personnel on March 28, 1978.

Table 3.--Estimated long-term mean monthly and mean annual streamflow, in cubic feet per second, at selected sites based on (1) basin characteristics or (2) drainage-area discharge

Stream	Lake	Method	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
10. La Crosse River	Angelo Pond (outlet)	1	36.3	40.0	114	134	117	112	71.6	55.7	61.2	68.8	71.2	57.2	87.8
		2	57	72	130	111	87	90	70	64	72	70	75	63	79
11. Apple River at Amery		2	92.6	100	236	319	173	191	141	115	118	122	113	100	155
12. Harder Creek	Balsam (inlet)	2	1.70	2.16	7.40	12.9	3.44	5.98	3.15	2.61	2.61	2.38	2.19	2.05	3.09
13. Balsam Branch	Balsam (outlet)	2	10.1	11.8	28.2	48.3	19.3	27.2	16.5	13.9	14.4	13.5	12.8	11.8	16.0
14. Cedar Creek	Cedar (outlet)	1	19.6	20.3	34.4	48.4	34.4	31.6	24.3	19.0	21.9	22.7	20.3	22.3	27.9
		2	9.17	12.8	52.7	61.3	24.2	27.5	17.8	17.0	14.5	16.5	14.0	13.5	23.7
15. Elizabeth Lake outlet	Elizabeth (outlet)	1	3.58	4.37	9.52	18.7	9.62	6.57	4.00	2.91	2.82	4.06	5.48	4.25	7.76
		2	11.4	12.4	29.4	25.0	16.8	16.1	5.59	5.27	9.72	6.29	6.06	10.8	13.3
16. Ox Creek	Emery (outlet)	1	1.42	1.71	35.4	25.5	20.0	14.3	5.28	4.57	4.50	4.88	12.1	2.55	16.8
17. Harder Creek	Half Moon (outlet)	2	1.61	2.04	7.08	12.4	3.25	5.68	2.98	2.47	2.46	2.25	2.06	1.94	2.93
18. Allen Creek	Leota (outlet)	2	13.2	17.0	30.6	23.6	18.1	15.2	12.2	10.2	10.6	10.9	11.7	11.9	15.9
19. Pigeon River	Pigeon (outlet)	2	48.3	44.5	84.8	193	112	76.6	45.4	41.8	55.1	55.5	66.6	59.8	72.1
20. Fox River	Puckaway (outlet)	2	350	377	867	1,030	706	547	372	293	338	372	413	351	573
21. Humphrey Creek	Wild Rose Pond (outlet)	1	6.14	6.10	21.1	22.3	16.8	14.2	9.03	7.42	10.0	11.1	10.8	8.70	13.0
		2	14.9	13.1	22.5	30.1	27.0	23.2	16.7	13.5	17.4	17.3	18.0	15.7	19.2
22. Duck Creek	Wyona (outlet)	1	9.72	10.6	181	212	137	88.8	28.6	21.7	23.2	28.9	72.3	15.6	107
		2	45.8	42.8	85.3	113	92.3	77.8	54.6	45.2	57.5	58.6	62.8	50.8	66.2
23. Bark River	School Section (outlet)	2	2.64	3.41	4.78	3.80	3.87	3.68	2.39	2.00	2.30	2.87	3.06	2.80	3.05
24. Mukwonago River	Phantom (outlet)	2	29.8	37.0	71.0	63.1	49.8	39.7	26.7	21.8	24.7	29.1	31.4	29.0	38.1

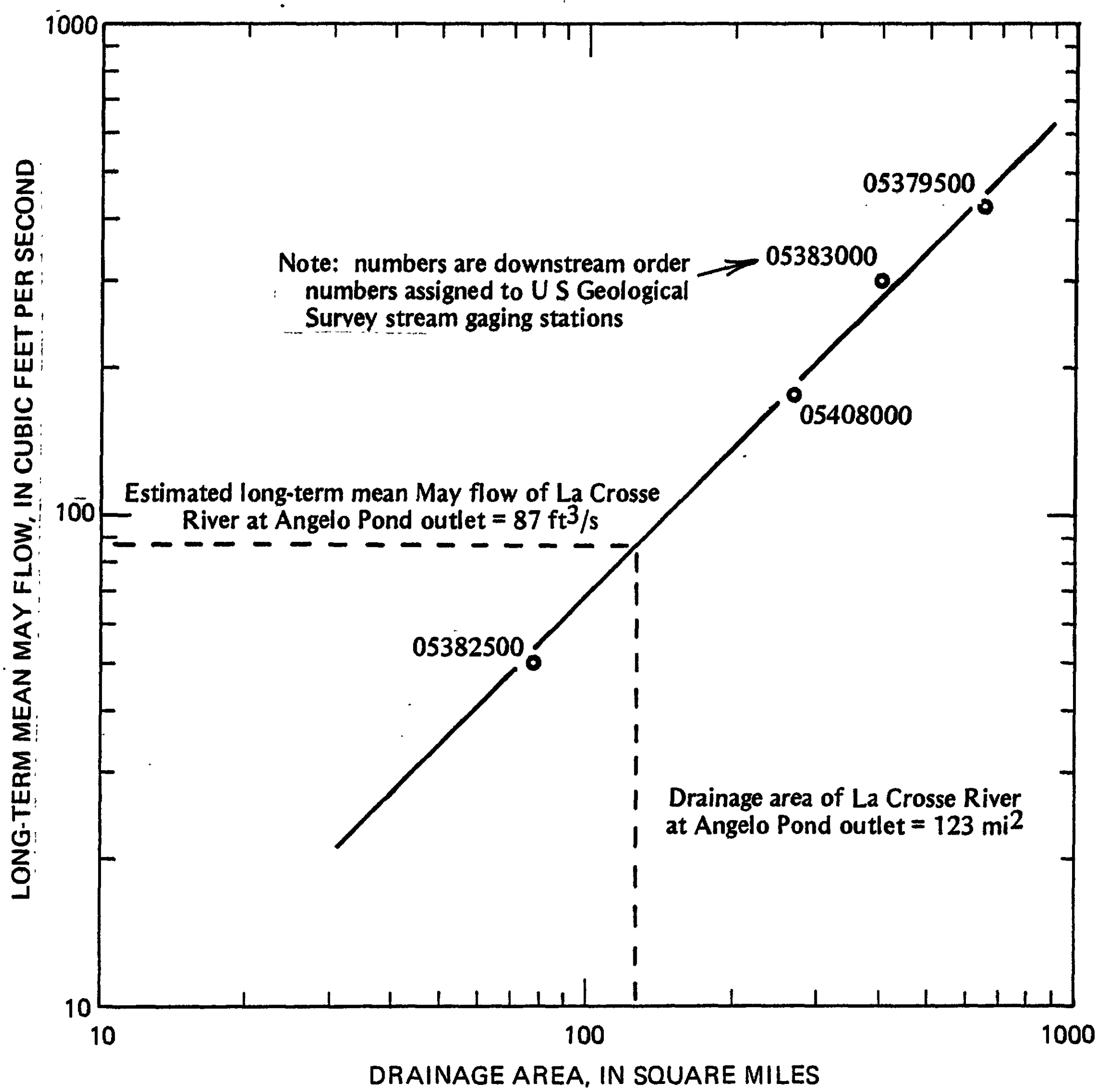

Figure 4. Example for determining long-term mean monthly flow at an estimate site (La Crosse River at Angelo Pond outlet) from drainage area-dishcarge relations defined by nearby gaging stations.

is desirable, although not strictly required, that the gaging stations used to develop the relations include drainage basins both larger and smaller than the drainage basin at the estimate site.

This technique apparently provided good results for the areas of the State represented by the selected sites. The correlation coefficients for the monthly relation lines were typically 0.95 or higher. However, most stream-gaging sites in Wisconsin are on large streams that do not have the variability of smaller streams, and they are typically selected to minimize the influence of storage, including that in natural lakes, so the streamflow estimates provided by the technique may be biased when they are applied in streams flowing out of large lakes. The drainage-area-discharge technique was used to estimate mean monthly and mean annual streamflow at 19 sites: 5 shown in table 1 and 14 shown in table 3.

SUMMARY

The three streamflow-estimation techniques each have unique characteristics. The midmonthly measurement technique probably provides the best estimates of long-term mean monthly and mean annual streamflow, particularly if the current year is a near-average year with streamflow distributed typically through the year. However, it is the most costly and requires 1 year of measurements. In addition, streamflow estimates cannot be obtained until data at stream-gaging stations near the estimate site are processed, which may cause delays of several months. The basin-characteristics technique is probably not as precise as the midmonthly, but it is theoretically somewhat better than the drainage-area-discharge technique that assumes that basin characteristics are similar and that streamflow is influenced only by basin size because it considers the unique characteristics of the basin. The basin-characteristics technique provides reasonable estimates but requires defining 11 basin characteristics and is valid only for basins larger than 50 mi^2. In Wisconsin, characteristics do not differ greatly among basins, so drainage-area-discharge relations provide estimates comparable to those determined from basin characteristics. The drainage-area-discharge technique is quick, convenient, and the least costly of the three. However, it may provide estimates that do not reflect storage in natural lakes, so it may be less desirable for estimating streamflow at the outflow of large lakes.

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