UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TIME-OF-TRAVEL STUDY

LAKE ERIE-NIAGARA RIVER BASINS

By Bernard Dunn

Open-File Report

Prepared in cooperation with the

New York State Department of Health

Albany, New York

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CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING ENGLISH UNITS USED IN THIS REPORT TO INTERNATIONAL SYSTEM (SI) UNITS

English units			SI units	
Length				
miles (mi)	x 1.609	=	kilometres (km)	
Volume				
ounces, fluid (oz)	x .02957	=	litres (l)	
Rate of flow				
feet per second (fps)	x .3048	=	metres per second	(m/s)
cubic feet per second (cfs)	x .02832	=	cubic metres per second	(m^3/s)
million gallons per day (mgd)	x .04381	=	cubic metres per second	(m^3/s)
Area				
square miles (sq mi)	x 2.590	=	square kilometres	(km^2)

TIME-OF-TRAVEL STUDY
LAKE ERIE-NIAGARA RIVER BASINS [1]

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SUMMARY

Time of travel was determined for 80.54 stream miles on Cattaraugus, Cayuga, Ellicott, Murder, and Tonawanda Creeks; Cazenovia Creek basin; and the Buffalo River. Two or three runs at different discharge rates were made in 13 subreaches on the 7 streams except for a subreach of Ellicott Creek. In the Ellicott Creek subreach from the Lehigh Valley Railroad bridge (above the Tonawanda Sewer District No. 3 sewage treatment plant) to the mouth, only one time-of-travel run could be made because of the unexpected shutdown of the treatment plant.

On Cattaraugus Creek, the reach was extended to Versailles after the first run. To complete the three runs, a partial run was made on November 16, 1964. On Ellicott Creek, in the subreach between Amherst sewage treatment plant and Sweet Home Road, a partial run was made to check a previous run.

Time-of-travel data for several subreaches are depicted in a series of graphs that show time-distance relationships for several discharge rates.

Flow-duration curves and minimum average consecutive 7-day discharges for a 10-year return period were determined for one site each on Cattaraugus, Cayuga, and Murder Creeks, and for two sites on Tonawanda and Ellicott Creeks. The 7-day frequency data were also developed for a site on Buffalo River.

Effluent discharge was measured at nine treatment plants. Considerable fluctuation in discharge was recorded at some of the plants.

In the Cazenovia Creek basin, time of travel was determined on the East Branch for 16.45 miles, on the West Branch for 13.8 miles, and on Cazenovia Creek for 16.62 miles. Three runs at different discharge rates were made at most subreaches. On those subreaches where less than three runs were made, a comparison of the relationship with other sites was made to determine the shape of the curves.

Time-of-travel data are shown in graphic form depicting the time-distance relationships for the three major reaches in the Cazenovia Creek basin for several discharge rates. The discharge shown is that at the gaging station on Cazenovia Creek at Ebenezer for which a value of minimum average consecutive 7-day discharge for a 10-year return period was determined.

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[1] Approved for release to the open file by the Director, U.S. Geological Survey, June 1966.

INTRODUCTION

In May 1964, New York State Department of Health requested the U.S. Geological Survey to cooperate in the studies of the waste-assimilation capacity of selected streams in Lake Erie and Niagara River basins. The studies were to include discharge of selected streams, flow-duration, determination of the minimum average consecutive 7-day discharge for a 10-year return period, and time-of-travel. The State's phase of the investigation was under the direction of Robert D. Hennigan, Director, Bureau of Water Resources Services, Division of Environmental Health Services.

STREAMFLOW

Data for Time-of-Travel Studies

Streamflow was obtained by using the records of currently operating gaging stations (fig. 1) or by establishing temporary gaging sites (fig. 1) and developing stage-discharge relations for those sites. The regular gaging stations are on Cattaraugus Creek at Gowanda, Buffalo Creek at Gardenville, Cayuga Creek near Lancaster, Cazenovia Creek at Ebenezer, Tonawanda Creek at Batavia, and Ellicott Creek at Millgrove. Temporary gaging sites were established on Tonawanda Creek at Stroh Road in Attica, Murder Creek at State Highway 93 and Swifts Mills Road near Akron, Ellicott Creek at Sand Ridge, and Ellicott Creek at Forest Road in Amherst. Mean daily discharges for these stations are published in the annual U.S. Geological Survey reports, "Water Resources Data for New York, Part 1, Surface Water Records."

Discharge of Buffalo River at the Cheektowaga sewage treatment plant was computed by summation of discharge for gaging stations at Cayuga Creek near Lancaster and Buffalo Creek at Gardenville.

Discharges at Sewage Treatment Plants

During July and August 1964, a team of New York State Department of Health and U.S. Geological Survey employees obtained chemical and flow data of the effluent at nine sewage treatment plants. At that time, the discharge of effluent was measured every 20 minutes for about 3 hours. Eastern daylight time was used during the months that daylight time was in effect. Treatment plants, receiving streams, effluent discharges, and time and date of discharges are listed in table 1.

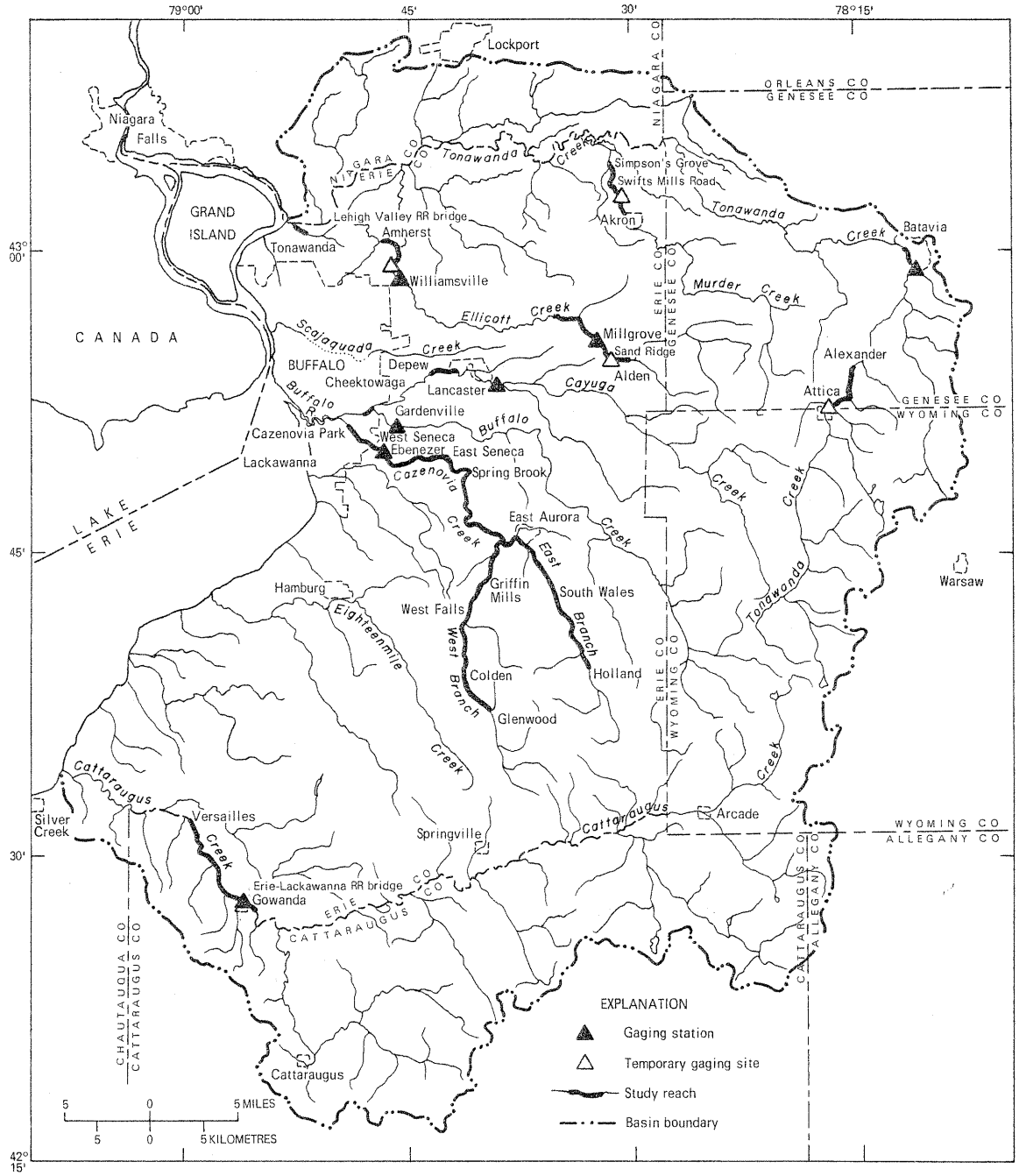

Figure 1.--Location of measurement sites and reaches, Lake Erie-Niagara River basins, New York.

Table 1.--Discharge of effluent by treatment plants

Treatment plant	Receiving stream	Date	Eastern daylight time	Effluent discharge (cfs)
Akron	Murder Creek	7/13/64	2110	0.51
			2130	.50
			2155	.51
			2225	.42
			2255	.42
			2330	.40
			2400	.39
		7/14/64	0025	.37
			0055	.37
Alden	Ellicott Creek	8/24/64	1930	.30
			1950	.34
			2010	.43
			2030	.55
			2050	.53
			2110	.40
			2130	.53
			2150	.53
			2210	.53
			2230	.51
Amherst	Ellicott Creek	7/15/64	1045	9.25
			1145	6.19
			1200	6.30
			1215	6.75
			1235	6.68
			1255	9.13
			1310	11.04
			1334	10.66
Batavia	Tonawanda Creek	8/19/64	1215	7.20
			1250	9.15
			1310	6.96
			1330	7.58
			1350	6.77
			1410	3.20
			1430	3.69
			1450	3.60
			1510	3.51
			1530	3.88
			1550	3.30
Cheektowaga	Buffalo River	8/25/64	1120	.54
			1140	.54
			1200	5.76
			1220	4.54
			1240	4.34
			1300	.54
			1320	4.34
			1340	4.34
			1400	4.34
			1420	.54

Table 1.--Discharge of effluent by treatment plants (Continued)

Treatment plant	Receiving stream	Date	Eastern daylight time	Effluent discharge (cfs)
Erie County Home, at Millgrove	Ellicott Creek	8/11/64	1210	0.06
			1230	.08
			1250	.08
			1310	.08
			1330	.08
			1350	.08
			1410	.08
			1430	.08
			1450	.09
			1510	.11
Erie County Penitentiary, at Millgrove	Ellicott Creek	8/11/64	0940	.18
			1000	.16
			1020	.17
			1040	.17
			1100	.17
			1120	.17
			1140	.18
			1200	.19
			1220	.19
			1240	.19
Lancaster	Cayuga Creek	8/26/64	1550	.60
			1610	.09
			1630	.57
			1650	.66
			1710	1.84
			1730	2.33
			1750	5.11
			1810	4.21
			1830	.83
			1850	.02
West Seneca	Buffalo River	8/25/64	1240	1.27
			1300	.88
			1320	1.33
			1340	1.16
			1400	.69
			1420	1.20
			1440	.97
			1500	.69
			1520	.71
			1540	.89

TIME OF TRAVEL

Methodology

Time of travel of streams in Lake Erie and Niagara River basins was studied from May 13 to July 19, 1963, May 4 to November 18, 1964, and May 10 to July 21, 1965, for various flow durations. Base flow is flow contributed primarily by ground-water discharge. Time of travel was observed by introducing a red-colored, fluorescent dye (40-percent solution of Rhodamine B by weight, specific gravity 1.032), into the waters and detecting movement of the dye by a Turner model 111 fluorometer[1]. Two-ounce water samples were collected at each sampling point at about 15-minute intervals to trace the passage of the dye. The samples were placed in the fluorometer to measure their relative fluorescence and to establish the arrival time of maximum concentrations.

Field Technique

Rhodamine-B solution was injected across the section of the stream at the beginning of the subreach. Two-ounce water samples were usually collected at 15-minute intervals at downstream points. A portion of each sample was analyzed at the site to determine arrival time of dye. The rest of each sample was saved for analysis in the laboratory. Results of the laboratory analyses were used to determine the time of travel. In most reaches, samples were also collected at intermediate points as requested by the State Department of Health. The reaches were divided into subreaches in the Cazenovia Creek basin and in Ellicott Creek, and each subreach was given an injection of dye at about the same time. Samples were collected at the end of each subreach.

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[1] Use of brand names in this report is for identification only and does not imply endorsement by the Geological Survey.

Reaches

Time-of-travel runs were made in the reaches listed in table 2.

Table 2.--Time-of-travel reaches

Stream	Reach	Mileage
Cattaraugus Creek	Gowanda village line to Versailles	8.05
Cayuga Creek	Lancaster STP[1] to Borden Road, Depew	2.99
Cazenovia Creek	Confluence to Cazenovia Park	16.62
Cazenovia Creek, East Branch	Holland to confluence	16.45
Cazenovia Creek, West Branch	Glenwood to confluence	13.8
Buffalo River	Cheektowaga STP[1] to S. Ogden St., Buffalo	.95
Tonawanda Creek	Prospect St., Attica, to Railroad Ave., Alexander	3.99
Tonawanda Creek	S. Lyon St. to off S. Main St., Batavia	.97
Murder Creek	Akron STP[1] to Simpson's Grove	4.34
Ellicott Creek	Alden STP[1] to Sand Ridge	1.67
Ellicott Creek	Erie County Penitentiary to Zoeller Road, Millgrove	2.47
Ellicott Creek	Amherst Sewer District No. 1 to Sweet Home Road	5.61
Ellicott Creek	Lehigh Valley RR bridge to E. Niagara St., Tonawanda (mouth)[2]	2.63
	TOTAL	80.54

[1] STP means sewage treatment plant.
[2] Only one run completed in this reach.

Analysis of Data

Time of travel of a stream is the time needed by the stream to move its water from a given point to a point downstream. Dye is commonly used to show movement of stream water. Turbulence and variable flow in the reach tend to spread the dye so that small concentrations usually arrive in advance of the maximum concentration. The maximum dye concentration is followed by decreasing concentrations, and eventually the dye disappears.

Results of each run in a reach or subreach are summarized in terms of mileage, date of run, discharge, time of travel, and velocity. Data for Buffalo River and Cattaraugus, Cayuga, Cazenovia, Ellicott, Murder, and Tonawanda Creeks are in table 3.

A relation between the time of travel and discharge was developed for each reach or subreach and is shown as one of figures 5 to 16, Appendix A. The curves in these figures have been extended to the minimum average consecutive 7-day discharge for a 10-year return period. (See section, "Low-Flow Characteristics.") From the curves, a relation was developed between time and distance for each reach for a selected range of discharges. These time-of-travel graphs are in figures 17 to 28, Appendix B.

Only one run was completed in the Ellicott Creek reach from the Lehigh Valley Railroad bridge (above the Tonawanda Sewer District No. 3 sewage treatment plant) to the mouth because of the unexpected shutdown of the plant. Time of travel for this 2.63-mile reach was 40 hours and 40 minutes. Discharge in the reach was not measured, and graphical results cannot be shown.

Cross-section plots of discharges measured during the study period were prepared for each site and are on file at the Geological Survey office in Albany, N.Y.

A typical curve showing dispersion and variation in concentration of dye with time is presented in figure 2. Curves for each sampling site are on file at the Geological Survey office in Albany, N.Y.

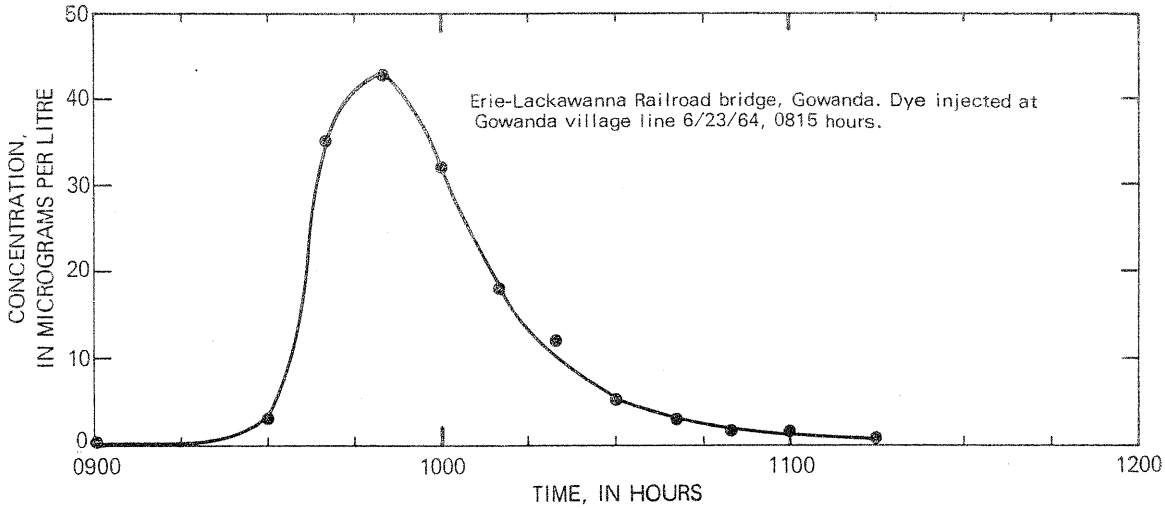

Figure 2.--Dispersion and variation in concentration of dye with time at Erie-Lackawanna Railroad bridge, Gowanda (typical curve).

is this peak concentration?

Table 3.--Time-of-travel data, Lake Erie-Niagara River basin

Stream site identification	Reach or Subreach		Mileage	First Run				Second Run				Third Run				Fourth Run			
	Initial Point	Terminal Point		Date	Discharge (cfs)	Time 2/	Velocity (fps)	Date	Discharge (cfs)	Time 2/	Velocity (fps)	Date	Discharge (cfs)	Time 2/	Velocity (fps)	Date	Discharge (cfs)	Time 2/	Velocity (fps)
Buffalo River Cheektowaga STP 1/	Cheektowaga STP	West Seneca STP	0.33	8/25/64	35	0:55	0.53	10/15/64	11	1:30	0.32	5/12/65	94	0:30	0.97	--	--	--	--
	West Seneca STP	S. Ogden St. Buffalo	.62	8/25/64	35	5:00	.18	10/15/64	11	6:30	.15	5/12/65	94	2:30	.36	--	--	--	--
Cattaraugus Creek Gowanda	Gowanda Village line	Gowanda STP	2.32	6/23/64	130	2:50	1.20	8/18/64	115	3:30	.97	--	--	--	--	5/13/65	474	1:30	2.27
	Gowanda STP	Versailles	5.73	--	--	--	--	8/18/64	115	7:45	1.08	11/16/64	84	13:35	.62	5/13/65	469	3:35	2.35
Cayuga Creek Lancaster	Lancaster STP	Broadway (U.S. Hwy. 20)	.20	8/26/64	6.9	1:35	.18	10/14/64	2.4	1:45	.17	5/12/65	27	0:45	.39	--	--	--	--
	Broadway (U.S. Hwy. 20)	Transit Road	1.84	8/27/64	6.9	12:40	.21	10/13/64 10/14/64	2.4	19:05	.14	5/12/65	27	4:45	.57	--	--	--	--
	Transit Road	Borden Road Depew	.95	8/27/64	6.9	8:00	.12	10/13/64 10/14/64	2.4	14:05	.10	5/12/65	27	3:00	.46	--	--	--	--
Ellicott Creek Alden	Alden STP	Sand Ridge	1.67	8/24/64	17.9	7:10	.34	11/16/64	.82	46:30	.05	5/11/65	8.44	15:20	.16	--	--	--	--
Ellicott Creek Amherst	Amherst STP	Maple Road	.65	7/15/64	24.1	1:40	.57	10/13/64	6.7	2:50	.34	5/13/65	24.9	1:35	.60	7/20/65	10.4	2:45	.35
	Maple Road	Millersport Road	2.07	7/15/64	24.1	7:45	.39	10/13/64	6.7	12:15	.25	5/13/65	24.9	6:45	.45	7/20/65	9.0	15:00	.20
	Millersport Road	Sweet Home Road	2.89	7/15/64	24.1	15:15	.28	10/14/64	6.7	32:00	.13	--	--	--	--	7/20/65	10.7	27:35	.15
Ellicott Creek Erie County Penitentiary	Penitentiary STP	Walden Ave.	1.01	6/26/64	1.15	38:00	.039	8/11/64	.57	78:00	.02	5/11/65	10	6:50	.23	--	--	--	--
	Walden Ave.	Erie County Home	.32	6/26/64	1.15	15:40	.030	8/11/64	.57	23:30	.02	5/11/65	10	3:20	.14	--	--	--	--
	Erie County Home	Zoeller Road	1.14	6/26/64	1.15	55:45	.030	8/11/64	.57	64:20	.026	5/11/65	10	10:40	.16	--	--	--	--
Ellicott Creek Tonawanda	Lehigh Valley RR bridge	E. Niagara St. (mouth)	2.63	6/10/64	--	40:40	.10	--	--	--	--	--	--	--	--	--	--	--	--
Murder Creek Akron	Akron STP	Simpson's Grove	4.34	6/10/64	9.43	17:40	.36	7/15/64	4.96	29:00	.22	5/12/65	22.4	10:15	.62	--	--	--	--
Tonawanda Creek Attica	Prospect St. Attica	Stroh Road	1.50	6/11/64	29	4:45	.46	5/10/65	53	3:00	.73	7/21/65	6.2	14:00	.16	--	--	--	--
	Stroh Road	Railroad Ave. Alexander	2.49	6/11/64	29	7:55	.46	5/10/65	53	4:55	.74	7/21/65	6.0	20:50	.18	--	--	--	--
Tonawanda Creek Batavia	S. Lyon St.	Off S. Main St.	.97	8/19/64	12.1	3:55	.36	10/12/64	8.9	4:20	.33	5/10/65	95.3	1:45	.81	--	--	--	--

Table 3.--Time-of-travel data, Lake Erie-Niagara River basin (Continued)

Stream site identification	Reach or Subreach		Mileage	First Run				Second Run				Third Run			
	Initial Point	Terminal Point		Date	Discharge (cfs)	Time 2/	Velocity (fps)	Date	Discharge (cfs)	Time 2/	Velocity (fps)	Date	Discharge (cfs)	Time 2/	Velocity (fps)
West Branch Cazenovia Creek	Glenwood	Colden	3.02	5/14/63	112	4:55	0.90	5/ 7/64	70	5:15	0.84	11/16/64	20	12:05	0.37
	Colden	West Falls (Burr Road)	4.68	5/14/63	112	6	1.14	5/ 7/64	70	7:50	.88	11/16/64	20	16:45	.41
	West Falls (Burr Road)	Griffin Mills	2.3	5/14/63	112	5:05	.66	5/ 6/64	76	7:35	.45	--	--	--	--
	Griffin Mills	Mouth	3.8	5/14/63	112	5:00	1.11	5/ 5/64	84	5:30	1.01	--	--	--	--
	West Falls	Grover Road	4.49	7/16/63	16	27	.24	--	--	--	--	--	--	--	--
	Grover Road	Holmwood Road	1.02	7/16/63	16	2:35	.58	--	--	--	--	--	--	--	--
	Holmwood Road	Mouth	.43	7/16/63	16	1:50	.34	--	--	--	--	--	--	--	--
East Branch Cazenovia Creek	Holland	South Wales (Darling Road)	6.12	5/15/63	98	9:10	.98	--	--	--	--	--	--	--	--
	Holland	North Canada Street Holland	1.46	7/11/63	9.2	5:45	.37	--	--	--	--	--	--	--	--
	North Canada St.	First bridge below Holland on State Highway 16	1.89	7/11/63	9.2	11	.25	--	--	--	--	--	--	--	--
	First bridge below Holland on State Highway 16	Second bridge below Holland on State Highway 16	1.13	7/11/63	9.2	6	.28	--	--	--	--	--	--	--	--
	Second bridge below Holland on State Highway 16	South Wales (State Highway 16)	1.51	7/11/63	9.2	6:15	.36	--	--	--	--	--	--	--	--
	South Wales (State Highway 16)	Emery Road	1.02	7/11/63	9.2	4:45	.32	--	--	--	--	--	--	--	--
	Emery Road	Sweet Road	3.50	7/16/63	17	14:30	.35	--	--	--	--	--	--	--	--
	Sweet Road	Above Lapham Road	1.95	5/ 5/64	84	6:20	.45	--	--	--	--	--	--	--	--
	East Aurora Dam	Mill Road	.93	7/16/63	17	7:45	.18	--	--	--	--	--	--	--	--
	Mill Road	Mouth	1.70	7/16/63	17	6	.42	--	--	--	--	--	--	--	--
	Holland	First bridge below Holland on State Highway 16	3.35	5/ 7/64	70	6:10	.80	--	--	--	--	--	--	--	--
	First bridge below Holland	South Wales (Darling Road)	2.6	5/ 6/64	76	4:50	.54	--	--	--	--	--	--	--	--
	South Wales (Darling Road)	Sweet Road	4.5	5/ 6/64	76	6:45	.98	--	--	--	--	--	--	--	--
	Above Lapham Road	Center St., East Aurora	1.18	5/ 5/64	84	12:40	.15	--	--	--	--	--	--	--	--
	Center St., East Aurora	Dam	.18	5/ 5/64	84	1:25	.19	--	--	--	--	--	--	--	--
	Dam	Mouth	2.63	5/ 5/64	84	4:45	.81	--	--	--	--	--	--	--	--
Cazenovia Creek	Confluence (U.S. Highway 20A)	Northrup Road Spring Brook	7.15	5/15/63	112	8	1.31	7/10/63	9.2	43	.24	--	--	--	--
	Northrup Road Spring Brook	Leydecker Road East Seneca	2.75	5/15/63	112	2:30	1.61	7/10/63	9.2	16	.25	5/ 4/64	83	2:50	1.43
	East Seneca	Ebenezer	3.9	5/15/63	112	3:40	1.56	7/10/63	9.2	16:30	.35	5/ 4/64	83	4:15	1.35
	Ebenezer	Cazenovia Park	2.82	5/15/63	112	5:45	1.13	7/10/63	9.2	23:30	.18	5/ 4/64	83	5:10	.80
	Confluence	Willardshire Road	3.0	5/ 5/64	84	3:20	1.32	--	--	--	--	--	--	--	--
	Willardshire Road	Northrup Road	4.15	5/ 4/64	83	5	1.22	--	--	--	--	--	--	--	--

1/ STP means sewage treatment plant.

2/ Elapsed time in hours and minutes (0:55 means 55 min; 2:50 means 2 hr and 50 min).

LOW-FLOW CHARACTERISTICS

A flow-duration curve is useful in the study of low-flow characteristics of a stream. The curve shows the frequency of occurrence of rates of streamflow without showing the chronological sequence and indicates the percentage of time, within a given period, during which selected discharges were equaled or exceeded. Flow-duration curves are presented for stations with a long period of record, for short-term records adjusted to a longer period, and for sites where only base-flow measurements have been made. To conform with the practice agreed upon by the World Meteorological Organization, all flow-duration curves have been adjusted to the standard 30-year period, water years 1931-60.

The shape of the flow-duration curve reflects hydrologic, topographic, and geologic characteristics of the drainage basin. The slope of the curve indicates variability of flow with time. A flat slope at the lower end of the curve reflects storage, which may be either on the earth's surface in lakes, ponds, or swamps, or in the ground. A steep slope at the low flow end of the curve indicates rapidly receding base flow because of either little storage and a low rate of return of ground water to the stream or a high rate of infiltration of the stream water to the ground.

Flow-duration data have been computed for the long-term gaging stations on Cattaraugus Creek at Gowanda, Cayuga Creek near Lancaster, Cazenovia Creek at Ebenezer, and Tonawanda Creek at Batavia, and for the short-term gaging station on Ellicott Creek at Millgrove. Discharge per square mile-duration relations for these stations are presented in figure 3. The curve for the gaging station on Tonawanda Creek at Batavia has not been adjusted for either the diversion of 1.7 million gallons of water per day upstream from the gage for water supply or for the effluent inflow below the gage.

Flow-duration curves for the sites on Murder Creek at State Highway 93 at Swifts Mills and on Tonawanda Creek at Stroh Road at Attica (fig. 4) have been developed by comparing the discharge data obtained at the sites with that of nearby gaging stations where long-term records are available, after it had been established that a definable relationship existed. The duration curve of daily flow for Ellicott Creek at Forest Road at Amherst was developed on the basis of a drainage area ratio with the gaging station on Ellicott Creek at Williamsville.

Low-flow frequency data for the minimum average discharge for 7 consecutive days with a 10-year return period have been developed for all sites and are presented in table 4. They are useful in that average flow for a period of consecutive days is combined with the probability of recurrence. The average flow for a 7-day period is customarily used for low-flow studies because of its greater stability than the flow for a single minimum day.

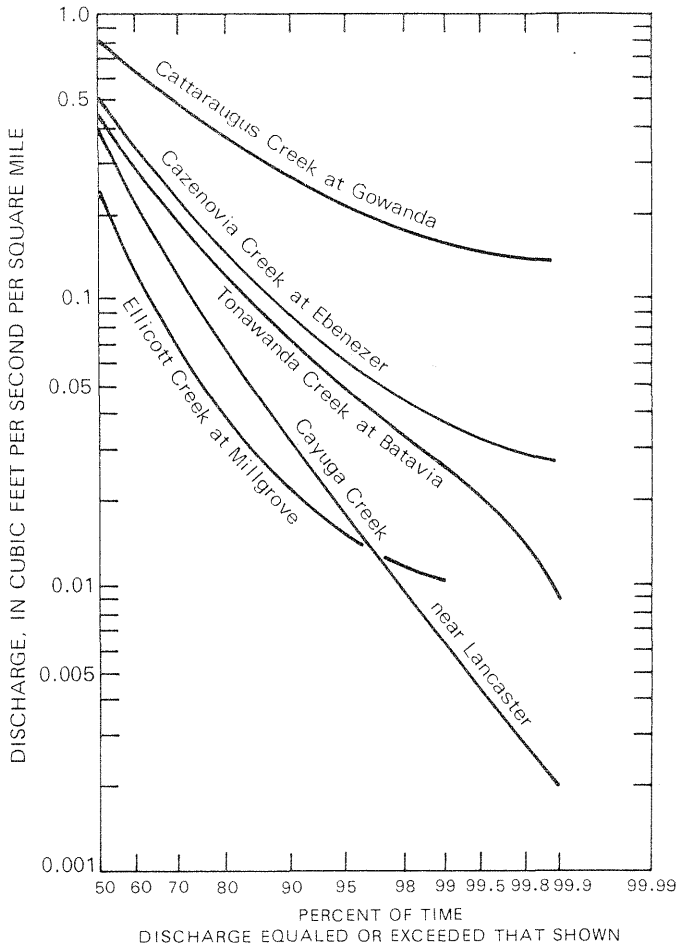

Figure 3.--Duration curves of daily flow for selected gaging stations in Lake Erie-Niagara River basins.

Table 4.--Minimum average consecutive 7-day discharge for a 10-year return period

Site	Discharge (cfs)
Cattaraugus Creek at Gowanda	56.6
Cayuga Creek near Lancaster	.35
Buffalo River at Cheektowaga STP[1]	[2]4.5
Tonawanda Creek at Stroh Road at Attica	[2]5
Tonawanda Creek at Batavia	2
Murder Creek at Swifts Mills Road	([3])
Ellicott Creek at Millgrove	[2].2
Ellicott Creek at Amherst	[2]0
Cazenovia Creek at Ebenezer	4.3

[1] STP means sewage treatment plant.
[2] Estimated.
[3] Little or no natural flow.

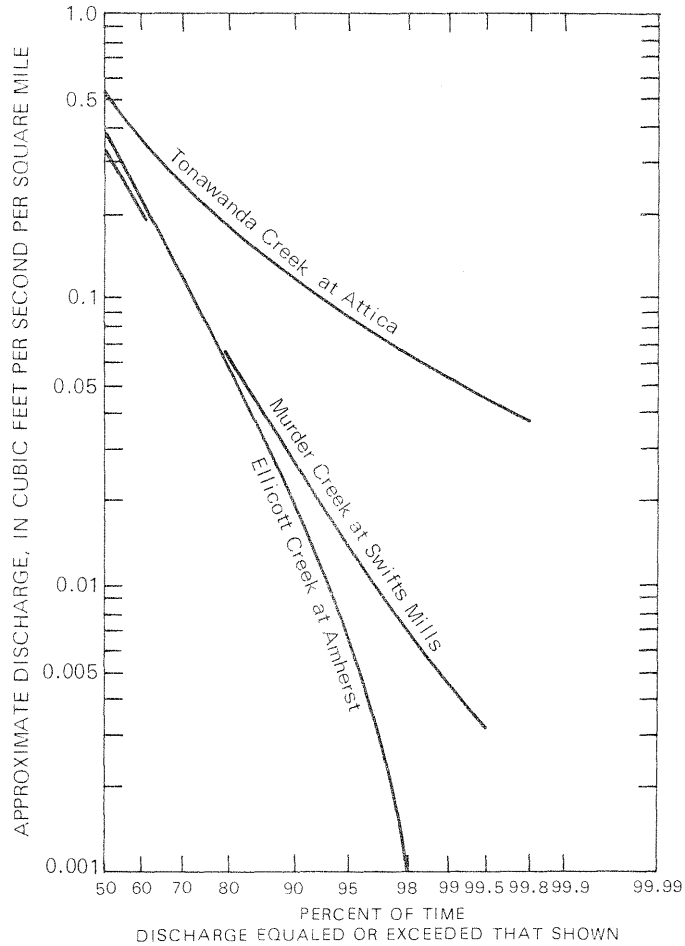

Figure 4.--Duration curves of daily flow for selected temporary gaging sites in Lake Erie-Niagara River basins.

DISCUSSION

At most sites, under ideal conditions, a good definition of the discharge time-of-travel curve could be obtained by making time-of-travel runs at approximately the 60, 85, and 99 percent flow-duration points. The upper limit (60 percent) would be sufficiently high for any low-water study; the middle point would help define any break in the curve; and the lower point would show the direction for an extension to define the minimum average consecutive 7-day discharge for a 10-year return period, which in this study was between 99.3 and 99.9 percent.

Time-of-travel runs were made on Cattaraugus, Cayuga, Ellicott, Murder, and Tonawanda Creeks, Cazenovia Creek basin, and Buffalo River at different duration points of flow, ranging from a high of 42 percent on Cattaraugus Creek at Gowanda to a low of 99.2 percent on Tonawanda Creek at Attica.

APPENDIX A

Figures 5-13. Graphs showing relation of discharge to peak time of travel:

Figures 14-16. Relation of discharge at Ebenezer gage to peak time of travel:

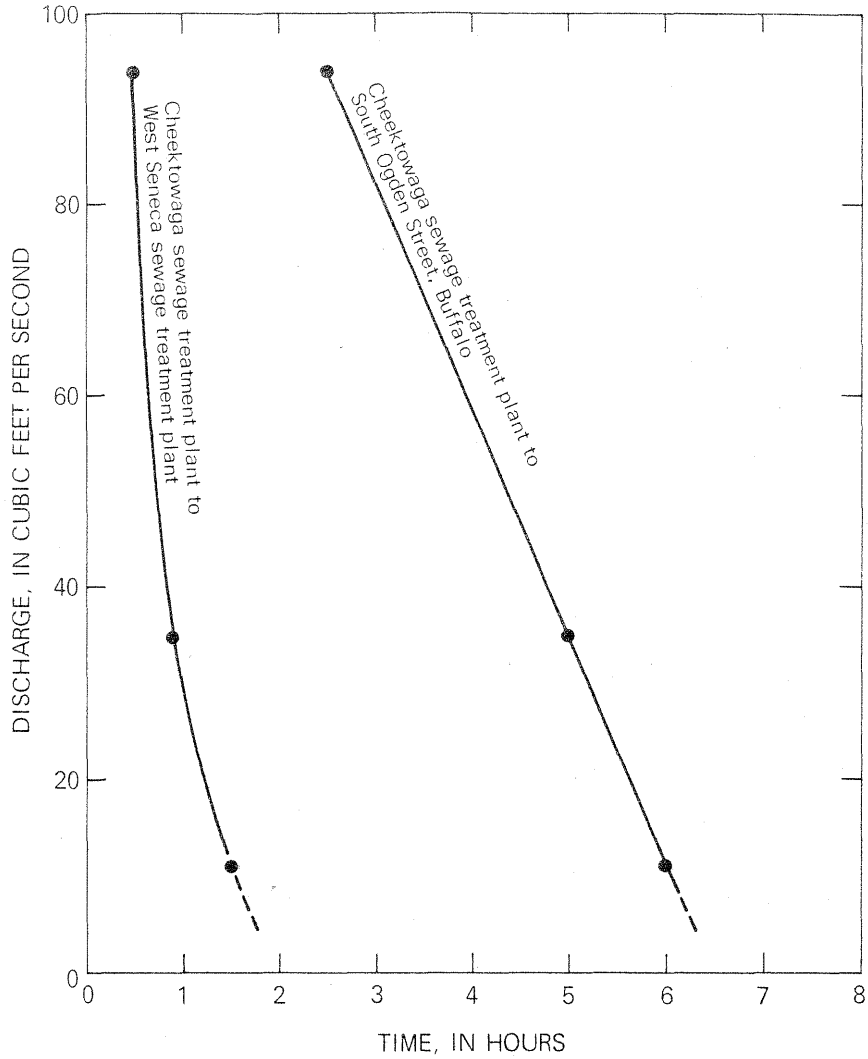

Figure 5.--Relation of discharge to peak time of travel, Buffalo River, from Cheektowaga sewage treatment plant to South Ogden St., Buffalo.

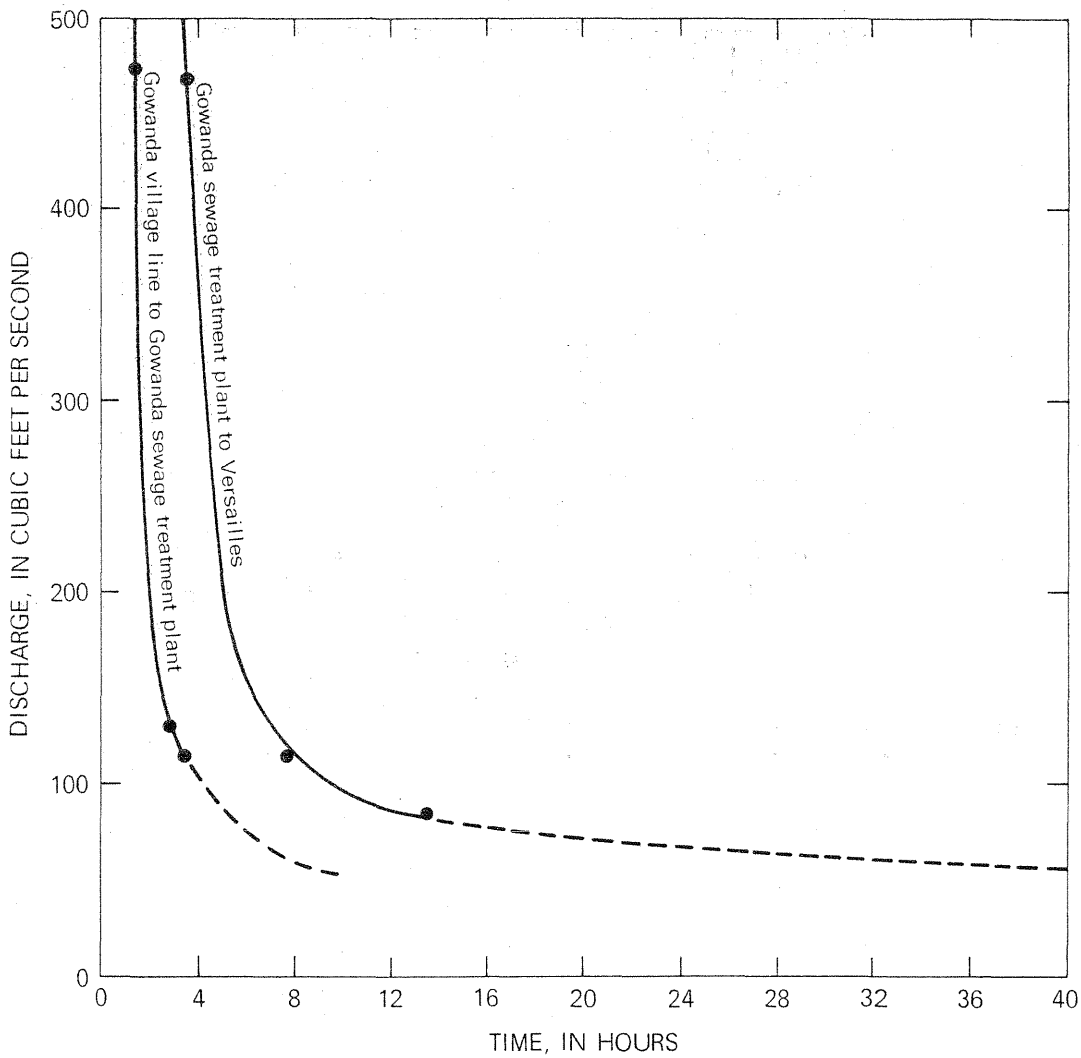

Figure 6.--Relation of discharge to peak time of travel, Cattaraugus Creek, from Gowanda village line to Versailles.

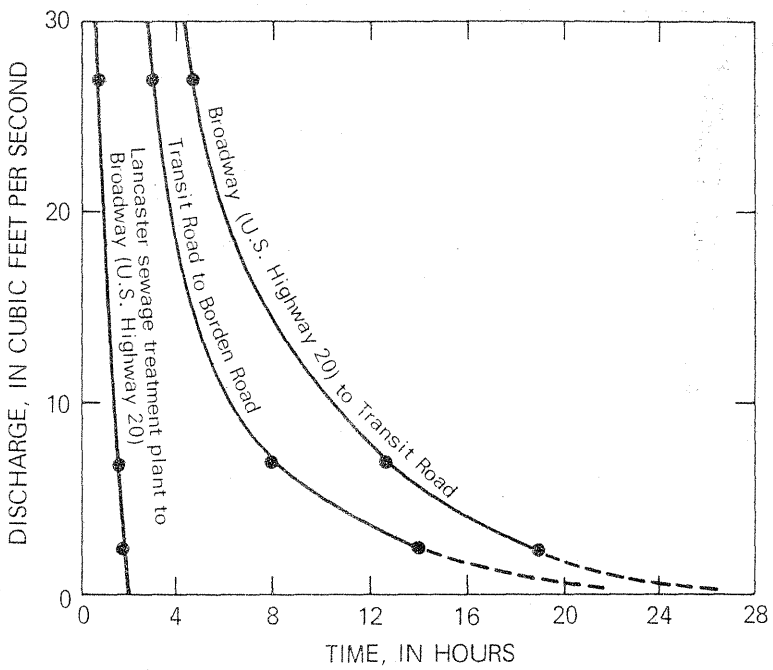

Figure 7.--Relation of discharge to peak time of travel, Cayuga Creek, from Lancaster sewage treatment plant to Borden Road, Depew.

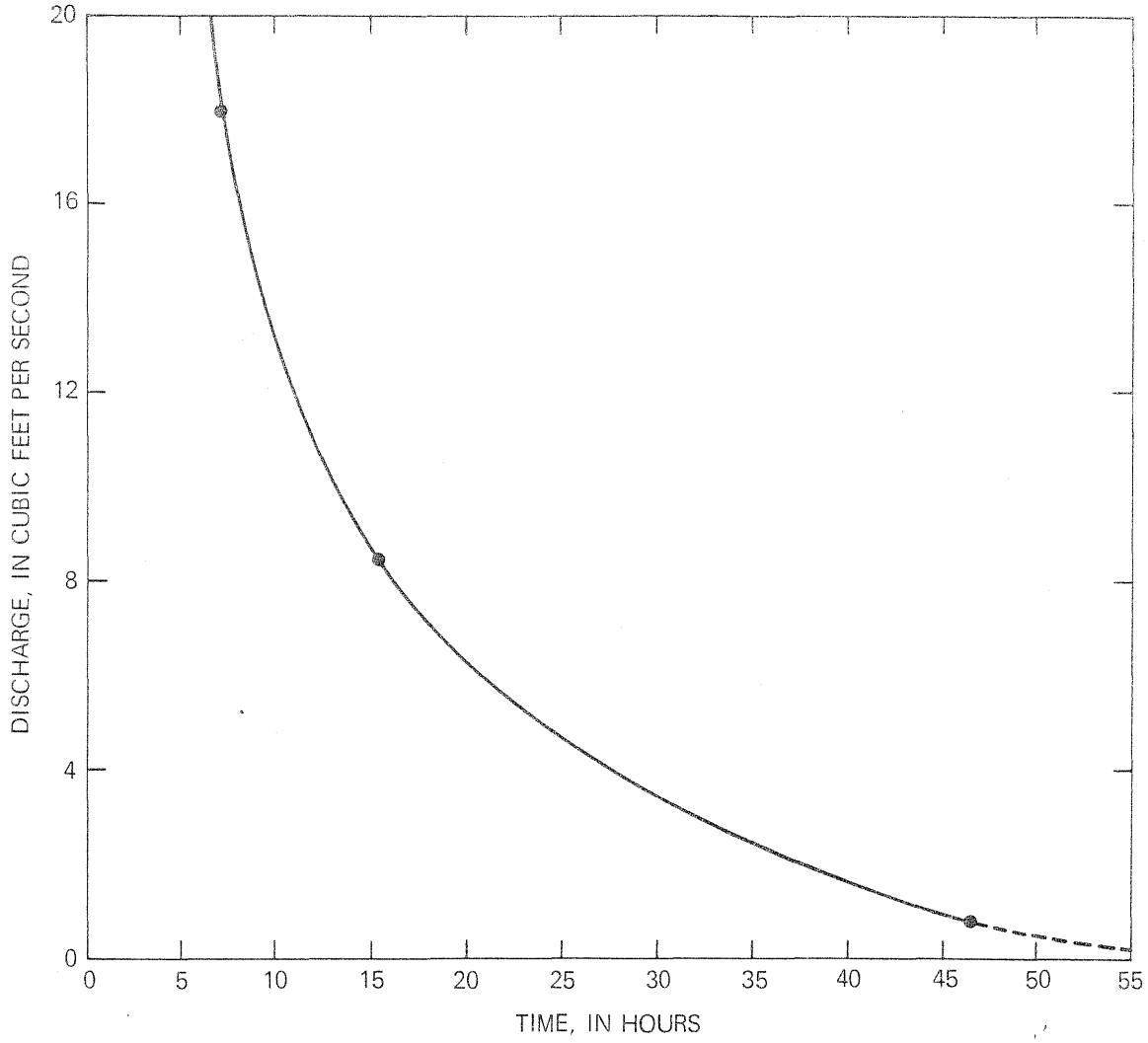

Figure 8.--Relation of discharge to peak time of travel, Ellicott Creek, from Alden sewage treatment plant to Sand Ridge.

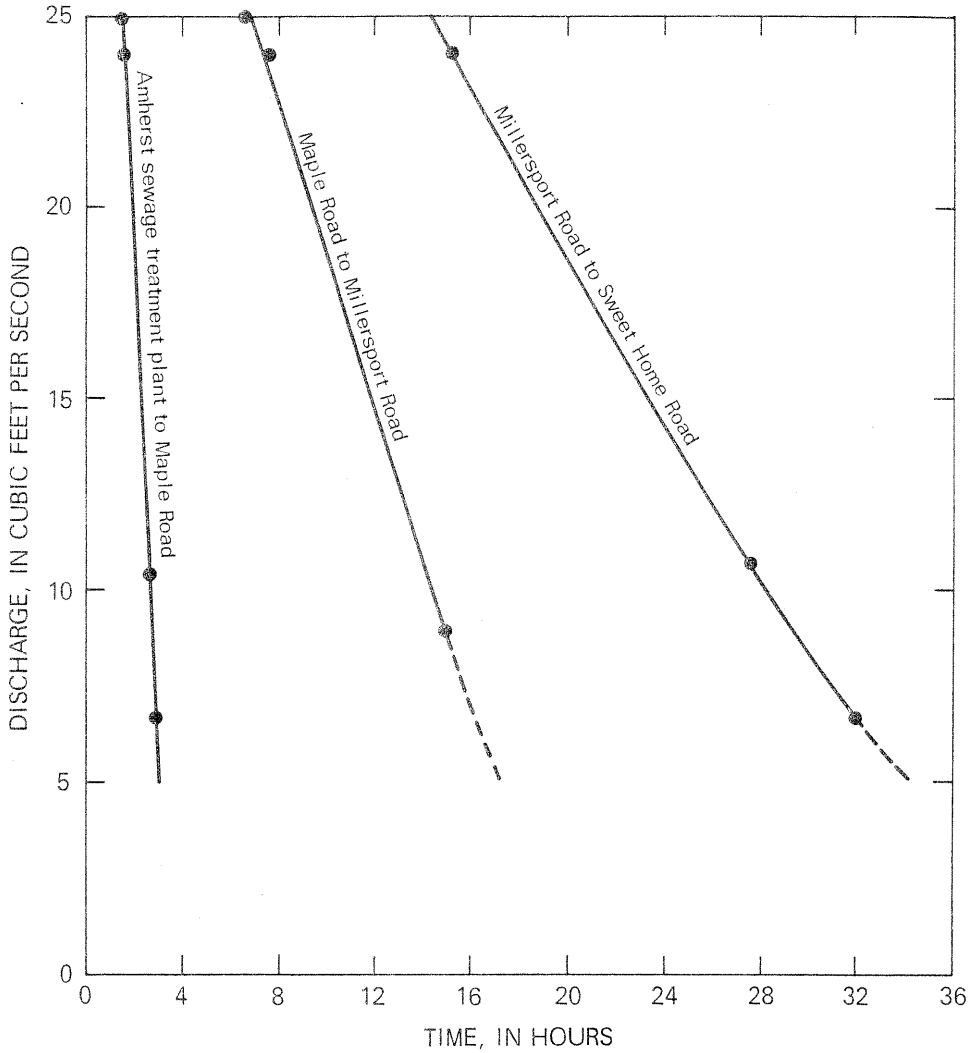

Figure 9.--Relation of discharge to peak time of travel, Ellicott Creek, from Amherst sewage treatment plant to Sweet Home Road.

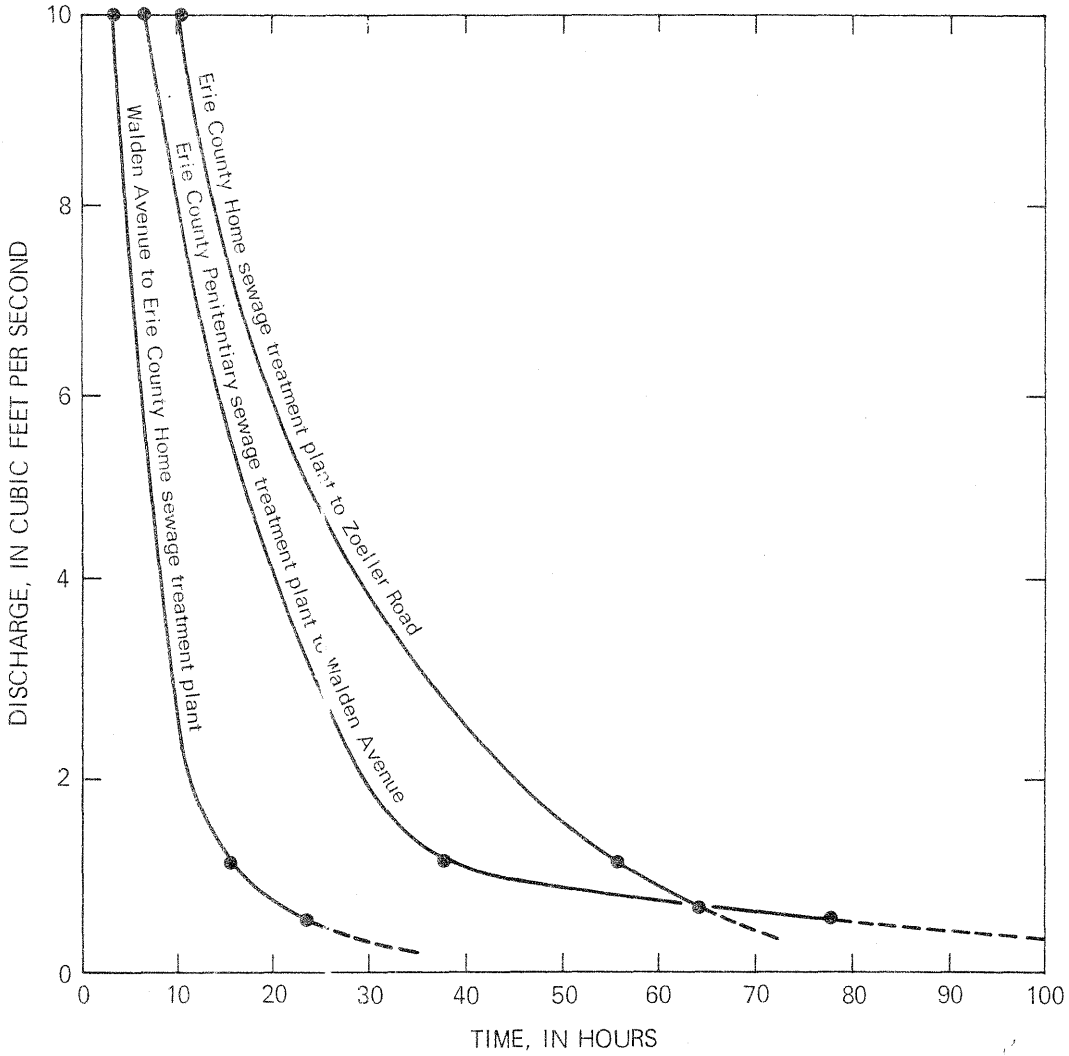

Figure 10.--Relation of discharge to peak time of travel, Ellicott Creek, from Erie County Penitentiary sewage treatment plant to Zoeller Road, Millgrove.

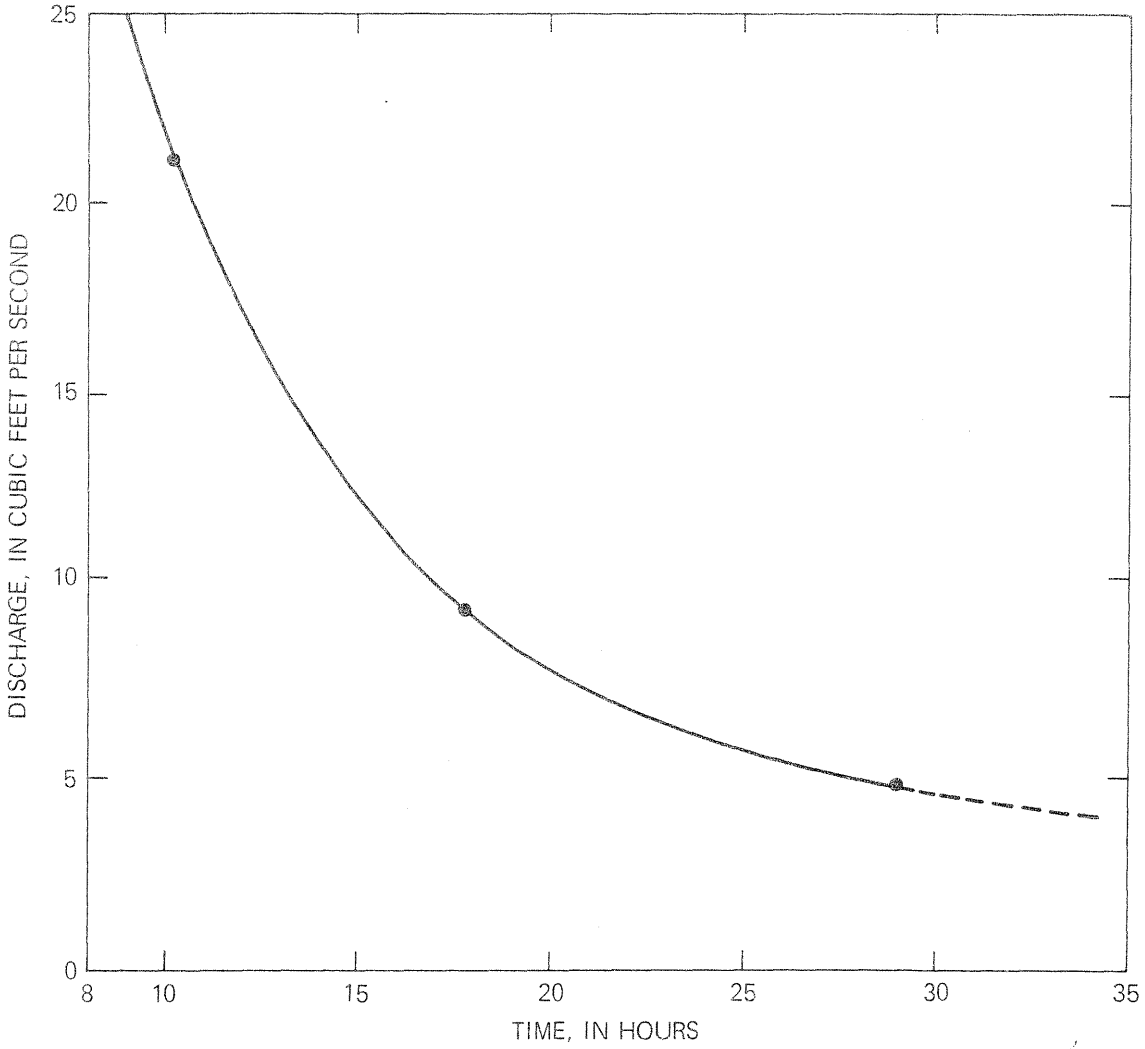

Figure 11.--Relation of discharge to peak time of travel, Murder Creek, from Akron sewage treatment plant to Simpson's Grove.

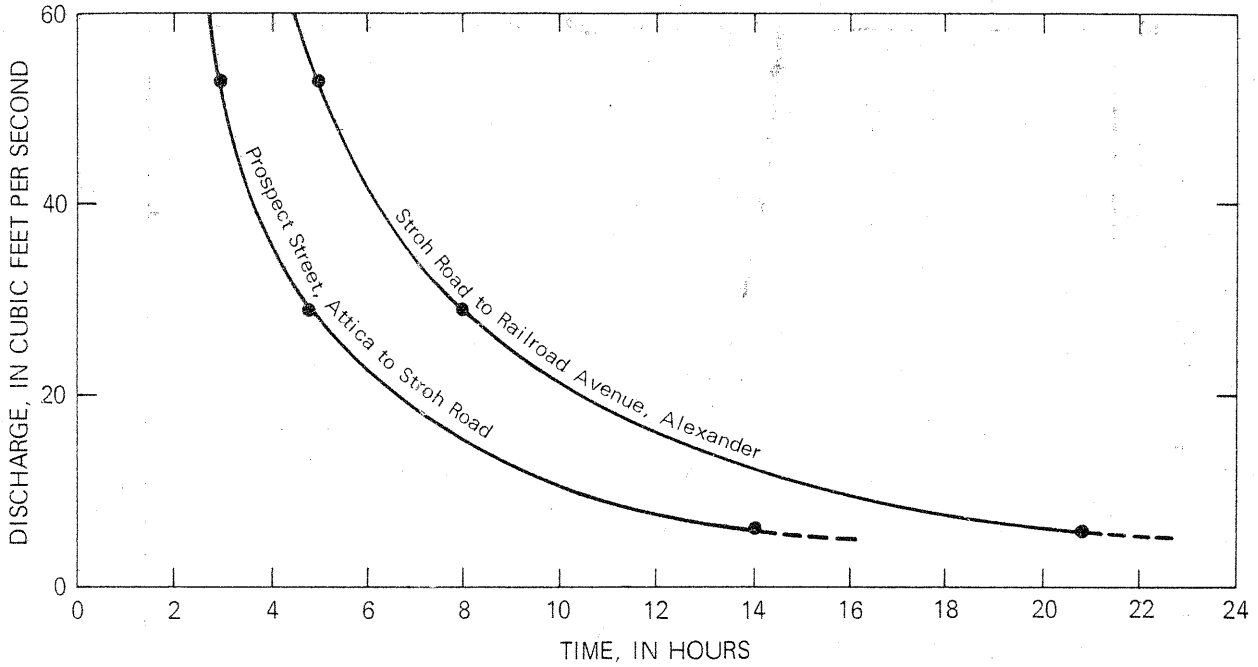

Figure 12.--Relation of discharge to peak time of travel, Tonawanda Creek, from Prospect St., Attica, to Railroad Ave., Alexander.

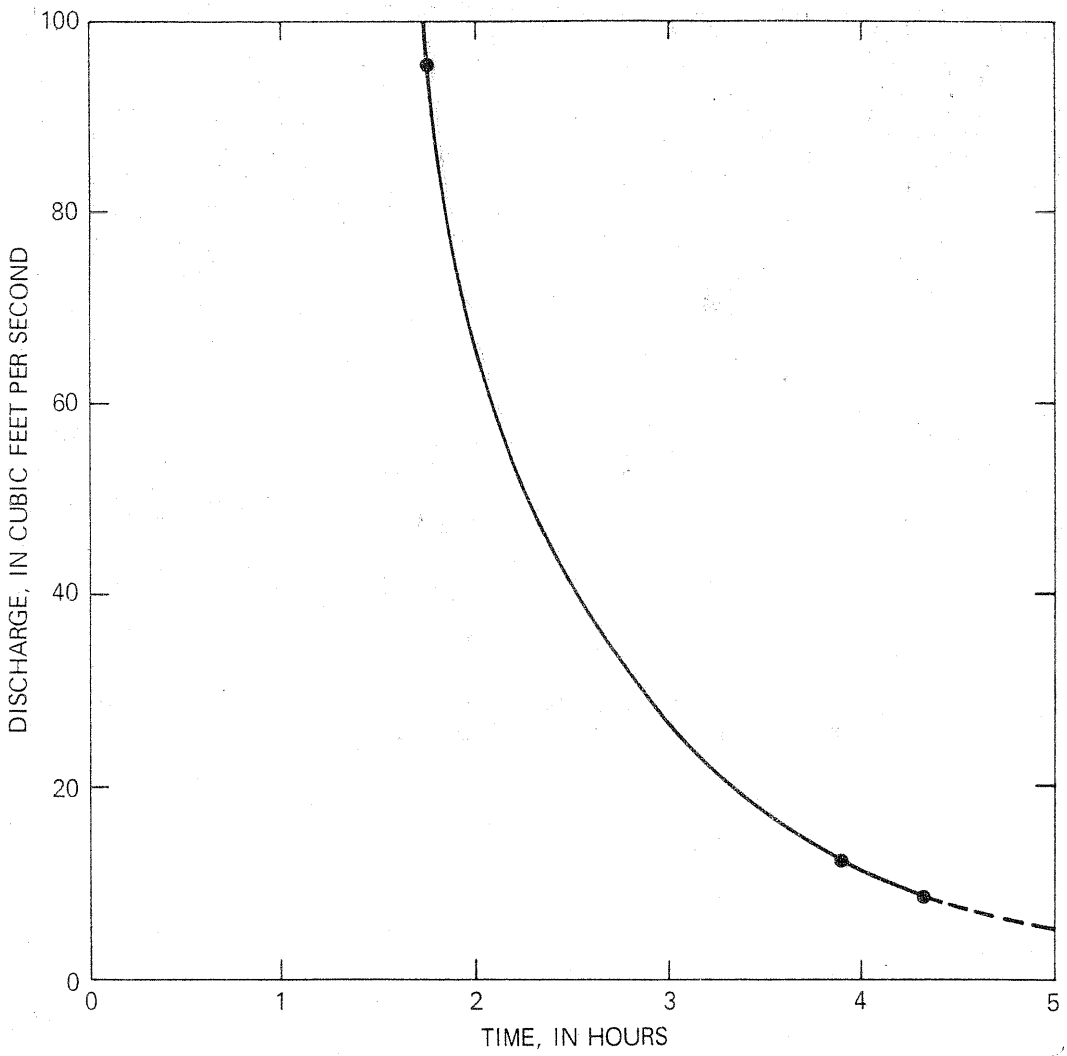

Figure 13.--Relation of discharge to peak time of travel, Tonawanda Creek, from South Lyon St. to off South Main St., Batavia.

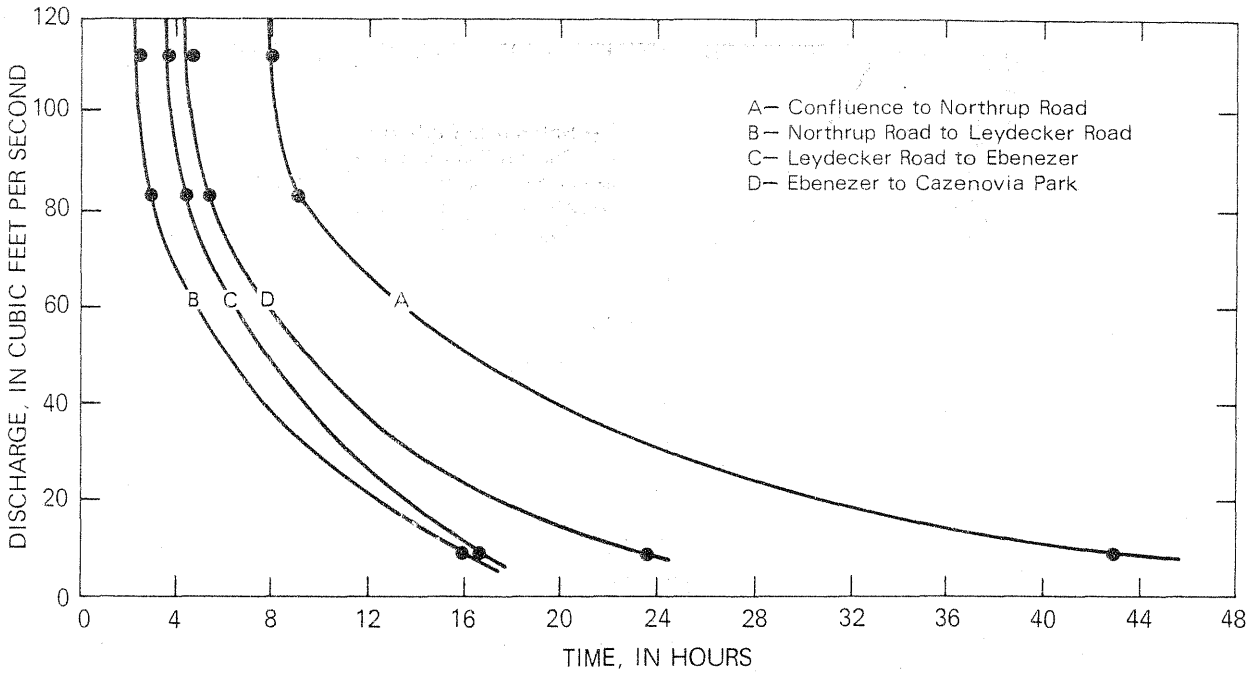

Figure 14.--Relation of discharge at Ebenezer gage to peak time of travel, Cazenovia Creek, from confluence of East Branch and West Branch to Cazenovia Park.

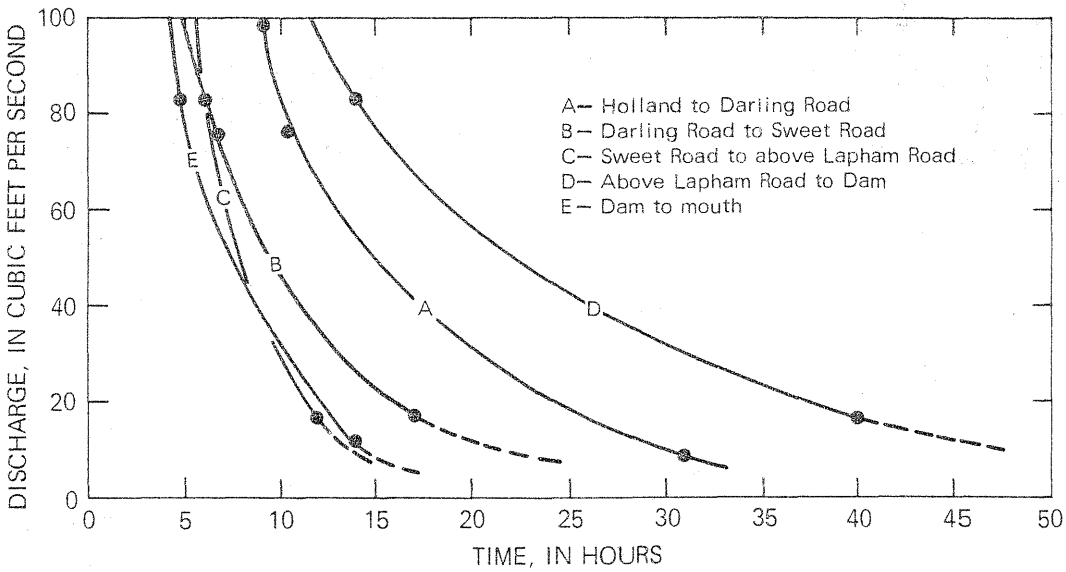

Figure 15.--Relation of discharge at Ebenezer gage to peak time of travel, East Branch Cazenovia Creek, from Holland to mouth.

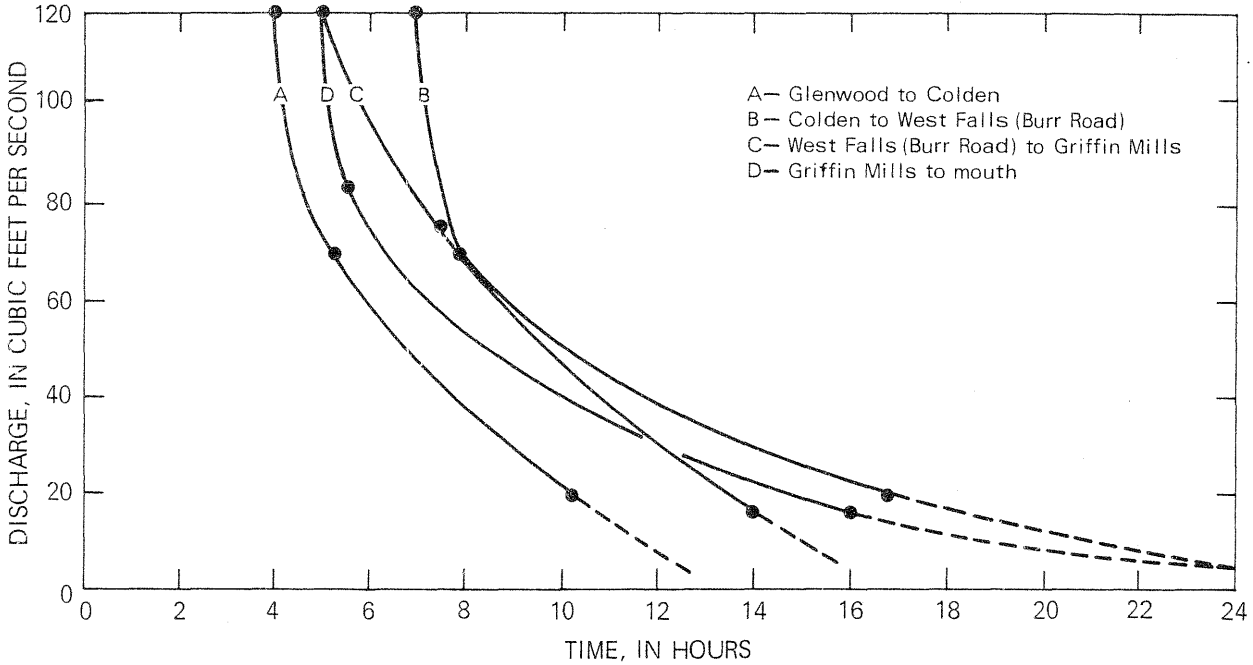

Figure 16.--Relation of discharge at Ebenezer gage to peak time of travel, West Branch Cazenovia Creek, from Glenwood to mouth.

28(Blank)

APPENDIX B

Figures 17-28. Graphs showing peak time of travel:

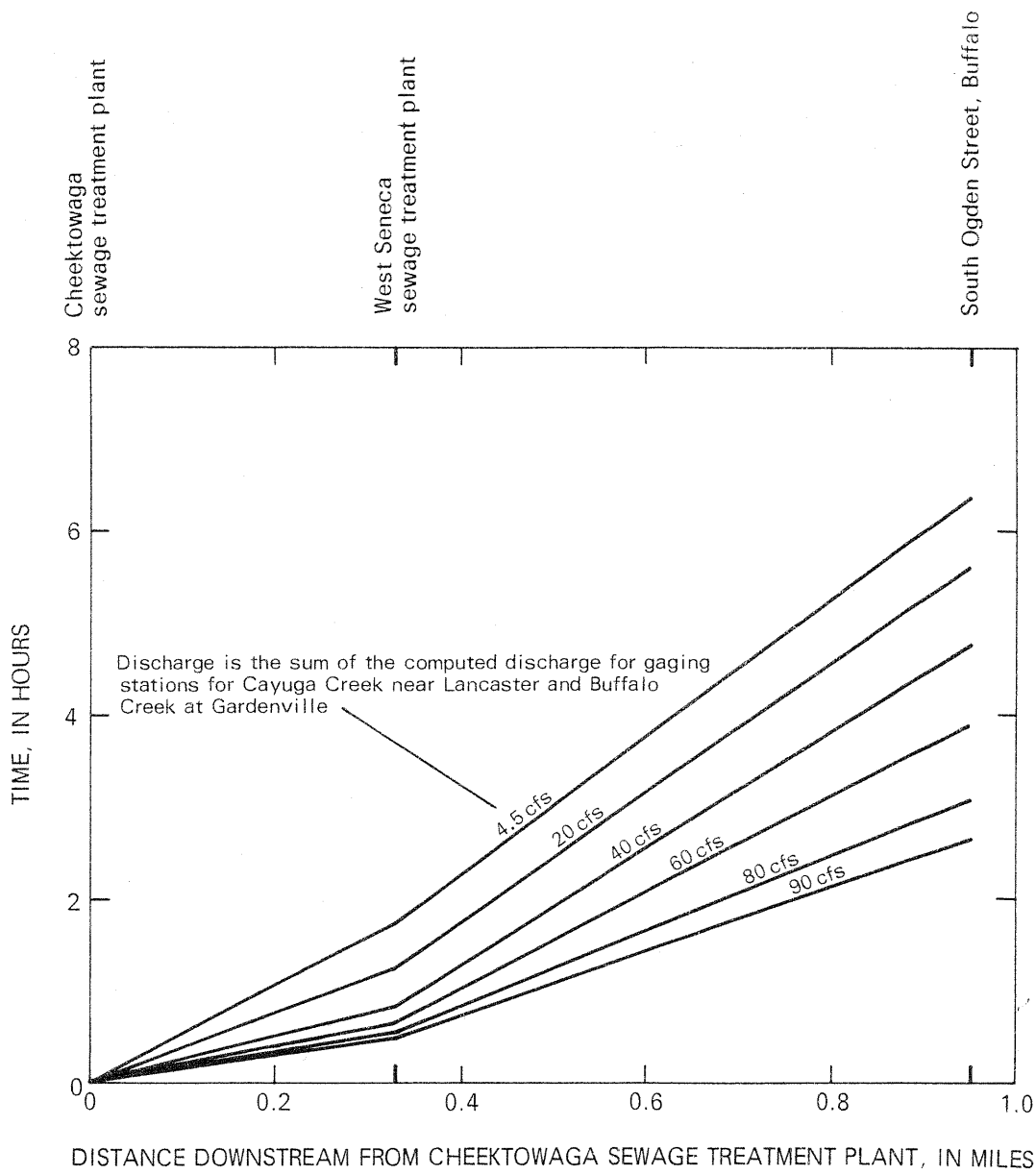

Figure 17.--Peak time of travel, Buffalo River, from Cheektowaga sewage treatment plant to South Ogden St., Buffalo.

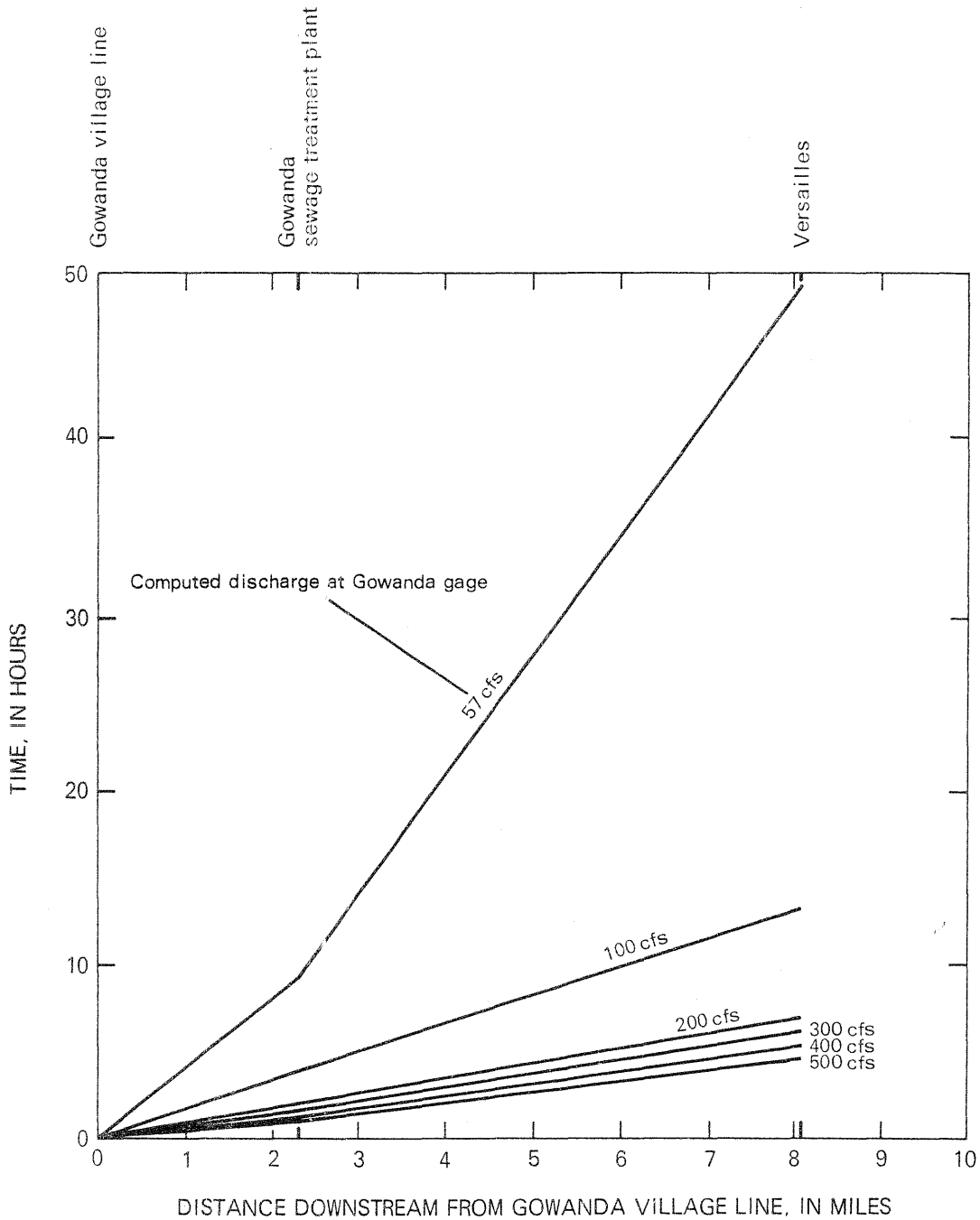

Figure 18.--Peak time of travel, Cattaraugus Creek, from Gowanda village line to Versailles.

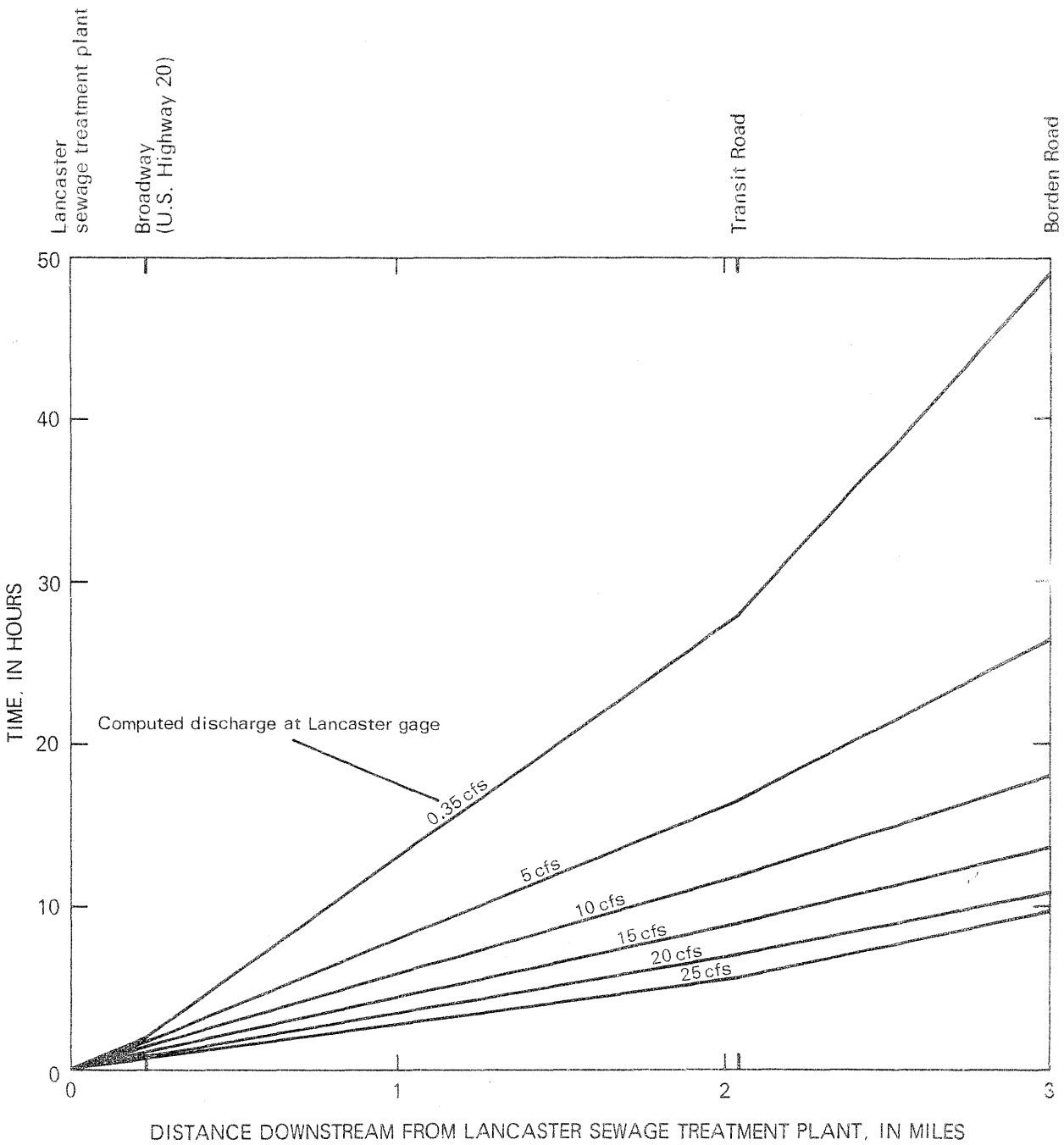

Figure 19.--Peak time of travel, Cayuga Creek, from Lancaster sewage treatment plant to Borden Road, Depew.

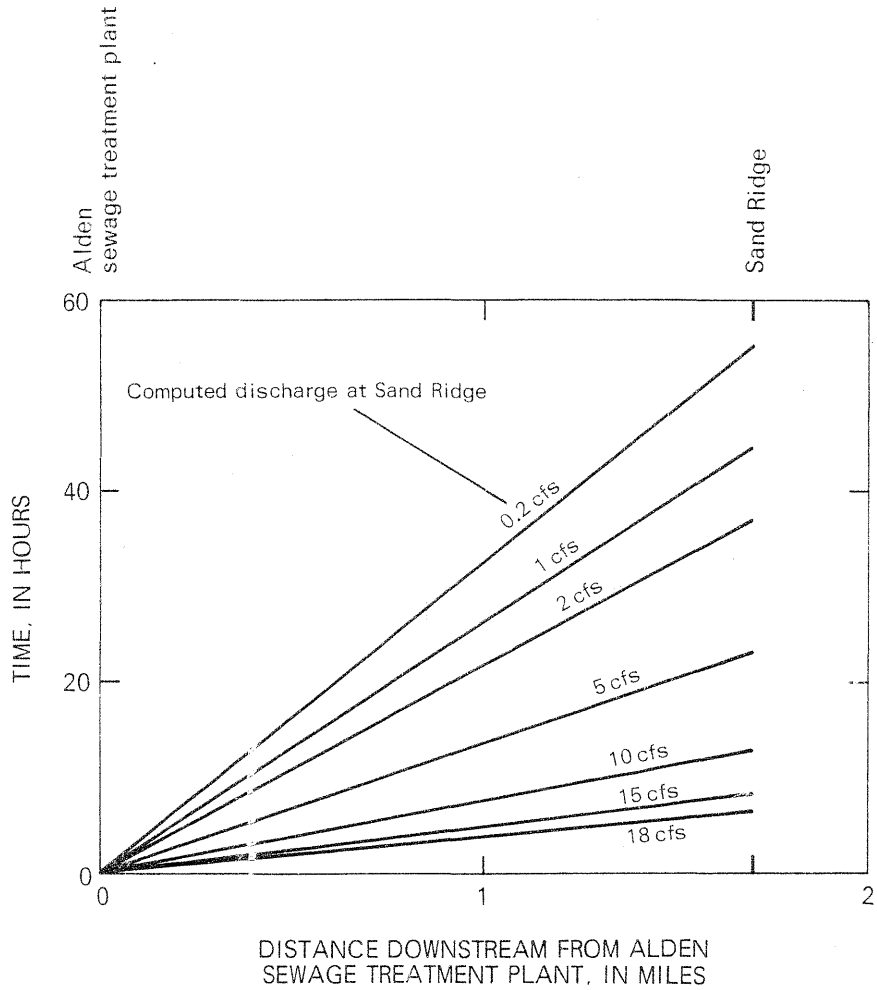

Figure 20.--Peak time of travel, Ellicott Creek, from Alden sewage treatment plant to Sand Ridge.

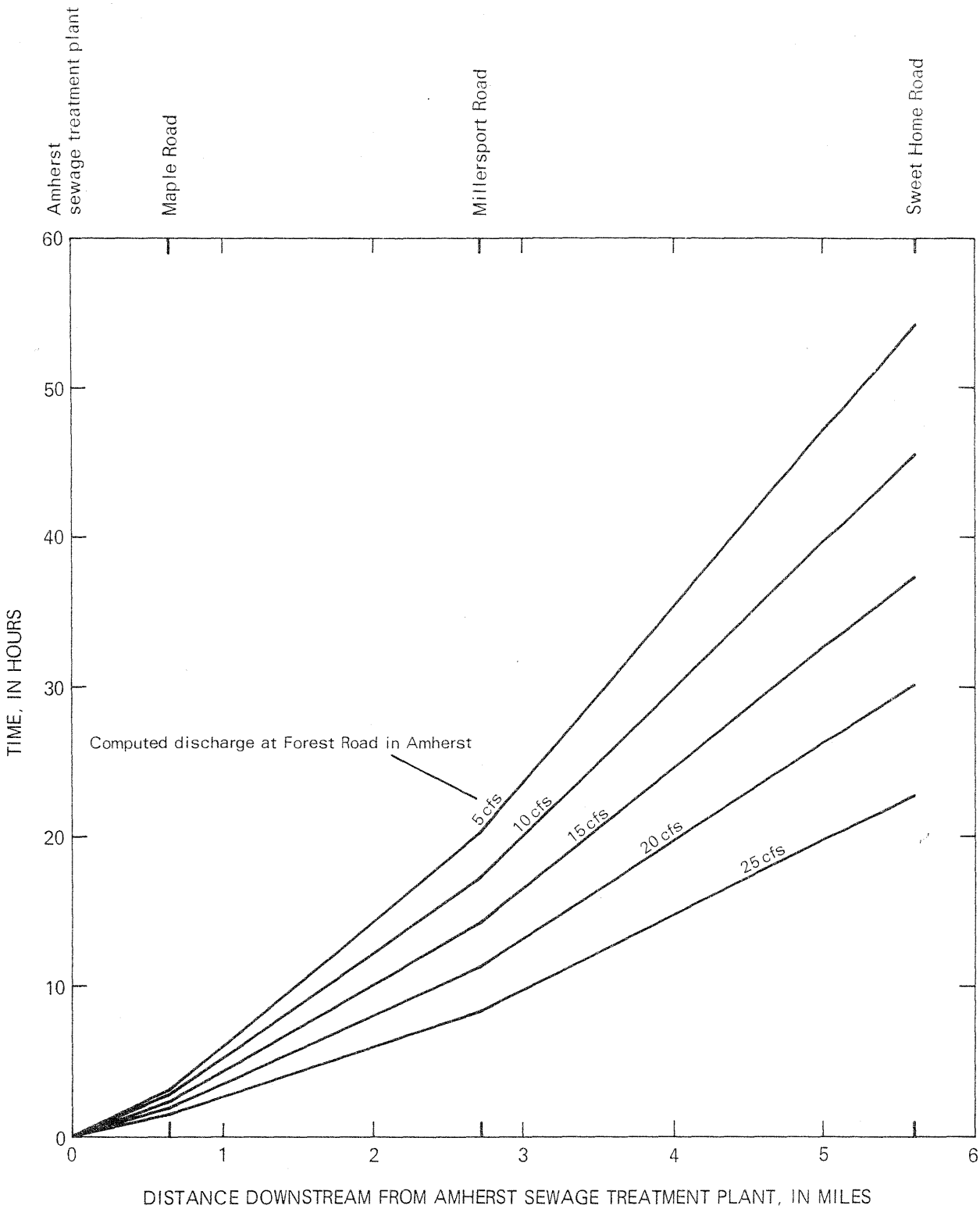

Figure 21.--Peak time of travel, Ellicott Creek, from Amherst sewage treatment plant to Sweet Home Road.

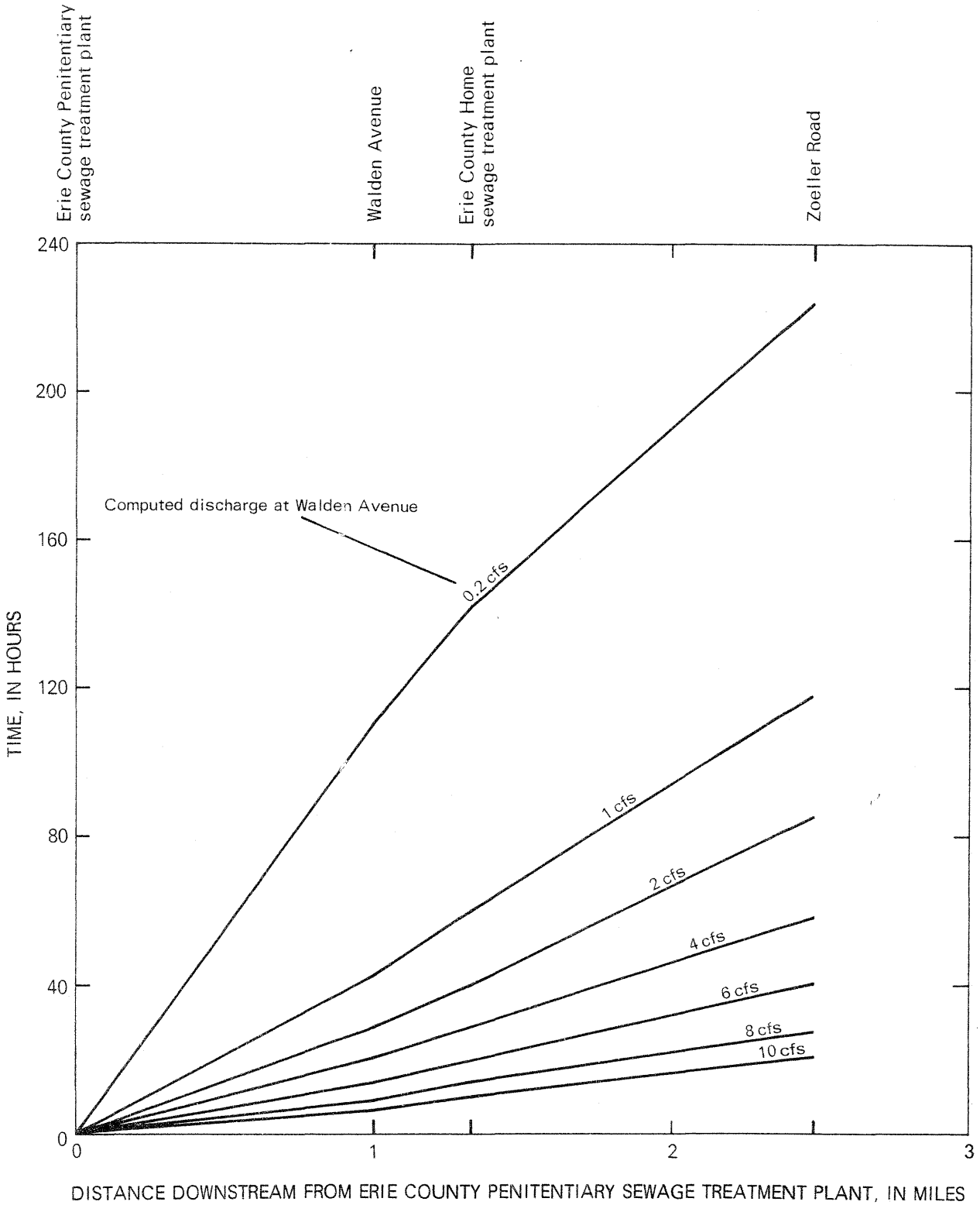

Figure 22.--Peak time of travel, Ellicott Creek, from Erie County Penitentiary sewage treatment plant to Zoeller Road, Millgrove.

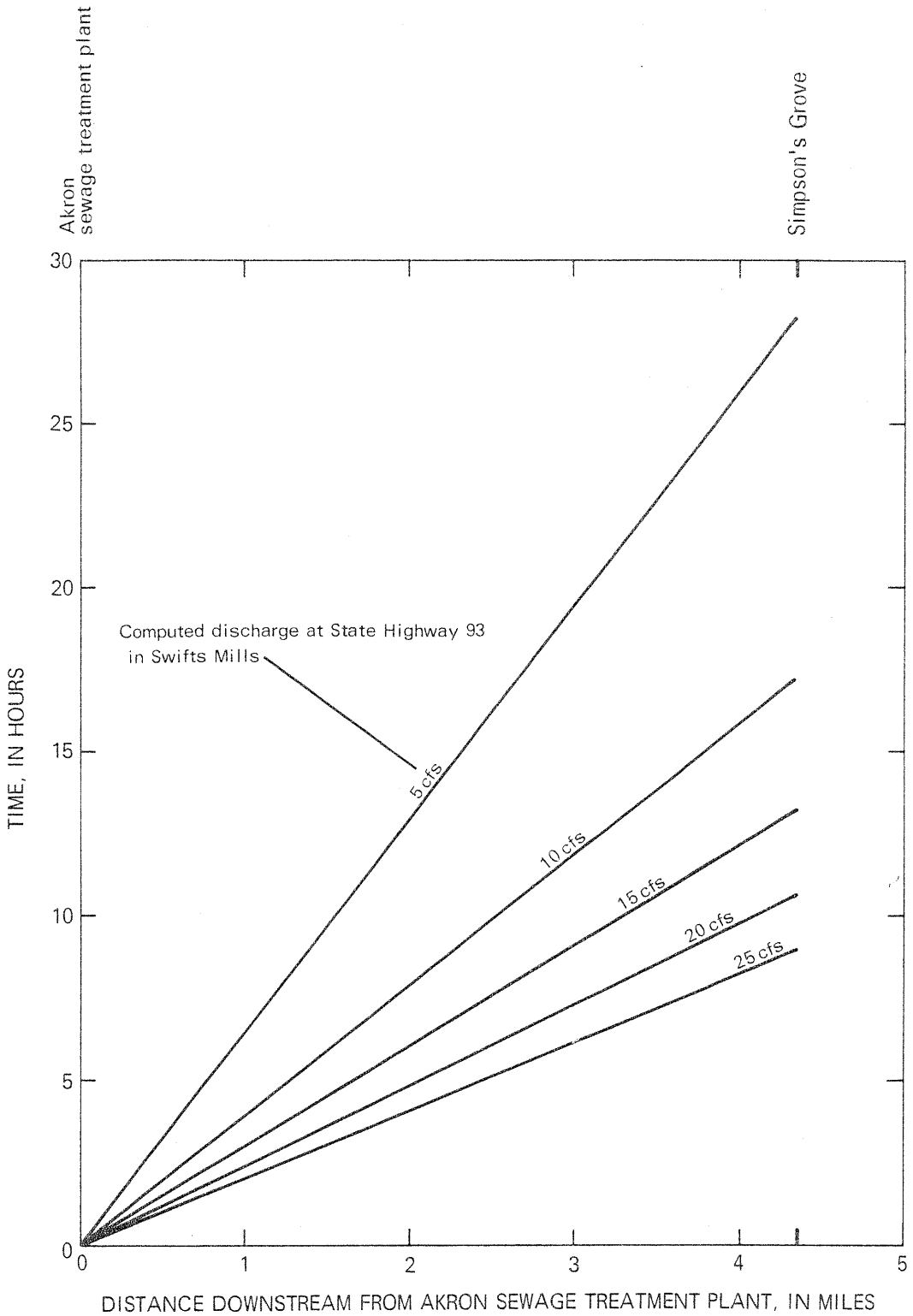

Figure 23.--Peak time of travel, Murder Creek, from Akron sewage treatment plant to Simpson's Grove.

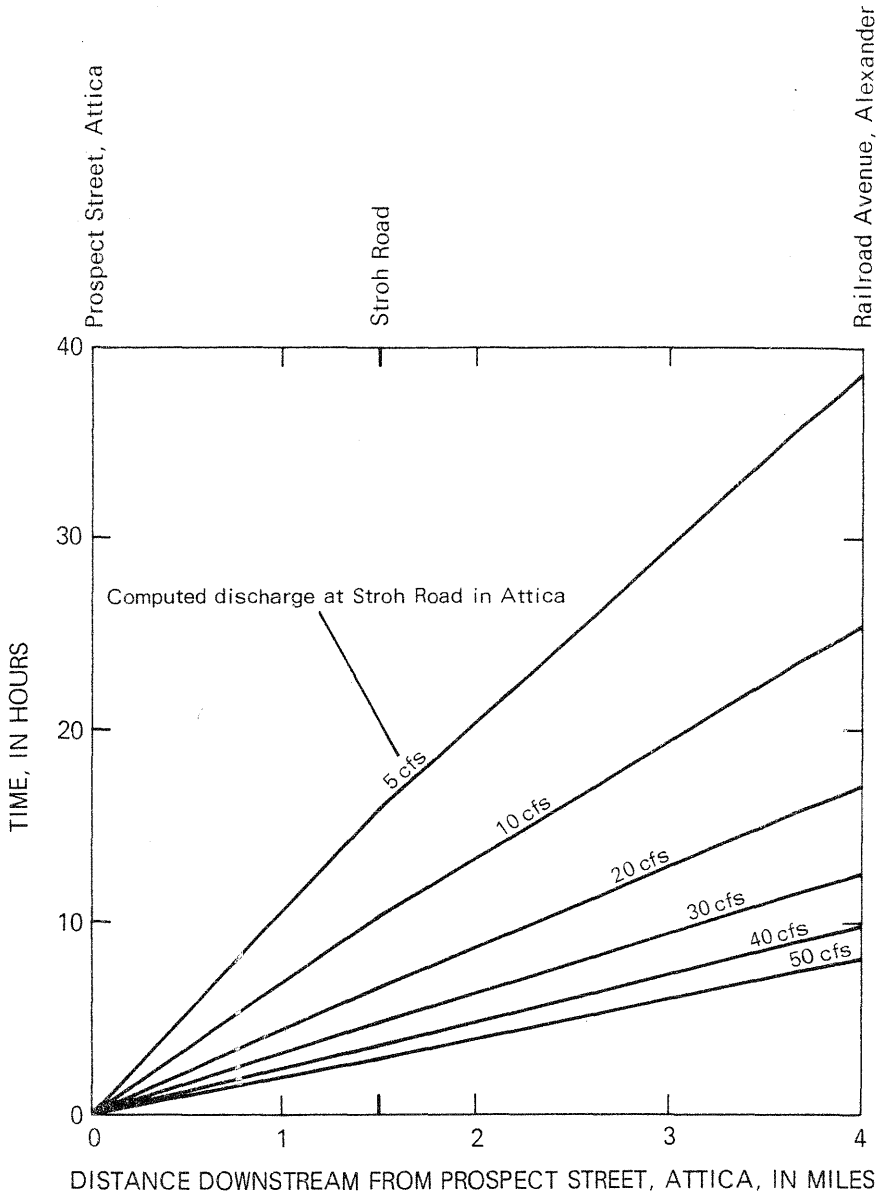

Figure 24.--Peak time of travel, Tonawanda Creek, from Prospect St., Attica, to Railroad Ave., Alexander.

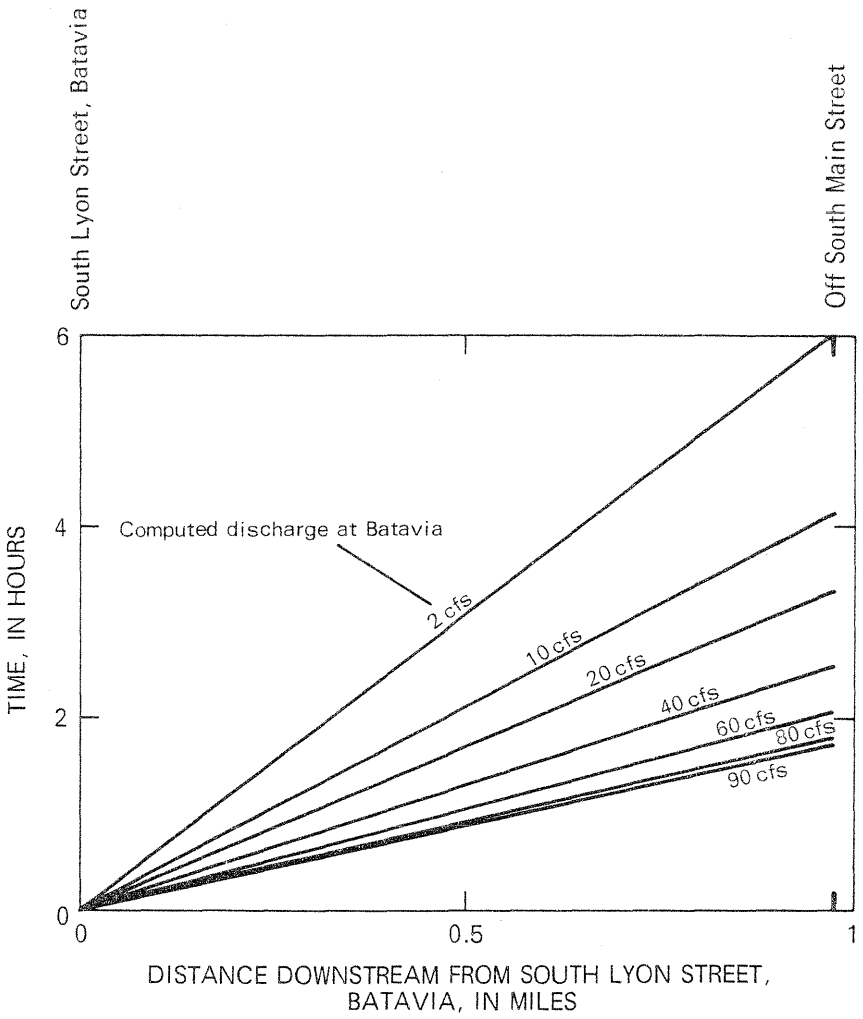

Figure 25.--Peak time of travel, Tonawanda Creek, from South Lyon St. to off South Main St., Batavia.

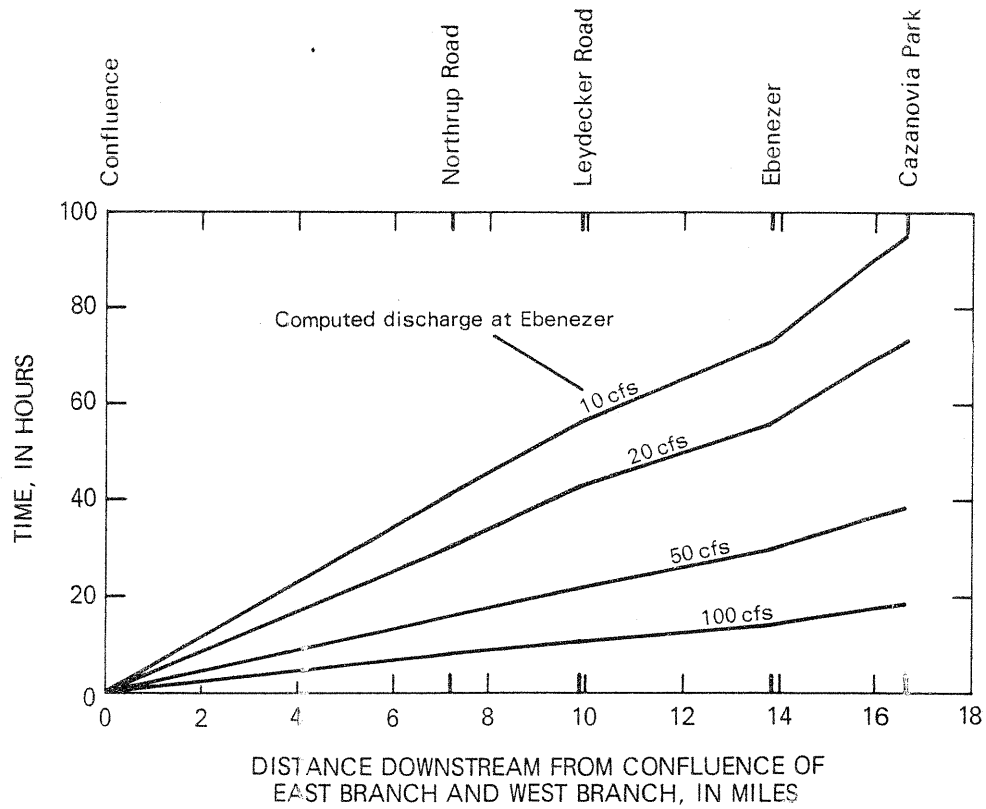

Figure 26.--Peak time of travel, Cazenovia Creek, from confluence of East Branch and West Branch to Cazenovia Park.

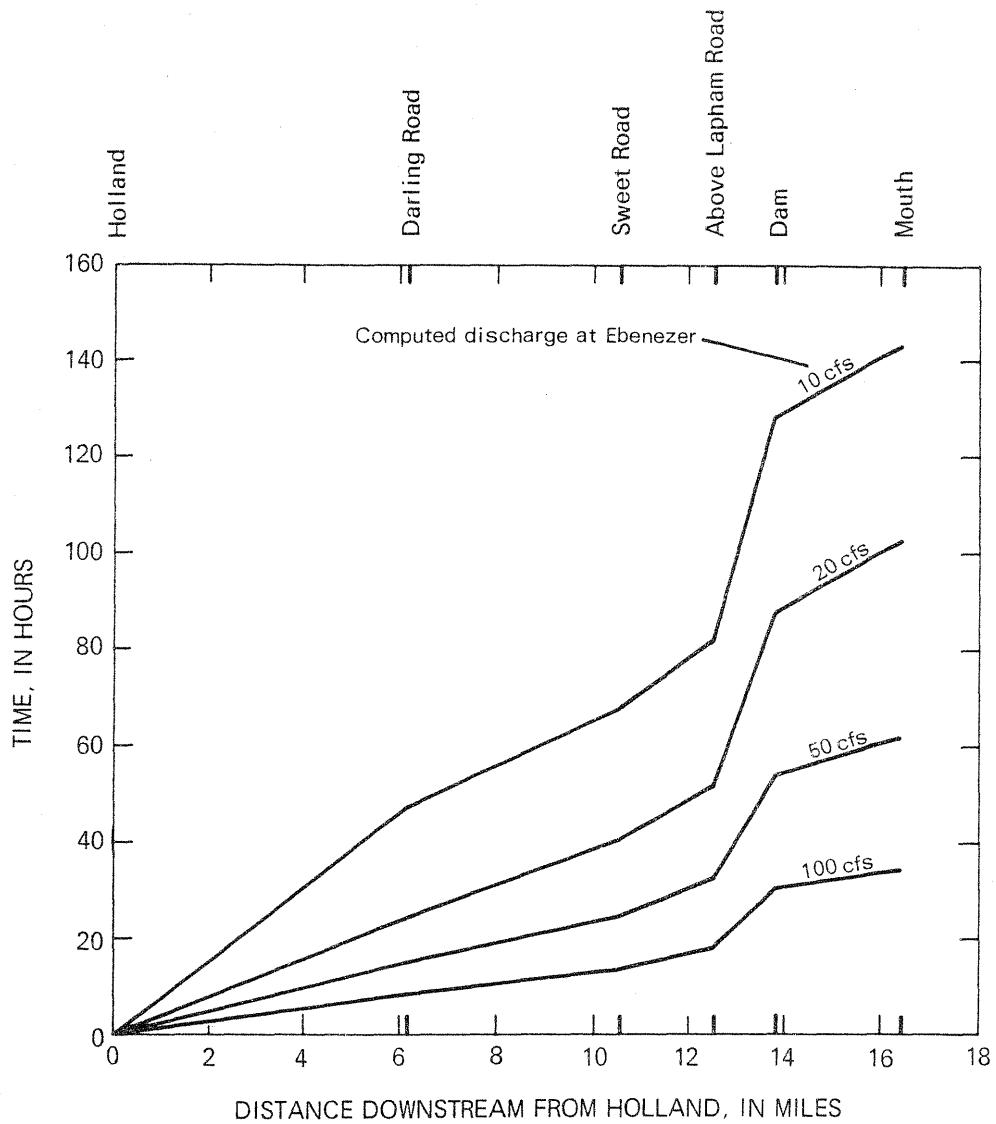

Figure 27.--Peak time of travel, East Branch Cazenovia Creek, from Holland to mouth.

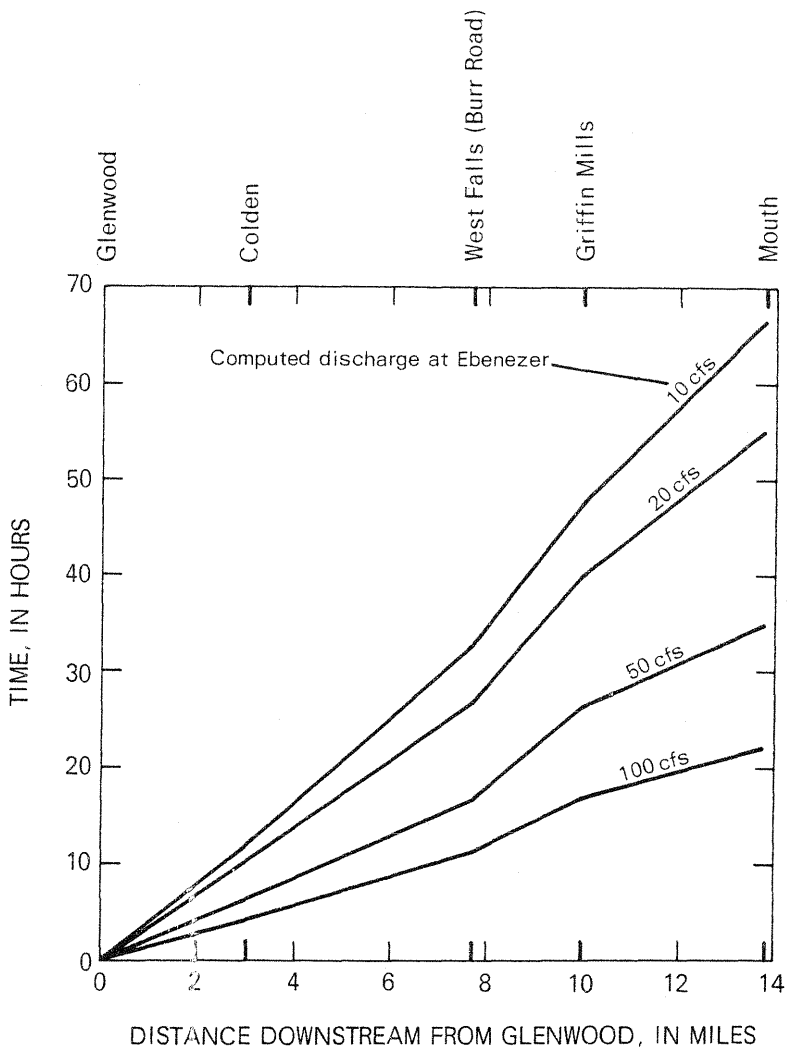

Figure 28.--Peak time of travel, West Branch Cazenovia Creek, from Glenwood to mouth.