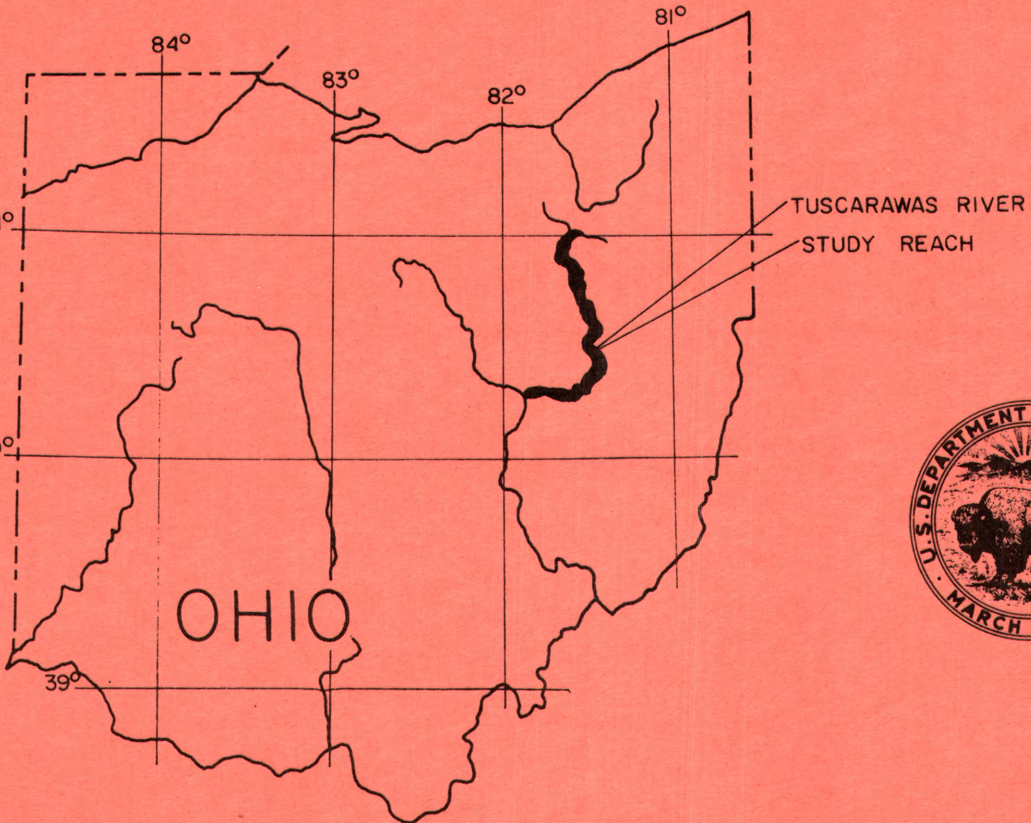
UNITED STATES GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR

PREPARED IN COOPERATION WITH
THE STATE OF OHIO
ENVIRONMENTAL PROTECTION AGENCY

TIME OF TRAVEL OF SOLUTES IN THE TUSCARAWAS RIVER BASIN, OHIO AUGUST AND SEPTEMBER, 1974

WATER RESOURCES INVESTIGATIONS 77-23



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A time-of-travel study was made on a 106-mile reach of the Tuscarawas River to determine average velocity and dispersion characteristics between selected points. The reach was divided into five subreaches, and a fluorescent dye used as a tracer material. At about the 50-percent flow-duration level, time-of-travel of the peak concentration was 137 hours.

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UNITED STATES DEPARTMENT OF THE INTERIOR

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Factors for converting English units to International System units (SI)

Multiply English units	by	to obtain SI units
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
feet per second (ft/sec)	.3048	meters per second (m/s)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)

TIME OF TRAVEL OF SOLUTES IN THE TUSCARAWAS RIVER BASIN IN OHIO AUGUST AND SEPTEMBER 1974

by Arthur O. Westfall and Earl E. Webber

ABSTRACT

A time-of-travel study was made on a 106-mile reach of the Tuscarawas River to determine average velocity and dispersion characteristics between selected points. The reach was divided into five subreaches, and a fluorescent dye used as a tracer material. At about the 50-percent flow-duration level, time of travel of the peak concentration was 137 hours.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the Ohio Environmental Protection Agency, made a time-of-travel study along the Tuscarawas River from a point 3 miles (4.8 km) downstream from Barberton, Ohio, to a point 0.3 mile (0.48 km) upstream from the confluence with the Walhonding River at Coshocton, Ohio. The study was made during the periods August 12 to 14, and September 24 to 29, 1974. The study reach, covering a distance of 106 river miles (171 km), is shown in figure 1.

The purpose of the study was to measure dispersion characteristics and velocity of flow between several points on the river. The information will be useful in determining the capacity of the river to dilute and disperse pollutants from municipal, industrial, and other sources.

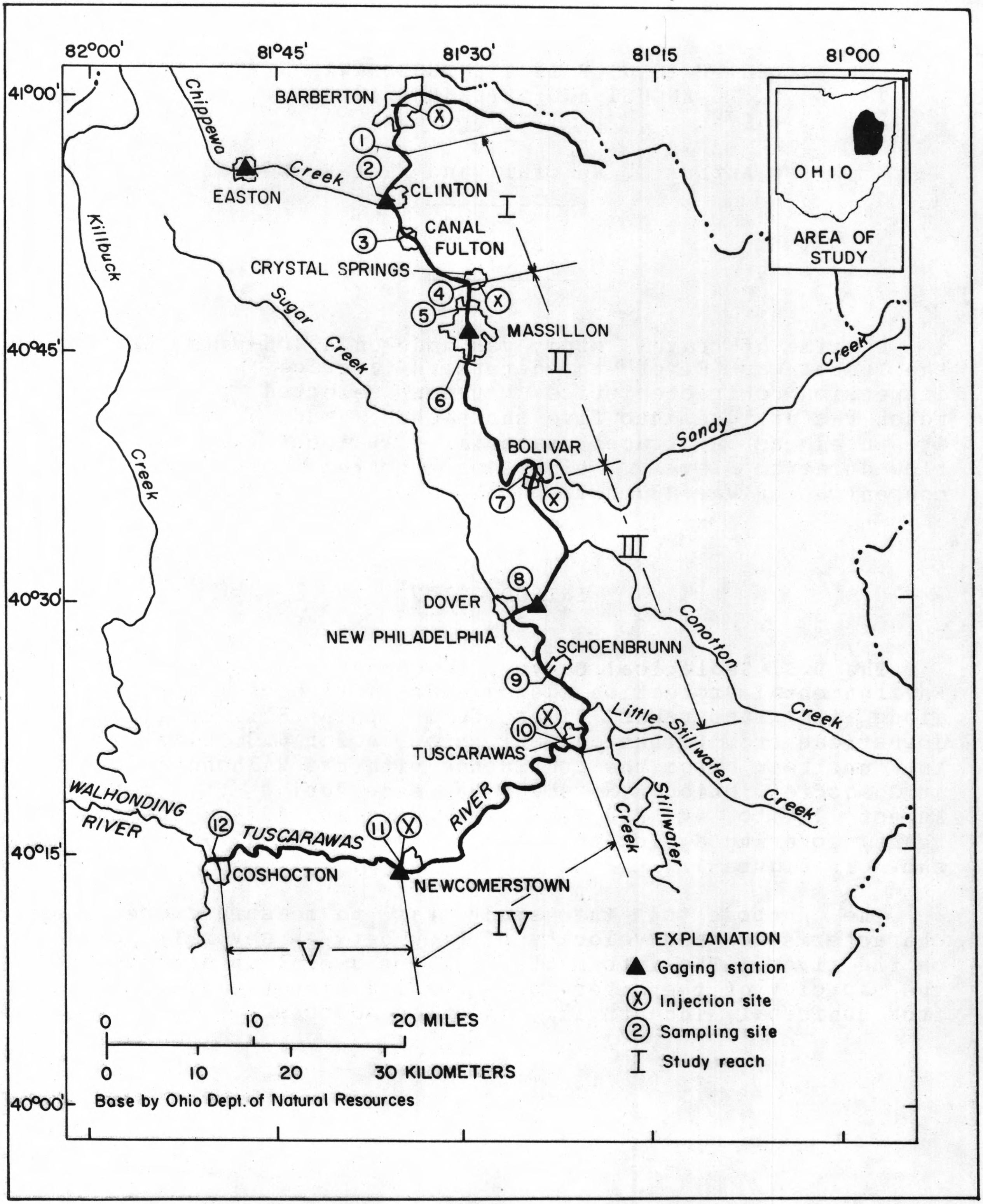

Figure 1.--Tuscarawas River study reaches and dye injection and sampling sites.

TIME OF TRAVEL AND DISPERSION CHARACTERISTICS

Time of travel was determined by injecting a fluorescent dye (rhodamine WT, 20 percent) as a tracer material into the river and observing its movement downstream by fluorometric analysis at selected sampling sites. The difference in time of travel of the leading edge and peak concentration of the dye cloud is an indicator of the dispersion characteristic of the river. The dispersion characteristic gives an insight into the river's ability to carry away municipal and industrial wastes, especially during summer periods when water temperatures are high and dissolved-oxygen concentrations are low. The methods and equipment used were similar to those described by Wilson (1968).

The data presented in table 1 summarize the results of the study. The part of the river studied was divided into five reaches. To insure complete mixing at the start of each reach, the dye was injected at least half a mile upstream from the upper end of each reach. Figure 1 shows the five reaches and the sites where the dye clouds were measured.

Figure 2 shows the time of travel of the dye cloud in relation to distance traveled. The change in slope of the curves indicates that factors other than distance can effect the average velocity through a river reach. Changes in slope, channel cross section, the presence or absence of pools and riffles or dams, and seasonal effects of vegetation and ice formation can affect the time-distance relation.

Table 1.--Time of travel of solutes.

Dye injection reach	Upstream end of reach	Site no.	Reach	River mile upstream from Walhonding River	Distance: Increment (miles)	Distance: Total miles traveled
I	Van Buren Rd ----	1		106.3		0
	USGS gage at Clinton -------	2	1- 2	102.0	4.3	4.3
	Canal Fulton ----	3	2- 3	97.0	5.0	9.3
	Crystal Springs -	4	3- 4	91.2	5.8	15.1
II	Crystal Springs -	4		91.2		
	Lake Ave Massillon -----	5	4- 5	89.4	1.8	16.9
	Warmington St Massillon -----	6	5- 6	84.5	4.9	21.8
	SR 212, Bolivar -	7	6- 7	69.6	14.9	36.7
III	SR 212, Bolivar -	7		69.6		
	USGS gage near Dover ---------	8	7- 8	60.0	9.6	46.3
	SR 259 Schoenbrunn ---	9	8- 9	48.8	11.2	57.5
	Tuscarawas ------	10	9-10	43.0	5.8	63.3
IV	Tuscarawas ------	10		43.0		
	USGS gage at Newcomerstown -	11	10-11	20.5	22.5	85.5
V	USGS gage at Newcomerstown -	11		20.5		
	Coshocton -------	12	11-12	0.3	20.2	105.7
	Walhonding River-		12-13	0	0.3	106

[1] Index station is sum of discharges for Tuscarawas River at Clinton and Chippewa Creek at Easton.

[3] Index station is Tuscarawas River below Dover Dam.

Table 1.--Continued.

Streamflow at index station		Travel time of dye cloud in hours			
		Leading edge		Peak	
Dis-charge (ft^3/s)	Dura-tion (pct)	Incre-ment	Cumula-tive total	Incre-ment	Cumula-tive total
		0	0	0	0
		3.58	3.58	4.00	4.00
		6.09	9.67	6.83	10.8
[1] 109	50	8.33	18.0	10.0	20.8
		4.67	22.7	5.90	26.7
		10.6	33.3	12.8	39.5
[2] 164	55	24.2	57.5	26.2	65.7
		10.5	68.0	12.1	77.9
		13.5	81.5	15.3	93.2
[3] 780	45	6.2	87.6	6.67	99.9
[4] 1200	48	16.3	104.	19.4	119.
[4] 1290	47	15.0	119.	17.7	137.
		-	-	-	-

[2] Index station is Tuscarawas River at Massillon.

[4] Index station is Tuscarawas River at Newcomerstown.

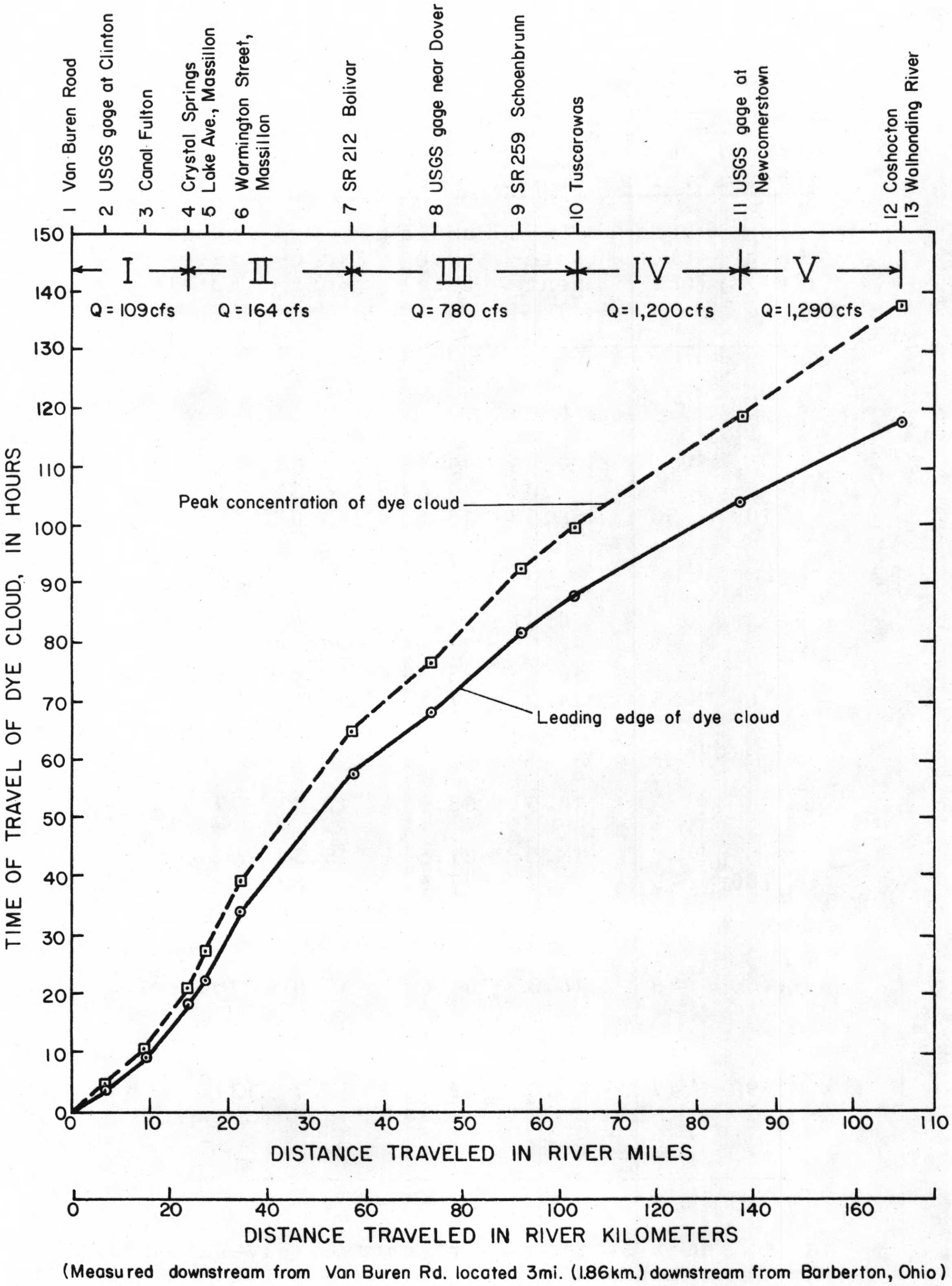

Figure 2.--Graph showing time-of-travel versus distance for leading edge and peak concentration of dye cloud.

STREAMFLOW

Streamflow conditions were stable during the dye runs. Dye runs in reaches IV and V were done during August 12 to 14. Storms began on August 15 and streamflow did not return to conditions similar to those of August 12 to 14 until September 24. Dye runs in reaches I, II, and III were made during September 24 to 28.

The discharge values given in table 1 and figure 2 are mean discharges at the index stations during the time of the dye runs. In pollution studies, the use of index station discharges would be more useful than point discharges because, in the event of an accidental spill of a pollutant, rating discharges would be readily available for making time-of-travel estimates.

CONCLUSIONS

Time of travel, because of its relation to streamflow, can be presented as a function of discharge. Time of travel versus discharge generally defines a straight-line relation on logarithmic coordinates in the mid-range of flow durations (30 to 70 percent) although the slope of the line may vary significantly from reach to reach. Ideally, at least two dye runs are needed to define the time-discharge relation, and if further definition of the low end of the curve is needed, a third dye run is desirable at flows less than 85-percent duration to evaluate the effects of channel and seasonal changes. For the purposes of this study, additional data are needed to define the time-discharge relation for discharges within the index-station flow range.

REFERENCES

Wilson, J. F., Jr., 1968, Fluorometric procedures for dye tracing: U.S. Geol. Survey Techniques of Water Resources Inv., book 3, ch. A12, 31 p.

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