TRAVELTIME AND DISPERSION IN THE NEW RIVER,
HINTON TO GAULEY BRIDGE, WEST VIRGINIA

By D. H. Appel and S. B. Moles

UNITED STATES GEOLOGICAL SURVEY

Water Resources Investigations Report 87-4012

Prepared in cooperation with the

NATIONAL PARK SERVICE

Charleston, West Virginia

1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
603 Morris Street
Charleston, WV 25301

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports
Box 25425, Federal Center
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION OF MEASUREMENT UNITS

The following factors may be used by readers who wish to convert the inch-pound units in this report to metric (International System) units.

Multiply inch-pound unit	by	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
pound (lb)	453.6	gram (g)
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

TRAVELTIME AND DISPERSION IN THE NEW RIVER, HINTON TO GAULEY BRIDGE, WEST VIRGINIA

By D. H. Appel and S. B. Moles

ABSTRACT

Traveltime and dispersion studies were conducted on a 65-mile-long reach of the New River between Hinton and Gauley Bridge, West Virginia. Four sets of measurements were made from August 1985 to May 1986 at river discharges of about 2,200, 3,200, 9,200, and 18,000 cubic feet per second, which correspond to flow durations of 85, 70, 26, and 9 percent, respectively.

The four sets of data were used to develop generalized procedures for estimating traveltimes and peak concentrations that result from spillage of water-soluble substances at any point within the study reach. The procedure will provide the approximate traveltimes and concentrations of soluble substances during periods of relatively steady flow from 1,500 to 30,000 cubic feet per second.

A sample problem and solution are presented for a hypothetical situation in which 500 pounds of soluble contaminant are spilled at a highway bridge near Sandstone. The river flow was 3,000 cubic feet per second for this example. The estimated times required for the leading edge and peak concentration of the solute cloud to reach Stone Cliff (25.9 river miles) were determined to be 23 and 28.5 hours. The cloud would take about 17 hours to pass Stone Cliff and the peak concentration would be 100 micrograms per liter.

INTRODUCTION

The New River flows northward from its headwaters in North Carolina, through western Virginia, and into south-central West Virginia, where it joins the Gauley River at Gauley Bridge to form the Kanawha River (fig. 1). The New River Gorge National River was established by Public Law 95-625 on November 10, 1978, and falls within the jurisdiction of the U.S. Department of Interior, National Park Service (NPS). The NPS is responsible for conserving the outstanding natural, scenic, and historical values and objects and for preserving a segment of the New River in West Virginia as a free-flowing stream for the enjoyment and benefit of present and future generations. The National River's main attraction is a combination of scenic wilderness, fishing, and excellent whitewater boating. Approximately 60,000 people rafted on the 34-mi (mile)-long reach of river between Prince and Hawks Nest, W. Va., and about 100,000 hr (hours) were expended by anglers between Bluestone Dam and Meadow Creek in 1980 (fig. 2). The recreational quality and safety depends in part on the regulated flow from Bluestone Dam and unregulated flow from the Greenbrier River.

Purpose and Scope

The purpose of this report is to describe the movement of water-soluble materials spilled or discharged into the New River between Hinton and Gauley Bridge, W. Va. (fig. 1). The potential for such spills is great because of a major east-west railroad that traverses the River gorge and the several rail and highway bridges that span the River. The U.S. Geological Survey, in cooperation with the National Park Service, studied the traveltimes and dispersion of soluble dyes in the New River. This report combines the results of four sets of dye measurements made in 1985 and 1986. The general methods used to conduct the dye study and analyze the data are those described by E. F. Hubbard and others (1982) and J. F. Wilson, Jr., and others (1986). Techniques are presented in this report to estimate traveltimes and concentration attenuation after a spill of any amount of soluble contaminant at any point along the river when river flow is approximately steady and is between 1,500 and 30,000 ft^3/s.

Previous Studies

A previous study of the time of travel of flood waves moving through the study reach was conducted in 1981 and 1982 by the U.S. Geological Survey in cooperation with the National Park Service (Appel, 1983). A flood wave moves downstream at a much faster rate than a water particle and, therefore, the results of the study by Appel (1983) cannot be used to predict traveltimes of a contaminant in the New River. The results of the flood-wave study can be used to help determine favorable and safe streamflow conditions for fishing and rafting activities.

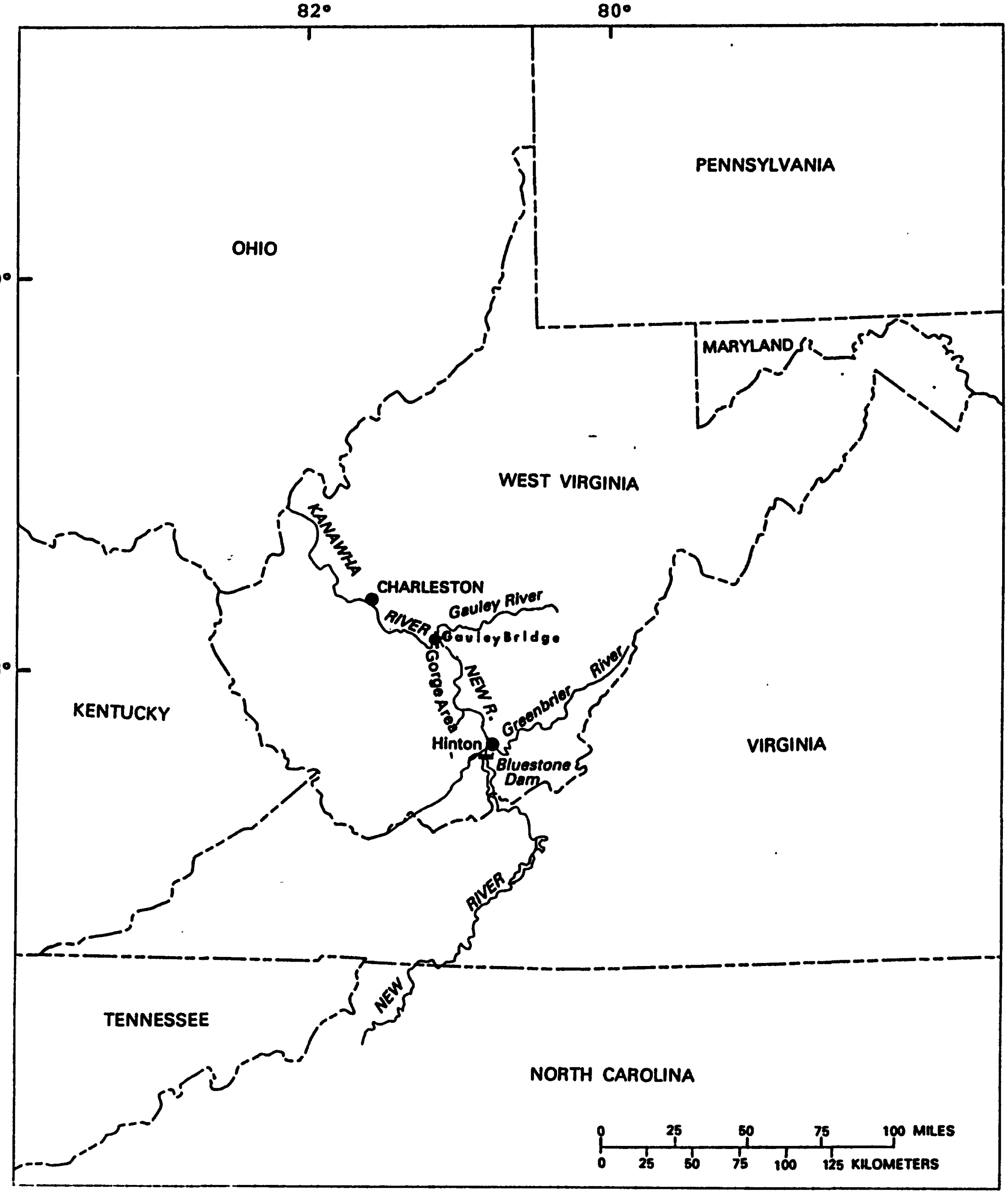

Figure 1. General location of the New River.

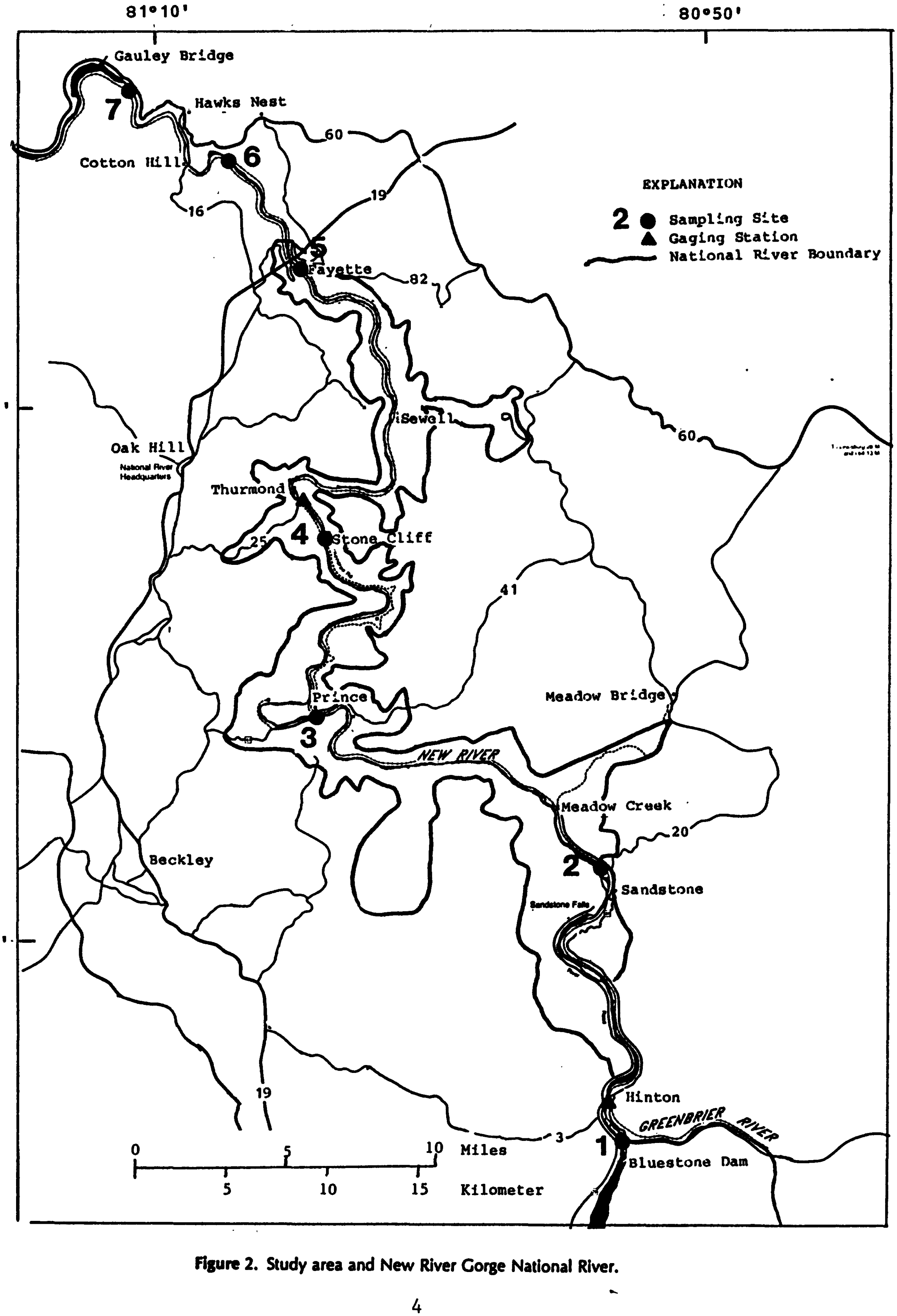

Figure 2. Study area and New River Gorge National River.

Table 1.--Mileages for bridges and other selected sites on New River

Site number[1/]	Location	Miles upstream from Gauley Bridge
-	Confluence of New and Gauley Rivers at Gauley Bridge----------	0.0
7	C&O Railroad bridge upstream from Gauley Bridge---------------	1.2
-	Highway 16 bridge at Cotton Hill------------------------------	5.7
6	C&O Railroad bridge at Hawks Nest-----------------------------	7.6
5	Highway 82 bridge at Fayette (Staff Gage)---------------------	12.3
-	C&O Railroad bridge near Sewell-------------------------------	18.3
-	C&O Railroad/Highway Bridge at Thurmond-----------------------	25.9
-	USGS gaging station Thurmond----------------------------------	26.0
4	Highway 25 bridge at Stone Cliff------------------------------	27.4
3	Highway 41 bridge at Prince-----------------------------------	39.8
-	C&O Railroad bridge at Prince---------------------------------	39.9
-	Meadow Creek (no bridge)--------------------------------------	50.9
2	I-64 Bridge near Sandstone------------------------------------	53.3
-	Highway 20 bridge at Hinton-----------------------------------	63.5
-	USGS gaging station (Hinton)----------------------------------	63.6
1	Highway 3 bridge at Hinton------------------------------------	65.2
-	Bluestone Dam---	65.9

[1/]See figure 2 for site locations.

River miles for all bridges and other selected points, measured upstream from the confluence with the Gauley River at Gauley Bridge are listed in table 1. Selected mileages are shown on figure 2.

Study Reach

The study reach can be divided into two hydraulically different subreaches (fig. 3). The subreach between Hinton and Thurmond has an average width of about 550 feet and an average slope of 8.5 ft/mi. The uppermost 10 mi of this subreach, from Hinton to Sandstone, has an average width of 850 ft. The downstream subreach from Thurmond to Gauley Bridge is much narrower and steeper with combinations of deep pools and white water. The average width of this subreach is 350 feet with an average slope of 16.5 ft/mi.

The pool upstream from Hawks Nest Dam extends from mile 6.9 to 11.1. The rate of movement of dye through the pool and tunnel to the hydroelectric turbines at mile 1.5 depends upon the power generation. This is especially true at low flows when nearly all flow is diverted through the tunnel to generate power.

Acknowledgments

The U.S. Army Corps of Engineers, Huntington District, regulated outflow from Bluestone Dam to provide steady flow conditions for the dye measurements. Personnel from the National Park Service assisted with data collection. Special acknowledgment is given to C. K. Cooper and B. C. Taylor, U.S. Geological Survey personnel who assisted the authors in collecting the data used in preparing this report.

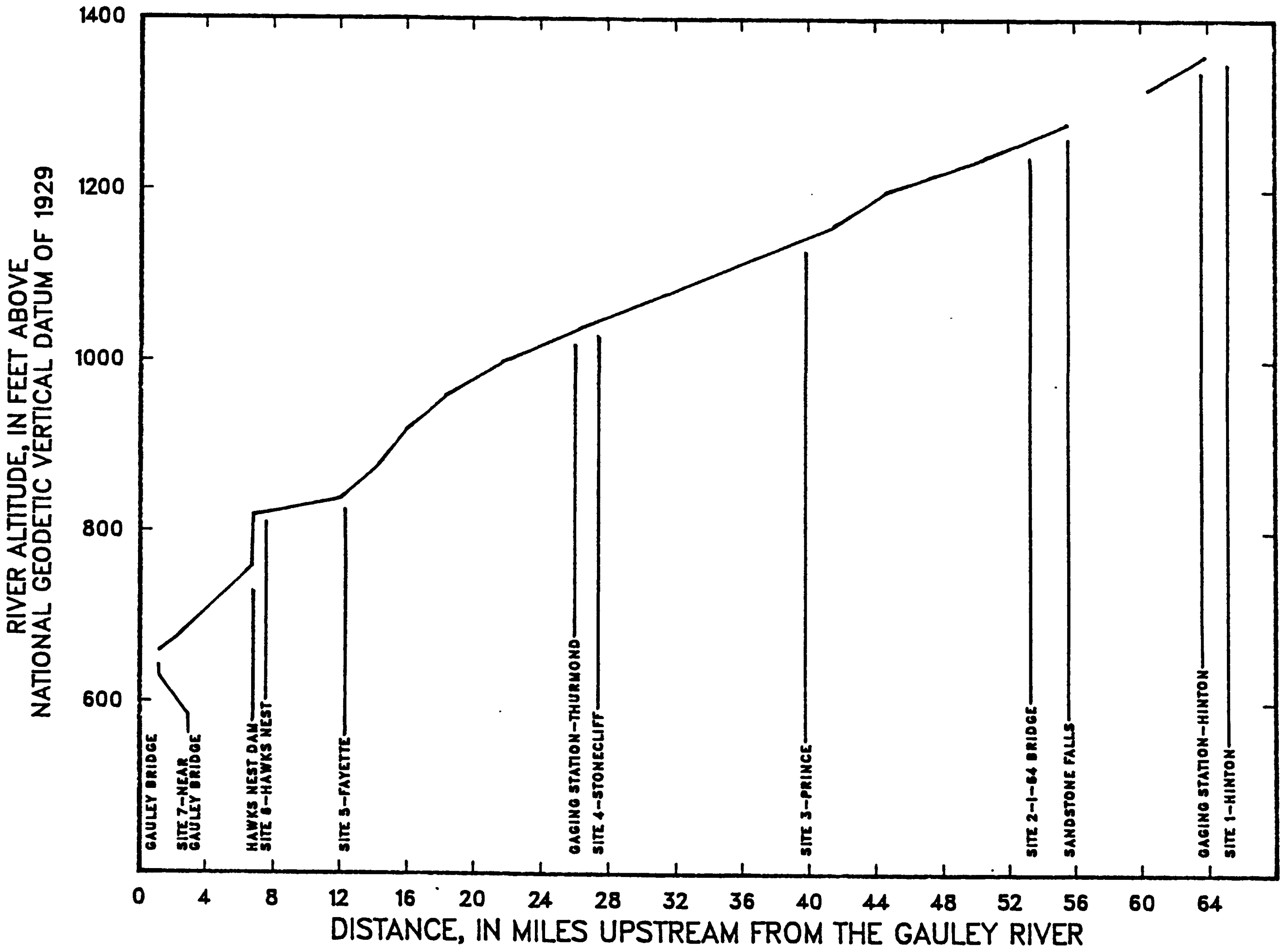

Figure 3.--New River profile.

FIELD PROCEDURES

Field procedures using dye tracers for conducting traveltime and dispersion studies on streams are well documented (see Hubbard and others, 1982). In general, the described procedures were followed closely in this study.

Releases from Bluestone Dam were controlled to provide steady flows throughout the study reach. The gaging station on New River at Hinton was used as the index gage. The dump or injection site for three measurements was at the Highway 3 bridge immediately upstream from the confluence with the Greenbrier River and 0.7 mi downstream from Bluestone Dam. Sampling frequencies at downstream sites were varied based on time since injection, river flow, and shape of the concentration curve at the next upstream site. Samples were collected at each site until concentrations were less than 5 percent of the peak concentration.

The study reach was divided into two subreaches during the low-flow measurement of August 1985 in order to shorten overall sampling time and, thereby, improve the chances of having favorable weather conditions and steady streamflow. Streamflow at the index gage at Hinton for this dye study was 2,200 ft^3/s which has a flow-duration frequency of 85 percent.

Dye was injected at Highway 3 bridge at Hinton August 14 and at Highway 41 bridge at Prince August 15. The dye took two days to pass through the upper reach from Hinton to Prince (25.3 miles) and about 2¼ days from Prince to Fayette (27.5 miles). The dye cloud at this low streamflow was not followed through the Hawks Nest Dam pool. Traveltime through the pool would be dependent upon dam and hydroelectric powerplant operations. Samples were collected at the upstream end of the pool to determine the arrival time and peak concentration of the dye.

The second dye measurement was conducted on October 24-26, 1985 between the Interstate Highway 64 bridge near Sandstone (mile 53.3) and Fayette (mile 12.3) at a flow of 3,200 ft^3/s (flow duration of 70 percent).

The third dye measurement was conducted during the high flow period of November 8-9, 1985, following the massive flooding in the Greenbrier River basin on November 4-7. The river flow was 18,000 ft^3/s at Hinton (flow duration 9 percent). The river was very turbid during this measurement. Dye was injected at the Highway 3 bridge in Hinton and took about 1¼ days to pass from the New River into the Kanawha River at Gauley Bridge, a distance of 65.2 mi.

The fourth dye measurement was conducted at a flow of 9,200 ft^3/s at Hinton (flow duration of 26 percent) during the period May 15-17, 1986. Dye was injected at Highway 3 bridge at Hinton on May 15 and took approximately 2 days to pass from the New River at Gauley Bridge.

Detailed information, including sampling sites, traveltimes, and other pertinent data for each dye measurement are shown in table 2.

Table 2.--Traveltime, dispersion, and related data from the dye studies of August, October, and November 1985 and May 1986 on the New River from Hinton to Gauley Bridge, W. Va.

Site number	Site location	Distance			Leading edge		Peak		Trailing edge		Velocity of peak (mi/hr)	Time of passage of dye cloud (hours)	Discharge at sampling site Q (ft³/s)	Percent recovery R_p (1)	Observed peak concentration C_{obs} (µg/L)	Conservative peak concentration C_p (µg/L)	Peak concentration produced by 1 lb of dye	Unit peak concentration C_{up} (2)
		From mouth (miles)	From point of injection (miles)	Between sites (miles)	Travel-time (hours)	Cumulative travel-time (hours)	Travel-time (hours)	Cumulative travel-time (hours)	Travel-time (hours)	Cumulative travel-time (hours)								
	Injected 50 lb of 20-percent Rhodamine WT dye at 2100 August 14, 1985																	
1	Highway 3 bridge at Hinton	65.2	0	--	--	--	--	--	--	--	--	--	2,200	--	--	--	--	--
2	I-64 bridge near Sandstone	53.3	11.9	11.9	14.0	14.0	16.0	16.0	30.0	30.0	0.74	16.0	2,200	91	3.80	4.10	0.42	920
3	Highway 41 bridge at Prince	39.8	25.4	13.5	15.5	29.5	20.0	36.0	21.0	51.0	0.68	21.5	2,200	87	1.85	2.13	0.21	469
	Injected 50 lb of 20-percent Rhodamine WT dye at 1345 August 15, 1985																	
3	Highway 41 bridge at Prince	39.8	0	--	--	--	--	--	--	--	--	--	2,200	--	--	--	--	--
4	Highway 25 bridge at Stone Cliff	27.4	12.4	12.4	12.5	12.5	15.5	15.5	25.0	25.0	0.80	12.5	2,200	96	3.80	3.96	0.40	871
5	Highway 82 bridge at Fayette Station	12.3	27.5	15.1	20.5	33.0	24.0	39.5	30.0	55.0	0.63	22.0	2,200	94	2.00	2.13	0.21	469
	Injected 75 lb of 20-percent Rhodamine WT dye at 1015 October 24, 1985																	
2	I-64 bridge near Sandstone	53.3	0	--	--	--	--	--	--	--	--	--	3,200	--	--	--	--	--
3	Highway 41 bridge at Prince	39.8	13.5	13.5	10.5	10.5	13.0	13.0	21.5	21.5	1.04	11.0	3,200	104	5.55	5.55	0.37	1,184
4	Highway 25 bridge at Stone Cliff	27.4	25.9	12.4	11.0	21.5	13.0	26.0	17.5	39.0	0.95	17.5	3,200	98	3.25	3.32	0.22	708
5	Highway 82 bridge at Fayette Station	12.3	41.0	15.1	16.0	37.5	18.5	44.5	17.5	56.5	0.82	19.0	3,200	88	2.50	2.04	0.19	606

Table 2.--Traveltime, dispersion, and related data from the dye studies of August, October, and November 1985 and May 1986 on the New River from Hinton to Gauley Bridge, W. Va.--Continued

Site number	Site location	Distance			Leading edge		Peak		Trailing edge		Velocity of peak (mi/hr)	Time of passage of dye cloud (hours)	Discharge at sampling site Q (ft³/s)	Percent recovery R_p (1)	Observed peak concentration C_{obs} (µg/L)	Conservative peak concentration C_p (µg/L)	Peak concentration produced by 1 lb of dye	Unit peak concentration C_{up} (2)
		From mouth (miles)	From point of injection (miles)	Between sites (miles)	Traveltime (hours)	Cumulative traveltime (hours)	Traveltime (hours)	Cumulative traveltime (hours)	Traveltime (hours)	Cumulative traveltime (hours)								
Injected 150 lb of 20-percent Rhodamine WT dye at 1200 November 8, 1985																		
1	Highway 3 bridge at Hinton	65.2	0	--	--	--	--	--	--	--	--	--	18,000	--	--	--	--	--
2	I-64 bridge near Sandstone	53.3	11.9	11.9	4.2	4.2	4.4	4.4	7.2	7.2	2.70	3.0	18,300	123	11.9	11.9	0.40	7,259
3	Highway 41 bridge at Prince	39.8	25.4	13.5	4.0	8.2	4.8	9.2	5.0	12.2	2.81	4.0	18,600	109	4.75	4.75	0.16	2,945
4	Highway 25 bridge at Stone Cliff	27.4	37.8	12.4	3.6	11.8	4.0	13.2	4.3	16.5	3.10	4.7	19,000	102	3.20	3.20	0.11	2,027
5	Highway 82 bridge at Fayette Station	12.3	52.9	15.1	4.9	16.7	5.6	18.8	6.2	22.7	2.70	6.0	19,000	--	--	--	--	--
6	C&O Railroad bridge at Hawks Nest	7.6	57.6	4.7	3.6	20.3	3.5	22.3	3.8	26.5	1.34	6.2	19,000	99	2.20	2.22	0.07	1,406
7	C&O Railroad bridge near Gauley Bridge	1.2	64.8	6.4	2.4	22.7	3.2	25.5	2.5	29.0	2.0	6.3	19,000	89	--	--	--	--

Table 2.--Traveltime, dispersion, and related data from the dye studies of August, October, and November 1985 and May 1986 on the New River from Hinton to Gauley Bridge, W. Va.--Continued

Site number	Site location	Distance			Leading edge		Peak		Trailing edge		Velocity of peak (mi/hr)	Time of passage of dye cloud (hours)	Discharge at sampling site Q (ft³/s)	Percent recovery R_p (1)	Observed peak concentration C_{obs} (μg/L)	Conservative peak concentration C_p (μg/L)	Peak concentration produced by 1 lb of dye	Unit peak concentration C_{up} (2)
		From mouth (miles)	From point of injection (miles)	Between sites (miles)	Travel-time (hours)	Cumulative travel-time (hours)	Travel-time (hours)	Cumulative travel-time (hours)	Travel-time hours)	Cumulative travel-time (hours)								
Injected 82.6 lb of 20-percent Rhodamine WT dye at 1530 May 15, 1986																		
1	Highway 3 bridge at Hinton	65.2	0	--	--	--	--	--	--	--	--	--	9,200	--	--	--	--	--
2	I-64 Bridge near Sandstone	53.3	11.9	11.9	5.5	5.5	6.0	6.0	10.5	10.5	1.98	5.0	9,300	105	8.10	8.10	0.49	4,560
3	Highway 41 bridge at Prince	39.8	25.4	13.5	5.9	11.4	7.0	13.0	7.2	17.7	1.93	6.3	9,900	102	2.78	2.78	0.17	1,666
4	Highway 25 bridge at Stone Cliff	27.4	37.8	12.4	4.6	16.0	6.4	19.4	9.0	26.7	1.94	10.7	10,500	102	1.87	1.87	0.11	1,189
5	Highway 82 bridge at Fayette Station	12.3	52.9	15.1	7.6	23.6	8.2	27.6	7.6	34.3	1.84	10.7	10,500	98	1.44	1.47	0.09	934
6	C&O Railroad brdige at Hawks Nest	7.6	57.6	4.7	5.5	29.1	6.2	33.8	6.5	40.8	.76	11.7	18,500	96	1.26	1.31	0.08	833
7	C&O Railroad bridge near Gauley Bridge	1.2	64.0	6.4	4.5	33.6	3.6	37.4	7.0	47.8	1.78	14.2	10,500	93	1.13	1.22	0.07	775

(1) $R_p = \frac{(2.248 \times 10^{-2}) Q A_c}{W_d}$ Values greater than 100 percent are indicative of incomplete mixing or inadequate definition of the discharge-weighted time-concentration curve.

(2) $C_{up} = \frac{C_p \times Q}{W_d}$

-- No data

TRAVELTIMES

All samples collected in the field were analyzed in the laboratory using a fluorometer under controlled-temperature conditions. The fluorometer was calibrated from standard solutions prepared from the same dye lot used in the study.

Dye concentrations were plotted as a function of time since injection for each sampling site. The dye measurement conducted in May 1986 when river flow was 9,200 ft^3/s produced time-concentration curves (fig. 4) typical for increasing distance from the point of injection. The traveltimes of the leading edge, peak concentration, and trailing edge of the dye cloud were determined from the time-concentration curve for each dye measurement and each sampling site. A plot of traveltimes and distance (fig. 5) for the August 1985 dye measurement, when river flow was 2,200 ft^3/s, was typical for this study area. The traveltime of the trailing edge of the dye cloud is defined for all uses in this report as the time between injection and the time the concentration reaches a level of 5 percent of the peak concentration observed at the sampling site.

Traveltime varies inversely with stream discharge. Over a long reach of river, stream discharge generally increases in the downstream direction as the drainage area increases. The drainage area of the New River increases from 6,251 mi^2 downstream from the confluence with the Greenbrier River to 6,943 mi^2 at the mouth. No major tributaries enter the New River in this reach. The stream discharges for the November 1985 and May 1986 dye measurements, when small tributary inflow was high, were adjusted as the dye moved downstream. No adjustment was necessary for the other two dye measurements.

The travel time was related to stream discharge (figs. 6-8) in order to estimate traveltimes which can be used over a wide range of stream discharges. The traveltime of the leading edge of the dye from the injection site to each sample site and stream discharge for all dye measurements were used to draw the curves in figure 6. This family of curves, one curve for each sampling site, can be used to estimate the arrival time of a solute at any site at any discharge between 1,500 and 30,000 ft^3/s. Curves in figures 7 and 8 were determined in a similar manner and are for estimating the arrival time of the peak concentration and trailing edge, respectively.

These figures can be used to estimate traveltimes, under steady streamflow conditions, between any two sites by simply subtracting the traveltime of the upstream site from that of the downstream site.

It also may be desirable to determine the time required for the solute cloud to pass a point of interest. As the solute cloud moves downstream, it disperses into a longer length of channel taking more time to pass the point. In computing time-of-passage data, it is necessary to subtract the traveltime of the leading edge of the solute cloud from the traveltime of the trailing edge. Utilizing the data from table 2, a family of curves was derived (fig. 9) which allows the user to determine time of passage. The user must determine (1) stream discharge and distance, (2) traveltime of the peak using figure 7, and finally (3) time of passage using figure 9.

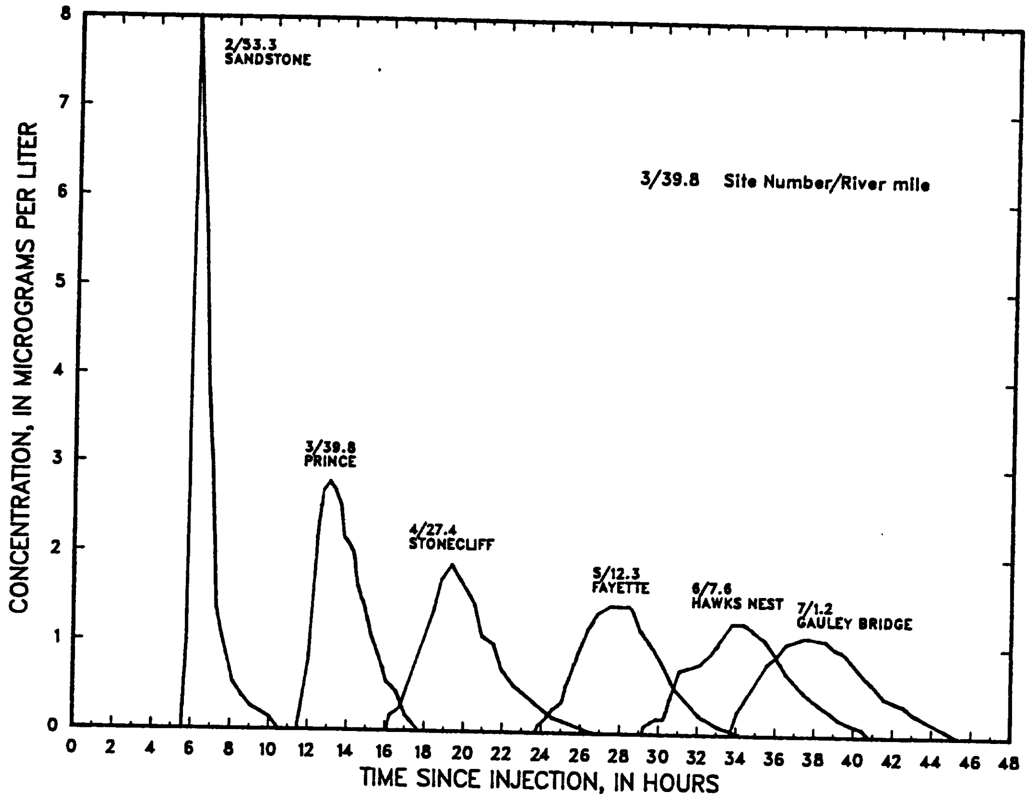

Figure 4.--Observed time-concentration curves for the May 1986 study.

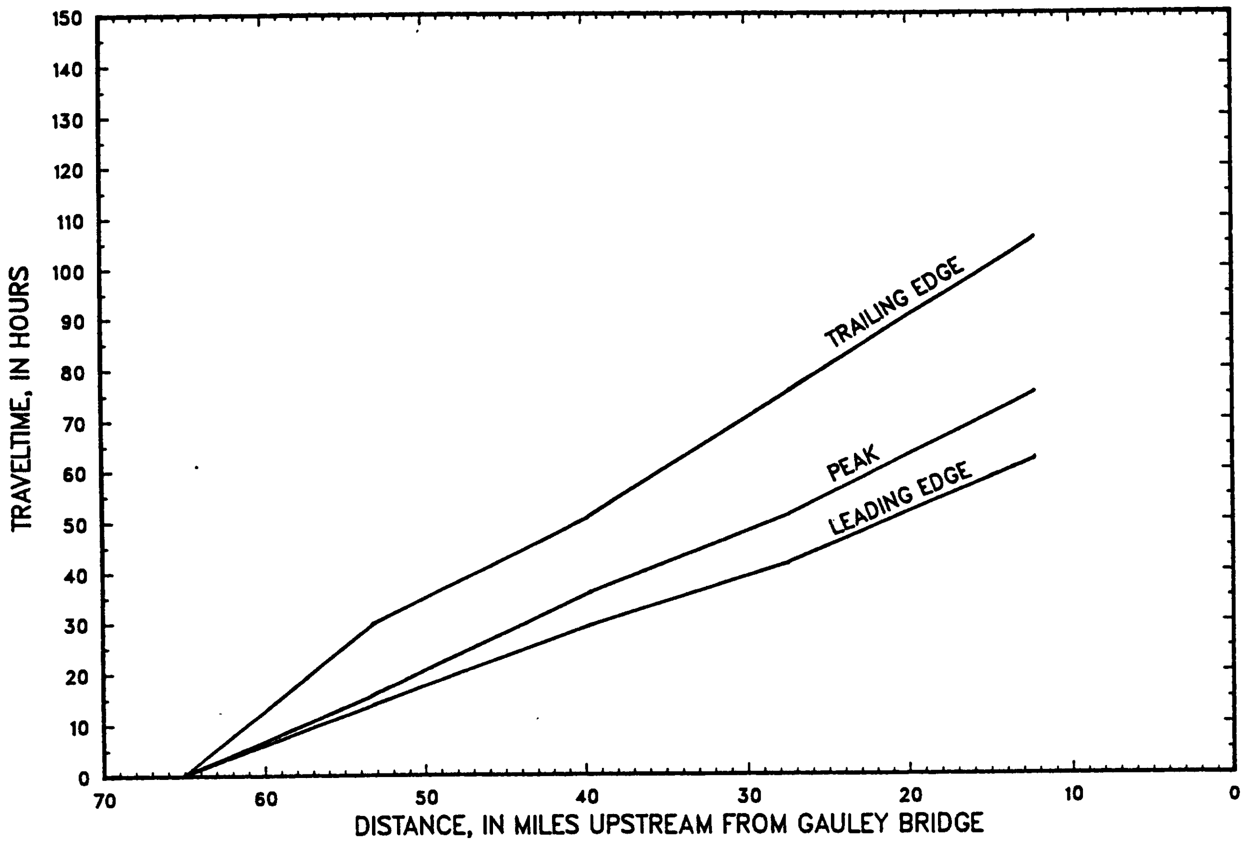

Figure 5.--Traveltime-distance relations for river flow of 2,200 cubic feet per second.

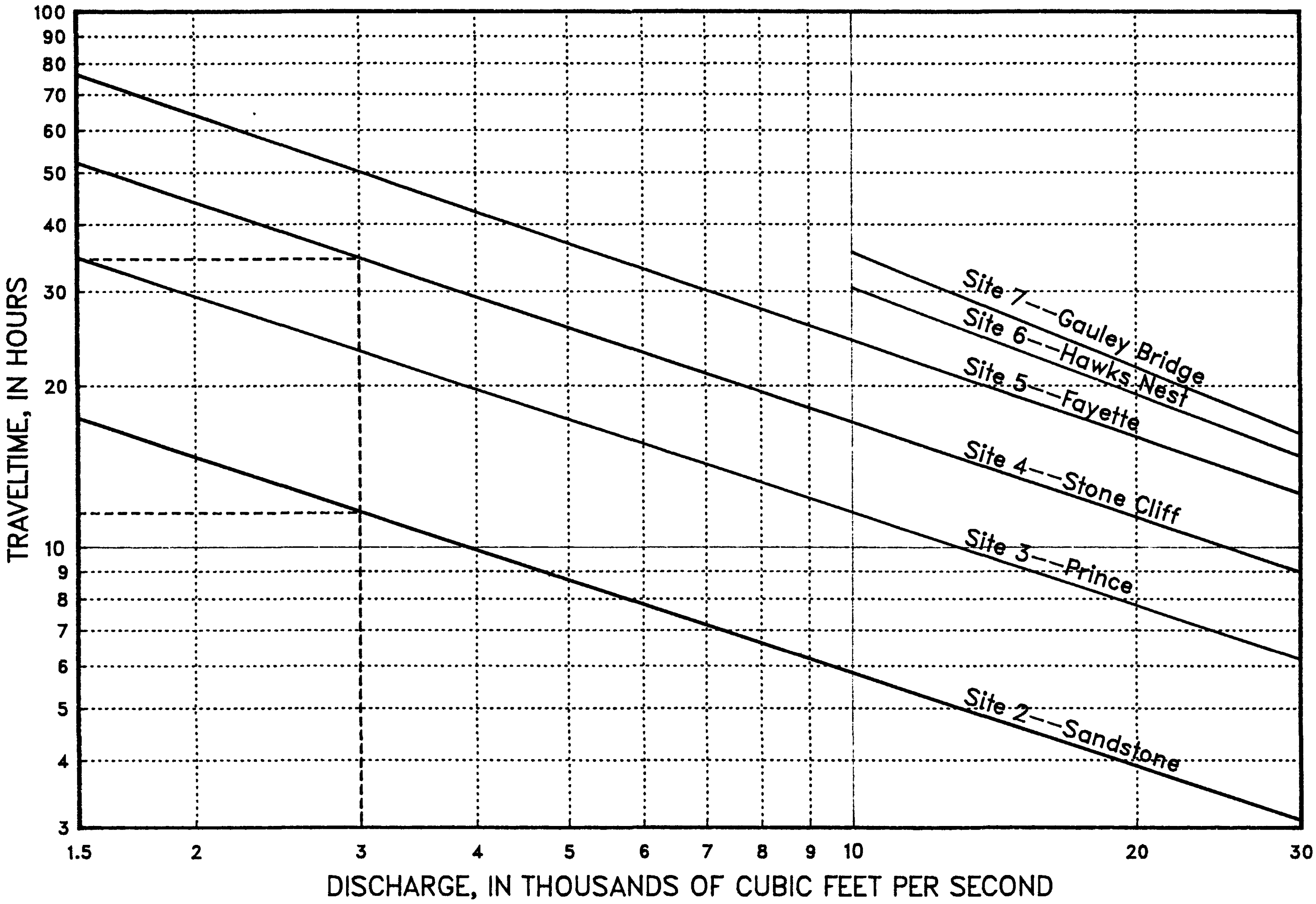

Figure 6.--Traveltime-discharge relations of leading edge of dye at selected sites.

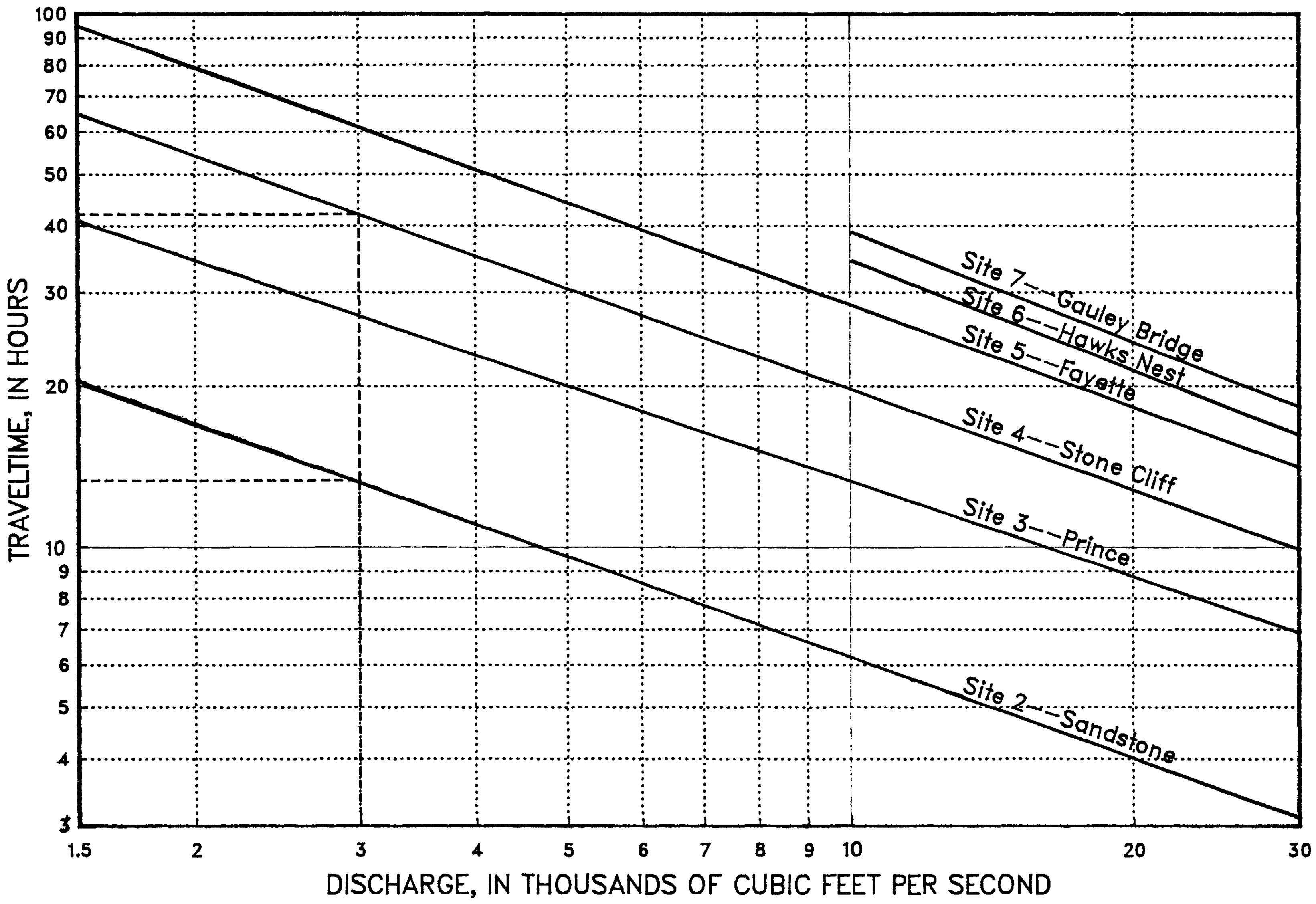

Figure 7.--Traveltime-discharge relations of peak concentration of dye at selected sites.

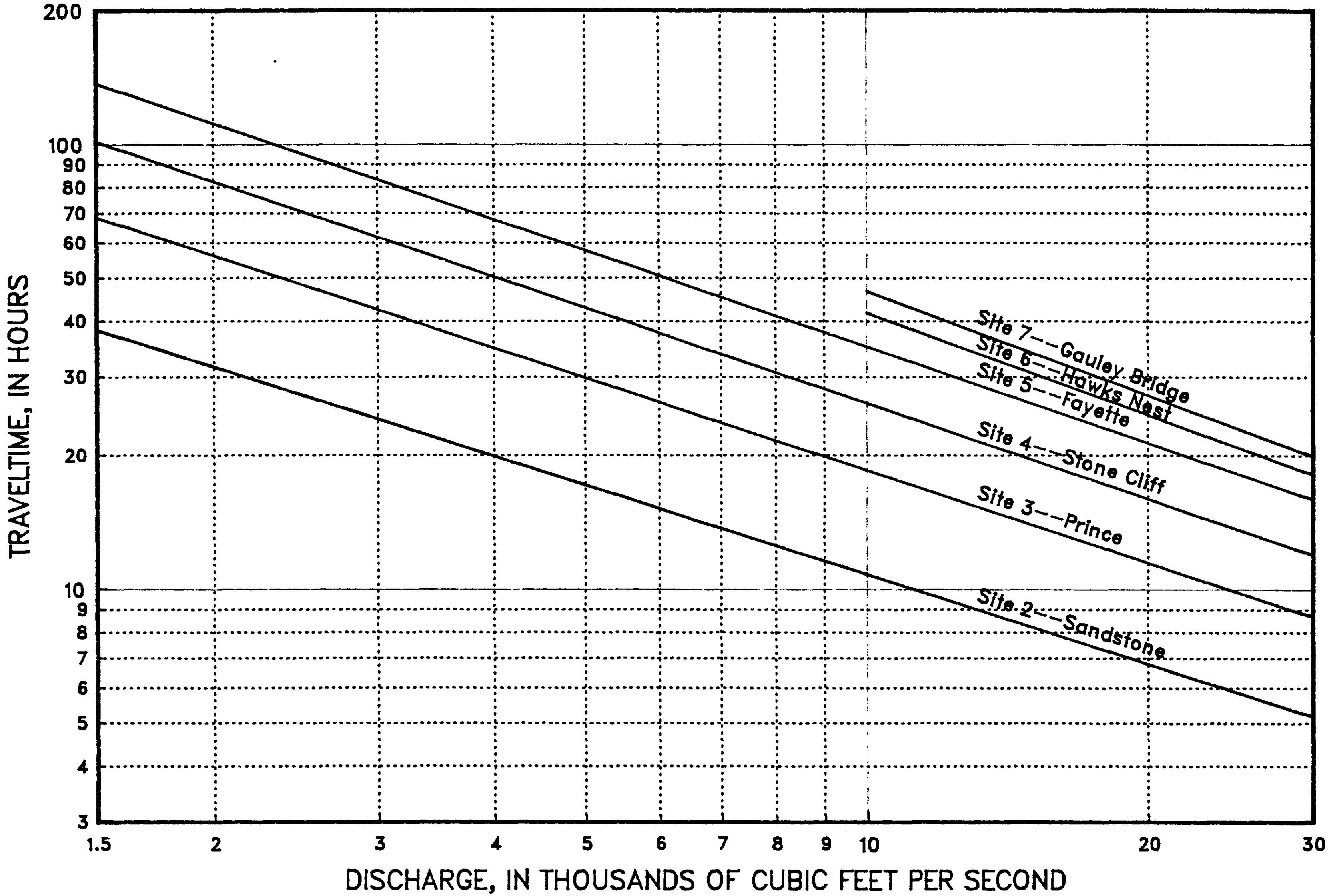

Figure 8.--Traveltime-discharge relations of trailing edge of dye at selected sites.

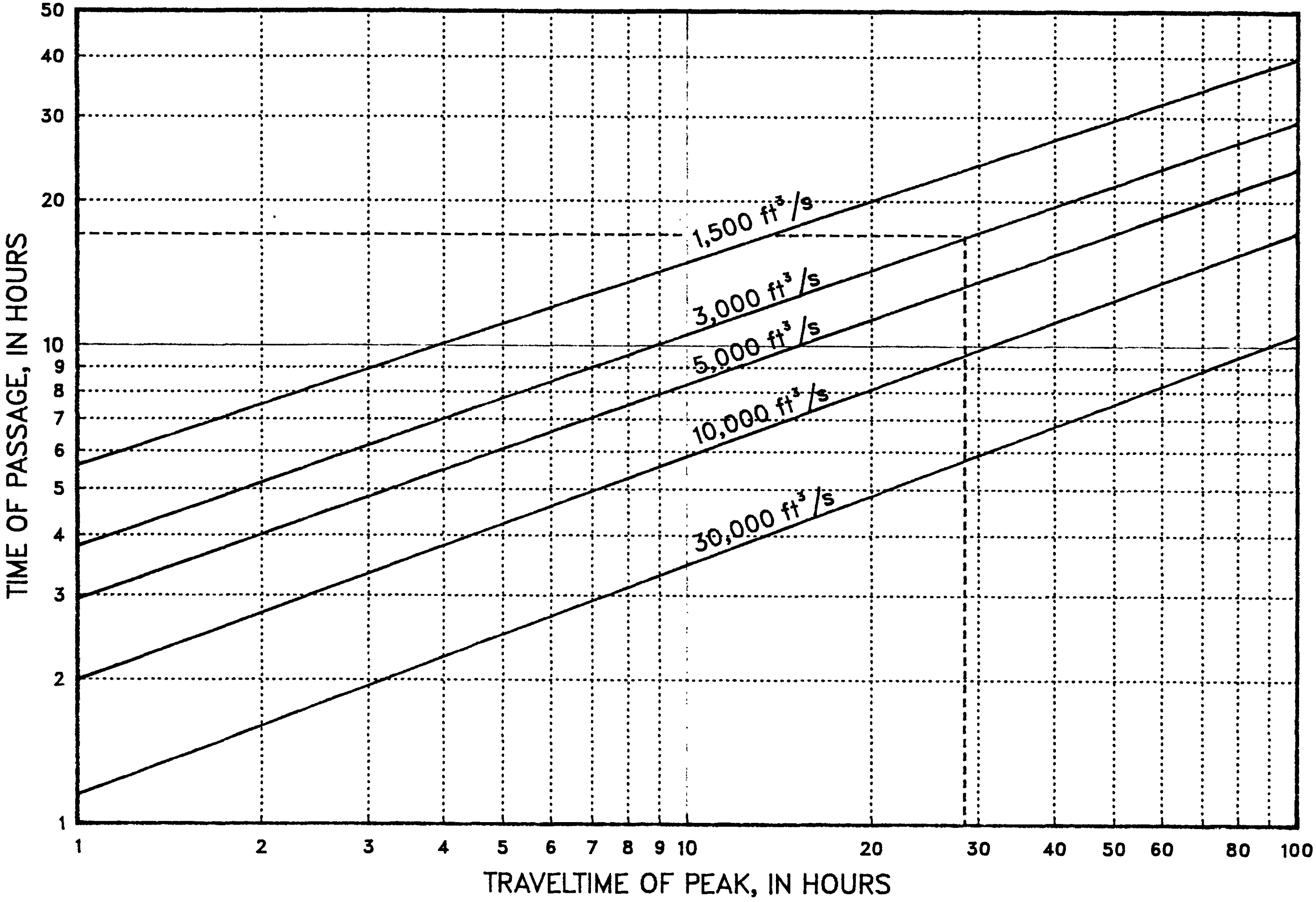

Figure 9.--Time of passage of a solute as related to traveltime of the peak.

DISPERSION

There is a need to estimate not just rates of movement but also the magnitude of contaminant concentrations to be expected. Dispersion data are useful in estimating the concentration of a soluble material as it moves downstream. After an initial period during which lateral and vertical mixing occurs, dispersion data represent the rate at which the stream dilutes a soluble substance by mixing it into an ever increasing volume of water as the solute cloud lengthens. By knowing the dispersion characteristics the water manager or regulatory authority can assess the seriousness of the spill.

The capacity of a stream to disperse a solute is usually presented in two ways--the decrease in peak concentration as a function of time as the solute cloud moves downstream and the time required for the solute cloud to pass a point of interest. The dispersion relations should be used with considerable caution in estimating the concentration of an insoluble or immiscible substance, such as oil or other floating materials, as the peak concentration of such substances tend to be greater, because the substances may not be undergoing dilution throughout the entire flow.

Similarly, unless the substances' decay characteristics are known, the relations will not predict the concentration of nonconservative substances, such as nutrients, dissolved gases, and other materials that are biologically or chemically degradable or volatile. In this instance, the estimated concentrations would be greater than the actual; therefore, estimates would be "safe" to use. Dispersion relations cannot predict with high accuracy the concentration or the passage time of a solute when flow conditions are unstable. Uncertainty of estimates increase with increasing instability of flow.

The dye concentrations defined by observed time-concentration curves depend on the quantity of dye injected, stream discharge, longitudinal dispersion, and dye losses. The concentration varies inversely and the passage time, directly, with the dispersion capability of a stream--that is, the greater the dispersion capability, the longer the passage time of the dye cloud and the lower the peak concentration.

Dyes used as tracers usually have some loss due to various physical, chemical, and biological processes. The observed time-concentration curves have the proper shape, but concentrations usually are lower than those expected from a conservative solute (one representing 100 percent recovery of the total weight of the injected dye). The conservative-concentration values shown in table 2 were computed by adjusting the observed concentrations of dye upward to reflect 100 percent recovery of the dye or a conservative solute. The percentage of recovery (R_p) is computed by using the equation:

$$R_p = \frac{kQA_c}{W_d} \qquad (1)$$

Where:

- k is a constant, 2.248×10^{-2};
- Q is the discharge at the sampling point, in ft^3/s;
- A_c is the mean area of the time-concentration curve in $\mu g/L \times hrs$ (micrograms per liter times hours); and
- W_d is the weight of pure dye injected, in pounds.

If complete mixing has not occurred, vertically and laterally, or the discharge-concentration curves are not adequately defined, computed R_p may exceed 100 percent.

The effect of the dye loss as it moves downstream can be eliminated by using the unit-concentration concept. Unit peak concentration (C_{up}) is defined as the concentration produced in 1 ft^3/s flow by the injection of 1 lb of conservative contaminant. Unit peak concentration can be computed by the equation:

$$C_{up} = \frac{C_p \times Q}{W_d} \qquad (2)$$

where C_p is the conservative peak concentration computed as $\frac{Cobs}{R_p} \times 100$.

No adjustment is made when R_p exceeds 100 percent.

Observed-concentration data were used to compute unit concentration for all studies. A more detailed discussion of the preceding paragraphs and development of the equations is presented in Hubbard and others (1982).

Peak attenuation is the decrease in peak concentration as a function of time as the solute moves downstream. Utilizing stream discharge, traveltime, and peak concentration produced by 1 lb of dye for each dye measurement (table 2), a family of curves was derived to allow a user to predict the peak concentration at any travel time for selected discharges and for any weight of solute injected anywhere in the reach (fig. 10). This family of curves applies to general hydraulic conditions in the study reach. In order to estimate the peak concentration of a soluble contaminant at a selected site, the user must (1) determine the stream discharge and distance from the spill site, then (2) use figure 7 to determine traveltime, and next (3) use figure 10 to determine the peak concentration per pound of contaminant. The concentration determined from figure 10 must be multiplied by the number of pounds of contaminant to compute actual concentration.

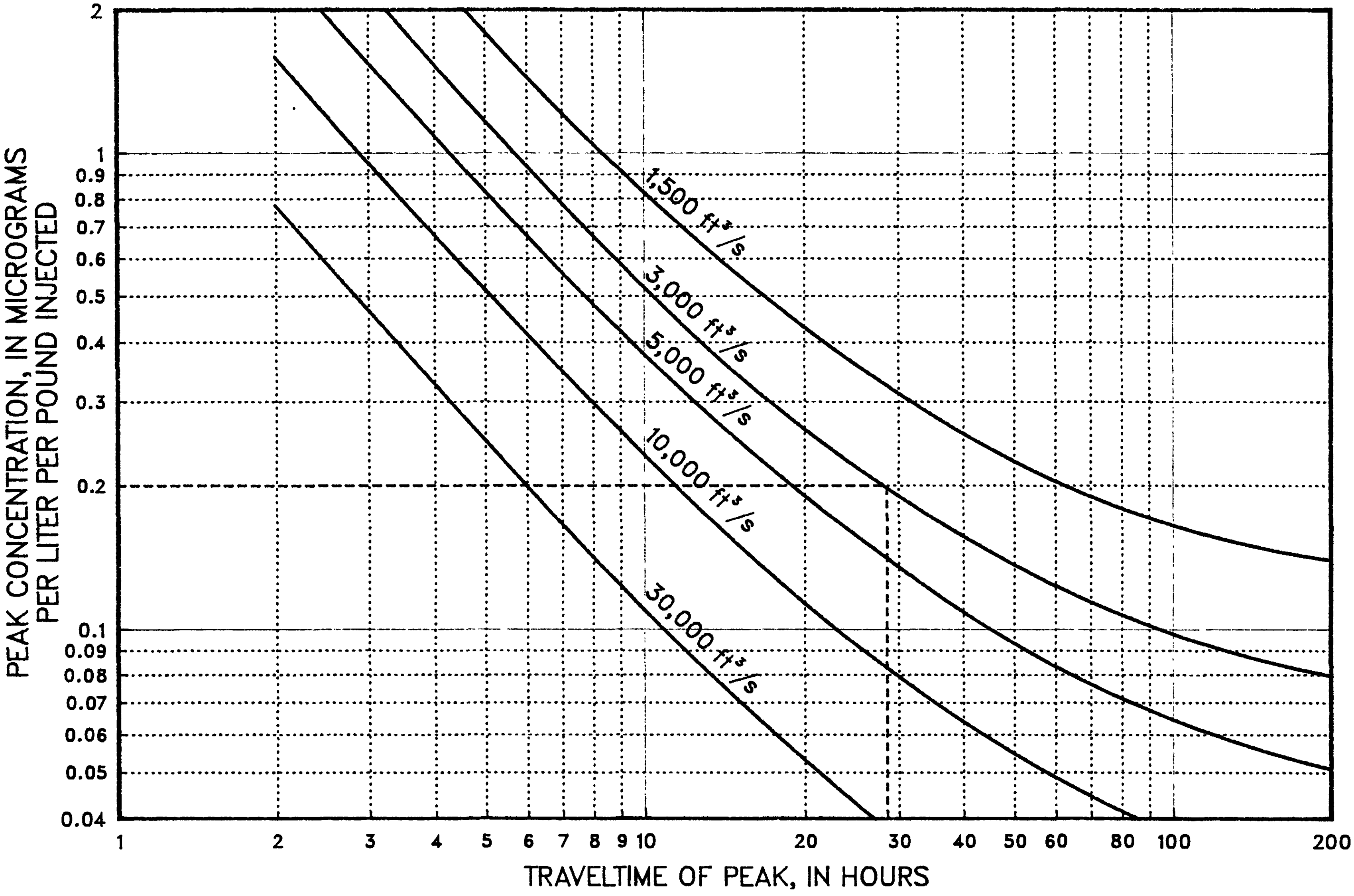

Figure 10.—-Peak concentrations resulting from the injection of 1 pound of a conservative soluble material at selected discharges.

SOLUTION OF SAMPLE PROBLEM

In order to demonstrate the use of curves presented in figures 6, 7, 9, and 10, assume that 500 lbs of soluble contaminant was spilled from the Interstate Highway Bridge (I-64) near Sandstone (mile 53.3 from table 1). River discharge at the time was 3,000 ft^3/s at the gage at Hinton. The traveltimes to Stone Cliff (mile 27.4) of the leading edge and peak, the time of passage of the contaminant cloud, and the peak concentration can be estimated as follows:

1. To estimate the arrival time use figure 6 (see dashed line on figure)--dye will arrive about 23 hr (34.5-11.5) after spill occurred, and to estimate peak traveltime use figure 7 (see dashed line on figure)--peak concentration will arrive about 28.5 hr after the spill occurred (42.0-13.5).

2. To estimate the time of passage use figure 9 (see dashed line on figure)--when peak traveltime is 28.5 hr at a river flow of 3,000 ft^3/s, the time of passage is approximately 17 hr.

3. To estimate the peak concentration use figure 10 (see dashed line on figure)--peak concentration at 3,000 ft^3/s and 28.5 hours traveltime will be 0.20 μg/L per pound. Because 500 lbs were spilled, the peak concentration would be 100 μg/L (500 lbs x 0.20 μg/L).

These relations can be used by the water manager in conjunction with the study of wave traveltimes on the New River (Appel, 1983) to estimate the effects of a spill of a soluble contaminant. A flood wave travels at a much greater speed than a particle of water or a solute. To use the previous example, assuming a spill near Sandstone, at a river flow of 3,000 ft^3/s, an increased release of water from Bluestone Dam could be used to increase the rate of flow in the New River. The increased flow would arrive at Sandstone within 3 hours and at Stone Cliff within 10 hours (Appel, 1983, p. 10). The increased flow, would increase the rate of movement of the contaminant and decrease the traveltimes and time of passage.

SUMMARY

Dye measurements on the New River between Hinton and Gauley Bridge, West Virginia, were made in 1985 and 1986. Data from the measurements were used to develop a generalized method for estimating traveltimes and concentration attenuation (dispersion) resulting from a spill of a soluble substance into the river.

The procedures are most accurate during periods of nearly steady rates of flow and will allow the user to construct approximate time-concentration curves at any point along the river for a spill of any amount of water-soluble material, at any point upstream, under a wide range of flow conditions.

An example computation that uses graphs and tables shows that with a river flow of 3,000 ft^3/s, a spill of 500 lbs of water-soluble contaminant near Sandstone would have the following effect on the river at Stone Cliff: (1) The leading edge of the contaminant cloud would reach Stone Cliff approximately 23 hr after the spill; (2) the peak concentration of contaminant would occur about 28 hr after the spill; (3) the magnitude of the peak concentration would be about 100 μg/L, if the contaminant were conservative; and (4) the contaminant would take about 17 hr to pass Stone Cliff (41 hr after the initial spill).

The methods and procedures are intended primarily as a reconnaissance tool for use by water managers and regulatory authorities. The tool will allow the user to rapidly assess the seriousness of a spill and more efficiently plan and execute a program to mitigate its effects. An even more important use of the report will be to provide the opportunity to understand, in advance of a serious spill, how the river transports, disperses, and dilutes a water-soluble substance.

The conditions under which the field data were collected and the assumption under which the data were interpreted have been described. The user is cautioned not to depend on the procedures under conditions that depart radically from those described. The user also is advised that many subjective decisions may be required to adjust the results to reflect the field situation existing at the time a problem occurs.

REFERENCES CITED

Appel, D. H., 1983, Traveltimes of flood waves on the New River between Hinton and Hawks Nest, West Virginia: U.S. Geological Survey Water-Supply Paper 2225, 14 p.

Hubbard, E. F., Kilpatrick, F. A., Martens, L. A., and Wilson, J. F. Jr., 1982, Measurement of time of travel and dispersion in streams by dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A9, 44 p.

Wilson, J. F. Jr., Cobb, E. D., and Kilpatrick, F. A., 1984, Fluorometric procedures for dye tracing: U.S. Geological Survey Techniques of Water Resources Investigations, Book 3, Chapter A12, 34 p.