TRAVELTIME AND DISPERSION DATA FOR THE KANAWHA RIVER, WEST VIRGINIA, 1989

By D.H. Appel

U.S. GEOLOGICAL SURVEY

Open-File Report 91-57

Prepared in cooperation with the
MARSHALL UNIVERSITY RESEARCH CORPORATION
and the
VIRGINIA ENVIRONMENTAL ENDOWMENT

Charleston, West Virginia

1991

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
mile per hour (mi/h)	1.609	kilometer per hour
pound, avoirdupois (lb)	0.4536	kilogram
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Traveltime and dispersion measurements using soluble dye were conducted on the Kanawha River study area from Hawks Nest Dam to the Ohio River. Data were collected by standard sampling techniques and also from boats moving at constant speed through the dye cloud. In August 1989, when streamflow was about 4,500 cubic feet per second, a traveltime measurement was conducted between Winfield Dam and the Ohio River. The dye cloud required more than 5 days to travel past Pt. Pleasant, a distance of 31 miles. In October 1989, dye was injected at Hawks Nest, London, and Marmet Dams. Kanawha River streamflow was about 11,000 cubic feet per second during these measurements. Each dye cloud was followed until it passed through the next dam downstream from the injection site. Data from each measurement are presented in tabular form.

INTRODUCTION

The Kanawha River drains 12,230 mi^2 (square miles) in parts of three States. Two-thirds of the basin is in West Virginia, one-fourth is in Virginia, and the remainder is in North Carolina. The New River (headwaters of the Kanawha River) flows northward about 330 mi (miles) from its source to where it combines with the Gauley River in south-central West Virginia to form the Kanawha River. The Kanawha River then flows 97 mi northwestward to its confluence with the Ohio River at Pt. Pleasant, West Virginia (fig. 1).

Kanawha River flood crests are regulated and low flows are augmented through the operation of four major multipurpose dams and reservoirs: Claytor and Bluestone on the New River, Summersville on the Gauley River, and Sutton on the Elk River.

The Kanawha River is canalized for a 9-foot navigation depth for a distance of about 91 mi upstream from the Ohio River through the operation of four lock and dam structures. These structures include Winfield at river mile (RM) 31.1, Marmet at RM 67.7, and London at RM 82.8 on the Kanawha River (fig. 2) and Gallipolis on the Ohio River. Hydroelectric power is generated at the three Kanawha River dams and also at Hawks Nest and Claytor dams on the New River. Flows are regulated for navigation and electric power generation. The 91 mi of navigable river possess both river and reservoir characteristics.

The Kanawha River Valley in West Virginia is the site of one of the largest and most diverse chemical-manufacturing complexes in the world. Although the river was once considered to be seriously polluted with municipal and industrial wastes, river water quality has steadily improved over the past 20 to 25 years, largely as a result of cooperative efforts by regulatory agencies, municipalities, and industry.

There remains a risk of accidental releases of hazardous chemicals into the river from the manufacturing, storage, and transportation of these chemicals in the valley. Large volumes of raw materials, chemical products, and chemical wastes are transported into and out of the area by water, rail, and highway. Recreation, aquatic life, and water consumption by industry would be adversely affected by accidental spills of contaminants in the river. No reliable methods to predict or estimate contaminant traveltimes and concentrations on the Kanawha River are currently available.

Purpose and Scope

This report describes the movement of a water-soluble dye in the Kanawha River at a selected streamflow. The U.S. Geological Survey, in cooperation with the Marshall University Research Corporation, conducted traveltime and dispersion measurements on the river from Hawks Nest Dam to its mouth at Pt. Pleasant, West Virginia. General methods used to conduct the dye measurements are described and the measurement data are presented in tabular and graphic formats.

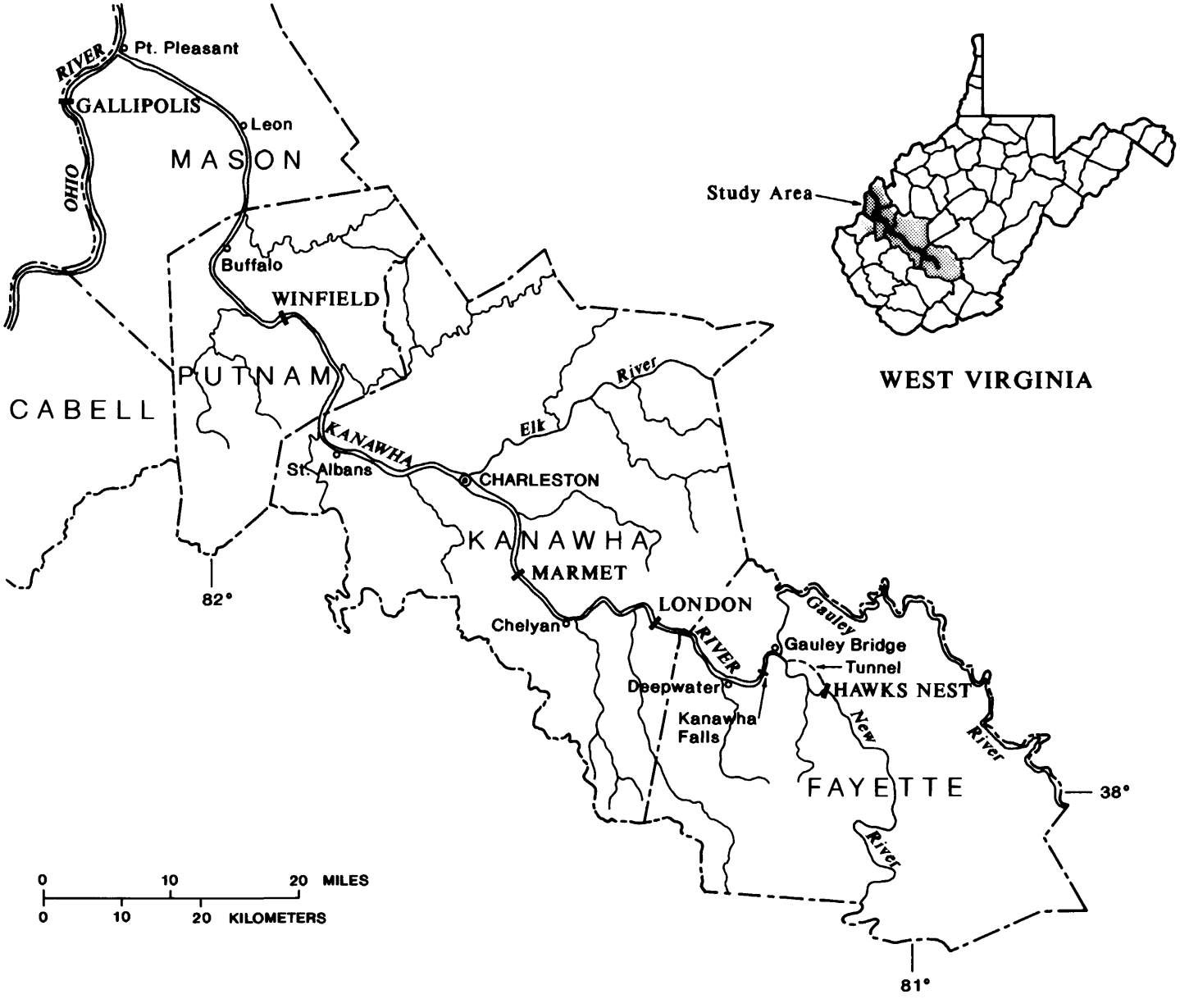

Figure 1.--The Kanawha River study area.

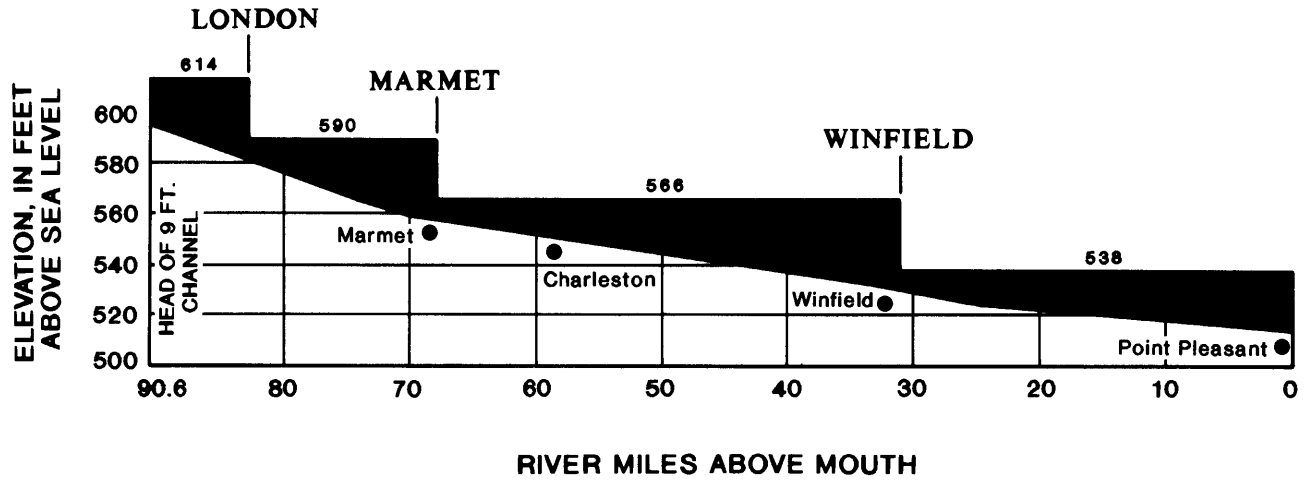

Figure 2.--Kanawha River profile, navigable section.

Acknowledgments

The U.S. Army Corps of Engineers, Elkem Metals Company, and Appalachian Power Company regulated outflow from the dams during the dye measurements. They also provided access to the forebay of the dams where the dye was injected. Dr. Marcus C. Waldron, Associate Professor from Marshall University, provided assistance with data collection and analyses. Additional support was provided by the Virginia Environmental Endowment.

FIELD PROCEDURES

Field procedures using dye tracers for conducting traveltime and dispersion studies on streams are well documented (see Kilpatrick and Wilson, 1989). In general, the described procedures were followed closely in this study. Samples were collected using standard methods at selected points such as bridges. However, because of the slow velocities in the pools behind the dams, additional samples were collected at a selected time interval from a boat moving at a constant speed through the dye cloud. The time and the location, as determined from navigation lights and day marks of each boat sample, were recorded. River miles at selected locations are shown in table 1.

The study reach is, for the most part, a series of pools controlled by dams. The study reach was divided into four subreaches as follows:

Subreach 1. Hawks Nest Dam forebay (RM 101.2) to London Dam tailrace (RM 82.8).
Subreach 2. London Dam forebay to Marmet Dam tailrace (RM 67.7).
Subreach 3. Marmet Dam forebay to Winfield Dam tailrace (RM 31.1).
Subreach 4. Winfield Dam forebay to Pt. Pleasant and the confluence with the Ohio River (RM 0.0).

Rhodamine WT dye was injected at the upstream face of each dam (forebay) where water was being drawn into the hydroelectric turbine penstocks. Because the entire river flow was being passed through the turbines for power generation except that used for locking boats, mixing occurred at the dam as the dye flowed through the penstocks and turbines and was discharged into the turbulent water at the tailrace.

The dye in subreach 1, after being released in the Hawks Nest Dam forebay, traveled through the 3-mi tunnel to the turbines and then discharged into the New River channel. The dye cloud then traveled 1.5 mi in the rough New River channel to Gauley Bridge, where the New River joins the Gauley River to form the Kanawha River (RM 96.6). The dye in the other three subreaches was discharged into the tailrace, which is also the head of the next navigation pool.

All samples collected in the field were analyzed in the laboratory using standard fluorometric procedures under controlled-temperature conditions. The fluorometer was calibrated by use of standards prepared from the dye lot used in the study.

Table 1.--Distance, in river miles, to selected sites on the Kanawha River

Location	River miles upstream from confluence with the Ohio River
Mouth of the Kanawha River	0.0
Pt. Pleasant, Highway 2 bridge	0.1
Leon, public boat ramp	12.1
Buffalo, public boat ramp	22.5
Winfield Lock and Dam	31.1
St. Albans, Highway 25 bridge	46.1
Charleston, Patrick Street bridge	56.4
Charleston, 35th Street bridge	60.9
Marmet Lock and Dam	67.7
Chelyan, Highway 61 bridge	73.6
London Lock and Dam	82.8
Deepwater railroad bridge	90.0
Kanawha Falls, Highway 13 bridge	94.2
Gauley Bridge, railroad bridge over New River	97.8
Elkem Metals Hydroelectric Power Plant tailrace on New River	98.1
Hawks Nest Dam on New River (through Hawks Nest Tunnel)	101.2

A rain storm occurred over the lower end of the Kanawha River system at midday on August 18, causing local overland runoff and the Kanawha River flows to increase to more than 12,800 ft^3/s (cubic feet per second) at Pt. Pleasant. Because the dye cloud was between Leon and Pt. Pleasant when the flow increased, the sample data collected from the Pt. Pleasant bridge cannot be used; however, a set of moving-boat data collected between RM 5.9 and 10.3 was usable and was collected before river flow increased.

TRAVELTIME AND DISPERSION DATA

August 1989

Dye was injected at Winfield Lock and Dam (RM 31.1) for subreach 4 on August 14, 1989, at a streamflow of 4,500 ft^3/s. Samples were collected using standard methods by boat in midstream at the public boat ramps at Buffalo (RM 22.5) and Leon (RM 12.1) and at the highway bridge at Pt. Pleasant (RM 0.1). Additional samples were collected from a moving boat as described earlier in this report. These samples were used to locate the leading edge, peak concentration, and trailing edge of the dye cloud at intermediate points as the dye moved slowly through the navigation pool. Detailed information, including sampling sites, traveltime, and other pertinent data for this dye measurement are shown in table 2.

A rainstorm occurred over the lower end of the Kanawha River basin midday on August 18, causing streamflow to increase as the dye cloud moved between Leon (RM 12.1) and Pt. Pleasant (RM 0.1). Both the leading edge and the peak passed Pt. Pleasant before samples could be collected. However, a set of samples collected by moving boat between RM 5.9 and 10.3 provided data prior to the increased flows.

October 1989

Dye was injected on October 26, 1989, at Marmet, London, and Hawks Nest Dams for subreaches 1-3. River flow ranged from 8,500 to 12,500 ft^3/s at Kanawha Falls and 10,000 to 13,000 ft^3/s at Charleston. Samples were collected by both conventional methods and from moving boat.

Subreach 1 contains several different hydraulic sections--3.0 mi of tunnel upstream from the turbine, 1.5 mi of rough natural channel, 2.2 mi of shallow-wide pool, 4.5 mi of rough natural channel, and then 7.2 mi of navigation pool behind London Dam. Sampling sites were selected as close to the transition of hydraulic sections as possible. Subreaches 2 and 3 are the navigation pools for Marmet and Winfield Dams, respectively.

Detailed information for each subreach, including sampling sites, traveltime, and other pertinent data are shown in tables 3, 4, and 5.

Streamflow in the Kanawha River was between 8,500 and 13,000 ft^3/s during the period October 26 to 28. This regulation, caused by hydroelectric power generation at Hawks Nest, introduces uncertainty in traveltime data.

Table 2.--Traveltime, dispersion, and related data from Winfield Dam to Pt. Pleasant, August 1989

[mi/hour, mile per hour; ft^3/s, cubic foot per second; µg/L, microgram per liter]

River mile	Site name	Distance from injection (mile)	Leading edge: Distance between sites (mile)	Leading edge: Time since injection (hour)	Leading edge: Travel time (hour)	Leading edge: Velocity (mi/hour)	Peak concentration: Distance between sites (mile)	Peak concentration: Time since injection (hour)	Peak concentration: Travel time (hour)	Peak concentration: Velocity (mi/hour)
Injected 125 pounds of 20-percent Rhodamine WT dye at 1015 hours on August 14, 1989										
31.1	Winfield Lock and Dam	0								
30.4		.7	--	--	--	--	--	--	--	--
28.7		2.4	--	--	--	--	2.4	5.2	5.2	0.46
28.1		3.0	3.0	5.0	5.0	0.60	--	--	--	--
25.5		5.6	--	--	--	--	--	--	--	--
23.6		7.5	--	--	--	--	5.1	25.0	19.8	.26
22.5	Buffalo boat ramp	8.6	5.6	25.0	20.0	.28	1.1	28.5	3.5	.31
18.6		12.5	--	--	--	--	3.9	48.5	20.0	.20
17.1		14.0	5.4	48.2	23.2	.23	--	--	--	--
18.0		13.1	--	--	--	--	--	--	--	--
16.3		14.8	--	--	--	--	2.3	57.3	8.8	.26
15.0		16.1	2.1	57.2	9.0	.23	--	--	--	--
12.1	Leon boat ramp	19.0	2.9	69.0	11.8	.25	4.2	77.0	19.7	.21
10.3		20.8	--	--	--	--	--	--	--	--
7.6		23.5	--	--	--	--	4.5	96.8	19.8	.23
5.9		25.2	6.2	97.0	28.0	.22	--	--	--	--
.1	Pt. Pleasant Bridge	31.0	5.8	--	--	--	7.5	--	--	--

Trailing edge								
Distance between sites (mile)	Time since injection (hour)	Travel time (hour)	Velocity (mi/hour)	Time of passage (hour)	Average discharge (ft^3/s)	Observed peak concentration (µg/L)	River mile	Site name
							31.1	Winfield Lock and Dam
0.7	5.5	5.5	0.13		4,500		30.4	
--	--	--	--				28.7	
--	--	--	--				28.1	
4.9	25.0	19.5	.25				25.5	
--	--	--	--				23.6	
3.0	38.0	13.0	.23	13.0		6.15	22.5	Buffalo boat ramp
--	--	--	--				18.6	
--	--	--	--				17.1	
4.5	57.5	19.5	.23				18.0	
--	--	--	--				16.3	
--	--	--	--				15.0	
5.9	89.5	32.0	.18	20.5		2.25	12.1	Leon boat ramp
1.8	96.5	7.0	.26				10.3	
--	--	--	--				7.6	
--	--	--	--		4,500		5.9	
10.2	127.0	30.5	.33		12,800 (measured)		.1	Pt. Pleasant Bridge

Table 3.--Traveltime, dispersion, and related data from Hawks Nest to London Dam, October 1989

[mi/hour, mile per hour; ft^3/s, cubic foot per second; µg/L, microgram per liter]

River mile	Site name	Distance from injection (mile)	Leading edge: Distance between sites (mile)	Leading edge: Time since injection (hour)	Leading edge: Travel time (hour)	Leading edge: Velocity (mi/hour)	Peak concentration: Distance between sites (mile)	Peak concentration: Time since injection (hour)	Peak concentration: Travel time (hour)	Peak concentration: Velocity (mi/hour)
Injected 37.5 pounds of 20-percent Rhodamine WT dye at 1400 hours on October 26, 1989										
[a] 101.20	Elkem Metals (Hawks Nest Dam) forebay	0.00								
98.10	Elkem Metals hydro plant tailrace	[a] 3.10	3.10	0.50	0.50	6.20	3.10	--	--	--
97.80	Railroad bridge upstream from Gauley Bridge	3.40	.30	.60	.10	3.00	--	0.75	--	--
94.20	Highway 13 bridge at Kanawha Falls	7.00	3.60	4.83	4.23	.85	3.60	6.17	5.42	0.66
90.00	Railroad bridge at Deepwater	11.20	4.20	7.00*	2.20	1.91	4.20	8.50	2.33	1.83
82.80	London Lock and Dam	18.40	7.20	19.30	12.30	.59	7.20	22.25	13.75	.53

[a] Discharge at Kanawha River at Kanawha Falls
[b] Through Hawks Nest Tunnel
* Estimated

Trailing edge								
Distance between sites (mile)	Time since injection (hour)	Travel time (hour)	Velocity (mi/hour)	Time of passage (hour)	Average discharge (ft^3/s)	Observed peak concentration ($\mu g/L$)	River mile	Site name
							[a] 101.20	Elkem Metals (Hawks Nest Dam) forebay
3.10	--	--	--	--	9,000	--	98.10	Elkem Metals hydro plant tailrace
3.40	1.50	--	--	0.9	9,000	24.75	97.80	Railroad bridge upstream from Gauley Bridge
3.60	10.00	8.50	0.42	5.2	[b] 8,500 - 12,500	1.86	94.20	Highway 13 bridge at Kanawha Falls
4.20	13.00	3.00	1.40	6.0	[b] 8,500 - 12,500	1.34	90.00	Railroad bridge at Deepwater
7.20	31.00*	18.00	.40	11.7	[b] 8,500 - 12,500	.50	82.80	London Lock and Dam

Table 4.--Traveltime, dispersion, and related data from London Dam to Marmet Dam, October 1989

[mi/hour, mile per hour; ft^3/s, cubic foot per second; µg/L, microgram per liter]

River mile	Site name	Distance from injection (mile)	Leading edge: Distance between sites (mile)	Leading edge: Time since injection (hour)	Leading edge: Travel time (hour)	Leading edge: Velocity (mi/hour)	Peak concentration: Distance between sites (mile)	Peak concentration: Time since injection (hour)	Peak concentration: Travel time (hour)	Peak concentration: Velocity (mi/hour)
Injected 37.5 pounds of 20-percent Rhodamine WT dye at 1100 hours on October 26, 1989										
82.80	London Lock and Dam forebay	0								
81.08		1.72	--	--	--	--	--	--	--	--
80.16		2.64	--	--	--	--	2.64	1.87	1.87	1.41
79.80		3.00	3.00	1.95	1.95	1.54	--	--	--	
79.70		3.10	--	--	--	--	--	--	--	--
79.23		3.57	--	--	--	--	0.93	3.03	1.16	.80
78.90		3.90	.90	2.97	1.02	.88	--	--	--	--
73.60	Highway 61 bridge at Chelyan	9.20	5.30	9.67	6.70	.79	5.63	10.33	7.30	.77
67.7	Marmet Lock and Dam forebay	15.10	5.90	21.00	11.33	.52	5.90	23.50	13.17	.45

a - Discharge of Kanawha River at Kanawha Falls
b - Discharge of Kanawha River at Charleston
* - Estimated

Trailing edge								
Distance between sites (miles)	Time since injection (hour)	Travel time (hour)	Velocity (mi/hour)	Time of passage (hour)	Average discharge (ft^3/s)	Observed peak concentration ($\mu g/L$)	River mile	Site name
					[a] 8,500 - 12,500 [b] 11,800 - 13,000		82.90	London Lock and Dam forebay
1.72	1.65	1.65	1.04	--		--	81.08	
--	--	--	--			10.71	80.16	
--	--	--	--				79.80	
1.38	3.16	1.51	.91	--		--	79.70	
--	--	--	--			5.73	79.23	
--	--	--	--			--	78.90	
6.10	15.0*	11.84	.52	5.3		1.79	73.60	Highway 61 bridge at Chelyan
5.90	32.0*	17.0	.35	11.0	[a] 8,500 - 12,500 [b] 11,800 - 13,000	.38	67.70	Marmet Lock and Dam forebay

Table 5.--Traveltime, dispersion, and related data from Marmet Dam to Winfield Dam, October 1989

[mi/hour, mile per hour; ft^3/s, cubic foot per second; µg/L, microgram per liter]

River mile	Site name	Distance from injection (mile)	Leading edge: Distance between sites (mile)	Leading edge: Time since injection (hour)	Leading edge: Travel time (hour)	Leading edge: Velocity (mi/hour)	Peak concentration: Distance between sites (mile)	Peak concentration: Time since injection (hour)	Peak concentration: Travel time (hour)	Peak concentration: Velocity (mi/hour)
Injected 125 pounds of 20-percent Rhodamine WT dye at 0800 hours on October 26, 1989										
67.70	Marmet Lock and Dam	0								
63.30		4.40	--	--	--	--	4.40	3.06	3.06	1.44
63.00		4.70	4.70	3.01	3.01	1.56	--	--	--	--
60.90	Charleston 35th Street bridge	6.80	2.10	4.50	1.49	1.41	2.40	4.92	1.86	1.29
58.28		9.42	--	--	--	--	2.62	7.38	2.46	1.06
57.86		9.84	3.04	7.27	2.76	1.10	--	--	--	--
56.40	Charleston, Patrick Street bridge	11.30	1.46	8.80	1.53	.95	1.88	9.67	2.29	.82
46.10	St. Albans bridge	21.60	10.30	22.17	13.37	.77	10.30	24.00	14.33	.72
44.50		23.20	1.60	24.87	2.70	.59	--	--	--	--
42.50		25.20	--	--	--	--	3.60	31.95	7.95	.45
40.00		27.70	4.50	32.37	7.50	.60	--	--	--	--
40.00		27.70	--	--	--	--	--	--	--	--
33.50		34.20	--	--	--	--	9.00	52.12	20.17	.45
31.72		35.98	8.28	51.82	19.45	.43	--	--	--	--
31.10	Winfield Lock and Dam	36.60	.62	53.25	1.43	.43	2.40	59.00	6.88	.35

[a]Discharge of Kanawha River at Charleston

Trailing edge								
Distance between sites (miles)	Time since injection (hour)	Travel time (hour)	Velocity (mi/hour)	Time of passage (hour)	Average discharge (ft^3/s)	Observed peak concentration ($\mu g/L$)	River mile	Site name
					[a]9,700 - 13,000		67.70	Marmet Lock and Dam
--	--	--	--			19.15	63.30	
--	--	--	--			--	63.00	
6.80	8.20	8.20	0.83	3.7		15.55	60.90	Charleston 35th Street bridge
--	--	--	--			7.21	58.28	
--	--	--	--				57.86	
4.50	17.00	8.80	.51	8.2		3.58	56.40	Charleston, Patrick Street bridge
10.30	36.00	19.00	.54	13.8		1.31	46.10	St. Albans bridge
--	--	--	--			--		
--	--	--	--			--	44.50	
--	--	--	--			.84	42.50	
--	--	--	--			--	40.00	
6.10	53.00	17.00	.36			--	40.00	
--	--	--	--			.58	33.50	
--	--	--	--			--	31.72	
8.90	75.00	22.00	.40	21.8	[a]9,700 - 13,000	.56	31.10	Winfield Lock and dam

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☆U.S. Government Printing Office : 1992 - 317-144/25367