TIME OF TRAVEL OF SOLUTES IN THE TRINITY RIVER FROM DALLAS TO TRINIDAD, TEXAS, MAY AND AUGUST 1987

By
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INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the city of Dallas, conducted a study of the time of travel of solutes during moderate flow conditions in a reach of the Trinity River from the outfall of the Dallas Central Wastewater Treatment Plant (DCWTP) to the USGS streamflow-gaging station 08062700, Trinity River at Trinidad, in May and August 1987. Previous USGS time-of-travel studies of this reach of the river (Ollman, 1973; 1975) provided low- and moderate-flow data. The data were included in the calibration of a mathematical water-quality model used by the city of Dallas and other public and private entities involved in water resources management of the area. The purpose of this study was to provide additional data to extend the calibration of that model to include moderately higher streamflow conditions.

DESCRIPTION OF THE STUDY

Solute travel times were determined by measuring the downstream movement of fluorescent dye (Rhodamine WT, 20-percent solution) after injection at selected points on the river. The specific gravity of the dye approximates that of natural water, thus its time of travel should approximate that of most soluble contaminants that might be introduced in the reaches studied. The length of the study reach, the natural tendency for a solute to disperse over time, and the detection limits of equipment made it impractical to track a single dye injection over the entire reach. Injections therefore were made at two points that created two subreaches, each covering about one-half of the distance from Dallas to Trinidad, and overlapping in the middle. Within each subreach, passage of the dye was observed and timed at a number of intermediate sites located at or near principal tributaries or sewage effluent discharges. The two subreaches (A and B), as well as the injection and observation sites. are shown in fiqure 1.

The first injection (subreach A) was made at 1700 hours on May 11, 1987, immediately upstream from the DCWTP (site 1). The injection was made from a boat and consisted of 4.1 gallons of dye. During the next three days, the movement of the dye was tracked at the following four locations: The outfall of the Dallas Southside Wastewater Treatment Plant (DSWTP) (site 2); the crossing at Malloy Bridge Road (site 3); the junction of the East Fork Trinity River (site 4); and the USGS streamflow-gaging station 08062500, Trinity River near Rosser, located at the crossing of State Highway 34 (site 5). The second injection (subreach B) was made at 1230 hours on August 3, 1987 at the junction of the East Fork Trinity River (site 4). The injection also was made from a boat and consisted of 7.1 gallons of dye. This dye was subsequently tracked during the next 4 days at the following downstream locations: The USGS streamflow-gaging station 08062500, Trinity River near Rosser, at State Highway 34 (site 5); the crossing of State Highway 85 (site 6); the outflow of Cedar Creek Reservoir (site 7); and the USGS streamflow-gaging station 08062700, Trinity River at Trinidad, (site 8). The study of both subreaches could not be conducted at the same time because rainfall in the lower part of the river basin increased discharges in subreach B above desired rates.

The dye had to be completely and uniformly distributed across the stream cross-section to be representative of solute transport. To facilitate rapid lateral dispersion and good representation of flow, the dye was released across the full width of the stream and in general proportion to the cross-sectional distribution of flow. The passage of the dye at points downstream was detected by fluorometric analysis of water samples withdrawn from the center of the stream at regular time intervals. Samples were collected manually or by automatic floating samplers, placed in clean 20-milliliter glass bottles with screw caps, and settled for 24 hours before being read on a calibrated fluorometer. These readings were then translated to dye concentrations using a calibration curve derived for serial dilutions of known concentration as described in detail by Wilson and others (1986). A more complete discussion of the methods and theory of time-of-travel studies is given by Hubbard and others (1982).

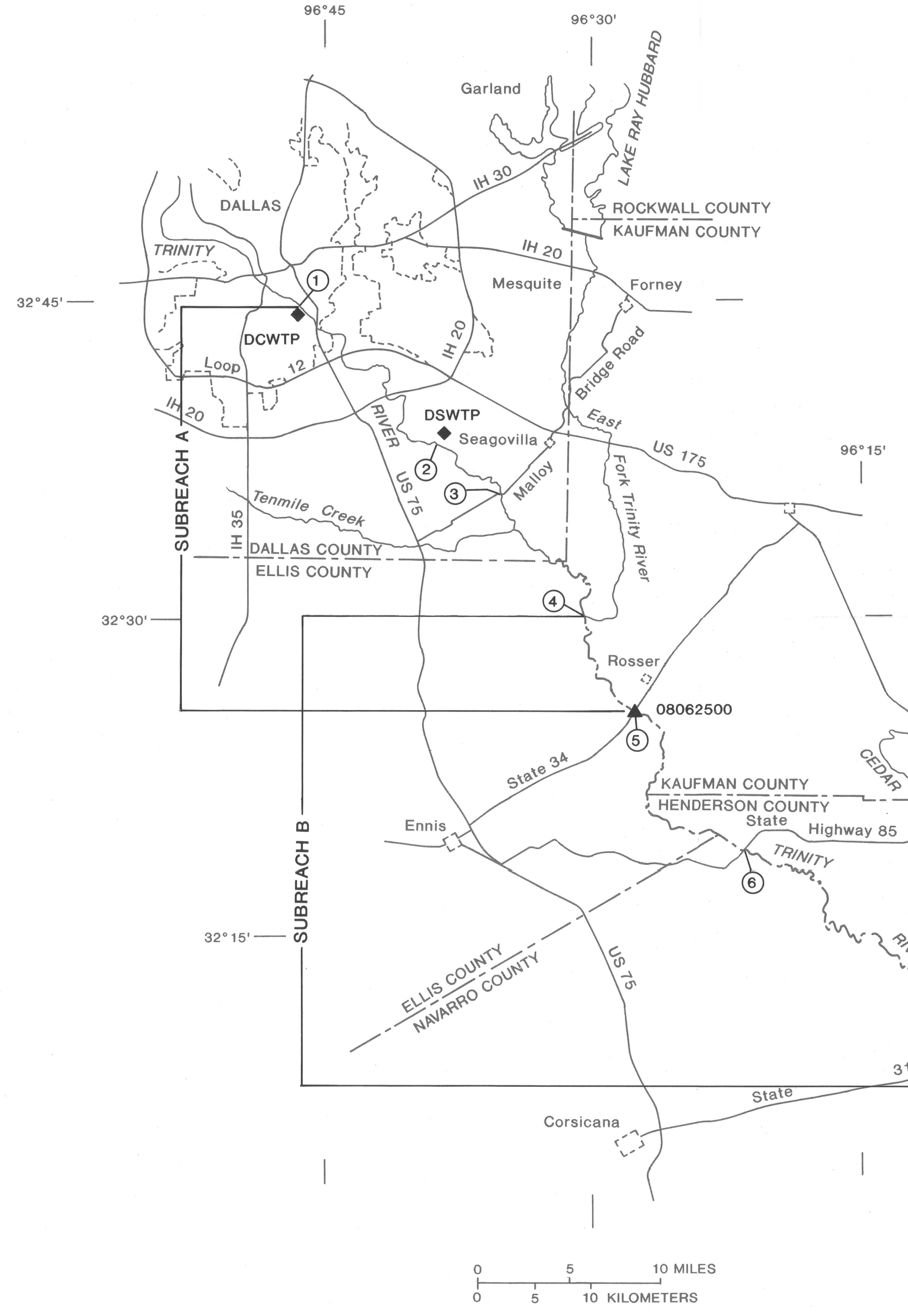
Streamflow was measured at each dye injection and at the beginning and ending of the observation period at each downstream monitoring site, except at site 8, where discharges were determined from gage-height records and a standard stage-discharge relation. At sites without gages, changes in stage during the observation period were measured with a temporary staff gage. Although there were some large differences in discharge among the sites, discharges at each site remained relatively constant throughout the period of the dye travel. Discharges during the study of subreach A (table 1) ranged from 735 ft^3/s at DCWTP (site 1) to 1,160 ft^3/s at the USGS gage near Rosser (site 5). Discharges during the study of subreach B ranged from 700 ft^3/s at the dye injection point (site 4) to 760 ft^3/s at sites 6, 7, and 8. By comparison, discharges during the previous study reported by Ollman (1975) ranged from 580 ft^3/s at DCWTP (site 1) to 696 ft^3/s near Trinidad (site 8).

RESULTS

Dye concentrations, in micrograms per liter, were plotted against the time after injection (fig. 2); and smooth-line interpolations between the data were used to determine the time of arrival of the leading edge, peak concentrations, and trailing edge of the dye at each observation point. The arrival of the trailing edge is defined as the time at which concentration has receded to one-tenth of the peak value. Sampling began after the arrival of the leading edge at two sites. In these cases, a curve was approximated from existing data and from the shape of curves for sites immediately upstream and downstream. As the dye progressed downstream, its peak concentration was attenuated and its duration increased as a result of diffusion.

The distance of each site downstream from the point of injection in the two subreaches is given in river miles in table 1. These values were provided by the Trinity River Authority (written commun., 1987). A summary of travel times from injection to each site and between sites, and mean travel velocities between adjacent sites for the leading edge, peak, and trailing edge also are shown in table 1. For subreach A, the travel time of the peak dye concentration was 53.9 hours for the 43.2 miles, which results in a mean velocity of 1.18 ft/s. By comparison, the peak concentration required 92.3 hours to travel the 64.1-mile reach of subreach B--a mean dye-peak velocity of only 1.02 ft/s. Ollman (1975) determined the mean rate of travel for the peaks to be 1.2 ft/s for subreach A and 1.05 ft/s for subreach B. The travel times determined in this study and by Ollman (1975) show that the differences in discharge in the two studies do not substantially affect the rate of travel of the peak dye concentration.

Travel times from injection to each site for the dye's leading edge, peak, and trailing edge are compared to the travel distance in figure 3. Interpolations from these plots can be used to estimate travel times between other sites within the subreaches. Inferences from these data for other solutes should take into account: (1) The rate of travel of the peak dye concentration represents the mode of molecular travel rates; (2) mean and median solute travel rates are probably somewhat slower than those for peaks--based on the extended trailing limb of the individual concentration curves; and (3) solute travel rates may be affected by the reactivity and dispersion of the solute.

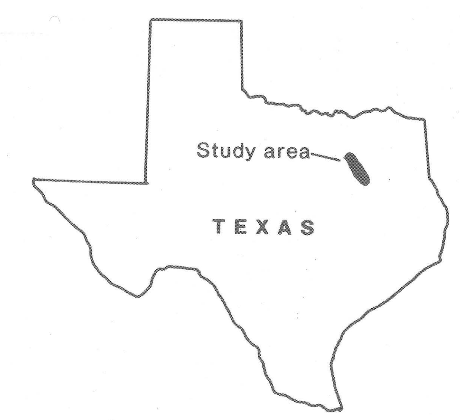


EXPLANATION

▲ U.S. GEOLOGICAL SURVEY (USGS) STREAMFLOW-GAGING STATION

SITES

1. Outfall of Dallas Central Wastewater Treatment Plant (DCWTP)
2. Outfall of Dallas Southside Wastewater Treatment Plant (DSWTP)
3. Crossing at Malloy Bridge Road
4. Junction at East Fork Trinity River
5. USGS streamflow station 08062500, Trinity River near Rossner, crossing at State Highway 34
6. Crossing at State Highway 85
7. Downstream from outflow of Cedar Creek Reservoir
8. USGS streamflow station 08062700, Trinity River at Trinidad



LOCATION MAP

Figure 1.--Location of the study area and monitoring sites.

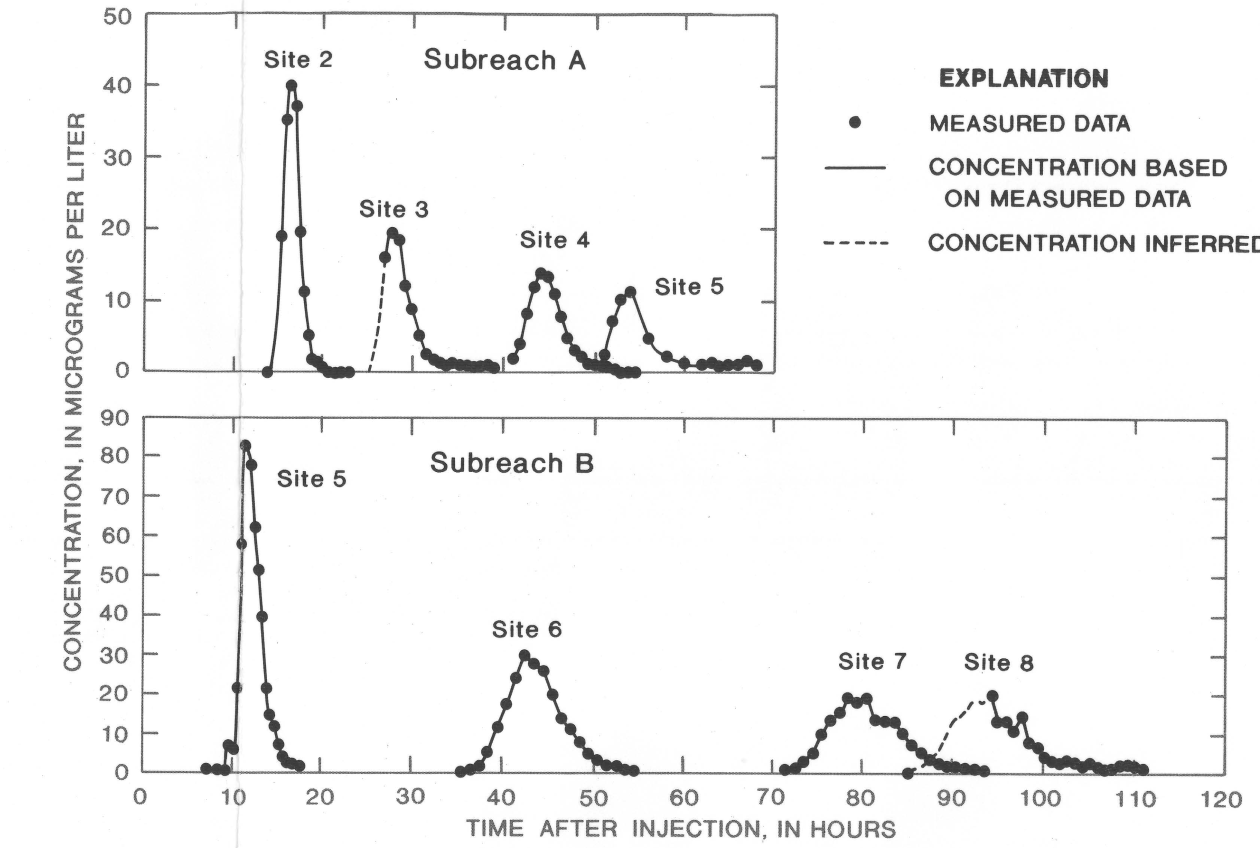


Figure 2.--Dye concentrations at monitoring sites in subreaches A and B.

TABLE 1.--Results of travel-time studies in subreaches A and B on the Trinity River, May and August 1987

[ft^3/s, cubic feet per second; mi, miles; hrs, hours; ft/s, feet per second; µg/L, micrograms per liter; --, no data; (), estimated values]

Site number	Streamflow at site (ft^3/s)	Distance: From injection site (mi)	Distance: From upstream site (mi)	Leading edge: Time from injection site (hrs)	Leading edge: Time from upstream site (hrs)	Leading edge: Mean velocity from upstream site (ft/s)	Peak: Time from injection site (hrs)	Peak: Time from upstream site (hrs)	Peak: Mean velocity from upstream site (ft/s)	Trailing edge 1/: Time from injection site (hrs)	Trailing edge 1/: Time from upstream site (hrs)	Trailing edge 1/: Mean velocity from upstream site (ft/s)	Duration of dye cloud passage (hrs)	Peak dye concentration (µg/L)
Subreach A (4.1 gallons of Rhodamine-WT dye injected at Dallas Central Wastewater Treatment Plant at 1700 hours, on May 11, 1987)														
1	735	0.0	0.0	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	--
2	736	14.9	14.9	(14.4)	(14.4)	(1.52)	16.5	16.5	1.33	18.6	18.6	1.18	4.1	40.5
3	925	21.2	6.3	24.9	10.5	.89	27.9	11.4	.81	32.1	13.6	.68	7.2	19.7
4	1,060	35.1	13.9	40.1	15.2	1.34	44.2	16.3	1.25	49.2	17.1	1.19	9.1	14.0
5	1,160	43.2	8.1	49.7	9.60	1.24	53.9	9.6	1.23	61.5	12.3	0.97	11.8	11.5
Subreach B (7.1 gallons of Rhodamine-WT dye injected at the mouth of the East Fork Trinity River at 1230 hours, on August 3, 1987)														
4	700	0.0	0.0	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	--
5	720	8.1	8.1	9.4	9.4	1.26	11.7	11.7	1.02	15.3	15.3	0.78	5.9	83.0
6	760	26.8	18.7	35.5	26.1	1.05	42.5	30.8	.89	51.0	35.7	.74	15.5	30.0
7	760	52.5	25.7	71.5	36.0	1.04	78.5	36.0	1.05	89.6	38.6	.98	18.1	20.0
8	760	64.1	11.6	(85.0)	(13.5)	(1.26)	(92.3)	(13.8)	(1.23)	106.3	16.7	1.02	(21.3)	20.0

1/ The point in the dye recession curve when concentration dropped below one-tenth of the peak concentration.

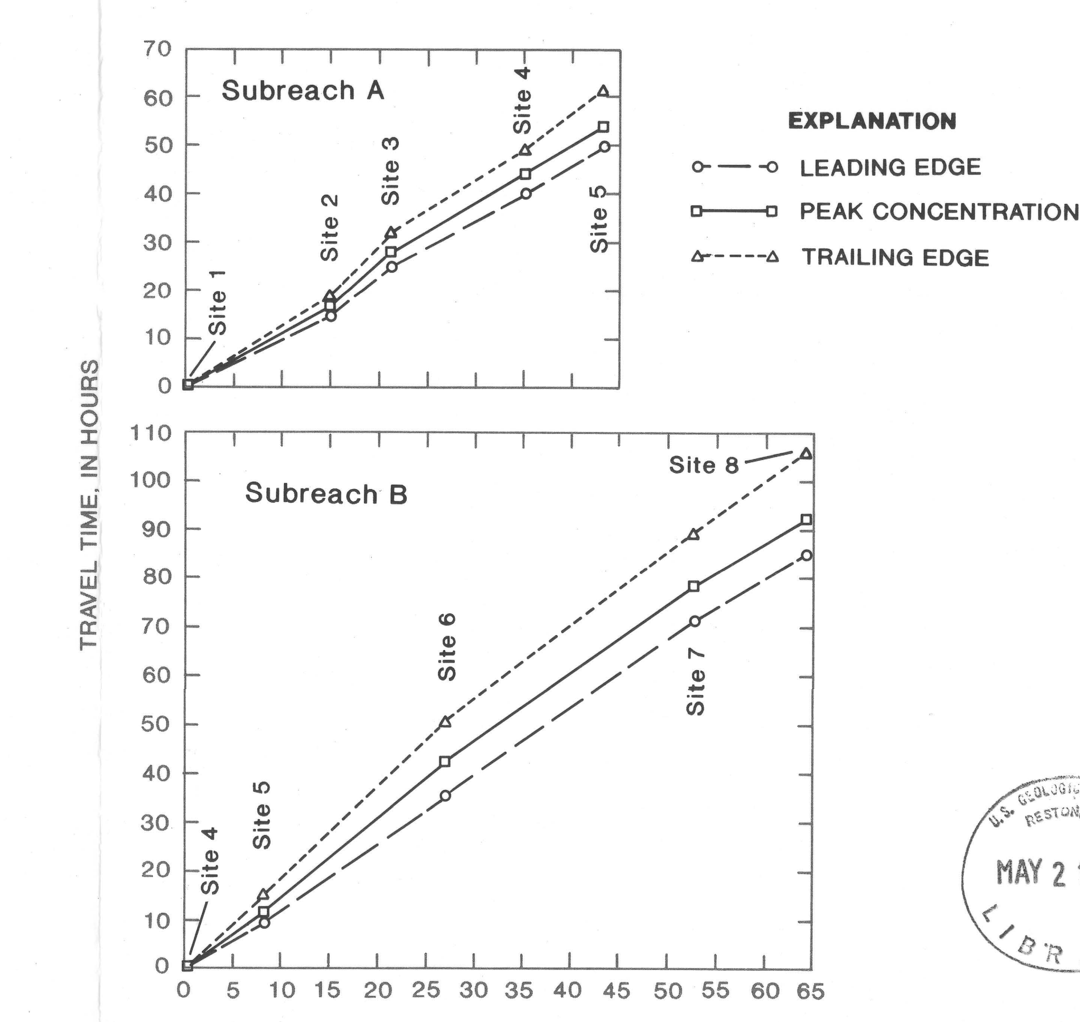


Figure 3.--Travel times for the leading edge, peak concentration, and trailing edge of dye from the injection sites to monitoring sites in subreaches A and B.

REFERENCES CITED

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, chap. A9, 44 p.

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METRIC CONVERSIONS

The inch-pound units of measurement used in this report may be converted to metric units (International System) by the following factors:

Multiply inch-pound unit	By	To obtain metric units
mile	1.609	kilometer
gallon	3.785	liter
foot per second (ft/s)	0.3048	meter per second
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 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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