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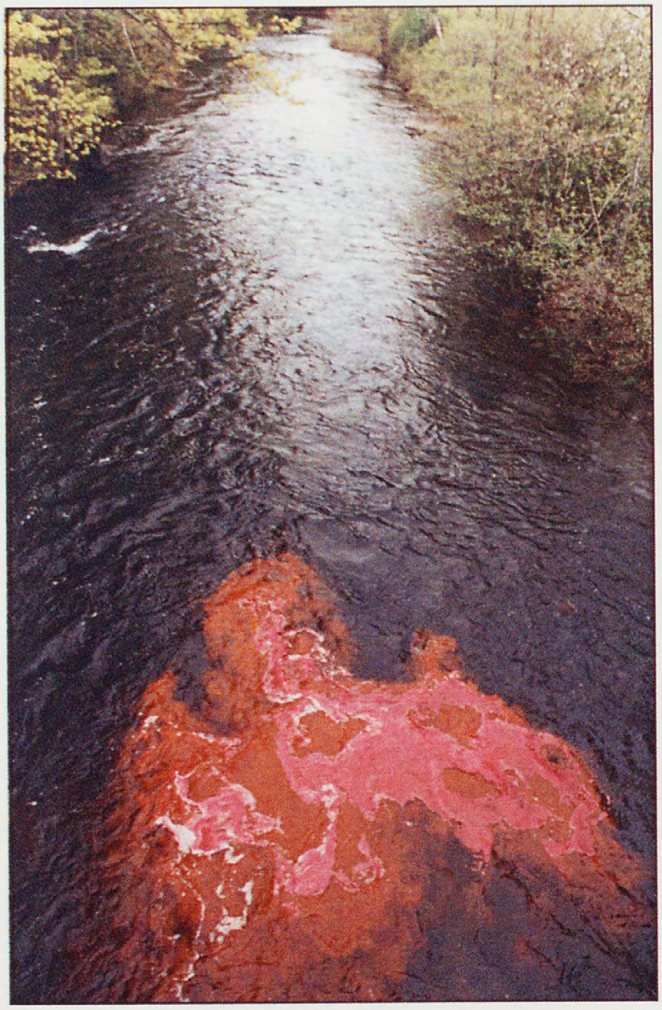
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

Travel Times and Dispersion of Soluble Dye in Thirteen New Hampshire Rivers

Open-File Report 02-226



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Travel Times and Dispersion of Soluble Dye in Thirteen New Hampshire Rivers

By Thor E. Smith

Open-File Report 02-226

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In cooperation with the
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

Pembroke, New Hampshire
2002

U.S. DEPARTMENT OF THE INTERIOR
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New Hampshire/Vermont District
361 Commerce Way
Pembroke, NH 03275-3718

or through our Web site at
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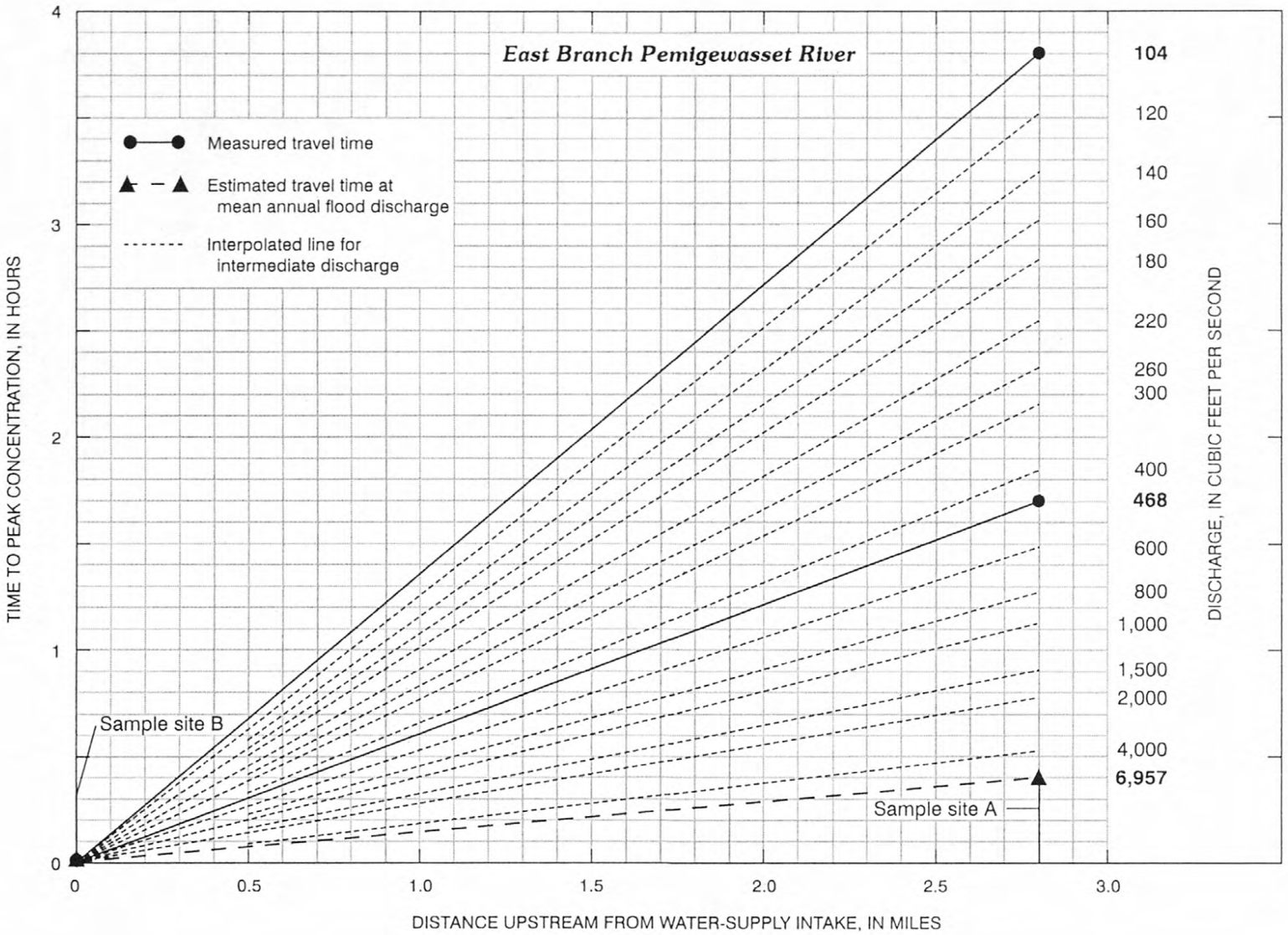


Figure 19. Travel time for dye-cloud peak and upstream distance from water-supply intake on the East Branch Pemigewasset River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01074520). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14a). See figure 6 for location of stream-gaging station and sampling sites.

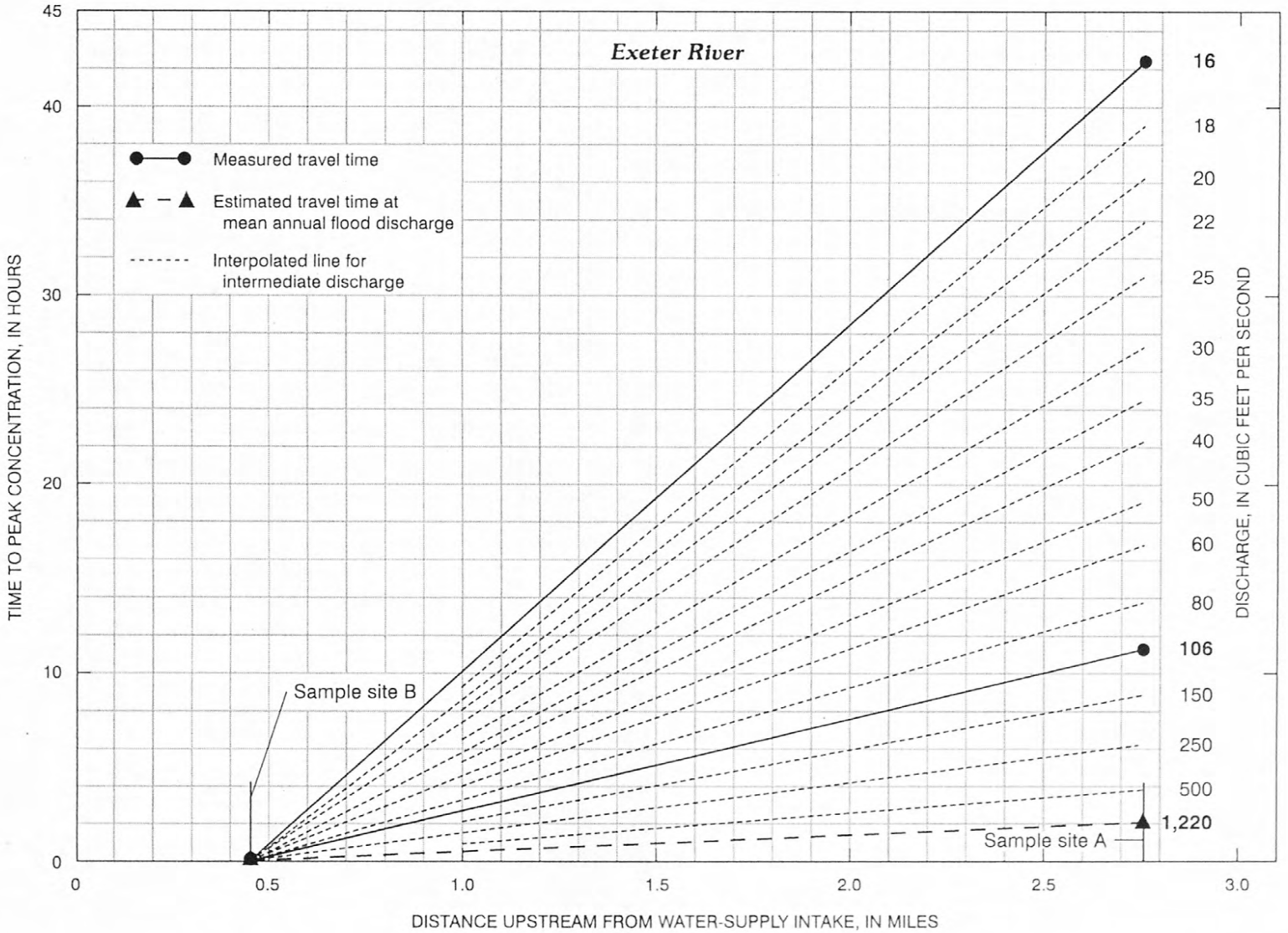


Figure 20. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Exeter River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01073587). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14a). See figure 7 for location of stream-gaging station and sampling sites.

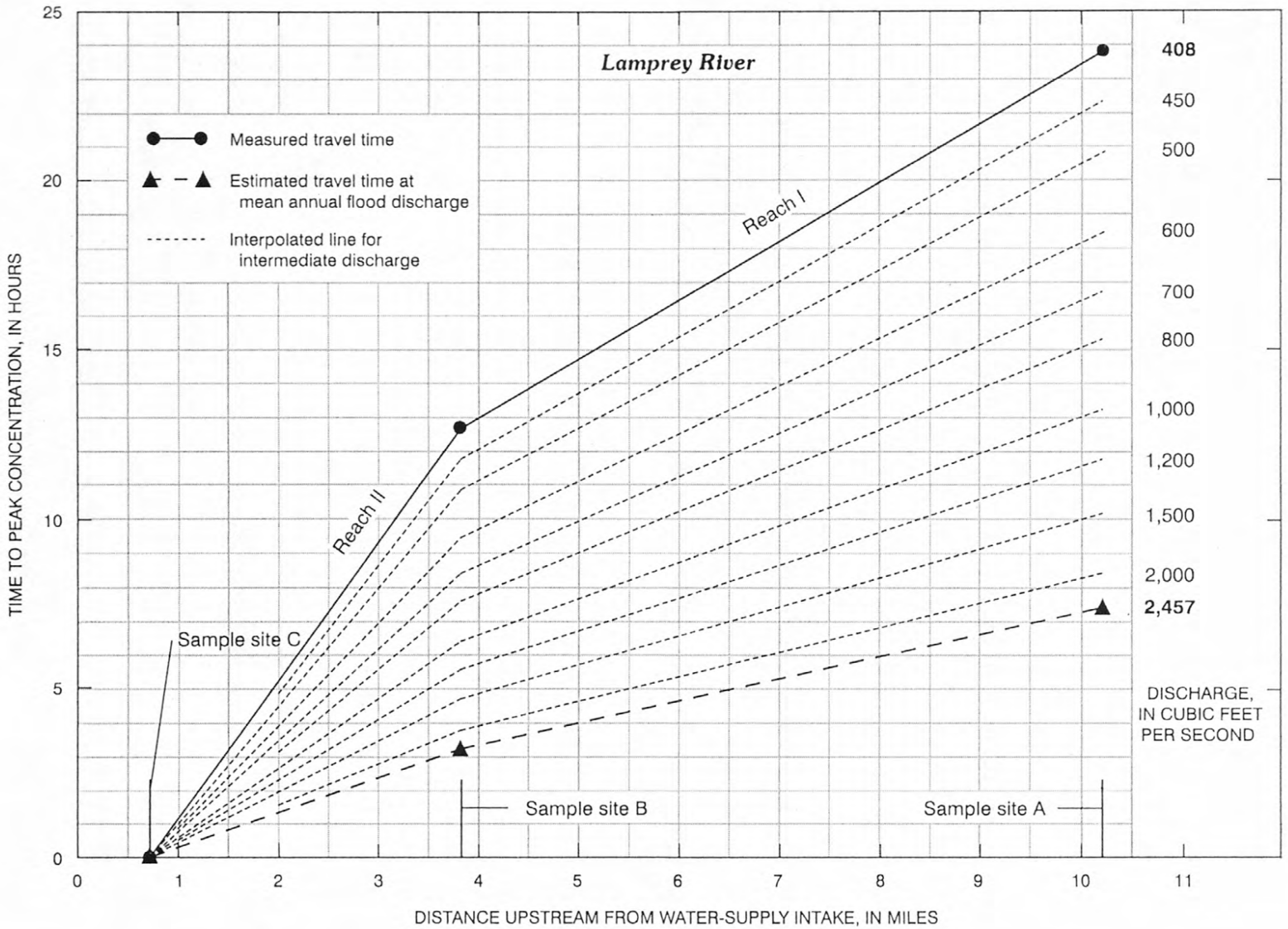


Figure 21. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Lamprey River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01073500). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 8 for location of stream-gaging station and sampling sites.

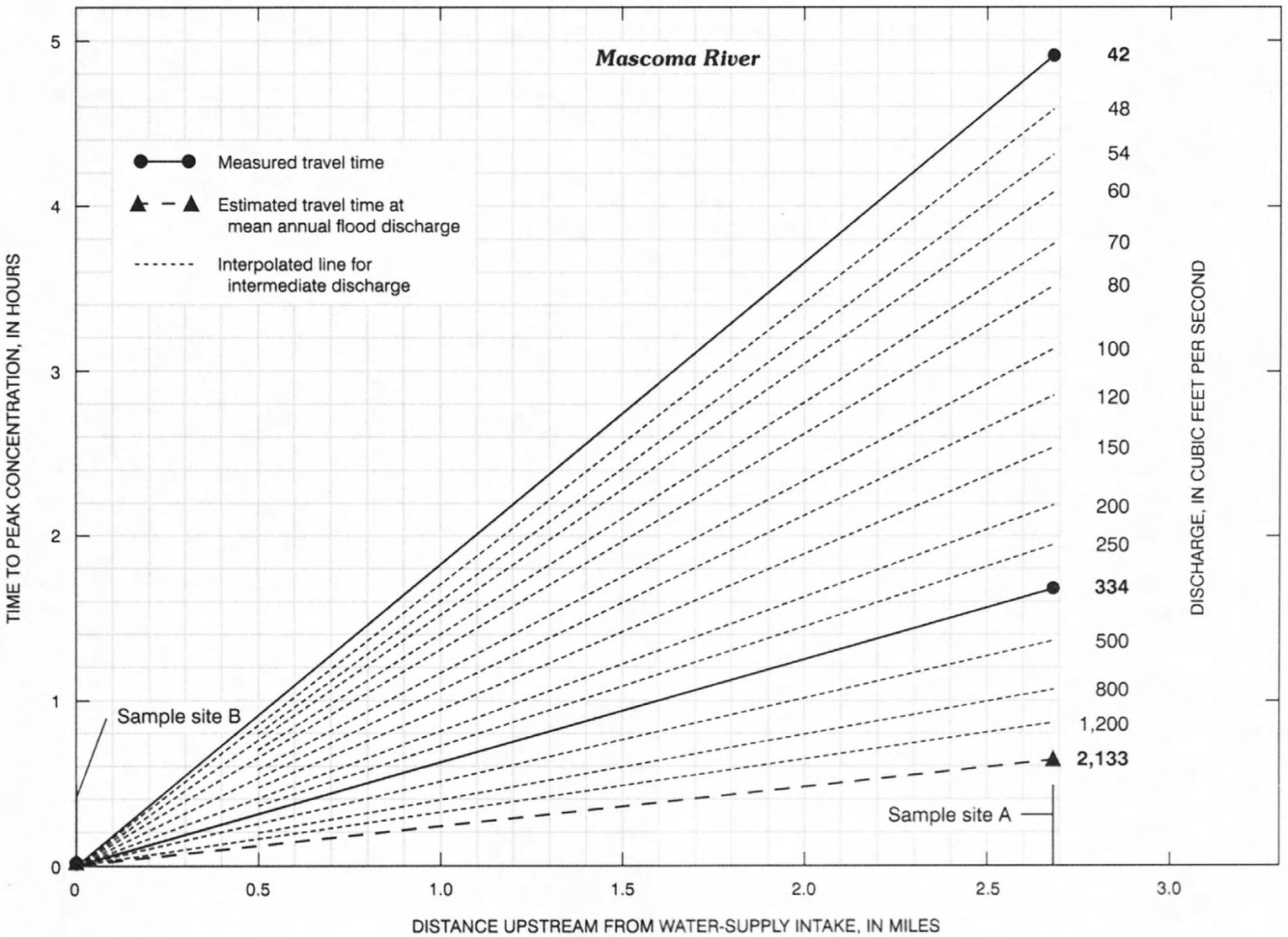


Figure 22. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Mascoma River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01150500). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 9 for location of stream-gaging station and sampling sites.

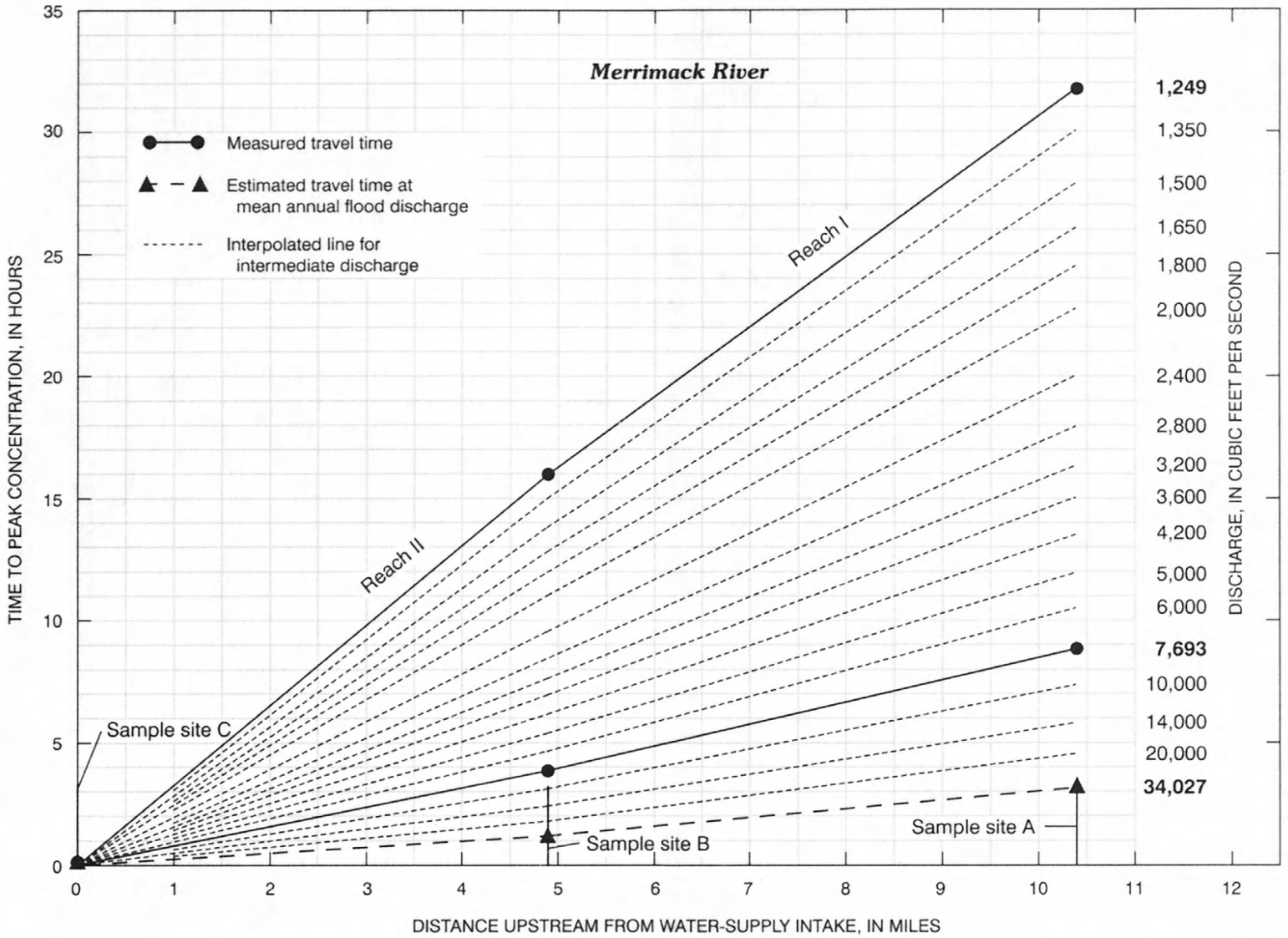


Figure 23. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Merrimack River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01092000). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 10 for location of stream-gaging station and sampling sites.

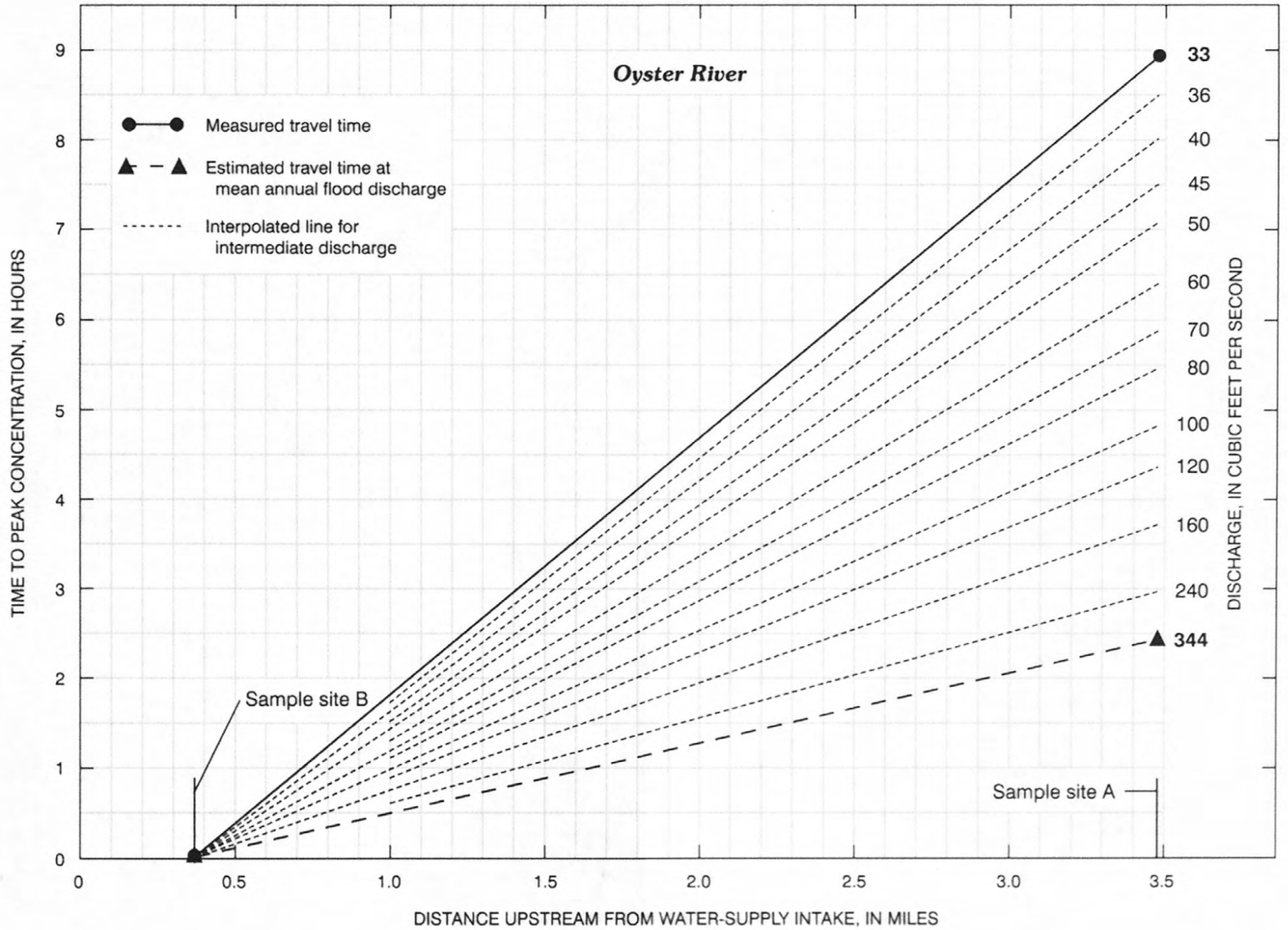


Figure 24. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Oyster River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01073000). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 11 for location of stream-gaging station and sampling sites.

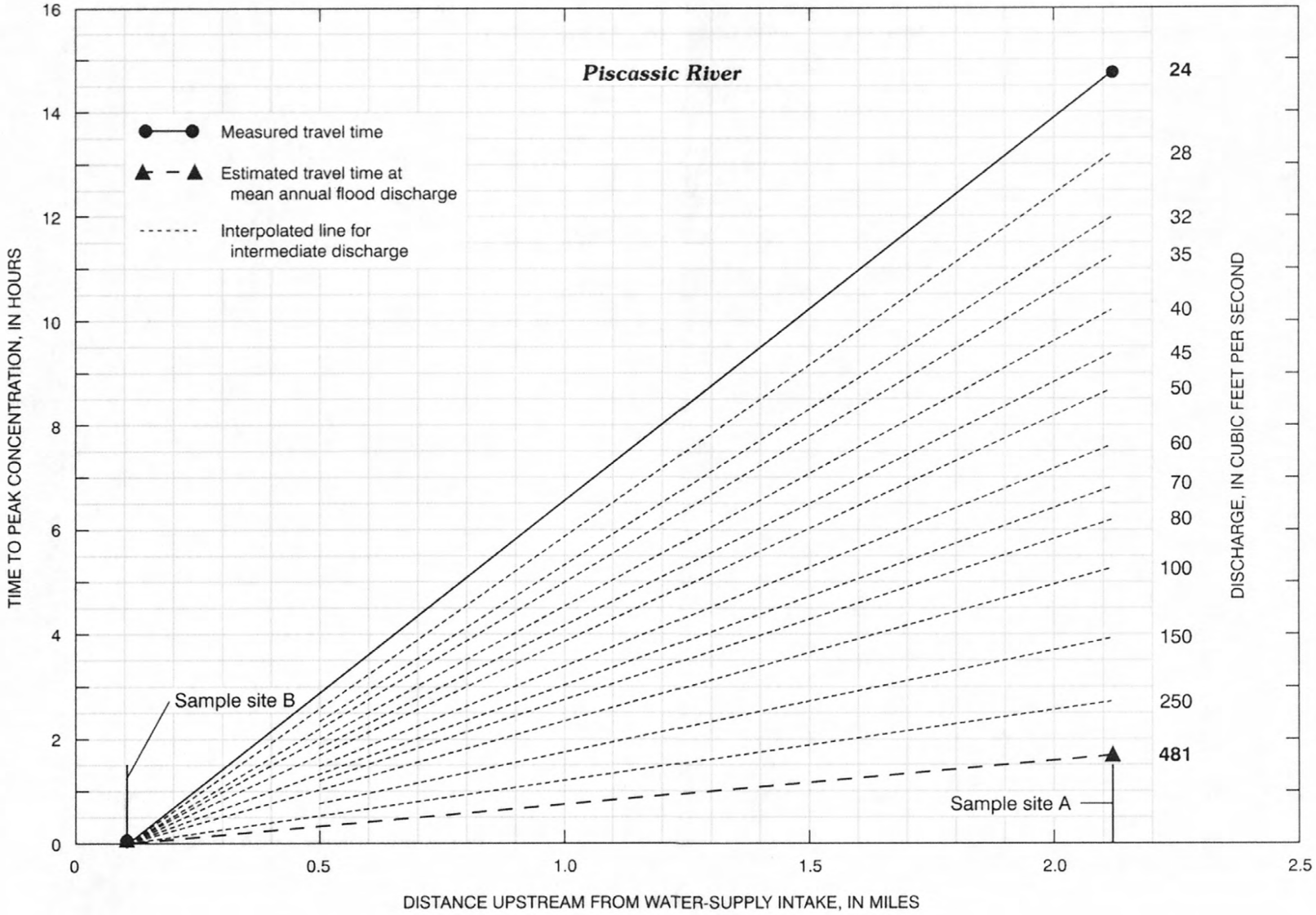


Figure 25. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Piscassic River, New Hampshire, in relation to discharge at index site. Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 8 for location of sampling sites.

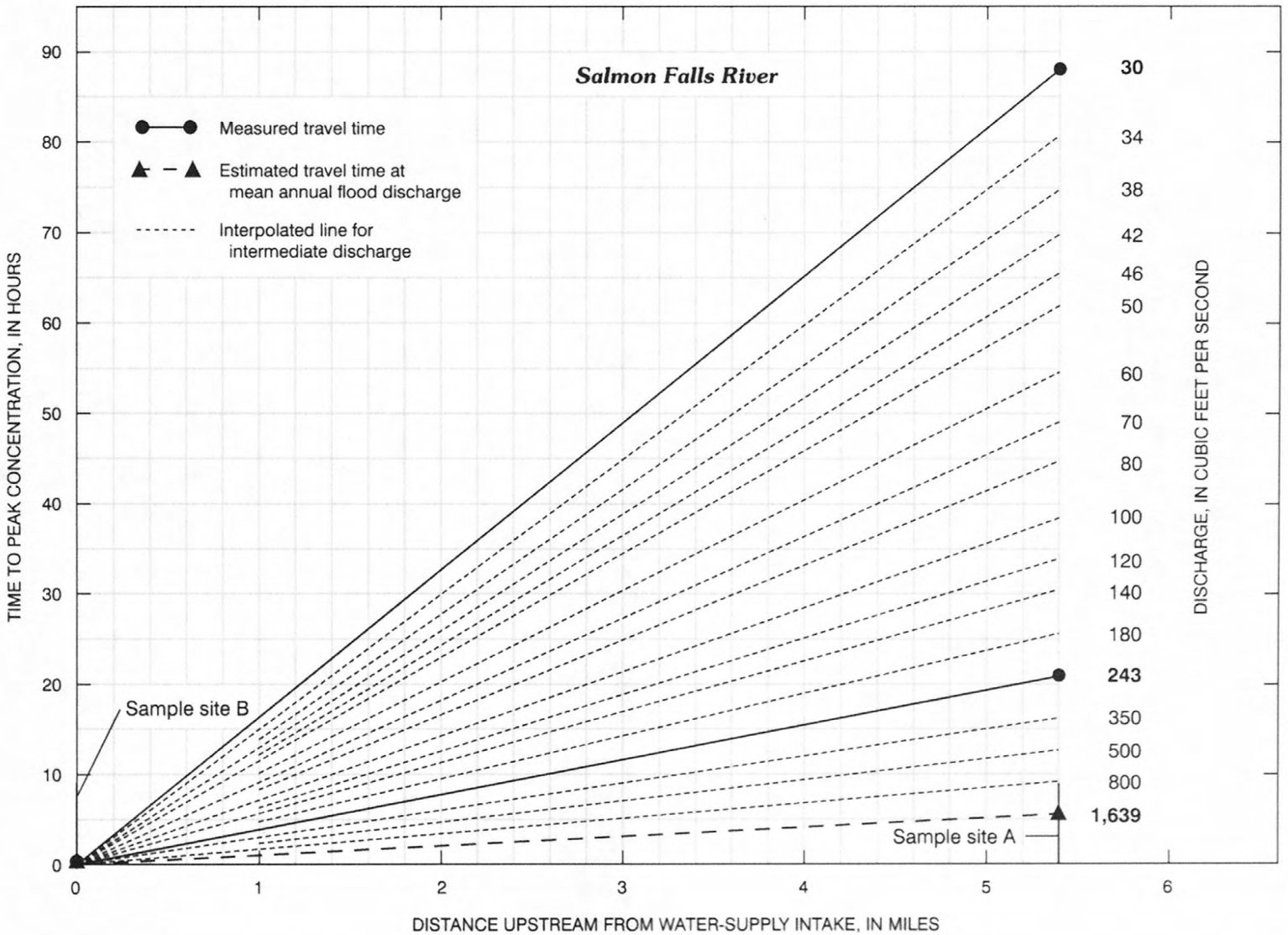


Figure 26. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Salmon Falls River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01072100). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 12 for location of sampling sites.

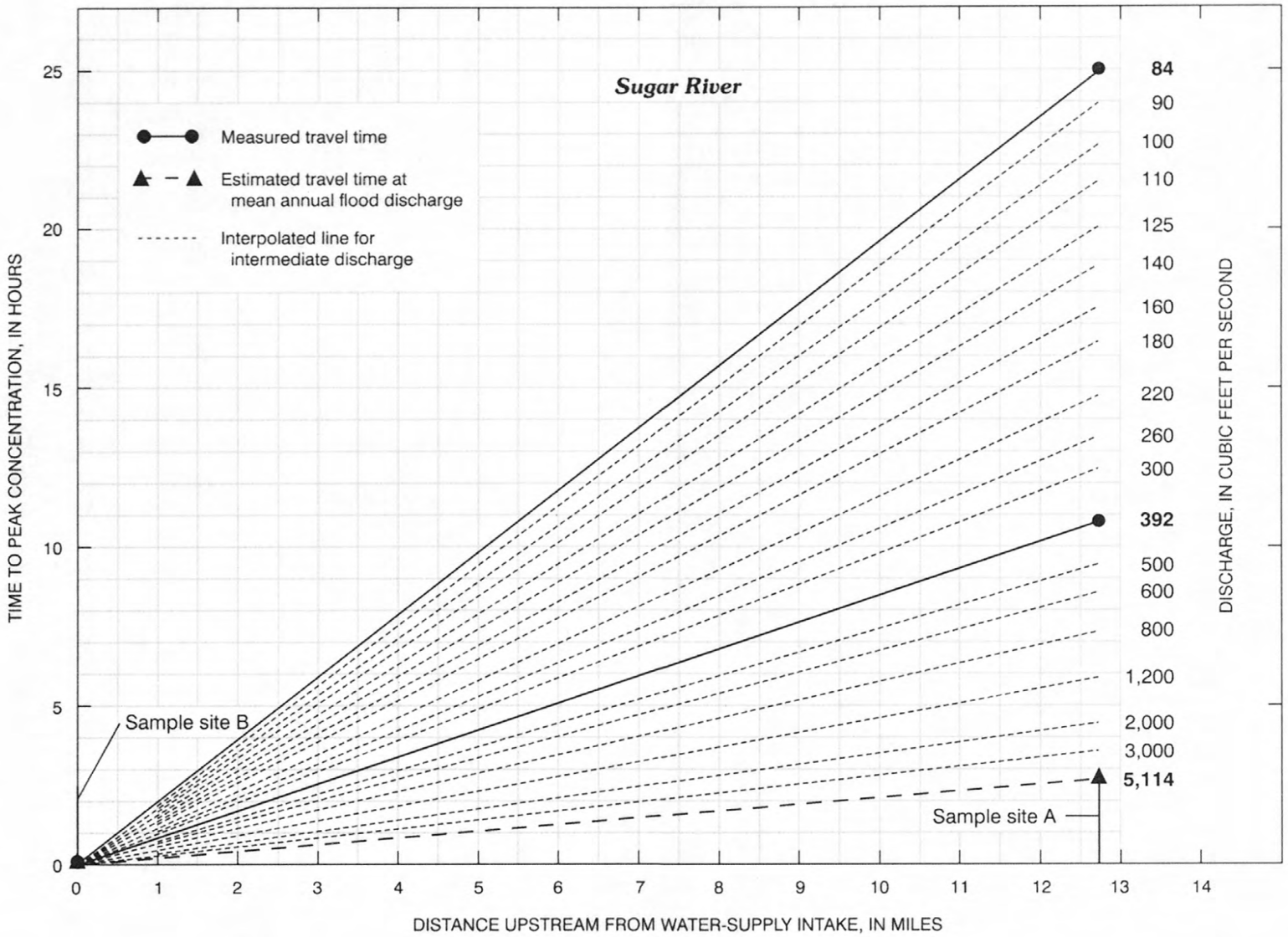


Figure 27. Travel time for dye-cloud peak and upstream distance from water-supply intake on the Sugar River, New Hampshire, in relation to discharge at index station (U.S. Geological Survey stream-gaging station number 01152500). Interpolated lines are based on log-linear relation of velocity and discharge (see fig. 14b). See figure 13 for location of sampling sites.

APPENDIX 1: Worksheet for Estimating Solute Movement

Appendix 1: Worksheet for Estimating Solute Movement

1. Identify the water-supply intake that may be threatened by the release of a solute into the river. Only those water-supply intakes listed in table 1 are addressed by the results and figures in this report. Also identify the index station associated with the affected river reach (table 1). For the Ammonoosuc and Piscassic Rivers, see the report section titled "Assumptions and Limitations."

_____ _____

Intake EPAID River

_____

Index stream-gaging station number

2. Determine what chemical species are present in the material released to the river, and whether these species are soluble in water. The expected movement of soluble species only can be calculated from the results described in this report.

_____

Name of chemical(s) released

Soluble species present? ___ Yes. Continue worksheet.

___ No. Stop.

3. (a) Estimate the total mass of soluble material released into the river, in kilograms (kg). Was it released instantaneously, or over a period of time? Leading-edge travel time can be computed for any release, but peak concentrations and the arrival times of the peak and trailing edge can be computed directly from the graphs in this report for instantaneous releases only. For continuous releases, estimates can be made using the principle of superposition (see Kilpatrick, 1993). (b) Note the date and time of solute release into the river. Travel time is independent of mass, and downstream arrival times can therefore be predicted from the release time even if mass is unknown.

Mass of soluble material released _____ (kg)

Date and time of release _____

___ Instantaneous or

___ Continuous

4. Determine the distance upstream from the water-supply intake, in miles (mi) along the river channel, that the material was released. This distance can be measured from a USGS 1:24,000 scale or similar topographic map. If the release occurred on a tributary of the water-supply river, measure the distance from the water-supply intake to the tributary's confluence with the river. This distance will provide a conservative (minimum) travel time estimate. Travel time on the tributary cannot be estimated from the measured dye velocities in the main river because discharge, bed slope, channel dimensions, and control conditions generally will be different in a tributary.

   Distance from release point to intake_____(mi)

5. Determine the discharge in cubic foot per second (ft^3/s) in the river at the time of the solute release. This is generally the discharge at the index station (see step 1). Current discharge ("streamflow") data for New Hampshire can be obtained from the USGS Web page at http://nh.water.usgs.gov. At sites where immediate non-internet access is needed for instantaneous streamflow data, the local water-resource managers will be provided with dial-up access to the index station.

   Discharge at index station _____ (ft^3/s)

6. Using the values for distance and discharge (steps 4 and 5), determine the expected travel time, in hours (h) to peak concentration from the appropriate plot for the river in question (figs. 15-27).

   Travel time to peak _____ (h)

   Time of release (step 3) + _____

   Time of peak concentration = _____

7. Multiply the travel time to peak concentration (from step 6) by 0.89 to estimate the time from solute release until the arrival of the leading edge of the solute cloud.

   Travel time to peak _____ (h)

   Ratio T_l/T_p * 0.89

   Travel time to leading edge = _____ (h)

   Time of release (step 3) + _____

   Solute-arrival time = _____

8. From the regression lines on figure 28, use the peak-concentration travel time (step 6, line 1) to find the estimated passage time of the dye cloud. Add the passage time to the solute-arrival time (from step 7) to obtain an estimate of the time at which the solute concentration will have receded to 10 percent of its peak value.

Solute-passage time (fig. 28)		_____	(h)
Solute-arrival time	+	_____	
Time of 10 percent peak	=	_____	

9. The peak solute concentration at the water-supply intake, for a conservative substance, can be estimated from figure 29. Locate the travel time to peak concentration (step 6, line 1) on the plotted regression line, and read the *y*-axis value to obtain an estimate of the peak unit conservative concentration. The unit concentration is a value that has been normalized by mass and discharge, and has a unit of microgram-cubic-foot per liter-second-kilogram ($\mu g \cdot ft^3/L \cdot s \cdot kg$). Multiply the unit concentration by the mass (kg) of solute released (from step 3), and divide by the river discharge (ft^3/s) at the index station (from step 5); the resulting value is the peak conservative concentration expected at the water-supply intake.

Unit concentration (fig. 29)		_____	($\mu g \cdot ft^3/L \cdot s \cdot kg$)
Mass of material released	*	_____	(kg)
Subtotal	=	_____	
Discharge at index station	÷	_____	(ft^3/s)
Peak conservative concentration	=	_____	($\mu g/L$)

APPENDIX 2: Latitude and Longitude of Dye-Injection and Sampling Sites on Rivers in New Hampshire Travel-Time Studies

Table A1. Latitude and longitude of dye injection and sampling sites on rivers in New Hampshire travel-time studies

[1927 North American Datum; ° ′ ″, degrees, minutes, seconds; --, no data because no sampling site C]

River	Injection site		Sampling site A		Sampling site B		Sampling site C	
	Latitude (north)	Longitude (west)	Latitude (north)	Longitude (west)	Latitude (north)	Longitude (west)	Latitude (north)	Longitude (west)
Ammonoosuc	44°12′10″	71°57′10″	44°11′04″	71°56′44″	44°09′15″	72°02′13″	--	--
Androscoggin	44°37′55″	71°14′56″	44°36′55″	71°13′09″	44°30′21″	71°09′28″	--	--
Connecticut	43°07′30″	72°26′15″	43°05′05″	72°26′01″	42°58′34″	72°27′58″	--	--
Contoocook	43°11′33″	71°44′47″	43°13′23″	71°42′51″	43°14′23″	71°40′45″	43°14′48″	71°37′20″
East Branch Pemigewasset	44°03′52″	71°35′18″	44°03′44″	71°35′43″	44°03′10″	71°38′50″	--	--
Exeter	42°57′41″	70°57′55″	42°57′41″	70°57′26″	42°58′07″	70°56′29″	--	--
Lamprey	43°05′27″	71°00′24″	43°04′59″	70°59′44″	43°06′36″	70°58′08″	43°05′26″	70°56′25″
Mascoma	43°38′55″	72°10′58″	43°38′39″	72°11′25″	43°38′23″	72°13′48″	--	--
Merrimack	43°00′07″	71°28′21″	42°57′10″	71°28′13″	42°52′47″	71°28′24″	42°48′55″	71°28′30″
Oyster	43°09′29″	70°57′54″	43°08′54″	70°57′55″	43°07′58″	70°56′51″	--	--
Piscassic	43°03′36″	70°57′59″	43°04′05″	70°57′42″	43°04′50″	70°56′58″	--	--
Salmon Falls	43°18′54″	70°54′56″	43°18′18″	70°54′23″	43°16′10″	70°52′23″	--	--
Sugar	43°21′47″	72°10′18″	43°22′16″	72°10′58″	43°22′26″	72°20′06″	--	--

APPENDIX 3: Graphs of Discharge, Dye Concentration, and Time for Sampling Sites on Rivers in New Hampshire Travel-Time Studies

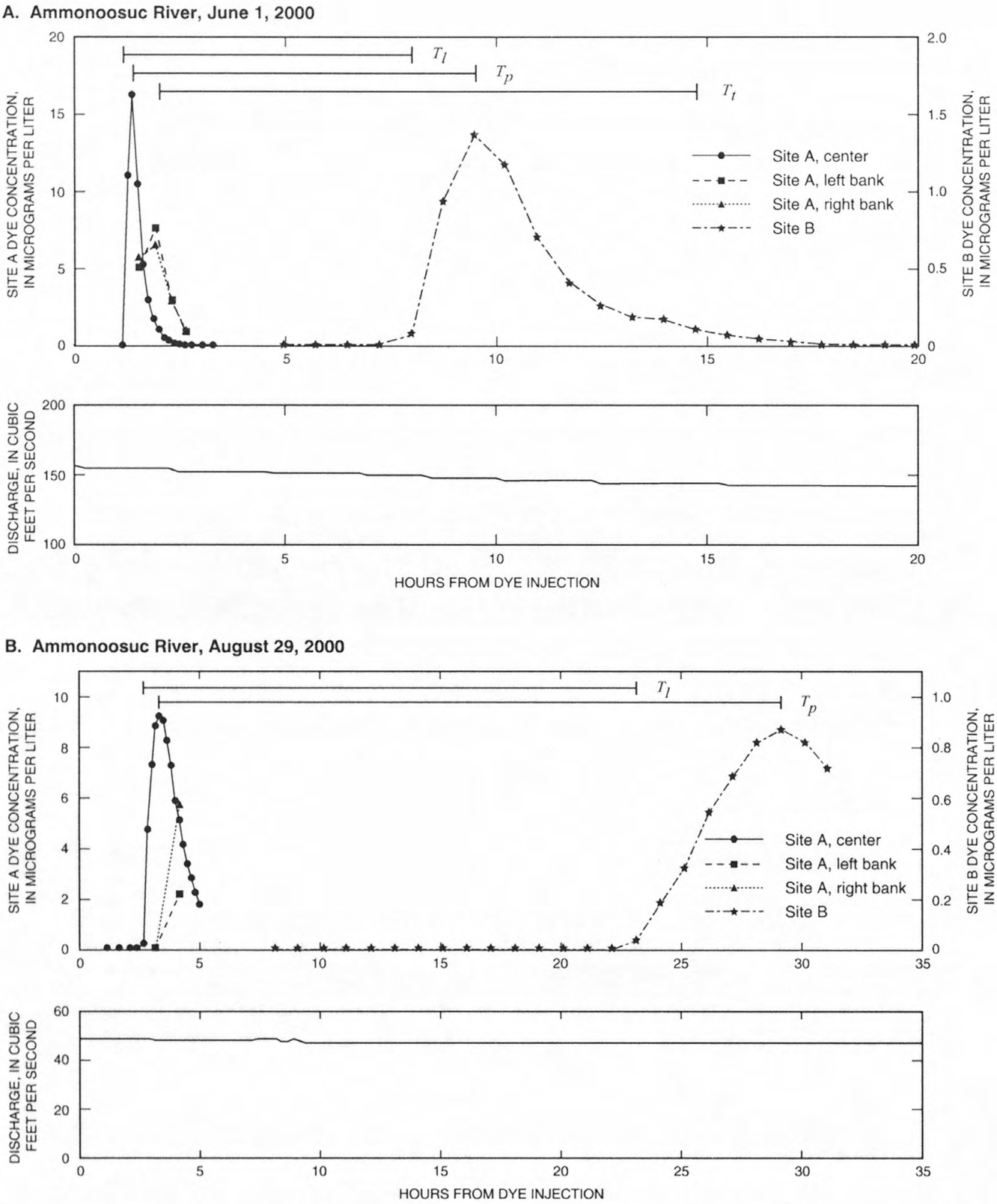


Figure A1. Discharge, dye concentration, and time for sampling sites on the Ammonoosuc River, New Hampshire; A, June 1, 2000; B, August 29, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01137500. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 2 for location of stream-gaging station and sampling sites.

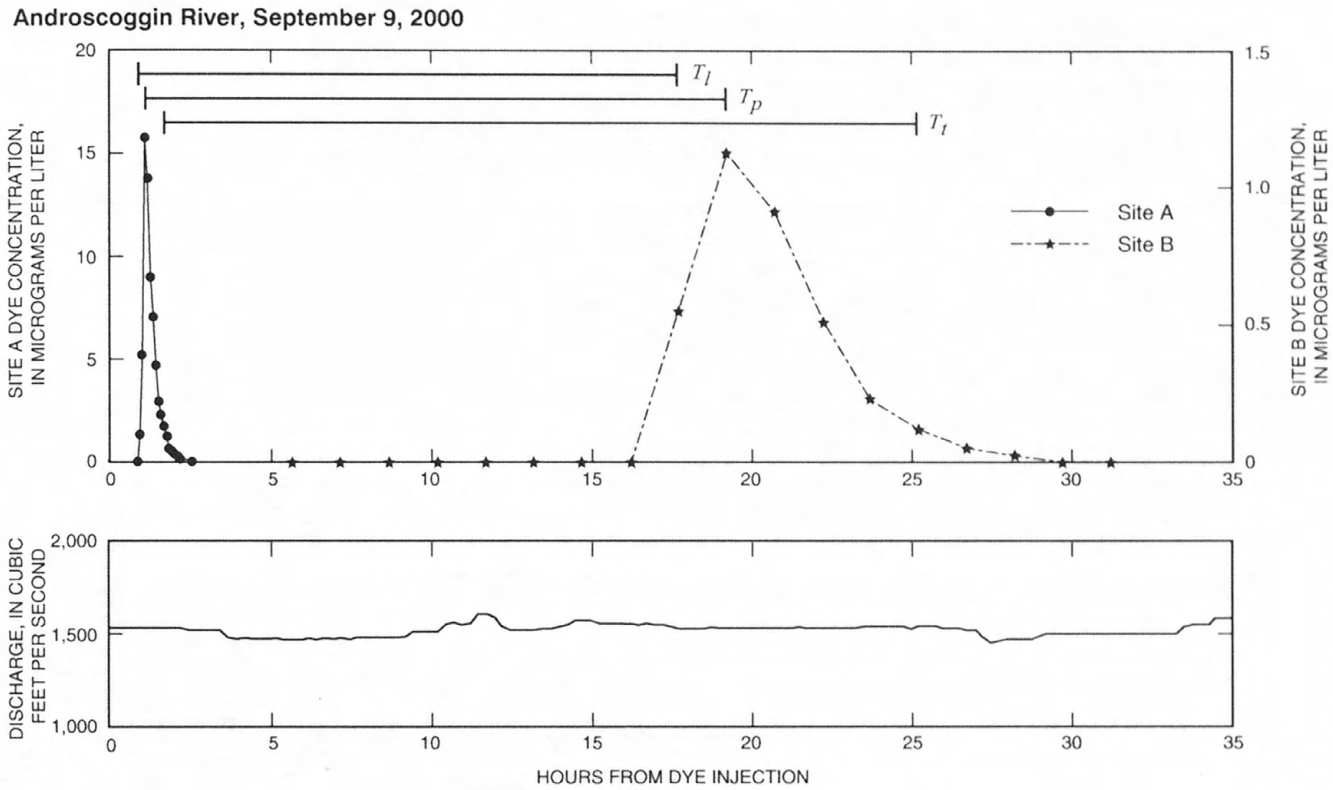


Figure A2. Discharge, dye concentration, and time for sampling sites on the Androscoggin River, New Hampshire, on September 9, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01054000. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 3 for location of stream-gaging station and sampling sites.

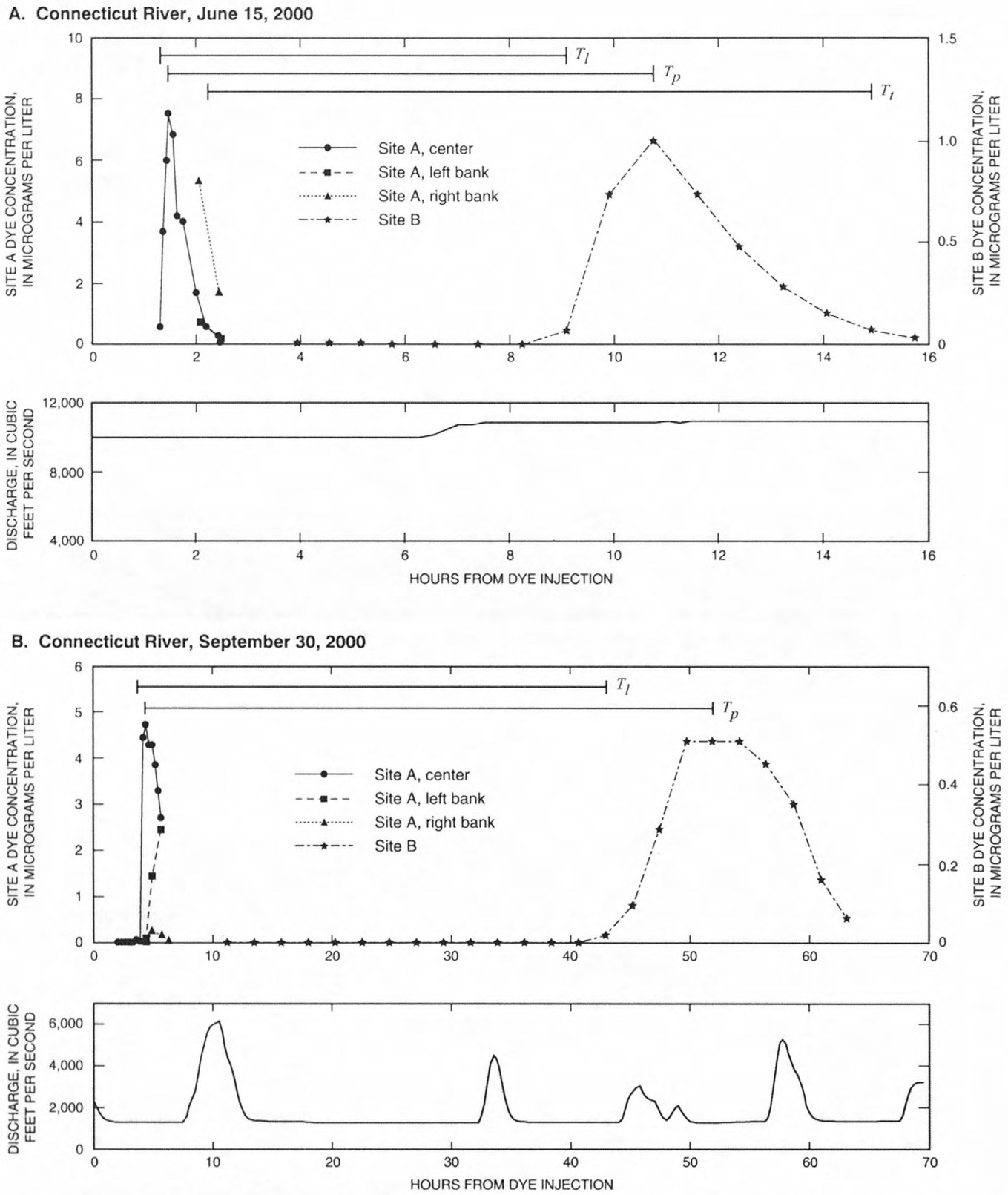


Figure A3. Discharge, dye concentration, and time for sampling sites on the Connecticut River, New Hampshire; A, June 15, 2000; B, September 30, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01154500. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 4 for location of stream-gaging station and sampling sites.

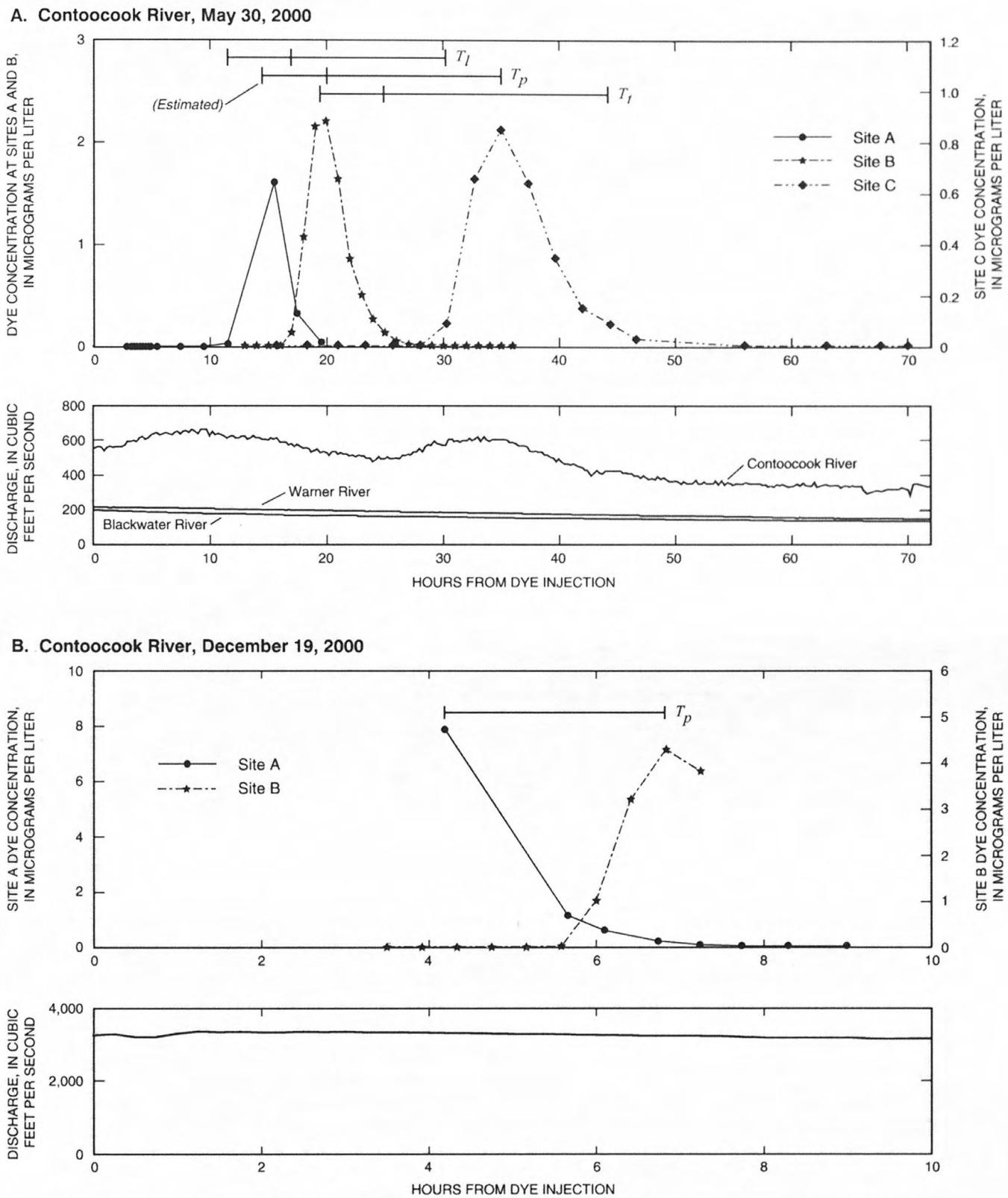


Figure A4. Discharge, dye concentration, and time for sampling sites on the Contoocook River, New Hampshire; A, May 30, 2000; B, December 19, 2000. Discharge measured at U.S. Geological Survey stream-gaging station numbers 01085500 (Contoocook River), 01086000 (Warner River), and 01087000 (Blackwater River). Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 5 for location of stream-gaging stations and sampling sites.

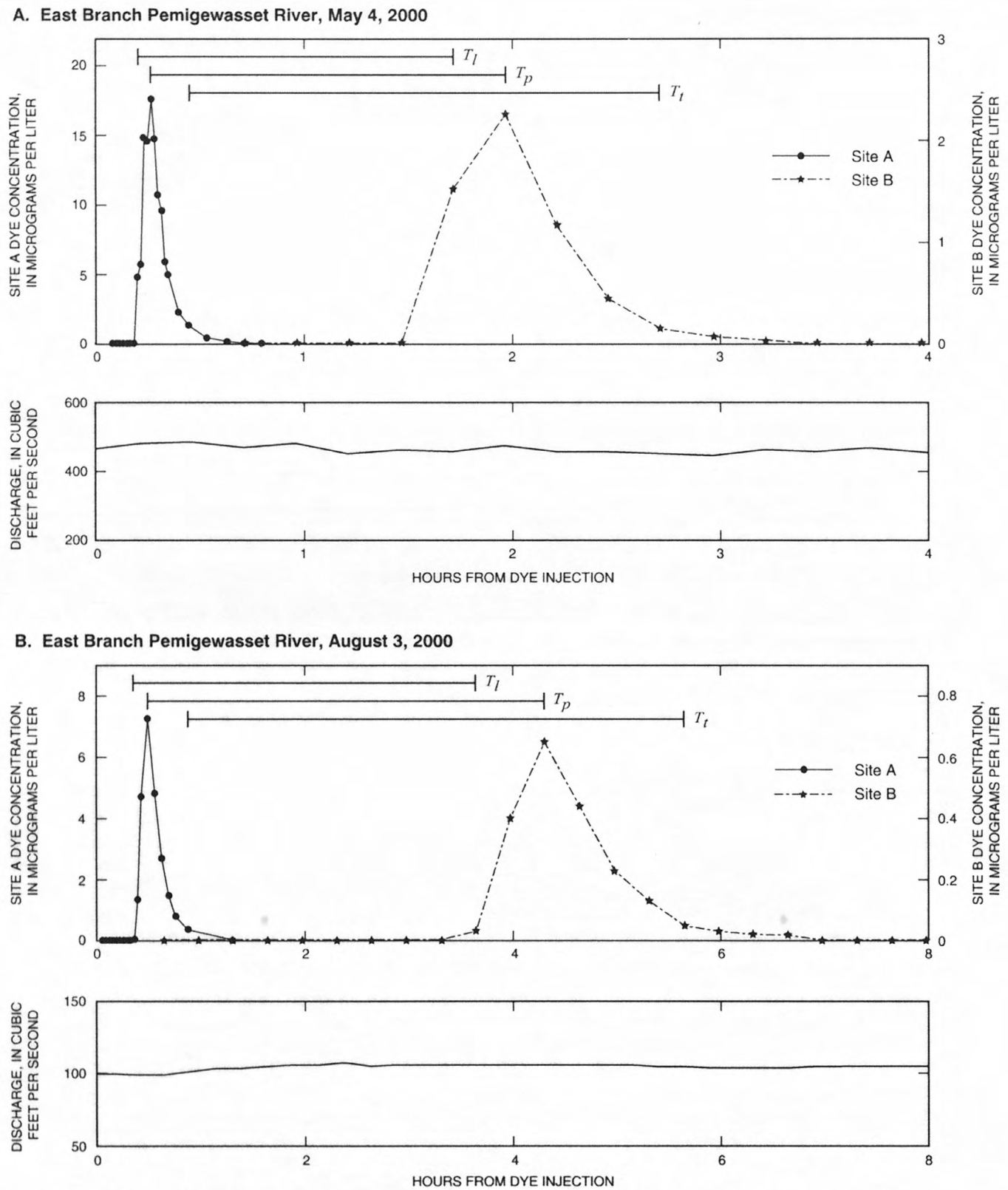


Figure A5. Discharge, dye concentration, and time for sampling sites on the East Branch Pemigewasset River, New Hampshire; A, May 4, 2000; B, August 3, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01074520. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 6 for location of stream-gaging station and sampling sites.

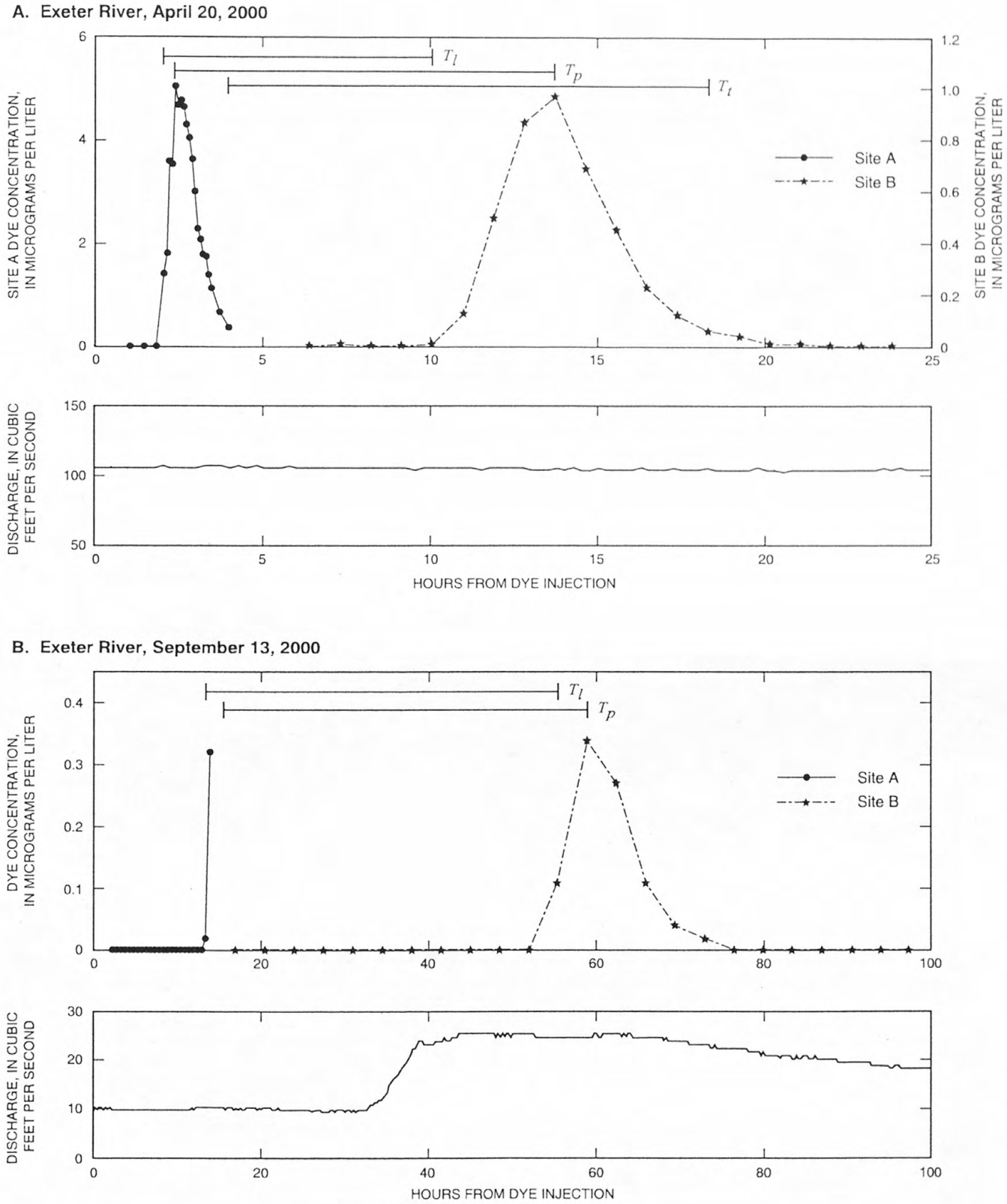


Figure A6. Discharge, dye concentration, and time for sampling sites on the Exeter River, New Hampshire; A, April 20, 2000; B, September 13, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01073587. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 7 for location of stream-gaging station and sampling sites.

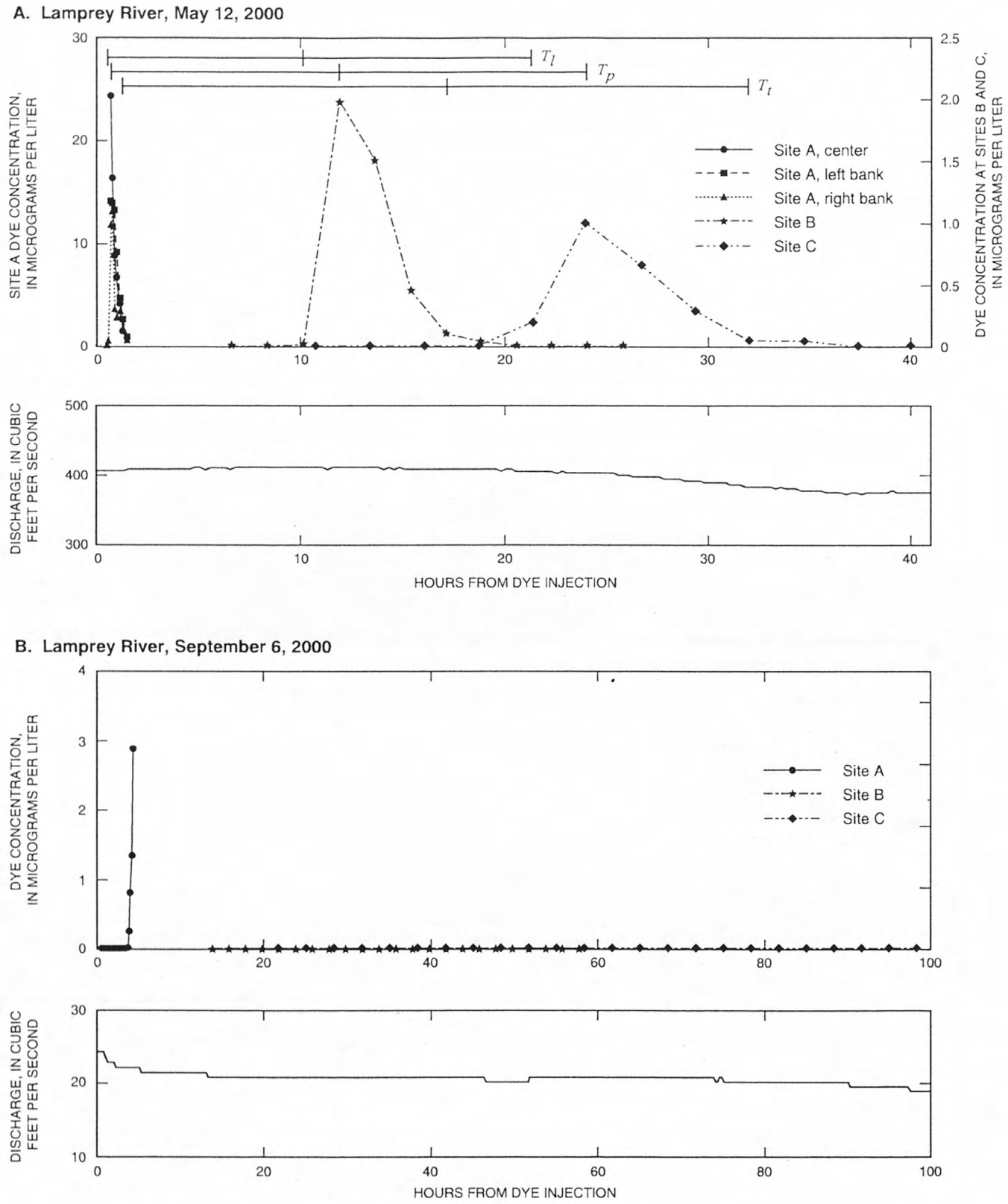


Figure A7. Discharge, dye concentration, and time for sampling sites on the Lamprey River, New Hampshire; A, May 12, 2000; B, September 6, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01073500. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 8 for location of stream-gaging station and sampling sites.

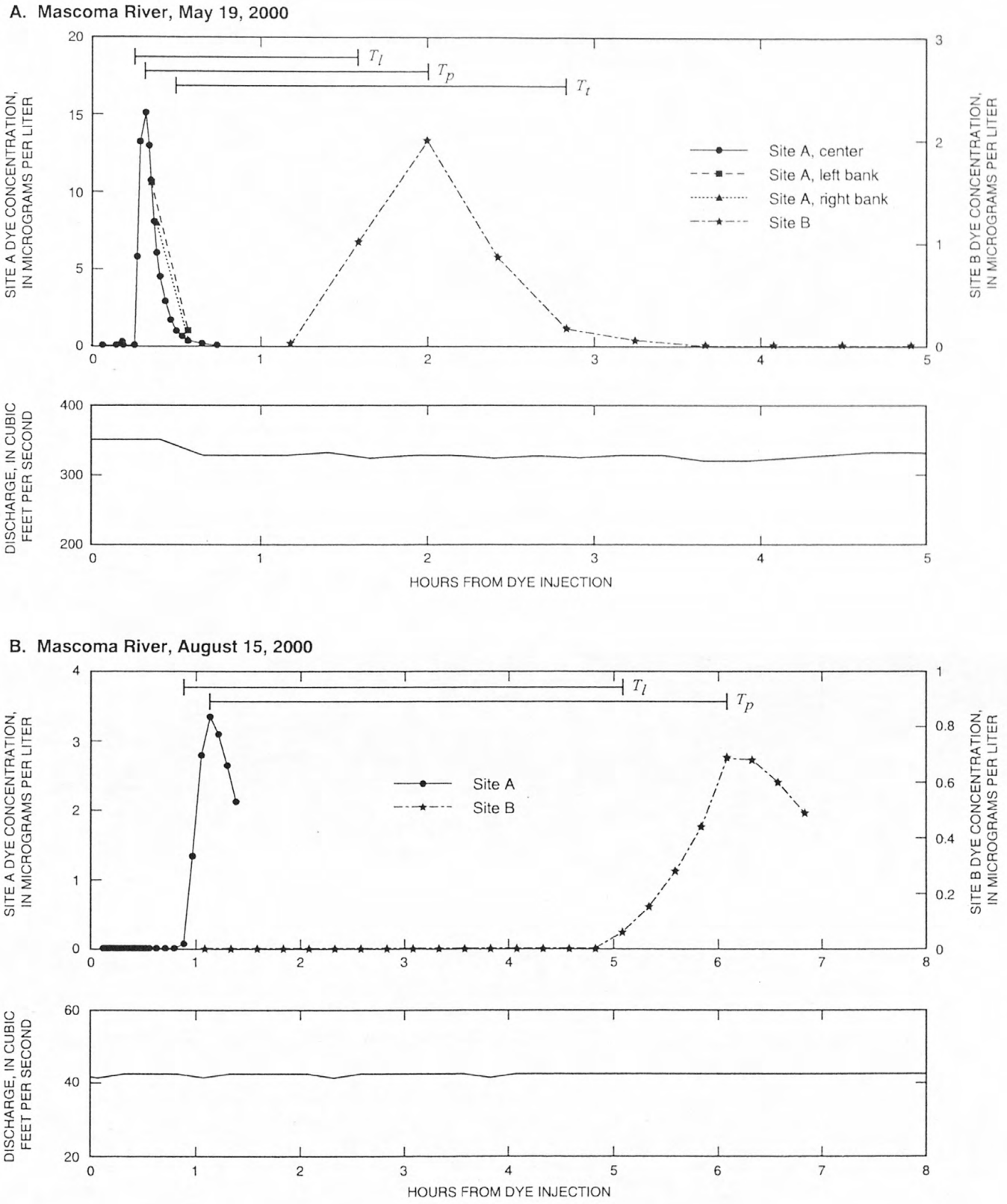


Figure A8. Discharge, dye concentration, and time for sampling sites on the Mascoma River, New Hampshire; A, May 19, 2000; B, August 15, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01150500. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 9 for location of stream-gaging stations and sampling sites.

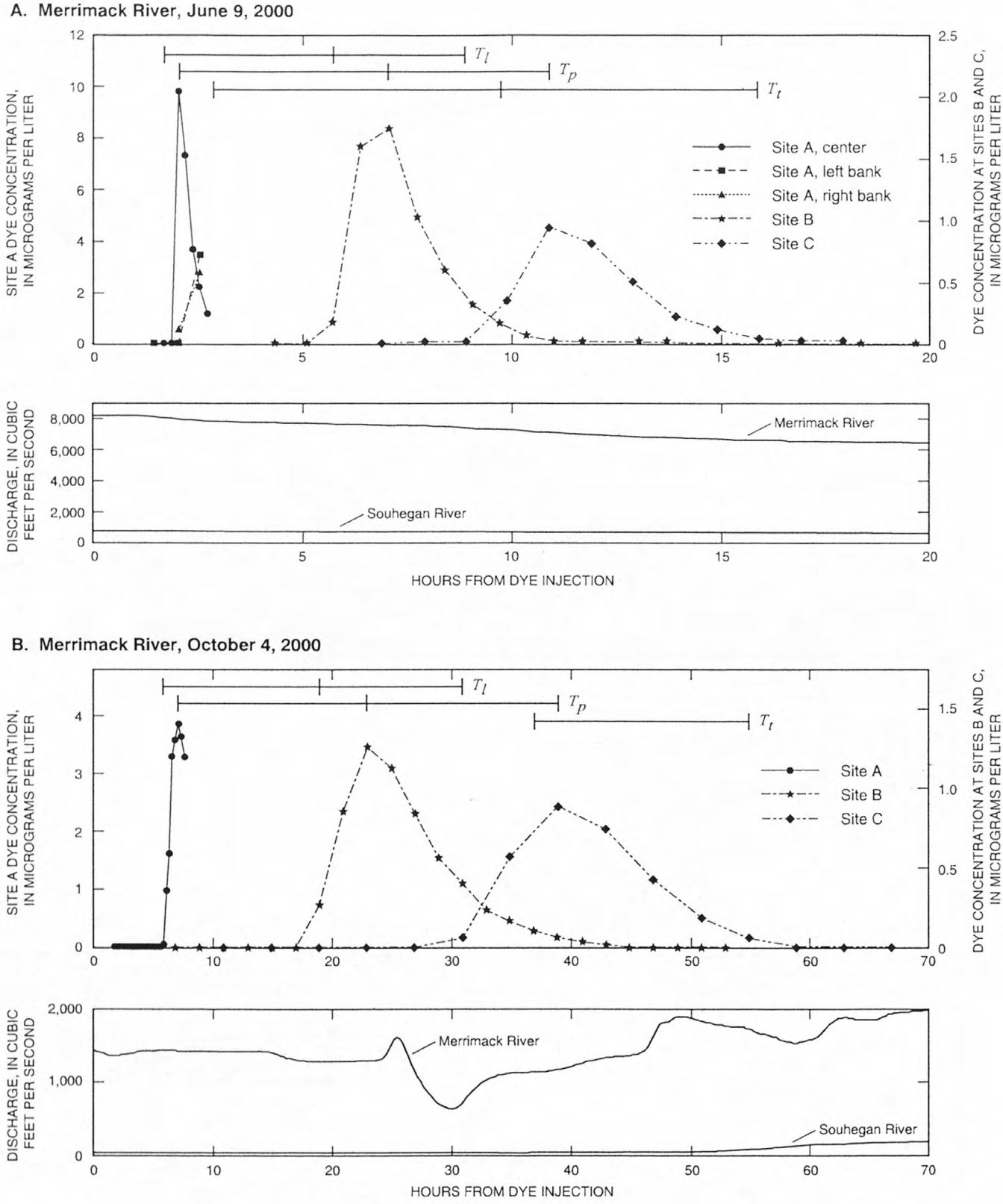


Figure A9. Discharge, dye concentration, and time for sampling sites on the Merrimack River, New Hampshire; A, June 9, 2000; B, October 4, 2000. Discharge measured at U.S. Geological Survey stream-gaging station numbers 01092000 (Merrimack River) and 01094000 (Souhegan River). Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 10 for location of stream-gaging stations and sampling sites.

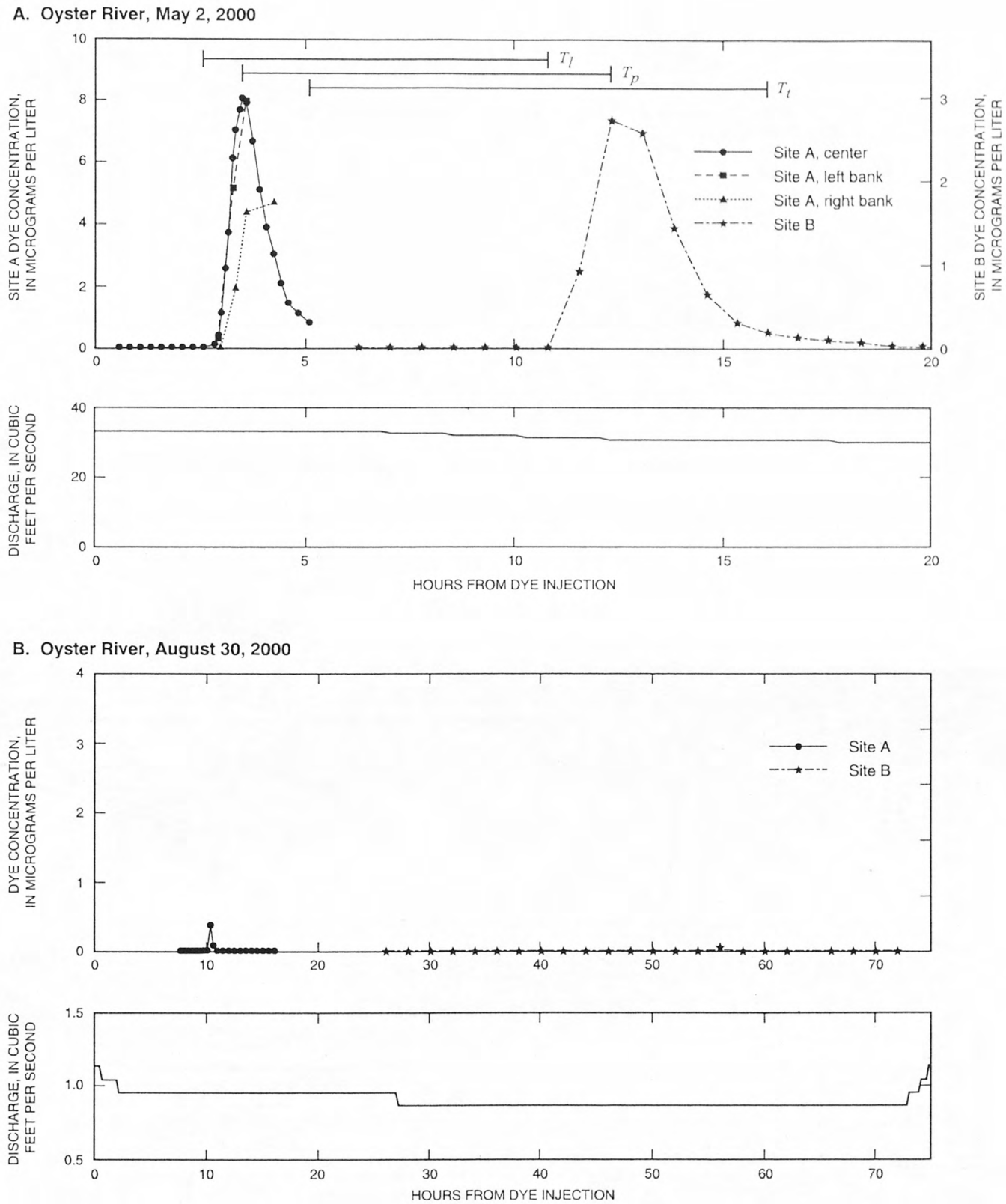


Figure A10. Discharge, dye concentration, and time for sampling sites on the Oyster River, New Hampshire; A, May 2, 2000; B, August 30, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01073000. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 11 for location of stream-gaging station and sampling sites.

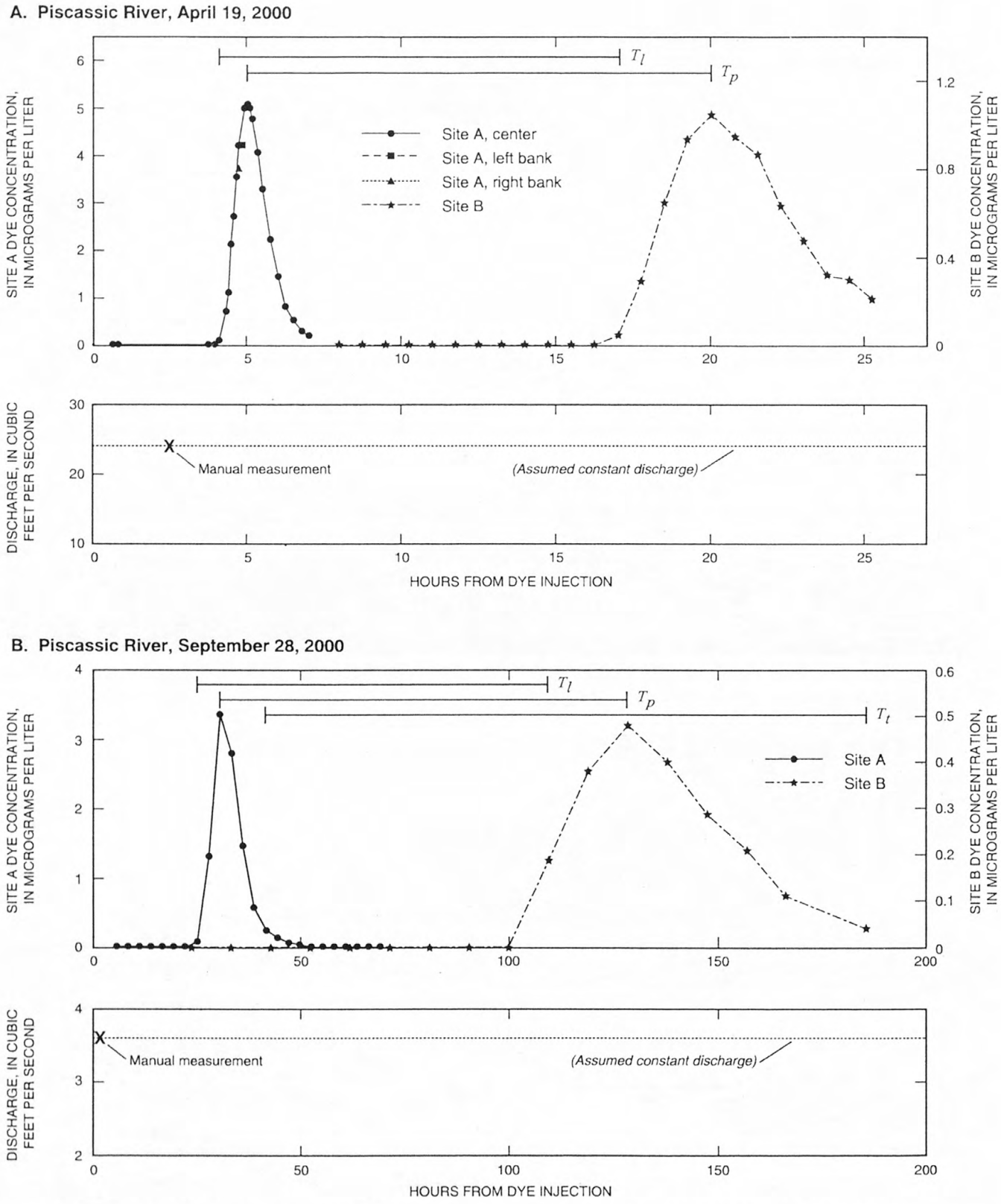
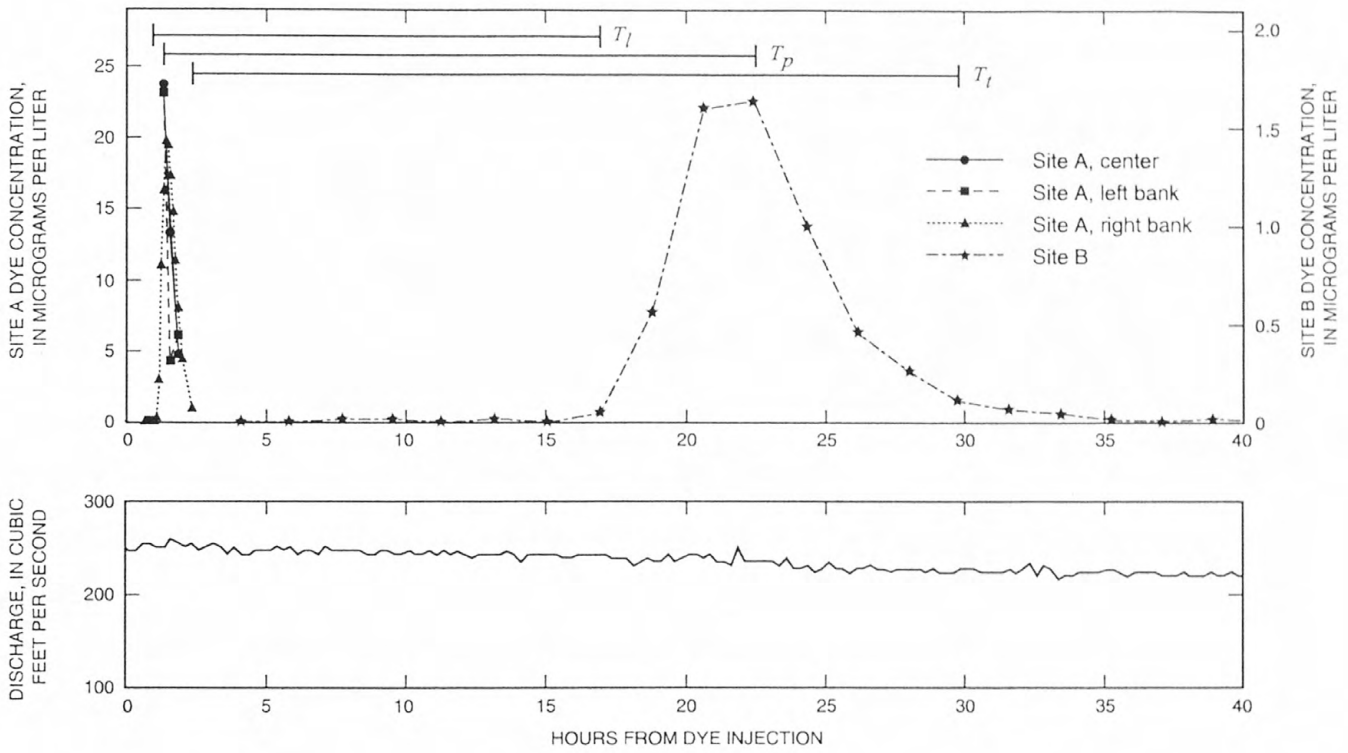


Figure A11. Discharge, dye concentration, and time for sampling sites on the Piscassic River, New Hampshire; A, April 19, 2000; B, September 28, 2000. Discharge measured manually at sampling site A. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 8 for location of sampling sites.

A. Salmon Falls River, May 15, 2000



B. Salmon Falls River, September 12, 2000

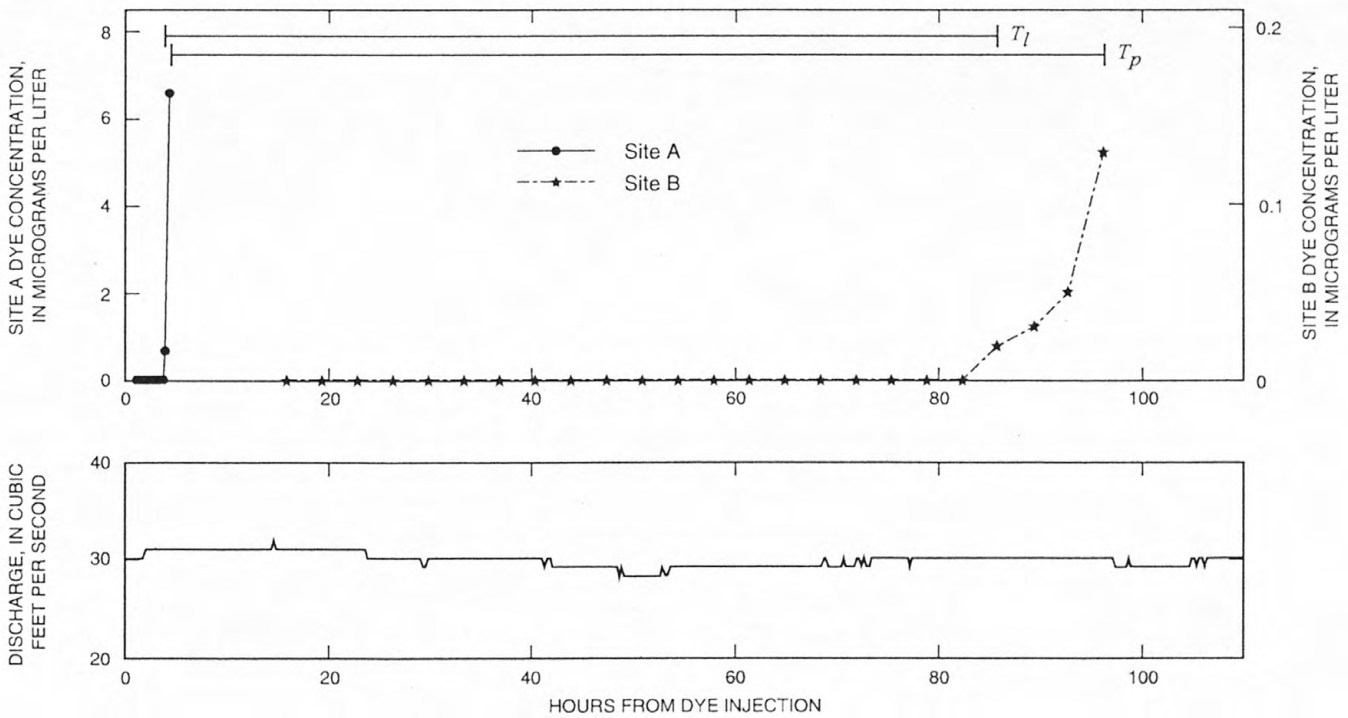


Figure A12. Discharge, dye concentration, and time for sampling sites on the Salmon Falls River, New Hampshire; A, May 15, 2000; B, September 12, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01072100. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 12 for location of stream-gaging station and sampling sites.

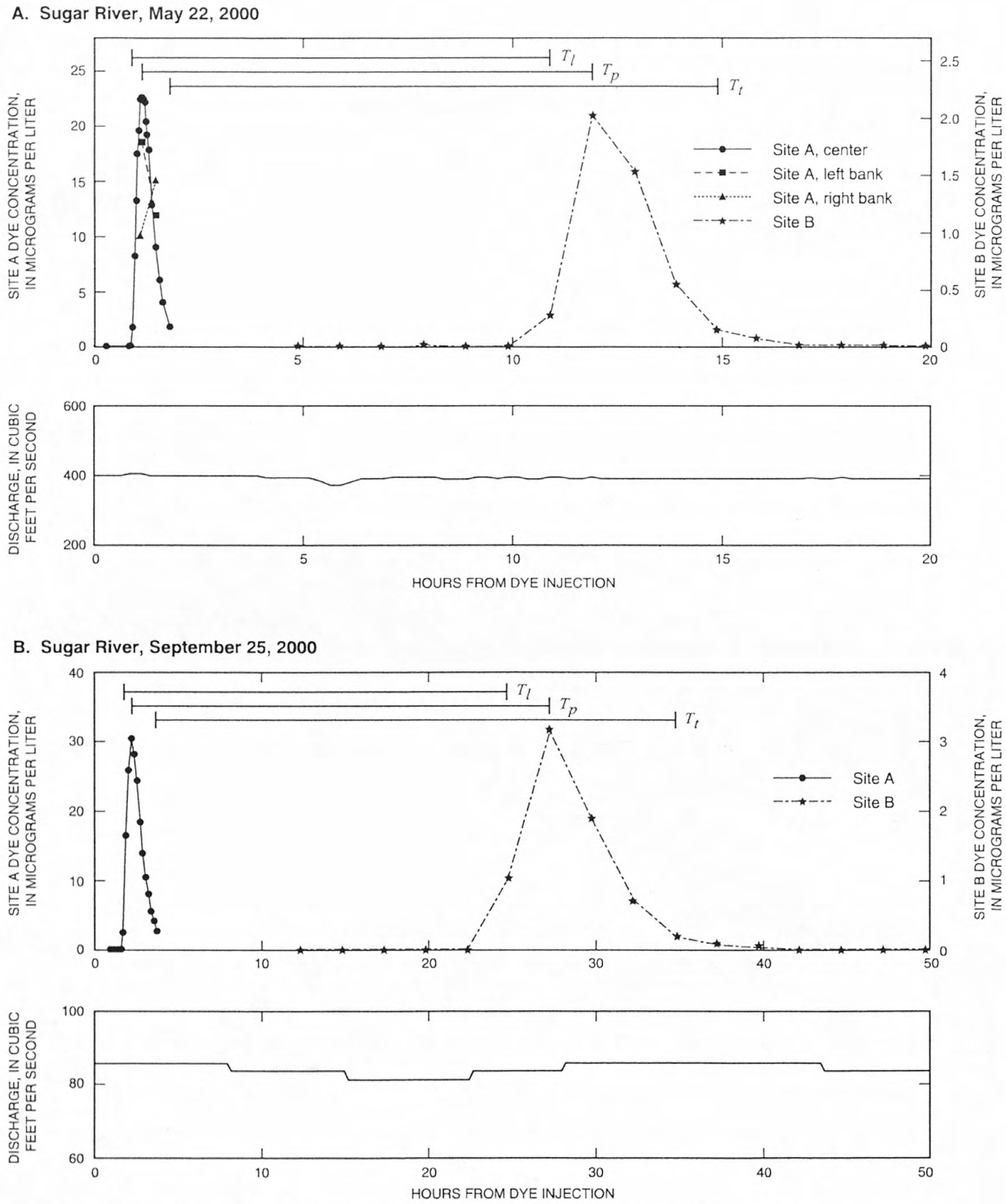


Figure A13. Discharge, dye concentration, and time for sampling sites on the Sugar River, New Hampshire; A, May 22, 2000; B, September 25, 2000. Discharge measured at U.S. Geological Survey stream-gaging station number 01152500. Length of horizontal bar between tick marks equals travel time between sampling sites. T_l, travel time of dye-cloud leading edge; T_p, travel time of dye-cloud peak; T_t, travel time of dye-cloud tail. Symbols indicate sample points. See figure 13 for location of stream-gaging station and sampling sites.

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