
4.0 HYDROLOGIC DATA COLLECTION SUMMARY

Streamflow measurements and time of travel measurements were collected as part of the Assabet River data collection program. Reference hydrologic data, streamflow measurements, and time of travel measurements are summarized below.

4.1 Reference Hydrologic Data

The United States Geologic Survey (USGS) maintains a continuous-recording streamflow gauging station on the Assabet River at Maynard (RM 7.4). [Figures 4-1, 4-2, and 4-3](#) contain daily average streamflow measurements collected at the USGS Maynard gauge during the Summer of 1999, the Winter/Spring of 2000, and the Summer of 2000, respectively. Daily precipitation data were also collected by the USGS at the Maynard gauge and are presented in these figures. Assabet River surveys are indicated in the figures to place each survey in hydrologic and meteorologic context. Measurements provided by the USGS streamflow gauging station at Maynard are an invaluable hydrologic reference resource.

4.2 Streamflow Measurements

Streamflow measurements were collected during 7 field surveys in the Assabet River and its tributaries. [Table 4-1](#) contains a summary of all streamflow measurements collected as part of the field program. USGS Maynard streamflow measurements collected concurrently with ENSR field measurements are provided in italics in [Table 4-1](#). The surveys captured streamflows under a range of flow conditions including summer low-flow (July 1999), summer below-average flow (August 2000), and winter flow conditions (February and March 2000).

Streamflow measurements collected during each survey are summarized below. A complete set of streamflow and associated measurements, including average water velocity, water levels, stage, river cross-sectional area, and river widths, is provided in Appendix A.

4.2.1 Intensive Summer 1999 Survey

[Figure 4-1](#) contains daily average streamflow measurements collected at the USGS Maynard gauge during July and August 1999. Daily average flows during the survey (July 19 – 25, 1999) ranged from 14 cfs to 22 cfs and were typically near 15 cfs. A rainfall event occurred towards the end of July 19, 1999 and resulted in an increase in streamflow at the Maynard gauge on July 20.

The $7Q_{10}$ flow at the Maynard gauge is estimated to be between 4.5 and 15.1 cfs (see Section 2.3.1). Based on these estimates of $7Q_{10}$ flow, river flowrates during the July 1999 survey were at or near

7Q₁₀ levels indicating that the survey was successful in capturing worst-case conditions in terms of minimal river flow.

On July 19 and July 21, 1999, streamflow measurements were collected at 4 river locations and 2 tributary locations. Streamflow measurements were collected on July 19, 1999, prior to commencement of a rainfall event. The rainfall event subsequently led to the postponement of sampling activities on July 20. Sampling was resumed on July 21, 1999. [Table 4-1](#) contains streamflow measurements collected during each of the two days of the July 1999 survey. Average water velocity measurements ranged from 0.2 to 0.5 ft/sec (see Appendix B-1). Review of the USGS Maynard gauge streamflow record ([Figure 4-1](#)) indicates that sampling was performed just prior to an increase in streamflow (on July 19) and during a decrease in streamflow (on July 21) associated with the precipitation event. Measurement of streamflow was intended to occur during “steady-state” or nearly constant conditions. Thus, the streamflow measurements collected during the July 1999 survey are useful, but not ideal for characterizing spatial variations in flow throughout the river.

4.2.2 Intensive Summer 2000 Survey

On August 28, 2000, ENSR measured instantaneous streamflow at 8 river locations and 10 tributary locations. Streamflow measurements collected during the Summer 2000 survey (#10) are presented in [Table 4-1](#). The Assabet River was experiencing below-average summer-time streamflow conditions (40 cfs) during Summer 2000 survey (based on the USGS Maynard gauge historic record, see [Figure 2-3](#)). Streamflow near the headwaters was nearly zero (0.01 cfs at RM 30.7) and increased to 11 cfs over the next 5 miles (at RM 25.6). Streamflows were observed to double in magnitude over the next 6 miles to a flowrate of 23 cfs at RM 19. Over the next 10 miles, streamflow increased by 50% reaching a flowrate of 35 cfs at RM 8.6 and remained nearly constant for the remaining 8 rivermiles to its mouth.

Assabet River tributary flows from Nashoba Brook, Elizabeth Brook, and North Brook were most substantial with measured streamflows of 9 cfs, 4 cfs, and 3 cfs, respectively. Measured streamflows from the remaining 7 tributaries were each 1.0 cfs or less. By comparison, the flow in the Assabet River at Maynard Street, Westborough(RM 30.7) was smaller than the flow from any of the 10 largest tributaries. Also, the flow entering from Nashoba Brook was of similar magnitude as the total Assabet River flow at Allen Street in Hudson, RM 25.1 (9 cfs and 11 cfs, respectively).

A simple water budget estimate based on the August 2000 survey indicates the following percentage distribution of total streamflow:

- Headwater contribution: ~0% (contributing 0.1 cfs of 35 cfs total)
- Tributary contribution: ~61% (contributing 21.3 cfs of 35 cfs total)
 - Nashoba Brook: ~26%
 - Elizabeth Brook: ~11%

- North Brook: ~9%
- Several Other tributaries: ~15%
- Point source contribution: ~ 34% (contributing ~12 cfs of 35 cfs total)

This simple water budget accounts for 95% of measured flow, but neglects important water balance processes, such as evaporative losses, groundwater/surface water exchange, and effects of impoundments on water movement.

4.2.3 Dry-weather surveys

Streamflow measurements were collected during the second and third dry-weather surveys (#3 and #5) in February and March 2000. Streamflow measurements collected during these surveys are presented in [Table 4-1](#). During this time, the Assabet River was experiencing winter baseflow conditions with streamflow five to ten times greater than that of summer-time conditions.

On February 8 and 9, 2000 (survey #3), streamflow measurements were collected at 9 river locations and 4 tributary locations. As seen in the Summer 2000 data, streamflow steadily increased with distance downstream from the headwater flow of 5 cfs (RM 30.7) to a flow of 95 cfs near the confluence (RM 6.1). Tributary streamflow measurements collected during the February dry-weather survey ranged from 5 cfs to 33 cfs, representing a significant portion of the total Assabet River flow.

On March 27, 2000 (survey #5), streamflow measurements were collected at 6 river locations and 9 tributary locations. High waters and strong currents made streamflow measurement untenable in some downstream river sampling locations (e.g., at RM 13.9). Streamflow measurements collected on March 27, 2000 were immediately prior to a rainfall event ([Figure 4-2](#)) included in the wet-weather survey program. Thus, tributary streamflow measurements performed on March 27, 2000 support both dry-weather (#5) and wet-weather (#6) baseflow assessments. On March 27, 2000, river streamflow measurements ranged from 16 cfs near the headwaters (RM 30.7) to 250 cfs in Maynard (RM 7.2). Tributary streamflow measurements ranged from 7 cfs to 76 cfs, representing a significant portion of the total Assabet River flow

4.2.4 Wet-weather Surveys

As part of each wet-weather tributary survey, streamflow measurements were collected at 10 tributary locations prior to commencement of a rainfall event. Streamflow data for the three wet-weather surveys (surveys #4, #6, and #12) are presented in [Table 4-1](#). Streamflow measurements collected during each of the wet-weather surveys were well correlated with basin areas of the tributaries.

On March 16, 2000 (survey #4), streamflow measurements were collected in the 10 tributaries. Tributary streamflow measurements ranged from 9 cfs to 163 cfs. The concurrent streamflow in the

Assabet River at Maynard was 375 cfs. Streamflow in Nashoba Brook was more than double that of the next largest tributary. Of the ten tributaries measured, Nashoba Brook has the largest contributing watershed area. Flows from Elizabeth Brook (77 cfs) and North Brook (50 cfs) were the next largest contributors.

On March 27, 2000 (survey #6), streamflow measurements were collected in the 10 tributaries. Tributary streamflow measurements ranged from 7 cfs to 76 cfs. The concurrent streamflow in the Assabet River at Maynard was 250 cfs. Of the ten tributaries measured, Nashoba Brook (76 cfs), Elizabeth Brook (44 cfs) and North Brook (35 cfs) were the largest contributors.

On September 12, 2000 (survey #12), streamflow measurements were collected in the 10 tributaries. Tributary streamflow measurements ranged from 0 cfs to 6 cfs. The concurrent streamflow in the Assabet River at Maynard was 30 cfs. Of the ten tributaries measured, Nashoba Brook (6 cfs), Elizabeth Brook (5 cfs) and North Brook (2 cfs) were the largest contributors.

4.3 Time of Travel Measurements

Time of travel measurements were collected to support mathematical modeling of the Assabet River system and to support the overall water quality assessment. Time of travel is important because the impact of chemical and biological processes of water in the system is time-dependent. For example, the impact of sediments and biological growth on water quality in river impoundments is a function of the time period that a given water parcel is in the river impoundment. The time of travel surveys were performed by releasing a conservative substance into the river and measuring how long it took to reach a downstream location. Through this process, the time of travel, residence time, and longitudinal dispersion characteristics of the river were measured.

Two surveys were performed to measure the time of travel of water moving through the Assabet River system. The results of each time of travel survey are presented below.

4.3.1 May 2000 Time of Travel Survey

A conservative and inert substance, Rhodamine WT dye, was released into the Assabet River at Boon Road, Stow (RM 11.4) in a single event (i.e., one “pulse” of dye) at 8:53 PM on Tuesday, May 9, 2000. Dye concentration measurements were collected 2.8 miles downstream at Rt. 117/62, Maynard (RM 8.6). The May 2000 time of travel survey measured the residence time of the Ben Smith Impoundment and adjacent reaches (see [Figure 3-1](#)).

[Figure 4-4](#) presents dye concentration measurements collected during the May 2000 survey at RM 8.6. The average USGS Maynard streamflow at the time of the survey is also presented in [Figure 4-4](#). The average USGS Maynard streamflow was 266 cfs for the survey period.

In the May 2000 survey, the mean time of travel was estimated to be ~0.84 days (20 hours and 17 minutes) and the average velocity was estimated to be 0.20 ft/sec. Mean dye travel time is defined as the time to the centroid (center of gravity) of the area under the time-concentration curve (Figure 4-4). To estimate mean travel time, the tail of the curve in Figure 4-4 was extended to the time when dye concentrations returned to background level using an exponential decay term. Area under the curve was calculated using the trapezoidal rule for integration (the sum of average concentrations multiplied by difference in times for each interval).

4.3.2 September/October 2000 Time of Travel Survey

Rhodamine WT dye was released into the Assabet River at Boon Road, Stow (RM 11.4) in a single event at 1:48 PM on Thursday September 28, 2000. Dye concentration measurements were collected at the following two downstream locations:

- At Rt. 117/62, Maynard (RM 8.6), below Ben Smith Impoundment and a distance of 2.8 miles downstream of the release point, and
- At Damonmill, Concord (RM 4.4), below Powdermill Impoundment and a distance of 7.0 miles downstream of the release point.

The September/October time of travel survey measured the residence time of the Ben Smith Impoundment, the Powdermill Impoundment, and adjacent reaches. Figure 4-5 presents dye concentration measurements collected at RM 8.6 and RM 4.4. USGS Maynard streamflow measurements are also presented in Figure 4-5. The average USGS Maynard streamflow measurement was 55 cfs during the study period.

Mean time of travel to the two sampling locations was estimated to be:

- Total distance 7.0 miles (Boon Road to Damonmill): ~4.7 days (112 hours 47 minutes)
- First reach (2.8 miles), including Ben Smith Impoundment: ~3.4 days (81 hours 32 minutes)
- Second reach (4.2 miles), including Powdermill Impoundment: ~1.3 days (31 hrs. 15 minutes)

Average river velocity estimated to be:

- Total distance (7.0 miles): 0.09 ft/sec
- First reach (2.8 miles): 0.05 ft/sec
- Second reach (4.2 miles): 0.20 ft/sec

Mean travel time was calculated using the method described in Section 1.6.2.1 above.

4.4 Summary

The following observations were made of hydrologic conditions in the Assabet River during the data collection program.

During the Summer 1999 survey:

- Streamflows were near 7Q₁₀ conditions (15 cfs at USGS Maynard gauge);
- Average water velocity measurements ranged from 0.2 to 0.5 ft/sec (~6 miles/day) in free-flowing (i.e. not impounded) reaches; and
- POTW effluent flows accounted for approximately 80% of river streamflows.

During the Summer 2000 survey:

- Streamflows were below-average for summer-time conditions (40 cfs at USGS Maynard gauge compared to an August average streamflow of 60 cfs);
- Average water velocity measurements typically ranged from 0.5 to 0.7 ft/sec (~10 miles/day) in free-flowing reaches;
- POTW effluent flows accounted for approximately 34% of river streamflows;
- Tributary streamflows accounted for approximately 61% of river streamflows with Nashoba Brook, Elizabeth Brook, and North Brook accounting for 75% of tributary flows.

During Dry-weather and Wet-weather surveys:

- Streamflows were measured under four different hydrologic regimes associated with USGS Maynard gauge streamflows of 30 cfs, 110 cfs, 250 cfs, and 350 cfs, and
- Nashoba Brook, Elizabeth Brook, and North Brook were consistently observed to be the largest tributary streamflows.

Time of Travel Studies

- Under relatively high streamflow conditions (266 cfs), the time of travel through the Ben Smith Impoundment (total distance 2.8 miles) was less than 1 day (20 hours).
- Under average summer-time streamflow conditions (55 cfs), the time of travel through the Ben Smith Impoundment was 3.4 days.

- Under average summer-time streamflow conditions (55 cfs), the time of travel through the Powdermill Impoundment and adjacent reaches (total distance 4.2 miles) was 1.3 days.

The hydrologic data collection program was successful in capturing streamflow, water velocity, and time of travel measurements under a variety of conditions. Hydrologic measurements will be applied to support estimates of nutrient loadings throughout the river system and to support the hydrologic component of the mathematical model of the Assabet River.

Table 4-1 Summary of Streamflow Data Collection Results for All Surveys (in cfs)

Sample Location			Survey1 – Summer 1999	Survey 3- Dry Weather	Survey 4 - Wet Weather	Survey 5 – Dry-weather	Survey 6 – Wet Weather	Survey 10 - Summer 2000	Survey 12 - Wet Weather
Station	Rivermile	Description	July 19 and 21, 1999	February 8-9, 2000	March 16, 2000	March 27, 2000	March 27, 2000	August 28th, 2000	September 12, 2000
R28	30.7	Maynard St. Westboro		5	21	16		0.1	
R27	29.8	Rt. 9 Westboro							
R26	28.9	Rt. 135 Westboro							
R25	28.0	School St. Northboro	5						
R24	25.9	River St. Northboro		23		80			
R23	25.1	Allen St. Impoundment						11	
R22	25.0	Below Allen St. Impoundment							
R21	23.9	Boundary St. Marlborough		40		87			
R20	23.5	Robin Hill Rd. Marlborough							
R19	21.7	Bigelow Rd. Berlin	16	47		118			
R18	19.2	Chapin Rd. Hudson						23	
R17	17.9	Hudson Center Impoundment							
R16	17.6	South St., Hudson		50		136			
R15	15.9	Cox St. Hudson	13	54		113		28	
R14	15.8	Below Cox St. Hudson							
R13	14.1	Gleasondale Impoundment							
R12	13.9	Below Gleasondale Dam, Stow		62				26	
R11	11.4	Boon Road, Stow							
R10	9.2	White Pond Road, Maynard							
R9	8.7	Ben Smith Impoundment							
R8	8.6	Rt. 117/62 Maynard						35	
R7	7.4	USGS Gauge, Maynard	15,16	147,111	375	250	250	40	30
R6	6.2	Powder Mill Impoundment							
R5	6.1	Below Powder Mill Dam		95				34	
R4	4.4	Damonmill, Concord							
R3	3.1	Rt. 62, Concord	18						
R2	2.4	Rt. 2 Bridge, Concord							
R1	1.6	Park Street, Concord						35	

Station	Tributary Sampling Locations		Summer 1999	Winter 2	Wet-weather 1	Winter 3	Wet-weather 2	Summer 2000	Wet-weather 3
T11	29.4	Hop Brook, Westboro	0.6	5	22		16	0.9	0.7
T10	26.0	Cold Harbor Brook, Northboro			23		17	0.5	0
T9	24.3	Stirrup Brook, Marlborough			9		7	0.2	0.1
T8	22.4	North Brook, Berlin		11	50		35	3	2
T7	18.1	Hog Brook, Hudson			10		9	1.0	0.6
T6	17.8	Mill Brook, Hudson			24		10	0.9	0.5
T5	12.9	Ft. Meadow Brook, Hudson			13		8	1	0.4
T4	9.4	Elizabeth Brook, Maynard		14	77		44	4	5
T3	4.3	Second Division Brook, Concord							
T2	3.0	Nashoba Brook, Concord	2	33	163		76	9	6
T1	1.3	Spencer Brook, Concord			21		16	0.8	0.1

Note: Streamflow units are cubic feet per second (cfs)

Figure 4-1 Summer Survey 1999: Assabet River Streamflow and Precipitation Data for Intensive

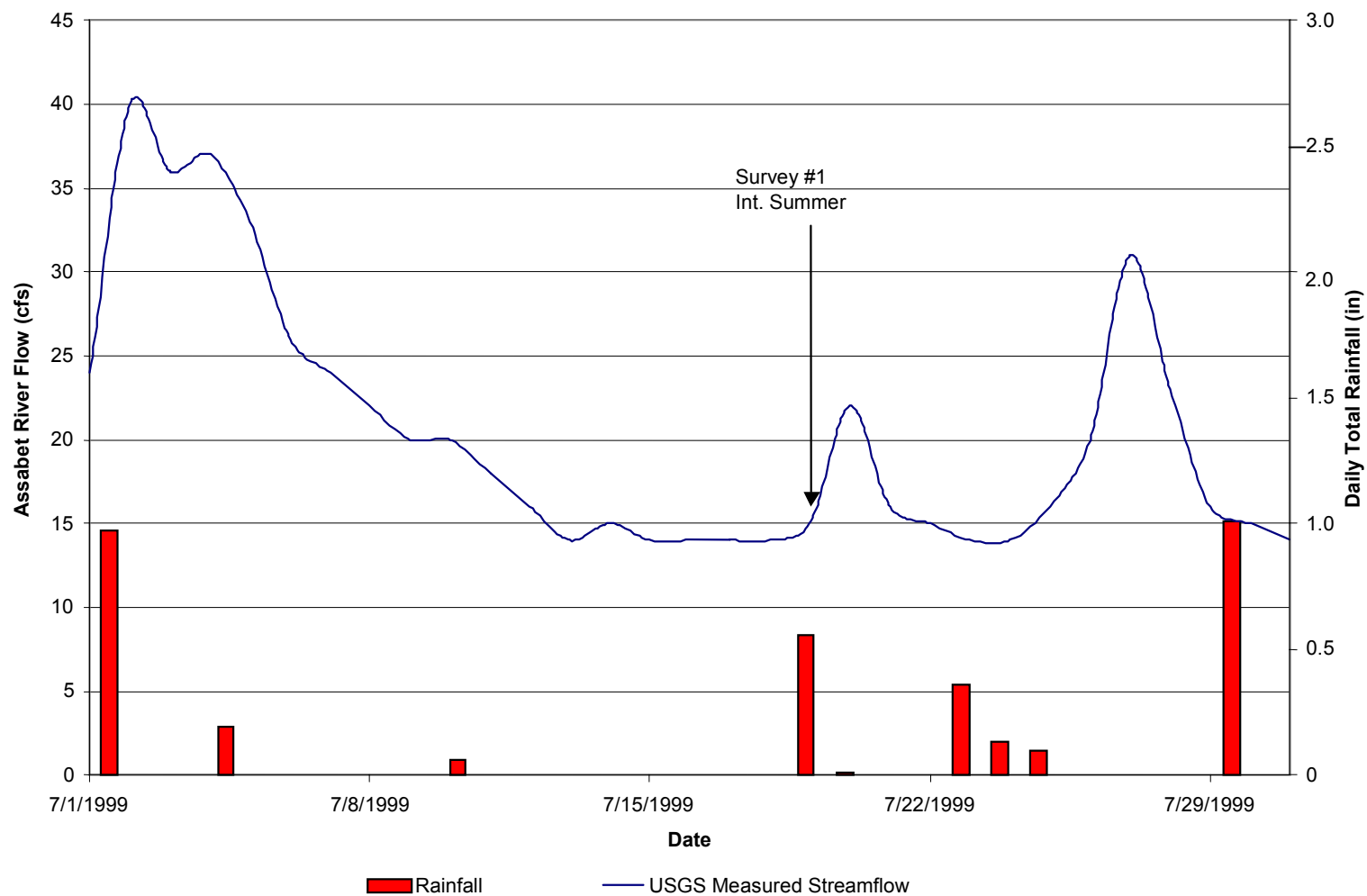


Figure 4-2 Surveys #2-#8: Assabet River Streamflow and Precipitation Data at USGS Maynard (RM 7.4)

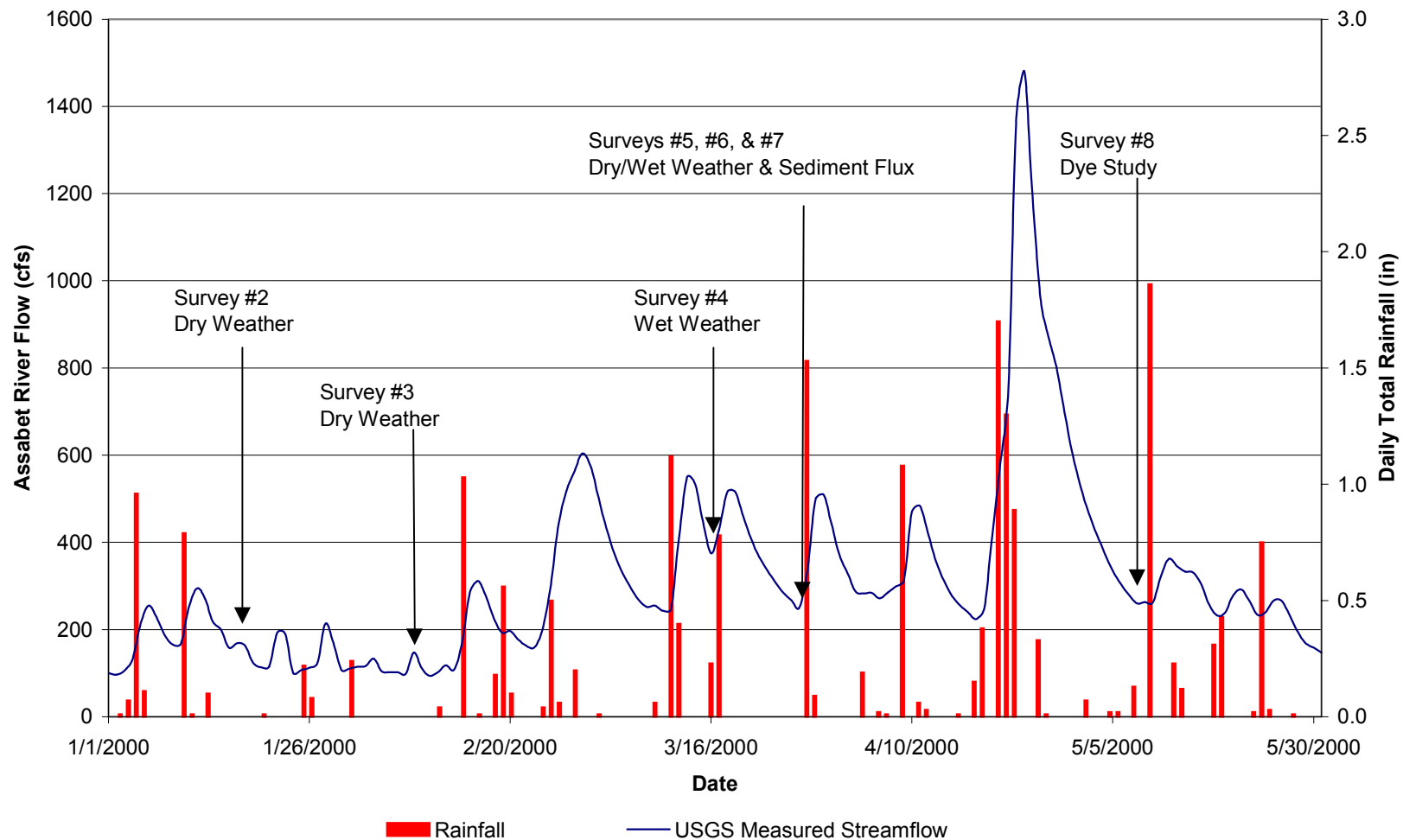


Figure 4-3 Surveys #10-#13: Assabet River Streamflow and Precipitation Data at USGS Maynard (RM 7.4)

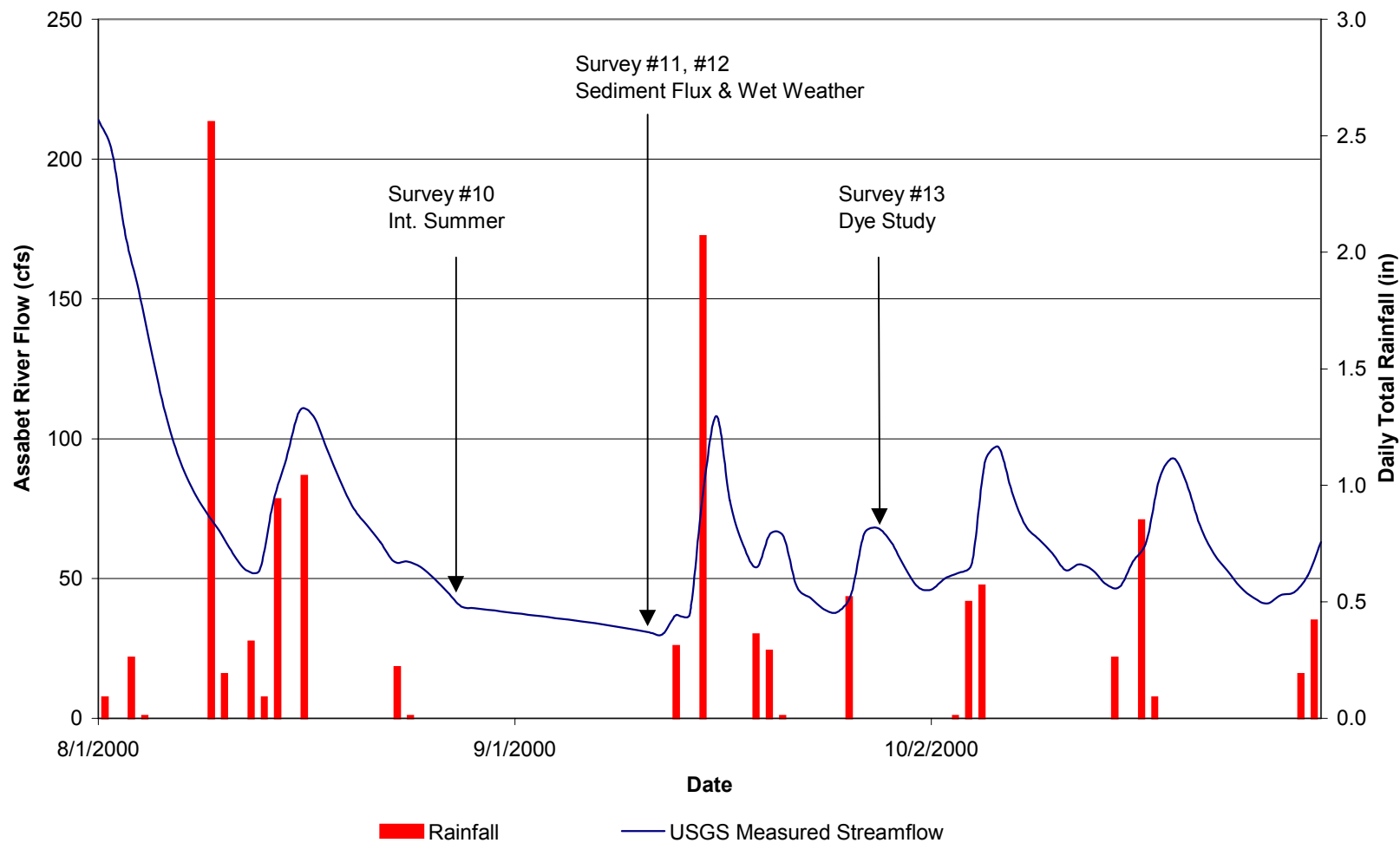


Figure 4-4 May 2000 Time of Travel Survey: Dye Concentration vs. Time at Rt. 117/62 (RM 8.6)

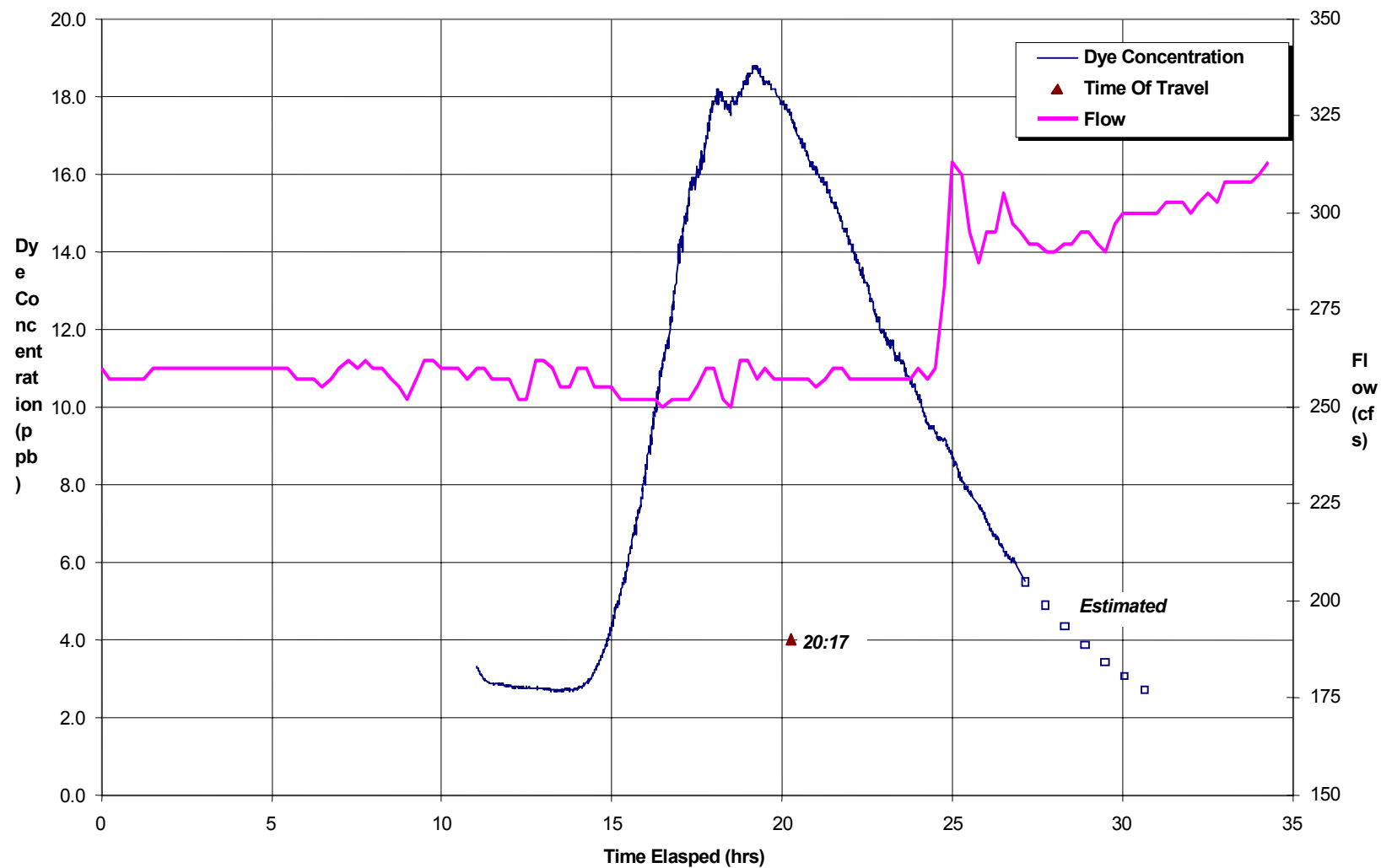


Figure 4-5 September/October 2000 Time of Travel Survey: Dye Concentration vs. Time at Two Locations (RM 8.6 and RM4.4)

