# Supplemental Final Report

Post-BMP Implementation Monitoring Results for the
Cooper Township Agricultural Site #2 Area A:

Potential for a Small-scale Agricultural Site to Generate
Phosphorus Credits in the Kalamazoo River Watershed

*Project 97-IRM-5C*

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**<u>"DISCLOSURE"</u>**

# Table of Contents

# LIST OF FIGURES

# LIST OF TABLES

## 1.0 PROJECT BACKGROUND

A community-based water quality trading demonstration project was initiated in July of 1997 to improve water quality and demonstrate how point/non-point source trading for phosphorus could be conducted in selected reaches of the Kalamazoo River Watershed of Michigan. The demonstration project was funded in part by the Water Environment Research Foundation (WERF) (including funds from EPA Assistance Agreement X824468).

The project established a local framework for trading, plus implemented and monitored voluntary non-point source (NPS) reductions to generate trading credits. Credits were for use by point source dischargers to accommodate growth and flexibility while complying with water quality-based effluent limitations. The project framework required surplus NPS reductions (i.e., reductions greater than those established by regulation, rule or permit) in order to generate a credit. Credits had to represent real reductions beyond an existing condition where physical or managerial improvements were made to create such a reduction. Credits also had to be quantifiable (measurable or estimated based on data, monitoring or established estimation techniques). A 2:1 trading ratio was adopted to provide a net loading reduction and water quality benefit with each trade. Two pounds of non-point source phosphorus reduction were required for each pound to be used by a point source.

Six non-point source demonstration sites were selected for the project. Of the two agricultural sites participating as partners in the project, the Cooper Township Agricultural Site #2 had extensive monitoring data collected from a nearby receiving stream discharging to the Kalamazoo River. Thirteen storm events were monitored from mid-May to mid-October of 1999 to estimate total phosphorus and sediment loads attributable to agricultural operations at this site.

These monitoring data were collected prior to implementation of Best Management Practices (BMPs) at the site. BMPs were ultimately installed after the formal completion of this WERF-funded project and following the publication of the project report (Kieser, 2000). Results of pre-implementation monitoring, and estimated load reductions were detailed in Appendix D of the final project report. Actual implementation of site controls (BMPs) occurred in December of 2000. These included animal exclusion from the stream, grass filter strips and manure management. As installation occurred after the formal completion of the project, inclusion of any post-implementation sampling results in the final report was not possible. This post-BMP implementation sampling was originally viewed as an important and planned element of the project to confirm water quality loading reductions, as well as verify the validity of loading estimates and models used to establish credits.

At the formal conclusion of the Trading Demonstration Project, unexpended funds from WERF were utilized to conduct post-implementation monitoring. The monitoring approach focused on sampling immediately below the agricultural site at locations consistent with pre-implementation monitoring. Previously conducted downstream monitoring near the receiving stream's confluence with the Kalamazoo River was not undertaken. Sufficient information was gleaned from early monitoring to examine delivery issues associated with the agricultural site's distant upstream location from the River (Kieser, 2000).

This Supplemental Final Report presents the results of monitoring conducted at the Cooper Township Agricultural Site #2. Data are used to:

- Determine whether loading reductions have occurred following BMP implementation.
- Assess the efficiency of BMPs installed at the site based on percent load reduction from baseline conditions.

- Examine the utility of simple loading models that may be used in trading projects to estimate non-point source loading reductions.
- Calculate the actual credits and costs per pound of phosphorus reduction for the site improvements.

## 2.0 SITE DESCRIPTION

The Cooper Township Agricultural Site #2 is located in Section 11 of Cooper Township (T1S, R11W) in Kalamazoo County, Michigan. Two areas of this site (Area A and Area B) were studied for the trading project. A series of BMPs were implemented in December 2000 for the small animal holding Area A while no changes were made in Area B (see Appendix D and Figure D-9 of Kieser, 2000). Post-implementation monitoring conducted by Kieser & Associates occurred in 2001 for Area A.

Area A consists of an eighteen-acre ‘hobby farm’ with a barn and feedlot area. Four fenced pastures covering twelve acres contained six horses and three steer which had access to a small tributary of the Kalamazoo River before BMPs were implemented. The stream banks at the animal access areas were highly eroded, and animal wastes could be deposited directly into the stream during watering visits.

The Natural Resources Conservation Service designed and installed a diversion watering system and relocated fencing to exclude livestock from the creek in December of 2000. A gravity fed pipe now transports approximately one-half of the stream flow from a point at the east end of the property, (the most upstream point of the creek on the property), to two watering troughs. Discharge water from the troughs flows through a vegetated swale before returning to the creek downstream of the former animal access area. Figure 1 illustrates the post-implementation condition of the property.

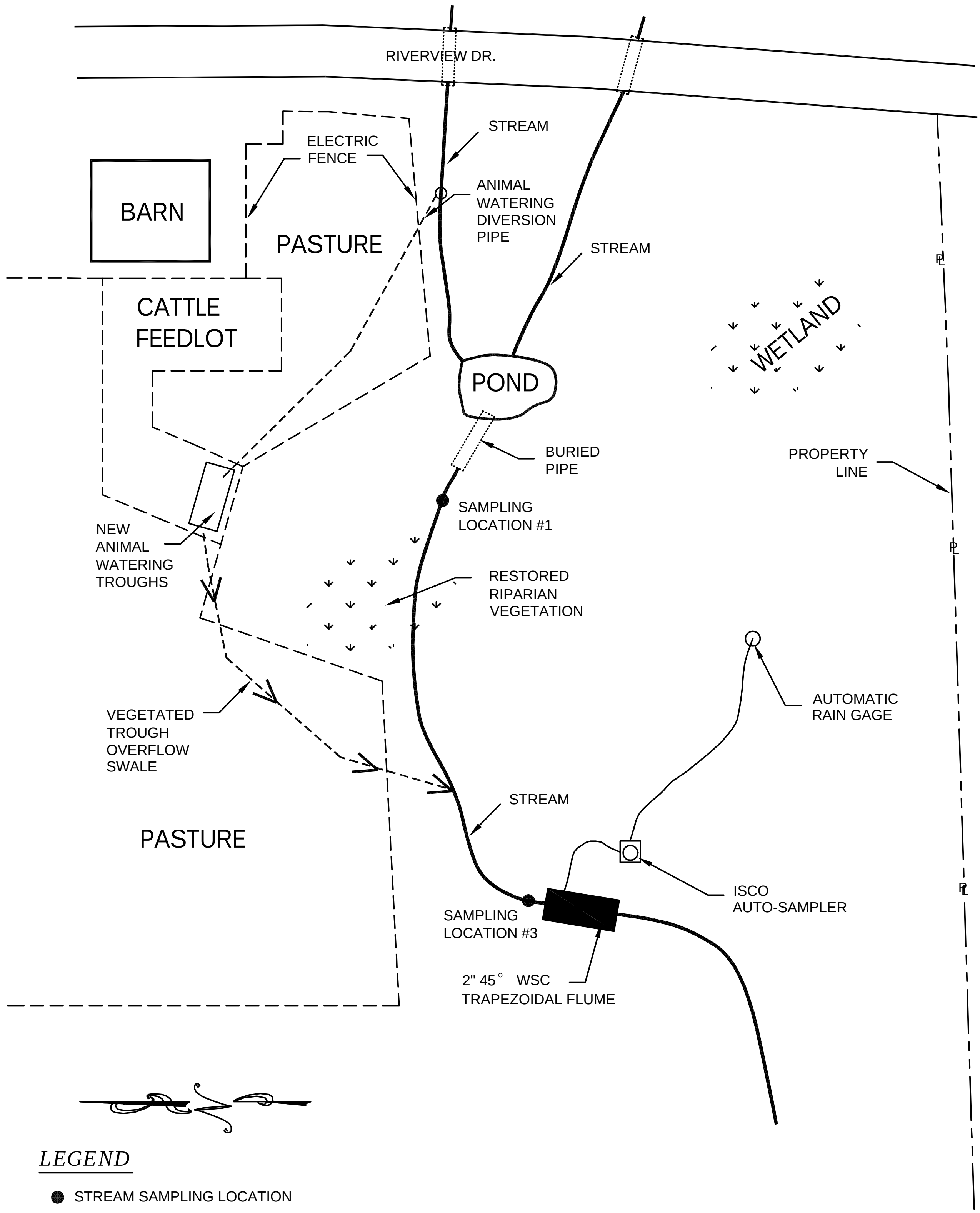
Following BMP implementation, the cattle were contained in small lots close to the barn, and the horses were contained in a large pasture no closer than thirty feet from the creek banks. The creek banks were stabilized and vegetation was re-established. As of this report, no visual evidence could be noted of historic animal impacts on the banks of the creek.

## 3.0 POST-BMP IMPLEMENTATION MONITORING

Post-BMP implementation water quality sampling was conducted in a manner consistent with pre-implementation monitoring during representative wet and dry periods in 2001 at Area A Sampling Locations #1 and #3. Nine storm events were monitored from April to August. All events were analyzed for total phosphorus (TP) and total suspended solids (TSS). Four of these events were also analyzed for soluble reactive phosphorus (SRP). All analyses were completed by the Upstate Freshwater Institute (UFI) of Syracuse, New York.

The first six wet weather events were monitored at Sampling Location #3 only (the location immediately downstream of the animal access and pastures of Area A). The last three were monitored at both Sampling Locations #1 and #3 (the upstream and downstream locations, respectively).

ISCO Autosamplers were used to monitor water levels continuously at five-minute intervals and to collect water samples during wet weather events at both locations. At Sampling Location #1, flow values were generated using a stage-discharge curve established during the pre-implementation monitoring for wet weather events. The curve, however, was not valid for low flow conditions due to an asymetrical channel geometry and seasonal rooted macrophyte growths at this upstream location that made precise comparisons of low flow measurements to stage height difficult. The originally installed 2-inch 45-degree trapezoidal




CONCEPTUAL DRAWING

NOT TO SCALE

Figure 1.
Conceptual Drawing for Area A of the Cooper Township Agricultural Site #2 Showing Sampling Locations and Land Use Modifications.

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flume at Sampling Location #3 was used to convert level readings to flows at the downstream station. (Early post-implementation flow monitoring at Location #3 was accomplished using a Global Water Level Logger.)

Eight baseline dry weather sampling events were additionally conducted from February to October, 2001. Samples were taken at 6:00 a.m., noon and 6:00 p.m. from both Sampling Locations #1 and #3. Samples were analyzed for total phosphorus and total suspended solids as well as soluble reactive phosphorus on selected occasions. Grab samples were collected manually, and flow measurements were collected using a March-McBirney Flow Mate 2000 Portable Flow Meter at Sampling Location #1. Flow measurements were computed at Sampling Location #3 by applying a standard equation to the levels measured by the Autosampler and the trapezoidal flume installed in the creek. Analytical results from both the wet and dry weather events are presented in Appendix A. (Appendix Table A-1 includes Location #3 wet weather data; Table A-2 contains wet weather data for Location #1; Table A-3 includes Location #3 dry weather data, and; Table A-4 includes Location #1 dry weather data.)

## 4.0 RESULTS

### 4.1 Wet Weather Sampling

Total phosphorus, soluble reactive phosphorus and total suspended solids were all measured in order to obtain an understanding of the nature of the loading to the creek related to BMP implementation. (Total phosphorus is the only parameter used for the phosphorus credit trading program with the trading currency expressed as pounds of TP reduced per year.)

Figures 2, 3 and 4 display total phosphorus, soluble reactive phosphorus and total suspended solids concentrations, respectively, measured during the May 14, 2001 storm event to illustrate the type of wet weather post-implementation monitoring data collected in this effort. This event lasted 15.5 hours and consisted of a 1.89-inch rainfall. The stream flow hydrograph is displayed in each figure to illustrate the behavior of the analytes in response to the hydrograph. Similar figures illustrating the eight other sampling events are presented in Appendix B for general reference.

Tables 1A and 1B present the characteristics of the storm events monitored at Sampling Locations #1 and #3, respectively. Loads passing each sampling location were calculated for each event using techniques consistent with pre-implementation monitoring (Kieser, 2000). (Low stream flows and thus, small changes in depth at Location #1 precluded accurate computation of corresponding flows in June, 2001.) Most storm events monitored during the post-implementation study consisted of rainfalls less than 0.7 inches. However, a 1.9-inch rainfall was monitored in May, 2001 and a 3-inch rainfall (statistically, a 10-year event) was monitored in August, 2001. Considerable loading occurred during the August event.

**Figure 2. Flow and Total Phosphorus Concentrations at Location #3, Area A of the Cooper Township Agricultural Site #2 during the May 14, 2001 Event.**

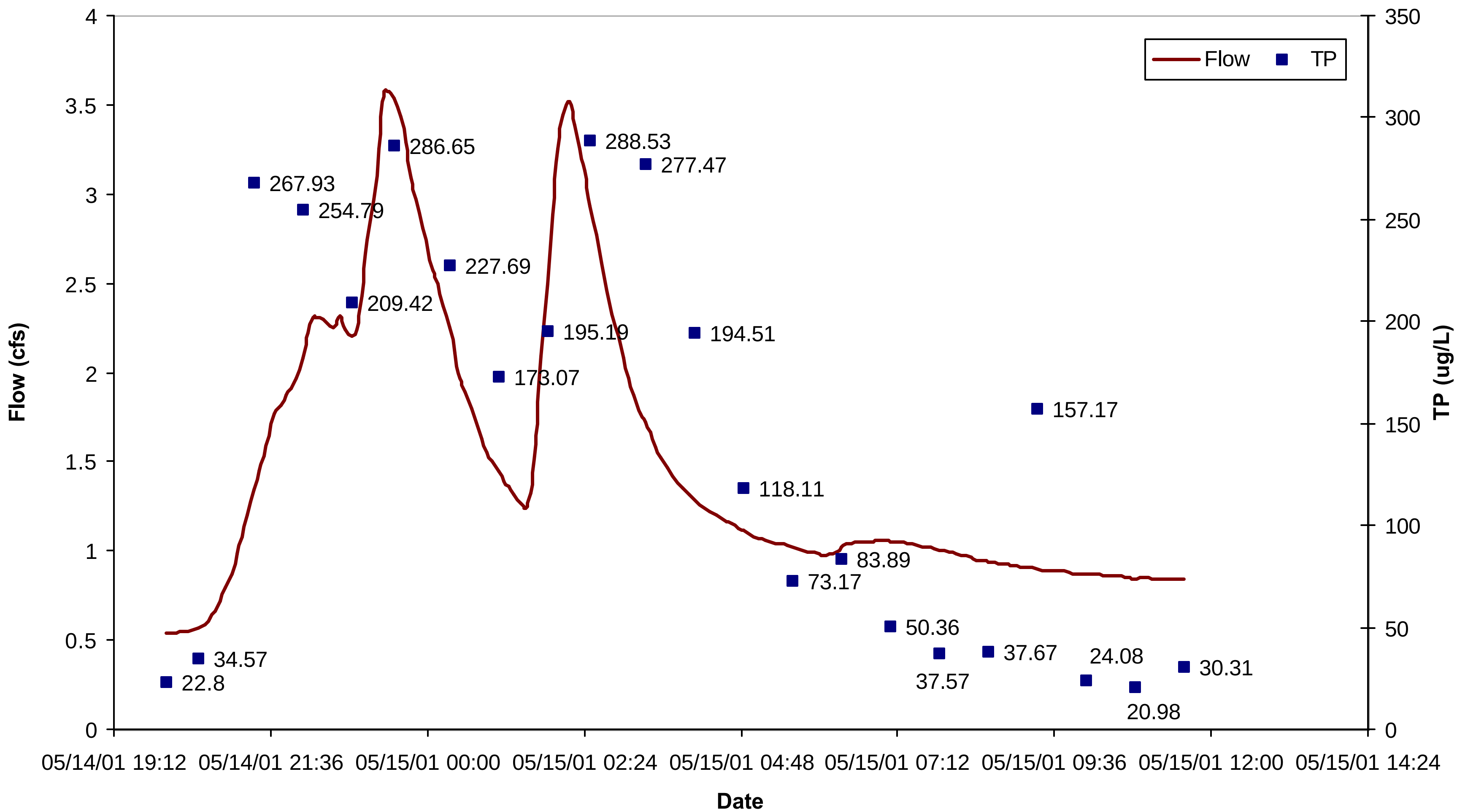


**Figure 3. Flow and Soluble Reactive Phosphorus Concentrations at Location #3, Area A of the Cooper Township Agricultural Site #2 during the May 14, 2001 Event.**

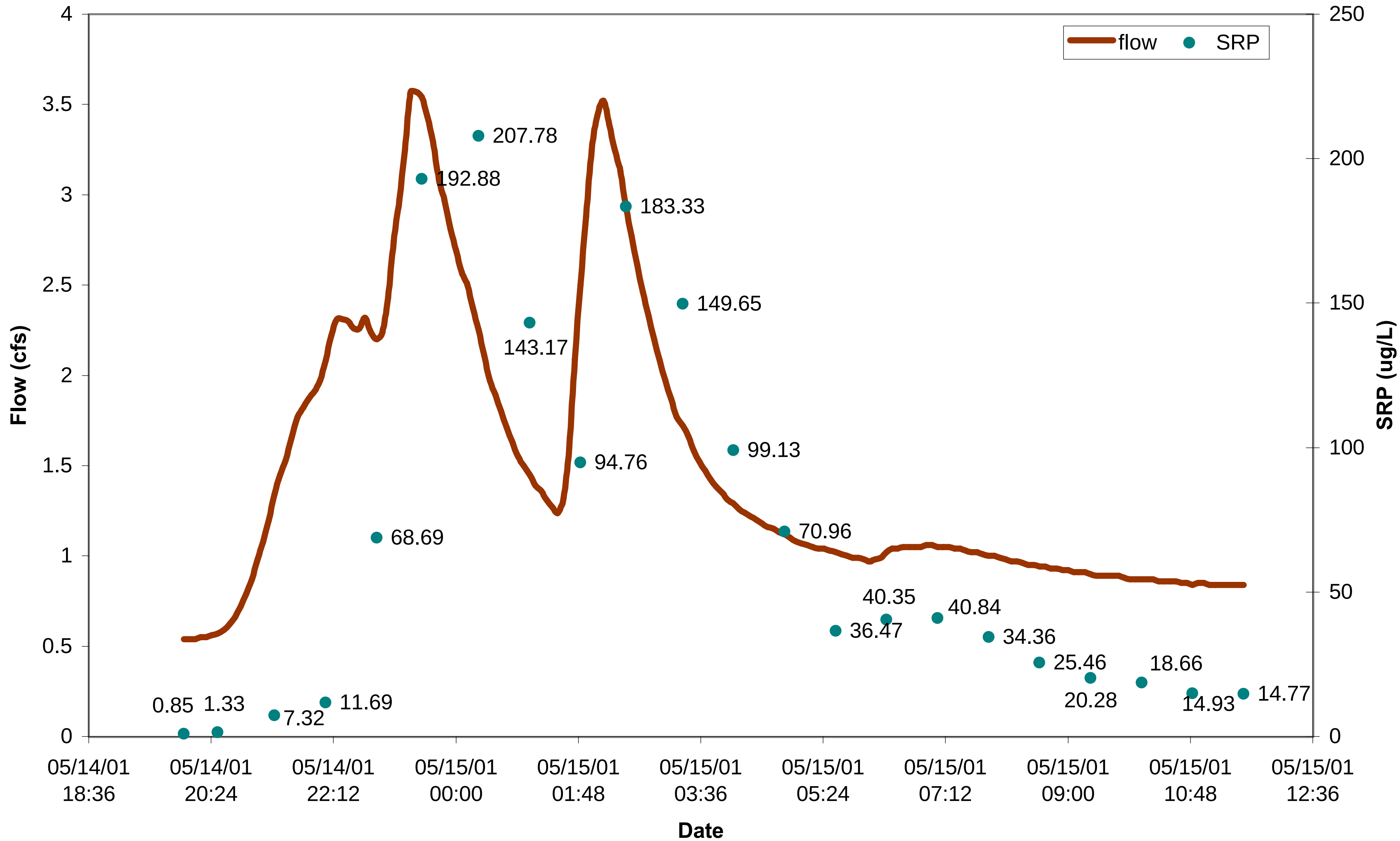


**Figure 4. Flow and Total Suspended Solids Concentrations at Location #3, Area A of the Cooper Township Agricultural Site #2 during the May 14, 2001 Event.**

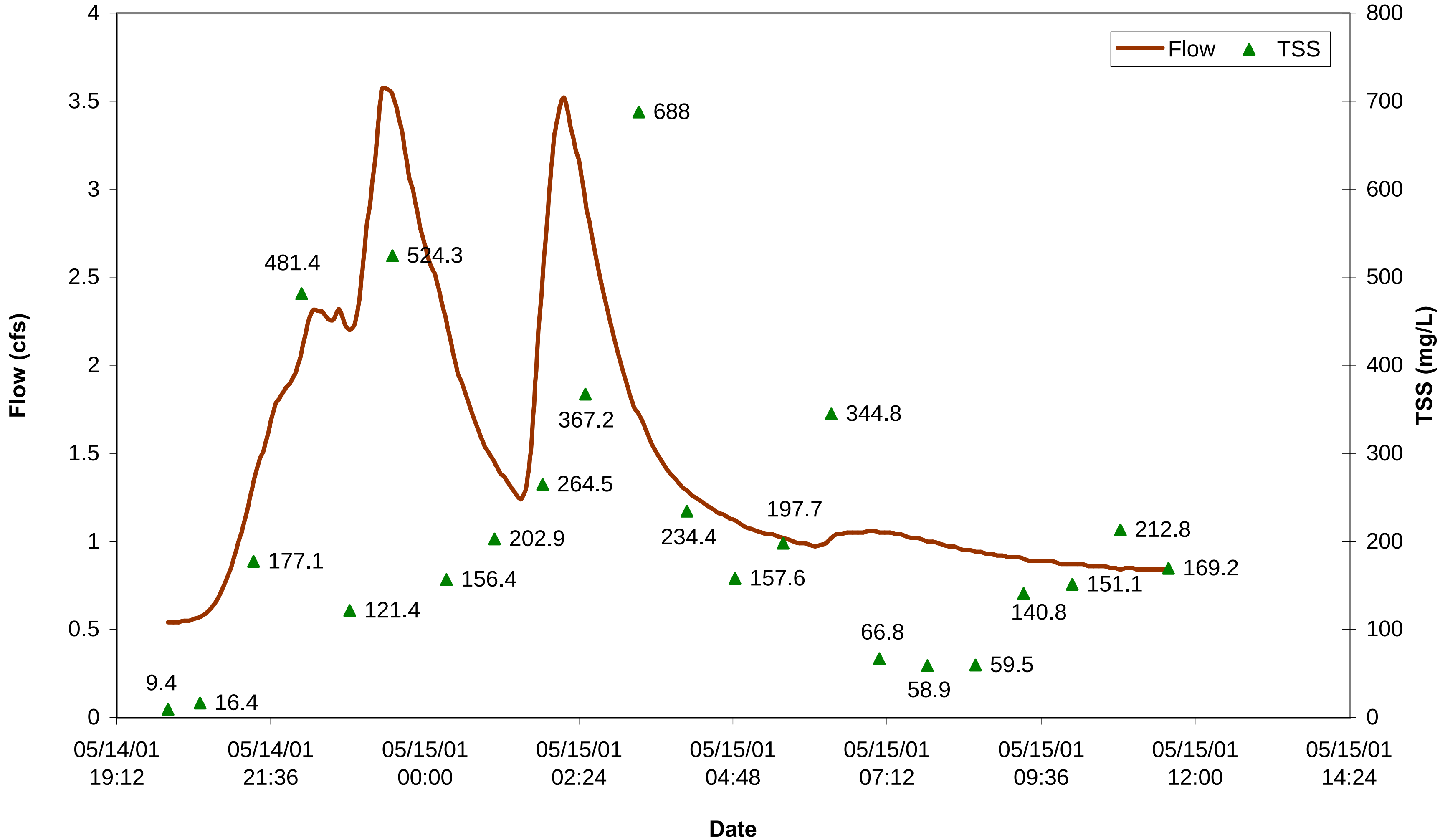


**Table 1A. Cooper Township Agricultural Site #2 Post-BMP Implementation Wet Weather Sampling Results for the Upstream Location #1. (NC = not computed; NM = not measured)**

| Date | Sampling Duration (hours) | Total Precipitation per Event (inches) | TSS Event Load (lbs) | TP Event Load (lbs) | SRP Event Load (lbs) |
|---|---|---|---|---|---|
| June 12, 2001 | 13.5 | 0.59 | (NC) | (NC) | (NM) |
| August 18, 2001 | 4.0 | 0.25 | 0.56 | 0.005 | (NM) |
| August 19, 2001 | 8.0 | 0.38 | 3.50 | 0.033 | (NM) |
| August 22, 2001 | 16.5<br>(9.0 for SRP) | 3.05 | 167.6 | 0.36 | 0.037 |

**Table 1B. Cooper Township Agricultural Site #2 Post-BMP Implementation Wet Weather Sampling Results for the Downstream Location #3. (NM = not measured)**

| Date | Sampling Duration (hours) | Total Precipitation per Event (inches) | TSS Event Load (lbs) | TP Event Load (lbs) | SRP Event Load (lbs) |
|---|---|---|---|---|---|
| April 20, 2001 | 9 | 0.4 | 8.53 | 0.034 | (NM) |
| April 23, 2001 | 7 | 0.18 | 25.99 | 0.06 | 0.004 |
| May 7-8, 2001 | 14 | 0.64 | 22.61 | 0.06 | 0.004 |
| May 10-11, 2001 | 16 | 0.46 | 11.98 | 0.04 | (NM) |
| May 14-15, 2001 | 15.5 | 1.89 | 1436.8 | 0.97 | 0.50 |
| May 31- June 1, 2001 | 12 | 0.39 | 33.36 | 0.10 | (NM) |
| June 12, 2001 | 13.5 | 0.62 | 61.5 | 0.18 | (NM) |
| August 18, 2001 | 3 | 0.27 | 11.59 | 0.03 | (NM) |
| August 19, 2001 | 7 | 0.38 | 34.36 | 0.132 | (NM) |
| August 22, 2001 | 17<br>(9.5 for SRP) | 2.78 | 1256.6 | 3.35 | 1.35 |

## 4.2 Dry Weather Sampling

Tables 2A and 2B present analytical results for the eight dry weather sampling events for the upstream Location #1 and the downstream Location #3, respectively. Average concentrations for each parameter and average daily flow are presented. Dry weather flows at Sampling Location #1 were measured manually three times for each event. Dry weather flows at Location #3 were recorded at 5-minute intervals by the ISCO Autosampler and averaged for the day. Two outliers were removed from

August 30, 2001 total phosphorus Location #1 sampling results due to what is believed to be contaminated sample bottles.

The water withdrawal from the creek to supply the new livestock watering troughs occurred at a location upstream of Sampling Location #1 (refer to Figure 1). The discharge from the trough was returned to the creek downstream of the former animal access area and upstream of Location #3. Therefore, the difference in flow (and thus, loading) between Locations #1 and #3 can not be attributed solely to runoff and/or erosion from the former animal access area. Groundwater inputs and the trough discharge contributed to downstream flow, and likely to some limited extent, the analyte concentrations collected at Sampling Location #3. As a result, the dry weather conditions of Location #1 during pre-implementation monitoring were compared to the post-implementation dry weather conditions in an effort to determine whether pre- and post-implementation concentrations had changed significantly. Table 3A presents this comparison. (Upstream loads are also used in the determination of loads specifically from the former animal access area in Section 5.3 of this report.)

**Table 2A. Summary of Post-BMP Implementation Dry Weather Sampling Event Data at the Upstream Location #1.**

| Date | Average Daily Flow (& Range) (cfs) (n=3) | Average TSS (mg/L)(+/- 1 S.D.; n = 3 unless otherwise noted) | Average TP (*u*g/l)(+/- 1 S.D.; n = 3 unless otherwise noted) | Average SRP (*u*g/l)(+/- 1 S.D.; n = 3) |
|---|---|---|---|---|
| February 21, 2001 | 0.31 (0.2 - 0.4) | 6.3 +/- 4.8 | 22.6 +/- 2.3 | 4.2 +/- 3.0 |
| March 28, 2001 | 0.10 (0.09 - 0.11) | 4.1 +/- 1.3 | 17.4 +/- 5.1 | |
| June 27, 2001 | 0.15 (0.11 - 0.19) | 3.8 +/- 1.5 | 23.0 +/- 2.3 | 1.5 +/- 0.9 |
| August 30, 2001 | 0.24 (0.05 - 0.36) | 15.6 +/- 12.2 | 50.9 n = 1 | 4.2 +/- 3.2 |
| September 5, 2001 | 0.10 (0.06 - 0.15) | 24.1 +/- 15.2 | 36.7 +/- 15.9 | 5.2 +/- 2.3 |
| September 13, 2001 | 0.19 (0.17 - 0.21) | 7.6 (n = 2) | 18.1 (n = 2) | (no samples collected) |
| October 1, 2001 | 0.41 (0.40 - 0.42) | 3.9 +/- 1.7 | 43.7 +/- 22.2 | 4.2 +/- 0.7 |
| October 9, 2001 | 0.36 (0.34 - 0.38) | 5.1 +/- 1.3 | 29.2 +/- 16.9 | 4.2 +/- 1.4 |

**Table 2B. Summary of Post-BMP Implementation Dry Weather Sampling Event Data at the Downstream Location #3.**

| Date | Daily Average Flow (+/- 1 S.D.) (cfs) | Average TSS (mg/L)(+/- 1 S.D.; n = 3 unless otherwise noted) | Average TP (*ug*/l)(+/- 1 S.D.; n = 3 unless otherwise noted) | Average SRP (*ug*/l) (+/- 1 S.D.; n = 3) |
|---|---|---|---|---|
| February 21, 2001 | 0.29 +/- 0.01 (global level logger) | 5.5 +/- 0.5 | 28.0 +/- 4.8 | 4.7 +/- 1.1 |
| March 28, 2001 | 0.31 +/- 0.05 | 3.0 +/- 1.6 | 13.2 +/- 2.7 | |
| June 27, 2001 | 0.68 +/- 0.03 | 7.8 +/- 4.4 | 25.5 +/- 3.4 | 3.6 +/- 0.8 |
| August 30, 2001 | 1.01 +/- 0.02 | 2.7 +/- 0.9 | 26.2 +/- 21.0 | 4.5 +/- 0.8 |
| September 5, 2001 | 1.07 +/- 0.02 | 1.7 +/- 0.2 | 25.7 +/- 3.4 | 2.3 +/- 1.8 |
| September 13, 2001 | 1.27 +/- 0.04 | 3.7 (n = 2) | 19.8 (n = 2) | (no samples collected) |
| October 1, 2001 | 1.57 +/- 0.01 | 5.8 +/- 6.9 | 37.9 +/- 12. 1 | 8.1 +/- 2.9 |
| October 9, 2001 | 1.74 +/- 0.01 | 2.5 +/- 0.6 | 22.1 +/- 1.3 | 4.2 +/- 3.4 |

**Table 3A. Comparison of Pre-BMP Implementation to Post-BMP Implementation Average Concentrations (+/- 1 S.D.) and Flow at the Upstream Location #1 for Dry Weather Conditions.**

| Monitoring Period | Average TP (+/- 1 S.D.) (*ug*/l) | Average SRP (+/- 1 S.D.) (*ug*/l) | Average TSS (+/- 1 S.D.) (mg/L) | Average Flow (cfs) |
|---|---|---|---|---|
| *Pre-implementation* | 22.2 +/- 8.5 (n = 3) | 6.9 (n = 1) | 5.4 +/- 3.6 (n = 3) | (no direct measurements) |
| *Post-implementation* | 29.5 +/- 15.2 (n = 21) | 3.9 +/- 2.1 (n = 18) | 8.9 +/- 9.5 (n = 23) | 0.238 (n = 21) |

Although data for dry weather pre-implementation sampling at Sampling Location #1 are very limited, comparisons in Table 3A suggest that concentrations measured at Sampling Location #1 have not changed significantly from the pre-implementation conditions. Table 3B presents a comparison of both pre- and post-BMP implementation data for dry weather and flow at Sampling Location #3.

**Table 3B. Comparison of Pre-BMP Implementation to Post-BMP Implementation Average Concentrations (+/- 1 S.D.) and Flow at the Downstream Location #3 for Dry Weather Conditions.**

| Monitoring Period | Average TP (+/- 1 S.D.) (*ug*/L) | Average SRP (+/- 1 S.D.) (*ug*/L) | Average TSS (+/- 1 S.D.) (mg/L) | Average Flow (+/- 1 S.D.) (cfs) |
|---|---|---|---|---|
| *Pre-implementation* | 45.3 +/- 23.1 (n = 16) | 6.0 +/- 1.7 (n = 16) | 40.5 +/- 22.5 (n = 16) | 0.348 (n = 16) |
| *Post-implementation* | 25.0 +/- 10.3 (n = 23) | 4.6 +/- 2.5 (n = 18) | 4.0 +/- 3.3 (n = 23) | 1.0 +/- 0.5 (n = 23) |

Average total phosphorus and soluble reactive phosphorus concentrations were lower for post-implementation monitoring than for pre-implementation sampling at this downstream location. However, they are not statistically different when examining standard deviations. Total suspended solids dry weather average concentration decreased significantly (ten-fold) following BMP implementation. This might be expected as the streambanks and nearby riparian areas, once trodden daily by horses and cattle, had since been stabilized and re-vegetated.

Tables 3C and 3D present pre- and post-implementation wet weather concentrations at Sampling Locations #1 and #3, respectively. These data describe the average concentrations of measured analytes. The standard deviations, which are often larger than the averages, indicate that measured concentrations fluctuate greatly within and between events. This is further illustrated by the pollutographs and hydrographs for each event as presented in Figures 2-4 and in Appendix B.

**Table 3C. Comparison of Pre-BMP Implementation to Post-BMP Implementation Average Concentrations (+/- 1 S.D.) at the Upstream Location #1 for Wet Weather Conditions.**

| Monitoring Period | Average TSS (+/- 1 S.D.) (mg/L) | Average TP (+/- 1 S.D.) (*u*g/L) | Average SRP (+/- 1 S.D.) (*u*g/L) |
|---|---|---|---|
| *Pre-implementation* | 7.35 +/- 7.68 (n = 19) | 28.70 +/- 11.47 (n = 19) | 5.64 +/- 2.65 (n = 19) |
| *Post-implementation* | 12.39 +/- 24.5 (n = 56) | 42.18 +/- 40.16 (n = 56) | 10.65 +/- 6.74 (n = 14) |

**Table 3D. Comparison of Pre-BMP Implementation to Post-BMP Implementation Average Concentrations (+/- 1 S.D.) at the Downstream Location #3 for Wet Weather Conditions.**

| Monitoring Period | Average TSS (+/- 1 S.D.) (mg/L) | Average TP (+/- 1 S.D.) (*u*g/L) | Average SRP (+/- 1 S.D.) (*u*g/L) |
|---|---|---|---|
| *Pre-implementation* | 65.9 +/- 161.7 (n = 121) | 153. 1 +/- 184.0 (n = 121) | 26.9 +/- 43.1 (n = 111) |
| *Post-implementation* | 63.2 +/- 89.9 (n = 58) | 91.8 +/- 121.9 (n = 142) | 56.1 +/- 114.6 (n = 144) |

Although wet weather averages presented in Tables 3C and 3D are not directly relevant to loading computations, they may provide some qualitative insight regarding potential BMP improvements. Post-implementation wet weather measured concentrations were higher and more variable at the upstream Location #1 than pre-implementation averages for TSS, TP and SRP. Downstream Location #3 averages and variations for TSS and TP, however, were generally lower than pre-implementation averages at this same locale. This is notable given the more variable upstream post-implementation concentrations that are contributing to the levels measured at the downstream sampling Location #3.

It was speculated in the pre-implementation monitoring phase (Kieser, 2000) that the animal exclusion BMP might have an appreciable effect on the relationship between total phosphorus and soluble reactive phosphorus in the creek during wet weather events at the downstream Location #3. A reduction in the amount of animal wastes reaching the creek was expected to decrease the levels of soluble reactive phosphorus relative to total phosphorus in the receiving stream. This is not necessarily evident from Table 3D. To examine this further, Figure 5 compares pre- and post-BMP implementation total phosphorus versus soluble reactive phosphorus concentrations during wet weather events at Sampling Location #3.

There was no strong relationship between total phosphorus and soluble reactive phosphorus during the pre-implementation monitoring. (Therefore, a comparison to a post-implementation relationship is not appropriate.) During post-implementation wet weather events, the relationship between soluble reactive phosphorus and total phosphorus was strong and exhibited a steep slope. These data potentially suggest that soils in riparian areas may still be compacted from former animal traffic and are likely still rich in animal waste. It is expected that as this riparian area continues to recover, the slope describing the relationship between soluble reactive phosphorus and total phosphorus will decrease.

## 5.0 LOADING REDUCTIONS

### 5.1 Wet Weather

Post-implementation wet weather loads were calculated in a manner consistent with pre-implementation load estimates (Kieser, 2000). The relationships between rainfall and event loads for TP, SRP and TSS were utilized to generate Figures 6A, 6B and 6C, respectively. Each figure represents a power function drawn from the dependence of analyte loading (per event) on rainfall (per event). The pre- and post-implementation trend lines are included in each figure. These suggest that the wet weather loading relationships to rainfall amount are similar between the pre- and post-implementation events.

The power functions for TP and TSS were utilized to estimate annual wet weather loading at Location #3 based on rainfall frequency for Kalamazoo, Michigan (see Appendix C). Each hypothetical 24-hour rainfall event was entered into the equation and event loads summed to compute the annual wet weather load at Location #3. Wet weather annual loads for TP and TSS computed in this manner are presented in Table 4 as compared to estimates from the pre-implementation period.

**Table 4. Annual Wet Weather Loading Estimates at the Downstream Location #3.**

| Monitoring Period | Annual Wet Weather TP Load (lbs/yr) | Annual Wet Weather TSS Load (tons/yr) |
|---|---|---|
| *pre-implementation* | 13.0 | 1.0 |
| *post-implementation* | 13.5 | 3.3 |

The TP wet weather load compares quite closely with the pre-implementation estimate and is not unexpected given very similar pre- and post-implementation relationships to rainfall amounts shown in Figure 6A. Soils in riparian areas may still be saturated with phosphorus from animal wastes and compacted from the former animal traffic. These recovering areas may therefore still be subject to higher TP loading during wet weather with overland surface flows draining across ground surfaces and potentially mobilizing dissolved phosphorus. The reduction in TSS by contrast may reflect the benefits of a vegetated riparian buffer impeding suspended sediment in runoff.

**Figure 5. Comparison of Trends in Soluble Reactive Phosphorus vs. Total Phosphorus in Pre- and Post-Implementation Wet Weather Events using Data from Location #3.**

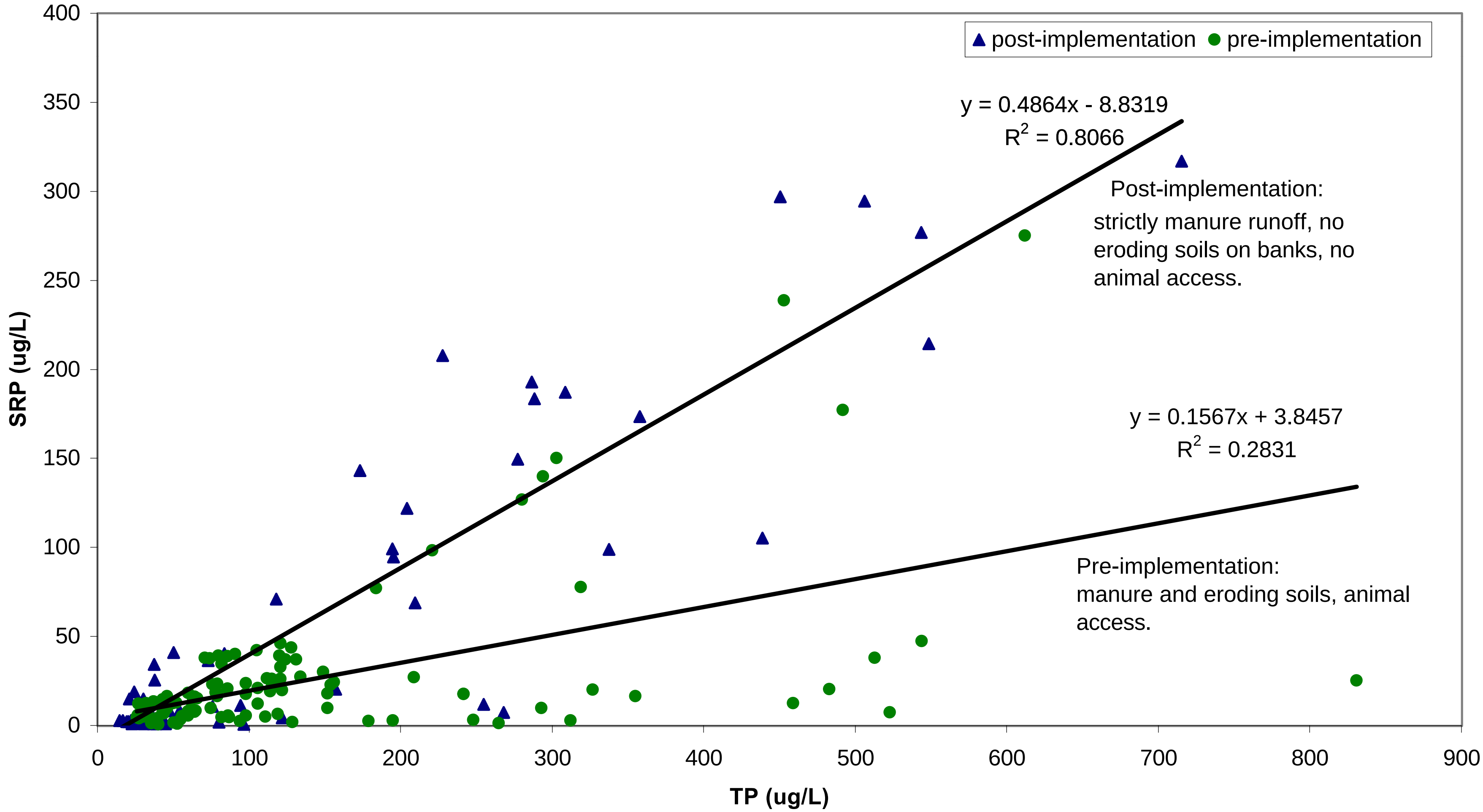


**Figure 6A. Relationship Between Rainfall and Total Phosphorus Loading for Wet Weather Events at Sampling Location #3.**

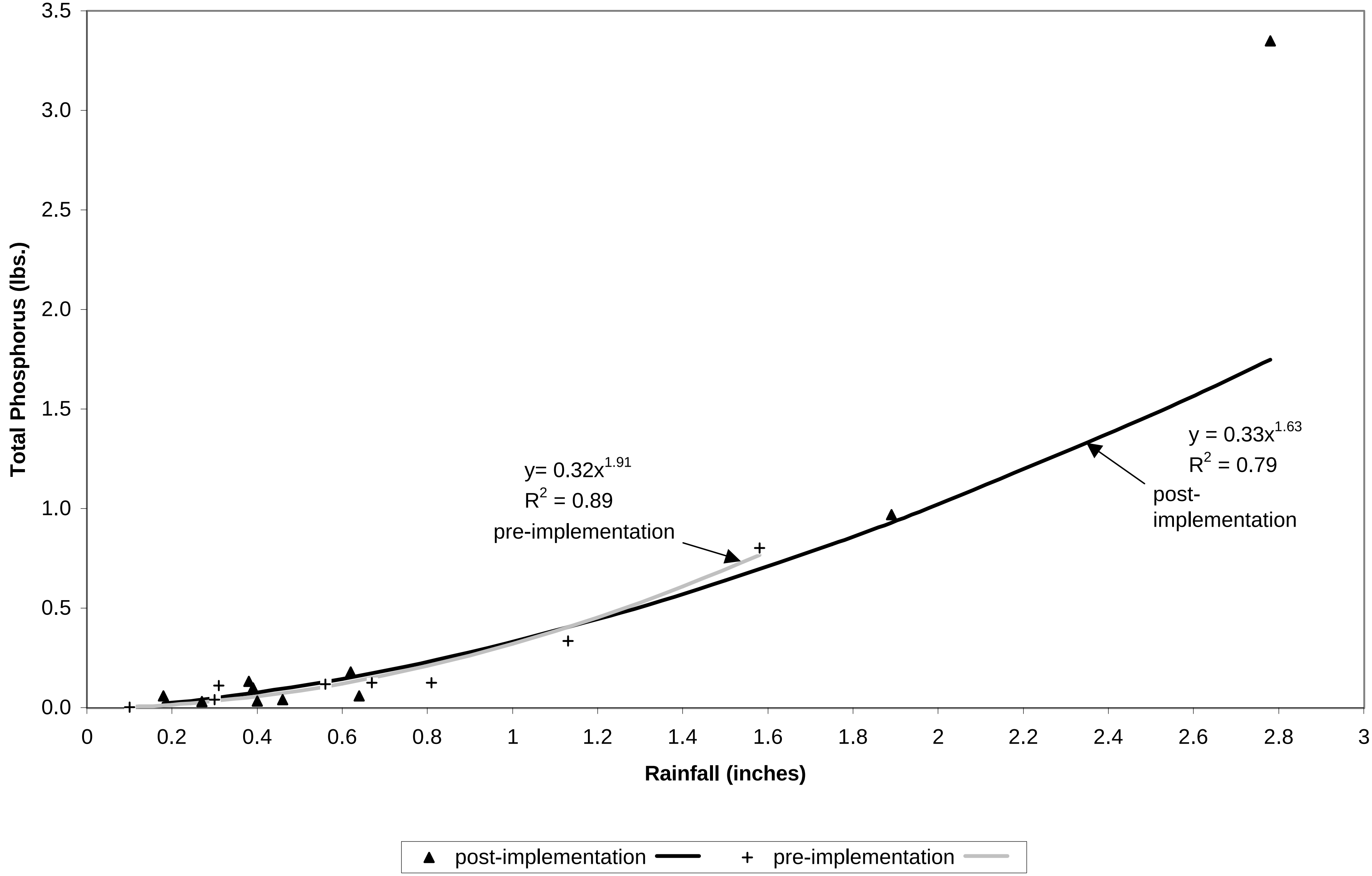


**Figure 6B. Relationship Between Rainfall and Soluble Reactive Phosphorus Loading for Wet Weather Events at Sampling Location #3.**

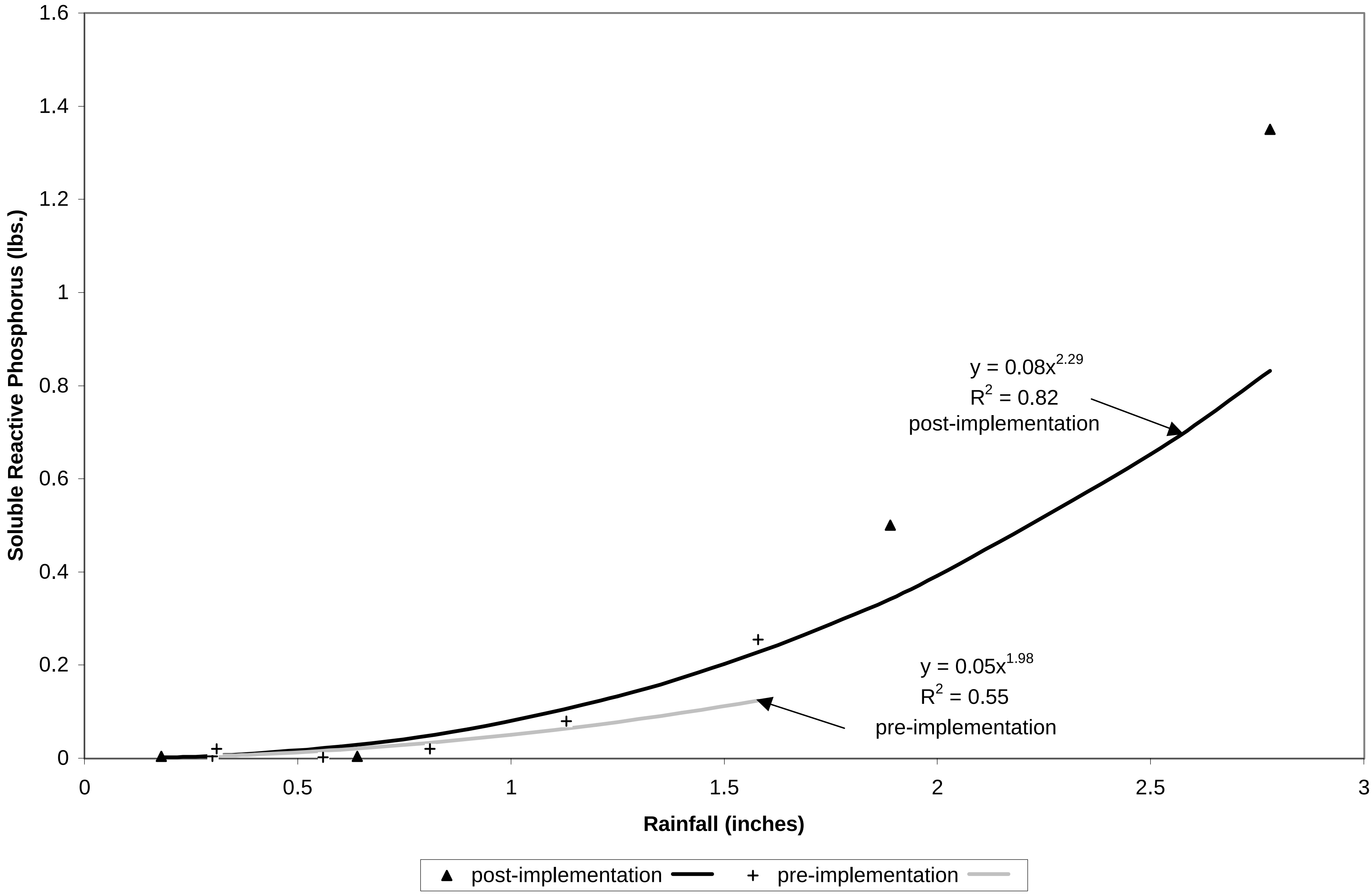
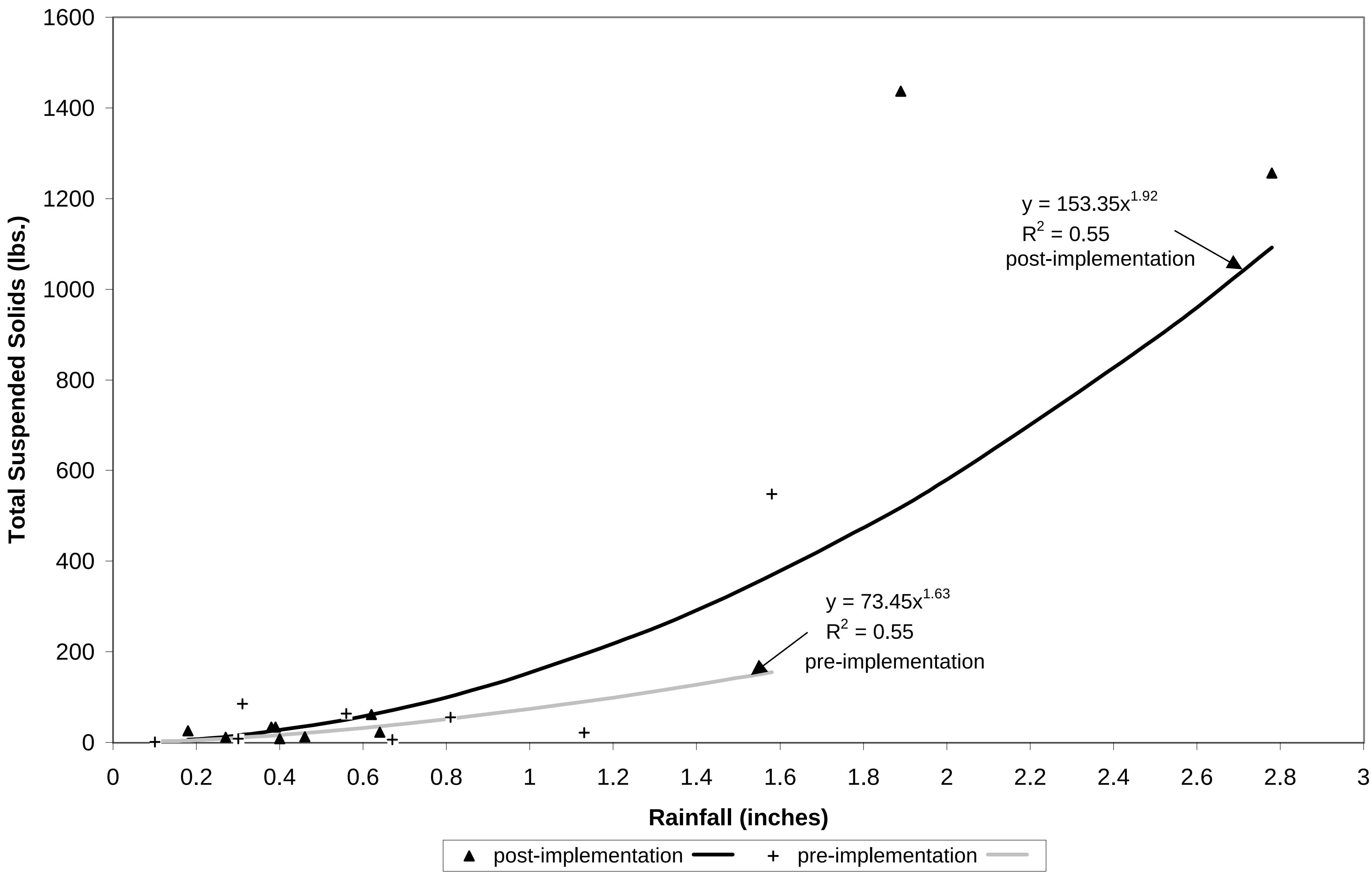


**Figure 6C. Relationship Between Rainfall and Total Suspended Solids Loading for Wet Weather Events at Sampling Location #3.**



## 5.2 Dry Weather Loading

Dry weather loads at Location #3 were computed using the post-implementation average dry weather concentration of 25 *u*g/l TP (Table 3B), flows measured at Sampling Location #3 for the entire dry weather period monitoring period (0.6 cfs) and Kalamazoo's historical average number of dry days per year (304). An annual dry weather load was similarly computed for TSS. These estimates are presented in Table 5 with pre-implementation estimates.

**Table 5. Post-BMP Implementation Dry Weather Annual Loads at the Downstream Location #3.**

| Monitoring Period | Annual Dry Weather TP Load (lbs/yr) | Annual Dry Weather TSS Load (tons/yr) |
|---|---|---|
| *pre-implementation* | 26.0 | 12.0 |
| *post-implementation* | 24.6 | 2.0 |

The dry weather average flow of 0.6 cfs is used to compute dry weather loads as opposed to the flow of 1 cfs shown in Table 3B. The latter flow was for a limited number of discrete measurements corresponding only to the date of grab sampling. The 0.6 cfs average is representative of the entire monitoring period of eight months using 5-minute interval flows during non-rain event periods. The baseflow measured at Location #3 in September and October, 2001 was typically higher than other periods. As selected dry weather phosphorus sampling occurred during this autumn period, use of discrete flow measurements from September and October skewed the average base flow and was not considered representative of the entire monitored period.

Using the computed wet weather loads from Table 4, and dry weather loads from Table 5, annual loading for total phosphorus and total suspended solids passing Sampling Location #3 were computed as 38.1 lbs/yr and 5.3 tons/yr, respectively. The 38.1 lbs/yr post-implementation TP load estimate is similar to the pre-implementation load of 39 lbs/yr at this location. The post-implementation TSS annual load of 5.3 tons/yr is less than half of the pre-implementation load estimated at 13 tons/yr for Location #3.

## 5.3 Loads from the Former Animal Access Area

The differences between the pre- and post-implementation total phosphorus and total suspended solids load estimates calculated at Location #3 can not be attributed solely to the BMP implementation. Upstream loads must be subtracted from these values to compute the estimated load attributable to the animal holding areas following BMP implementation. From pre-implementation monitoring, it was estimated that 19% of the total phosphorus reaching Location #3 came from Location #1. Therefore, 81% of the total phosphorus load was attributed to the animal access area. The estimated pre-implementation loading from the animal access area was projected to be 31.6 pounds (K&A, 2000).

For the post-implementation computation, total phosphorus loads between Locations #1 and #3 were compared for three comparable wet weather monitored events (see Tables 1A and 1B). On average, 17.5% of the TP load occurring at Location #3 could be attributed to that delivered from Location #1. Therefore, the total phosphorus wet weather annual load of 13. 5 lbs/yr at Location #3 attributable to the former animal access area and the watering trough discharge was computed as 11.1 pounds/yr.

An average annual upstream dry weather total phosphorus load of 11.5 pounds/year was calculated for Location #1 utilizing an average flow of 0.238 cfs and an average concentration of 29.5 *u*g/L (Table 3A), multiplied by 304 days of dry weather. This indicates that 46.7% of the dry weather load calculated at Location #3 (i.e., 38.1 lbs/yr) is attributable to upstream contributions. Therefore, an annual dry weather load of 13.1 pounds of total phosphorus is attributable to the former animal access area and the water trough discharge. A total annual TP load of 24.2 lbs/yr is therefore associated with the former animal access Area A.

Similar computations were made for total suspended solids. Wet weather contributions from Location #1 averaged 9.3% of the TSS measured at Location #3. Dry weather TSS contributions from the upstream Location #1 represented 88% of the TSS load measured at Location #3. Therefore, the annual TSS load attributable to Area A is 3.2 tons.

Post-implementation annual loads for Area A are compared to those from the pre-implementation monitoring in Table 6. Efficiency of the BMPs installed in the former animal access areas are computed by the division of the pre- versus post-implementation loads for Area A. The BMP efficiencies for total phosphorus and total suspended solids were 23.4% and 75%, respectively as shown in Table 6.

**Table 6. Comparison of Pre- and Post-BMP Implementation Loads for Area A and BMP Efficiency**.

| Loading Parameter | Pre-Implementation Load | Post-Implementation Load | Load Reduction | BMP Efficiency |
|---|---|---|---|---|
| Total Phosphorus | 31.6 lbs/yr | 24.2 lbs/yr | 7.4 lbs/yr | 23.4% |
| Total Suspended Solids | 13.0 tons/yr | 3.2 tons/yr | 9.8 tons/yr | 75.4% |

Using a consistent application of a soil delivery ratio (Vanoni, 1975) as reported for pre-implementation monitoring (Kieser, 2000), the total phosphorus load reduction to the Kalamazoo River is estimated at 7.1 lbs/yr. This compares to the originally estimated 26.4 lbs/yr reduction to the River based on a projected 87% BMP efficiency versus the post-implementation monitored estimate of 23.4%. A greater BMP efficiency was noted for suspended solids reductions. The original projection was for a 65% reduction whereas monitoring identified a 75.4% BMP efficiency.

## 6.0 CONCLUSIONS

Load reductions at the Cooper Township Agricultural Site #2 were noted primarily during dry weather periods. This is believed to be largely due to: a) stabilization and re-vegetation of soils in riparian areas of the creek where animals previously had direct access; b) the elimination of direct loading of manure to the stream, and; c) reduction of soil losses due to exposed streambank soils and undercutting at baseflows. A lower than predicted TP removal efficiency measured in 2001 is not necessarily unexpected as it is commonly recognized that agricultural BMPs may not become fully effective for nutrient retention until several growing seasons have passed. As Area A BMPs were not instituted prior to a full growing season (i.e., December 2000 installation followed by monitoring beginning in February of 2001), results of post-implementation sampling support these general observations. The newly-established vegetative growth is expected to eventually utilize phosphorus remaining from residual animal waste and alleviate soil compaction as root structures develop. Additional phosphorus loading reductions are anticipated as phosphorus levels in soils equilibrate to additional growing seasons of the re-established riparian vegetation.

First-year costs per pound of phosphorus reduced at this site were previously identified at $268.93 (Kieser, 2000). Amortized estimates over five and ten-year periods were also projected at $53.78 and $26.89 per pound, respectively. Based on measured first-year estimates of total phosphorus loading reductions to the Kalamazoo River (7.1 lb/yr), the first-year revised cost estimate is $1,056 per pound (i.e., BMP implementation costs of $7,500 divided by 7.1 pounds of TP reduction). As BMP efficiency is expected to improve over time, amortization to five and ten year periods may not necessarily be applicable for these additional cost projections.

Selected models to estimate load reductions were utilized in the pre-implementation investigation (refer to Section 5.2.1 of Kieser, 2000). The Minnesota Pollution Control Agency (MPCA, 1997) model predicted a 48% load reduction for total phosphorus with animal exclusion. In a matter of months, the BMPs instituted at the Cooper Township Agricultural Site #2 achieved nearly one-half of this predicted TP reduction. A modeling estimate for use of a vegetative filter (MDEQ, 1999) predicted additional reductions up to 83% of the original load. Based on monitoring data, the predicted reduction for animal exclusion may have overestimated the actual improvement while it is too early to assess the benefits of the re-vegetated riparian areas.

The modeling estimate for vegetative filter placement (MDEQ, 1999) also predicted a 65% reduction in sediment loading to the stream. Sediment loads estimated from 2001 monitoring data suggested a 75.4% load reduction. Given the finite scale of this site, and the typical uncertainty associated with non-point source loading estimation techniques, the MDEQ approach appears reasonable for predicting sediment loading reductions. In time, it is believed that predicted total phosphorus load reductions will be realized as riparian areas continue to stabilize and phosphorus-saturated soils reach an equilibrium through additional seasonal growth cycles.

It can also be noted that small sites of this size may not be well-suited to readily participate in a trading program. Costs, and the ability to easily estimate or measure incremental loading reductions for operations with small pre-implementation baseline loads, may preclude some operations from participation. Cost considerations would likely apply to both a generator and buyer of credits. Uncertainty associated with quantifying or estimating small scale reductions without substantial verification (such as monitoring), may further discourage potential purchasers; a situation that was specifically noted during the demonstration project (Kieser, 2000). The timing of post-implementation monitoring at the Cooper Township site supports the notion that agricultural or riparian BMPs may not provide immediate reductions in nutrient loads. Such delays may be accounted for by trading ratios, however.

For purposes of the Kalamazoo River trading demonstration project, the information obtained from this endeavor is valuable. Post-implementation monitoring confirmed that BMPs resulted in loading reductions for total phosphorus and sediments. This was a critical objective of the project to demonstrate that trading can result in voluntary non-point source reductions that are quantifiable. A point/non-point source trading ratio of 2:1 may also reasonably account for non-point source loading uncertainty, expected lags in BMP phosphorus reductions, as well as providing a margin for achieving additional water quality improvements with each trade. Estimation techniques published by the Michigan Department of Environmental Quality (MDEQ, 1999) and recommended for use in Michigan's Water Quality Trading Rules, also initially appear to be reasonable where monitoring data are not available for load quantification.

**7.0 REFERENCES**

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Vanoni, V.A., ed. 1975. *Sediment Engineering*. Am. Soc. Civil Engrs. New York, N.Y., 745.

# APPENDIX A

# Post-Implementation Water Quality Monitoring Data

Appendix A. Table A-1. Location #3 Wet Weather Analytical Results, as reported by the Upstate Freshwater Institute (UFI).

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 04/20/01 | 06:00 | 26.74 | NM | 9.20 |
| | 06:10 | bottle broken | NM | 6.70 |
| | 06:19 | 10.03 | NM | 5.60 |
| | 06:28 | 13.37 | NM | 5.30 |
| | 07:13 | 23.40 | NM | 9.80 |
| | 07:58 | 31.76 | NM | 5.90 |
| | 08:43 | bottle broken | NM | 3.50 |
| | 09:28 | 36.77 | NM | 13.30 |
| | 10:13 | 33.43 | NM | 14.30 |
| | 10:58 | 25.07 | NM | 8.70 |
| | 11:43 | 20.06 | NM | 5.60 |
| | 12:28 | 30.09 | NM | 9.50 |
| | 13:13 | 25.07 | NM | 4.00 |
| | 13:58 | 26.71 | NM | 3.70 |
| | 14:43 | 23.40 | NM | 2.20 |
| 04/23/01 | 14:50 | 45.02 | 1.00 | 15.70 |
| | 19:12 | 121.93 | 4.10 | 65.90 |
| | 19:58 | 45.35 | 9.60 | 12.80 |
| | 20:43 | 33.85 | 9.50 | 6.10 |
| | 21:28 | 30.24 | 7.10 | 7.50 |
| | 21:50 | 26.62 | 7.90 | 8.80 |
| 05/07/01 | 15:53 | failed QC | 0.73 | 116.80 |
| | 16:08 | 96.64 | 0.73 | 47.10 |
| | 16:53 | 80.32 | 1.87 | 36.80 |
| | 17:38 | 44.26 | 1.22 | 13.30 |
| | 18:23 | 36.72 | 1.06 | 10.10 |
| | 19:08 | 38.69 | 1.06 | 8.50 |
| | 19:53 | 30.82 | 1.06 | 6.70 |
| | 20:38 | 30.82 | 1.38 | 7.50 |
| | 21:23 | 28.52 | 1.38 | 6.70 |
| | 22:08 | 22.92 | 1.71 | 6.50 |
| | 22:53 | 21.96 | 2.69 | 5.00 |
| | 23:38 | 20.33 | 2.20 | 6.00 |
| | 00:23 | 20.28 | 2.20 | 4.10 |
| | 01:05 | 16.69 | 2.86 | 6.90 |
| | 05:04 | 19.31 | 2.20 | 3.20 |
| | 05:38 | 14.72 | 2.86 | 3.40 |
| 05/10/01 | 19:52 | 52.38 | NM | 15.30 |
| | 20:42 | 21.35 | NM | 6.20 |
| | 02:47 | 25.23 | NM | 8.90 |
| | 03:28 | 25.58 | NM | 11.80 |
| | 04:12 | 28.40 | NM | 19.80 |
| | 04:57 | 26.64 | NM | 4.00 |
| | 05:42 | 26.29 | NM | 5.20 |
| | 06:27 | 25.23 | NM | 3.40 |
| | 07:12 | 15.35 | NM | 2.40 |
| | 07:57 | 17.82 | NM | 1.10 |

NM = not measured

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 05/10/01 | 08:42 | 18.53 | NM | 2.90 |
| | 09:10 | 15.35 | NM | 1.20 |
| | 12:15 | 15.00 | NM | 1.80 |
| 05/14/01 | 20:00 | 22.80 | 0.85 | 9.40 |
| | 20:33 | 34.57 | 1.33 | 16.40 |
| | 21:18 | 267.93 | 7.32 | 177.10 |
| | 22:03 | 254.79 | 11.69 | 481.40 |
| | 22:48 | 209.42 | 68.69 | 121.40 |
| | 23:33 | 286.65 | 192.88 | 524.30 |
| 05/15/01 | 00:18 | 227.69 | 207.78 | 156.40 |
| | 01:03 | 173.07 | 143.17 | 202.90 |
| | 01:48 | 195.19 | 94.76 | 264.50 |
| | 02:33 | 288.53 | 183.33 | 367.20 |
| | 03:18 | 277.47 | 149.65 | 688.00 |
| | 04:03 | 194.51 | 99.13 | 234.40 |
| | 04:48 | 118.11 | 70.96 | 157.60 |
| | 05:33 | 73.17 | 36.47 | 197.70 |
| | 06:18 | 83.89 | 40.35 | 344.80 |
| | 07:03 | 50.36 | 40.84 | 66.80 |
| | 07:48 | 37.57 | 34.36 | 58.90 |
| | 08:33 | 37.67 | 25.46 | 59.50 |
| | 09:18 | 157.17 | 20.28 | 140.80 |
| | 10:03 | 24.08 | 18.66 | 151.10 |
| | 10:48 | 20.98 | 14.93 | 212.80 |
| | 11:33 | 30.31 | 14.77 | 169.20 |
| 05/31/01 | 22:45 | 31.05 | NM | 7.58 |
| 06/01/01 | 00:56 | 29.97 | NM | 12.78 |
| | 01:17 | 29.61 | NM | 80.60 |
| | 02:02 | 23.90 | NM | 5.65 |
| | 02:47 | 21.19 | NM | 2.50 |
| | 03:32 | 97.06 | NM | 62.00 |
| | 04:17 | 52.45 | NM | 19.38 |
| | 05:02 | 41.75 | NM | 9.55 |
| | 05:47 | 33.44 | NM | 6.72 |
| | 06:32 | 25.59 | NM | 4.58 |
| | 07:17 | 21.66 | NM | 2.95 |
| | 08:02 | 22.73 | NM | 2.60 |
| | 08:47 | 24.16 | NM | 5.12 |
| | 09:32 | 22.38 | NM | 8.06 |
| | 10:42 | 24.52 | NM | 2.77 |
| 06/12/01 | 01:43 | 56.44 | NM | 953.64 |
| | 02:17 | 29.64 | NM | 28.09 |
| | 03:02 | 37.84 | NM | 22.27 |
| | 03:47 | 75.05 | NM | 40.61 |
| | 04:32 | 59.91 | NM | 25.20 |
| | 05:17 | 45.41 | NM | 13.33 |
| | 06:02 | 53.60 | NM | 18.00 |
| | 06:47 | 52.66 | NM | 15.50 |
| | 07:32 | 48.61 | NM | 10.67 |

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 06/12/01 | 08:17 | 49.19 | NM | 15.85 |
| | 09:02 | 49.51 | NM | 10.45 |
| | 09:47 | 80.72 | NM | 26.06 |
| | 10:32 | 74.73 | NM | 14.39 |
| | 11:17 | 68.69 | NM | 8.92 |
| | 12:02 | 57.34 | NM | 9.69 |
| | 12:47 | 40.63 | NM | 8.21 |
| | 13:32 | 38.42 | NM | 34.15 |
| | 14:17 | 33.38 | NM | 30.76 |
| | 15:02 | 26.13 | NM | 4.39 |
| 08/18/01 | 15:47 | 21.20 | NM | 5.22 |
| | 16:01 | 45.67 | NM | 22.46 |
| | 16:46 | 57.52 | NM | 30.66 |
| | 17:35 | 59.21 | NM | 15.04 |
| | 18:08 | 52.44 | NM | 7.29 |
| 08/19/01 | 10:57 | 27.97 | NM | 39.62 |
| | 11:31 | 71.05 | NM | 27.91 |
| | 12:16 | 120.10 | NM | 38.46 |
| | 13:01 | 17.96 | NM | 9.70 |
| | 13:46 | 65.19 | NM | 6.62 |
| | 14:31 | NM | NM | 25.89 |
| | 15:16 | 130.25 | NM | 20.31 |
| | 16:01 | 8.12 | NM | 10.23 |
| | 16:46 | 77.03 | NM | 9.38 |
| | 17:31 | 53.34 | NM | 4.62 |
| | 17:59 | 49.96 | NM | 4.62 |
| 08/22/01 | 04:56 | 75.94 | 10.54 | 33.08 |
| | 05:18 | 54.00 | 8.13 | 19.08 |
| | 06:30 | 47.25 | 8.13 | 11.64 |
| | 06:48 | 94.51 | 11.34 | 42.31 |
| | 07:33 | 337.52 | 98.78 | 138.31 |
| | 08:18 | 438.77 | 105.19 | 654.31 |
| | 09:03 | 548.47 | 214.29 | 2384.68 |
| | 09:48 | 357.77 | 173.38 | 116.98 |
| | 10:33 | 715.54 | 316.96 | 361.63 |
| | 11:18 | 543.41 | 276.85 | 103.15 |
| | 12:03 | 506.28 | 294.5 | 69.08 |
| | 12:48 | 450.60 | 296.91 | 32.66 |
| | 13:33 | 308.83 | 187.01 | 34.15 |
| | 14:16 | 204.20 | 122.04 | 18.46 |
| | 15:03 | 1.68 | NM | 12.46 |
| | 15:48 | 109.19 | NM | 23.08 |
| | 16:33 | 120.11 | NM | 47.38 |
| | 17:18 | 184.78 | NM | 23.77 |
| | 18:03 | 302.37 | NM | 34.93 |
| | 18:48 | 245.28 | NM | 12.73 |
| | 19:33 | 183.10 | NM | 7.88 |
| | 20:18 | 129.34 | NM | 7.16 |
| | 21:03 | 107.51 | NM | 8.48 |
| | 21:48 | 97.43 | NM | 13.18 |

Appendix A. Table A-2. Location #1 Wet Weather Analytical Results, as reported by UFI.

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 06/12/01 | 02:28 | 27.39 | NM | 11.24 |
| | 03:13 | 15.41 | NM | 3.97 |
| | 03:58 | 15.09 | NM | 10.29 |
| | 04:43 | 37.53 | NM | 14.35 |
| | 05:28 | 27.39 | NM | 9.57 |
| | 06:13 | 21.08 | NM | 6.29 |
| | 06:58 | 17.93 | NM | 6.32 |
| | 07:43 | 17.93 | NM | 5.38 |
| | 08:28 | 16.67 | NM | 7.31 |
| | 09:13 | 17.29 | NM | 4.12 |
| | 09:58 | 17.29 | NM | 4.00 |
| | 10:43 | 19.82 | NM | 4.56 |
| | 11:28 | 21.08 | NM | 5.26 |
| | 12:13 | 25.81 | NM | 5.53 |
| 08/18/01 | 15:48 | 22.90 | NM | 8.12 |
| | 16:36 | 16.13 | NM | 1.70 |
| | 17:21 | 16.13 | NM | 1.45 |
| | 18:06 | 17.82 | NM | 0.83 |
| | 18:43 | 16.13 | NM | 2.57 |
| | 19:49 | 19.51 | NM | 0.86 |
| 08/19/01 | 10:58 | 24.59 | NM | 4.00 |
| | 11:21 | 60.11 | NM | 17.90 |
| | 12:06 | 26.28 | NM | 4.06 |
| | 12:51 | 22.9 | NM | 4.44 |
| | 13:36 | 19.51 | NM | 1.30 |
| | 14:21 | 19.51 | NM | 3.33 |
| | 15:06 | 21.2 | NM | 3.33 |
| | 15:51 | 17.82 | NM | 2.48 |
| | 16:36 | 200.51 | NM | 1.88 |
| | 17:21 | 21.2 | NM | 1.76 |
| | 18:06 | 19.51 | NM | 3.61 |
| | 19:00 | 21.2 | NM | 1.30 |

NM = not measured

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 08/22/01 | 04:56 | 30.34 | 8.94 | 2.88 |
| | 05:08 | 28.65 | 6.53 | 2.92 |
| | 05:53 | 25.28 | 5.73 | 2.99 |
| | 06:38 | 23.59 | 4.12 | 1.43 |
| | 07:23 | 57.34 | 4.12 | 34.51 |
| | 08:08 | 52.31 | 2.52 | 20.14 |
| | 08:53 | 84.38 | 4.92 | 52.00 |
| | 09:38 | 71.88 | 10.54 | 20.85 |
| | 10:23 | 183.95 | 21.77 | 124.17 |
| | 11:08 | 165.39 | 19.36 | 133.38 |
| | 11:53 | 87.76 | 8.13 | 24.49 |
| | 12:38 | 86.07 | 17.76 | 31.74 |
| | 13:23 | 82.69 | 14.55 | 14.48 |
| | 14:08 | 74.26 | 20.17 | 1.27 |
| | 14:53 | 53.34 | NM | 13.95 |
| | 15:38 | 49.96 | NM | 7.32 |
| | 16:23 | 34.74 | NM | 5.62 |
| | 17:08 | 44.89 | NM | 5.83 |
| | 17:53 | 73.64 | NM | 7.92 |
| | 18:38 | 44.89 | NM | 6.57 |
| | 19:23 | 1.68 | NM | 4.93 |
| | 20:08 | 43.19 | NM | 3.66 |
| | 20:57 | 39.81 | NM | 2.69 |
| | 21:35 | 41.50 | NM | 4.71 |

Appendix A. Table A-3. Location #3 Dry Weather Analytical Results, as reported by UFI.

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 02/21/01 | 07:20 | 31.70 | 5.60 | 5.34 |
| | 13:00 | 29.70 | 3.50 | 5.20 |
| | 17:42 | 22.60 | 5.00 | 6.08 |
| 03/28/01 | 07:10 | 12.20 | NM | 2.10 |
| | 12:30 | 11.10 | NM | 2.11 |
| | 18:15 | 16.20 | NM | 1.90 |
| 06/27/01 | 06:30 | 28.55 | 2.73 | 12.22 |
| | 12:00 | 26.27 | 3.97 | 7.66 |
| | 18:30 | 21.81 | 4.12 | 3.47 |
| 08/30/01 | 05:30 | 47.50 | 4.74 | 3.09 |
| | 12:00 | 5.51 | 3.60 | 1.70 |
| | 17:30 | 25.67 | 5.24 | 3.30 |
| 09/05/01 | 06:00 | 22.31 | 2.05 | 1.85 |
| | 12:00 | 29.03 | 0.69 | 1.62 |
| | 18:00 | 25.67 | 4.25 | 1.50 |
| 09/13/01 | 06:30 | 22.31 | NM | 3.60 |
| | 12:30 | 17.27 | NM | 3.85 |
| 10/01/01 | 06:30 | 51.67 | 5.00 | 13.66 |
| | 12:25 | 32.63 | 8.58 | 0.95 |
| | 18:25 | 29.30 | 10.76 | 2.69 |
| 10/09/01 | 06:55 | 20.47 | 0.42 | 3.20 |
| | 12:30 | 23.08 | 5.17 | 2.02 |
| | 18:55 | 22.76 | 7.07 | 2.27 |

NM = not measured

Appendix A. Table A-4. Location #1 Dry Weather Analytical Results, as reported by UFI.

| Date | Time | TP (ug/L) | SRP (ug/L) | TSS (mg/L) |
|---|---|---|---|---|
| 02/21/01 | 07:25 | 21.00 | 7.60 | 11.84 |
| | 13:10 | 21.60 | 2.90 | 3.65 |
| | 17:54 | 25.20 | 2.10 | 3.50 |
| 03/28/01 | 07:20 | 16.80 | NM | 4.82 |
| | 12:37 | 12.60 | NM | 2.70 |
| | 18:23 | 22.80 | NM | 4.90 |
| 06/27/01 | 06:30 | 25.34 | 1.03 | 3.22 |
| | 12:00 | 22.78 | 2.57 | 2.68 |
| | 18:30 | 20.86 | 0.98 | 5.52 |
| 08/30/01 | 05:30 | **799.59** | 4.25 | 16.34 |
| | 12:00 | 178.53 | 7.36 | 3.00 |
| | 17:30 | 50.86 | 0.99 | 27.30 |
| 09/05/01 | 06:05 | 59.26 | 2.56 | 41.70 |
| | 12:05 | 29.03 | 6.52 | 15.11 |
| | 18:05 | 35.75 | 6.46 | 15.60 |
| 09/13/01 | 06:35 | 20.63 | NM | 11.86 |
| | 12:35 | 15.59 | NM | 3.40 |
| 10/01/01 | 06:35 | 29.30 | 4.69 | 5.85 |
| | 12:30 | 32.63 | 3.44 | 2.59 |
| | 18:30 | 69.30 | 4.38 | 3.15 |
| 10/09/01 | 07:00 | 48.74 | 3.43 | 3.85 |
| | 12:35 | 20.47 | 3.43 | 5.13 |
| | 19:00 | 18.51 | 5.80 | 6.39 |

NM = not measured

# APPENDIX B

# Hydrographs and Pollutographs for Wet Weather Monitoring Events

**Figure B-1. Flow and Total Phosphorus Concentrations at Location #3 for the April 20, 2001 Event.**

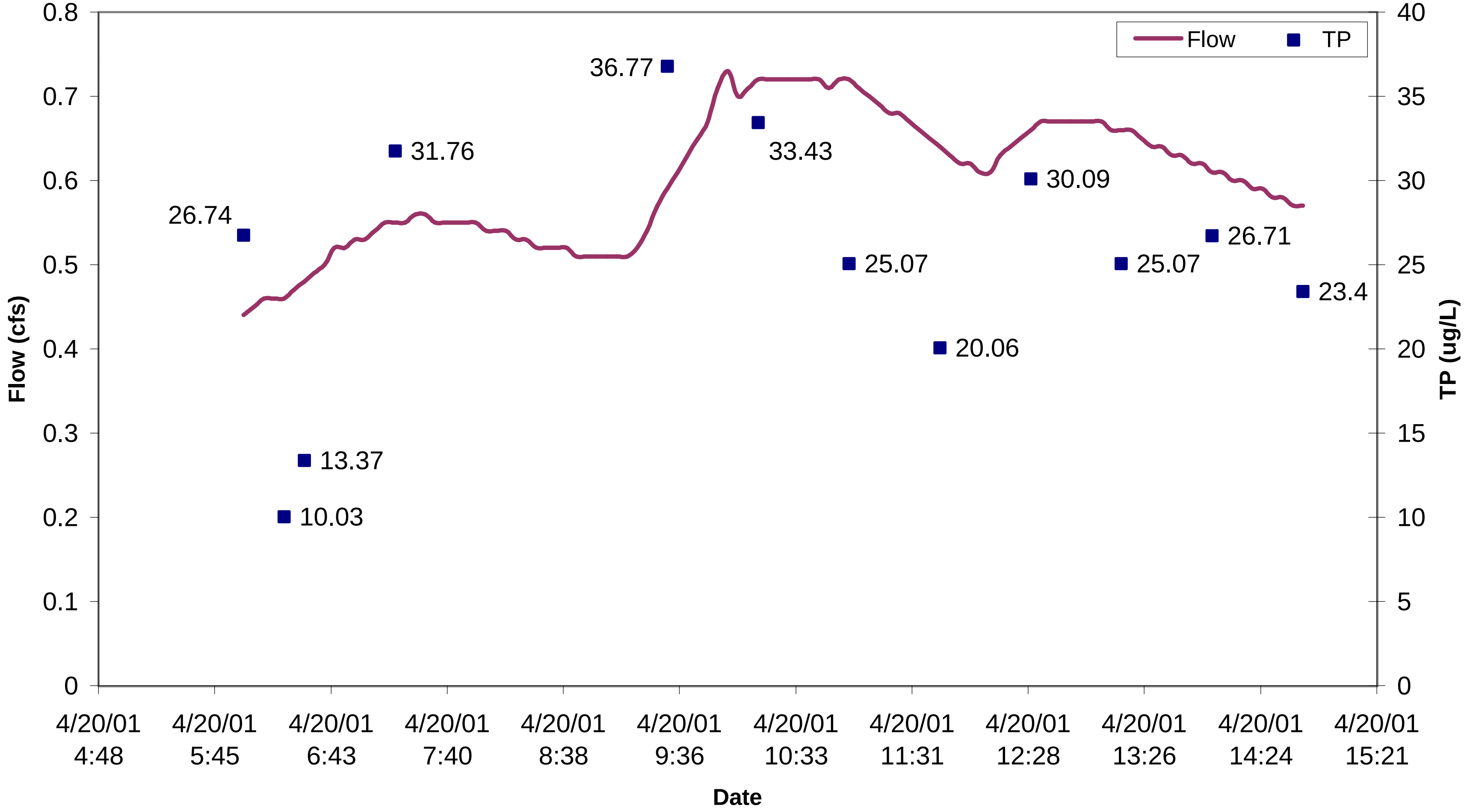


**Figure B-2. Flow and Total Suspended Solid Concentrations at Location #3 for the April 20, 2001 Event.**

**Figure B-3. Flow and Total Phosphorus Concentrations at Location #3 for the April 23, 2001 Event.**

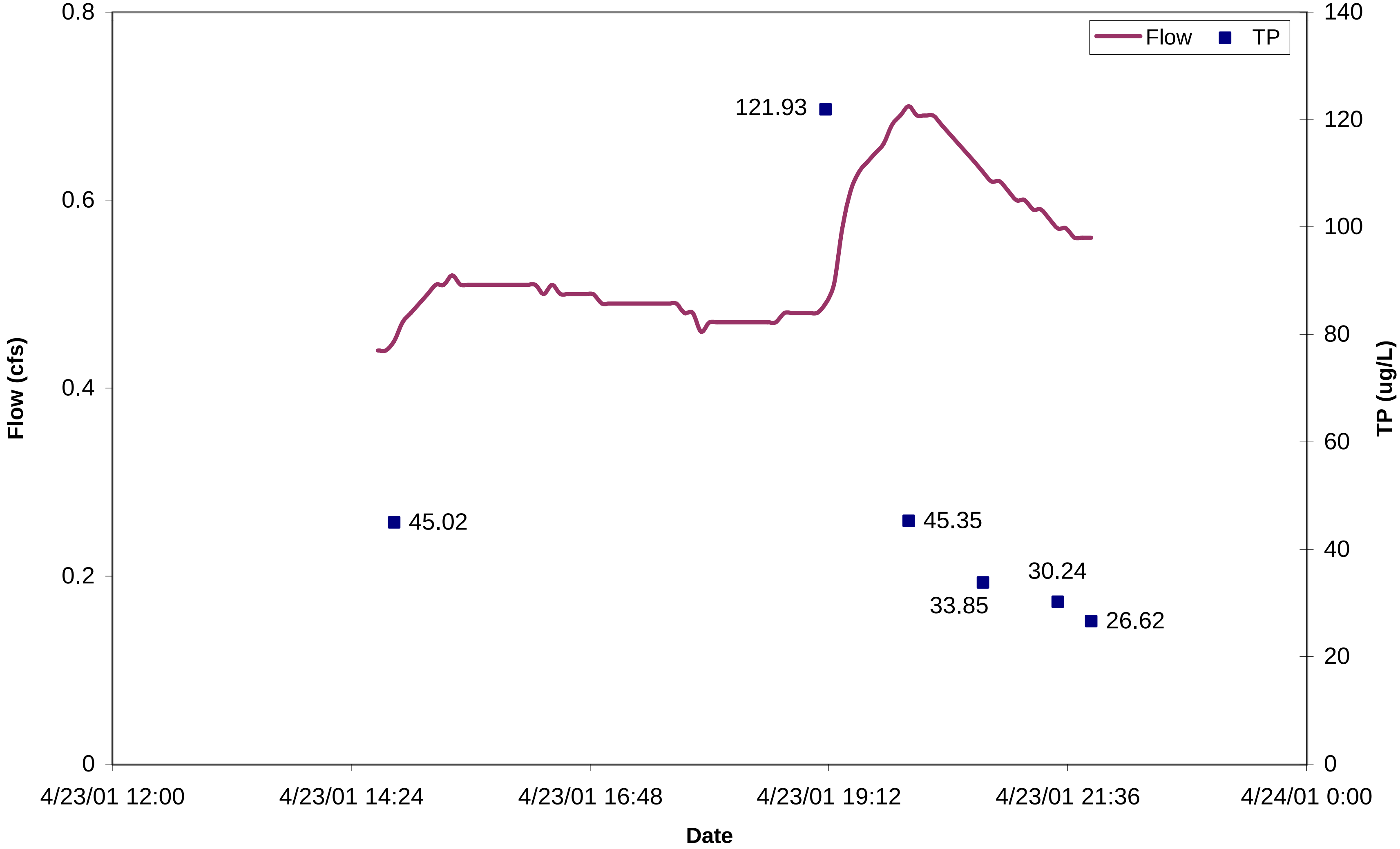


**Figure B-4. Flow and Soluble Reactive Phosphorus Concentrations at Location #3 for the April 23, 2001 Event.**

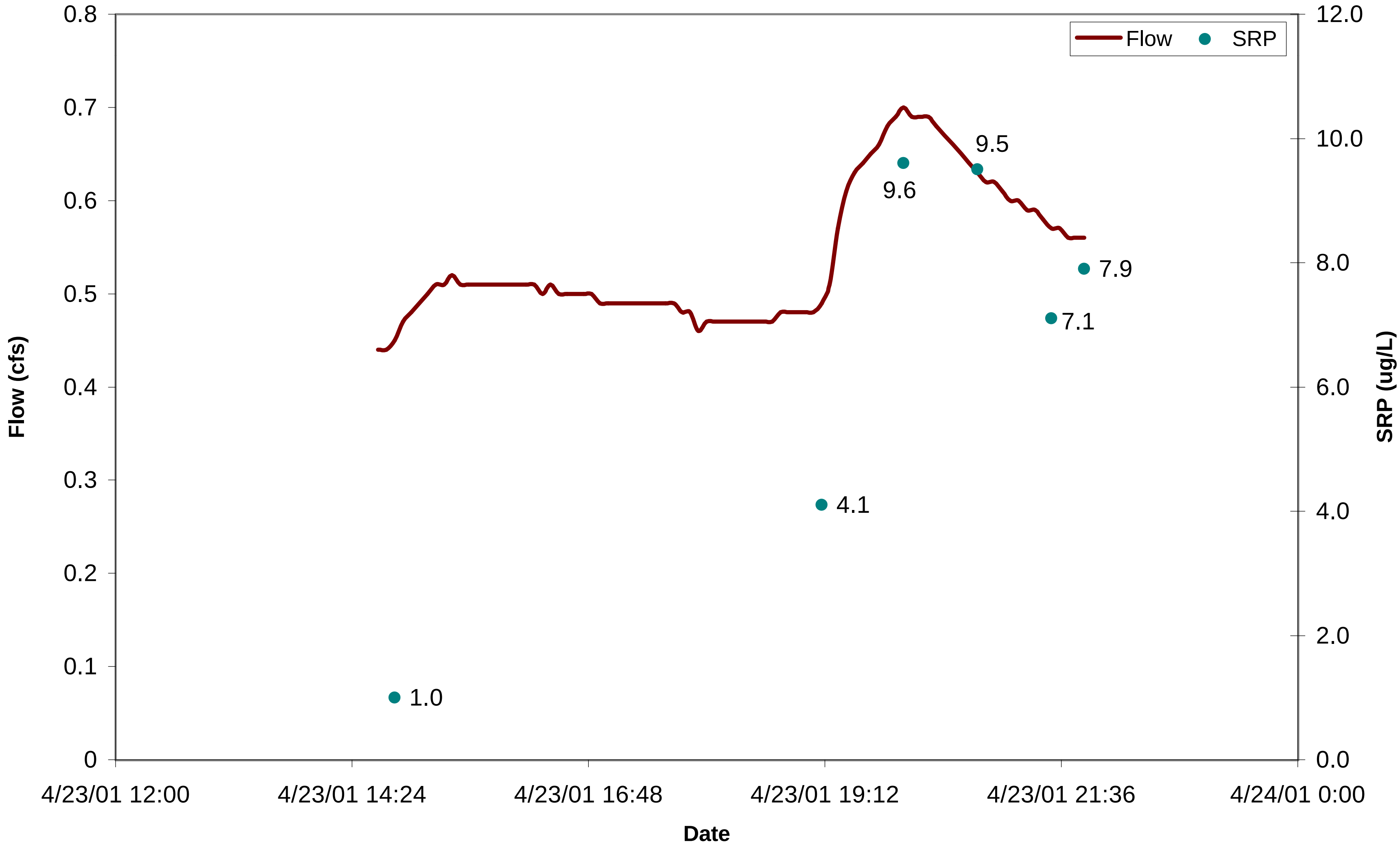


Figure B-5. Flow and Total Suspended Solid Conentrations at Location #3 for the April 23, 2001 Event.

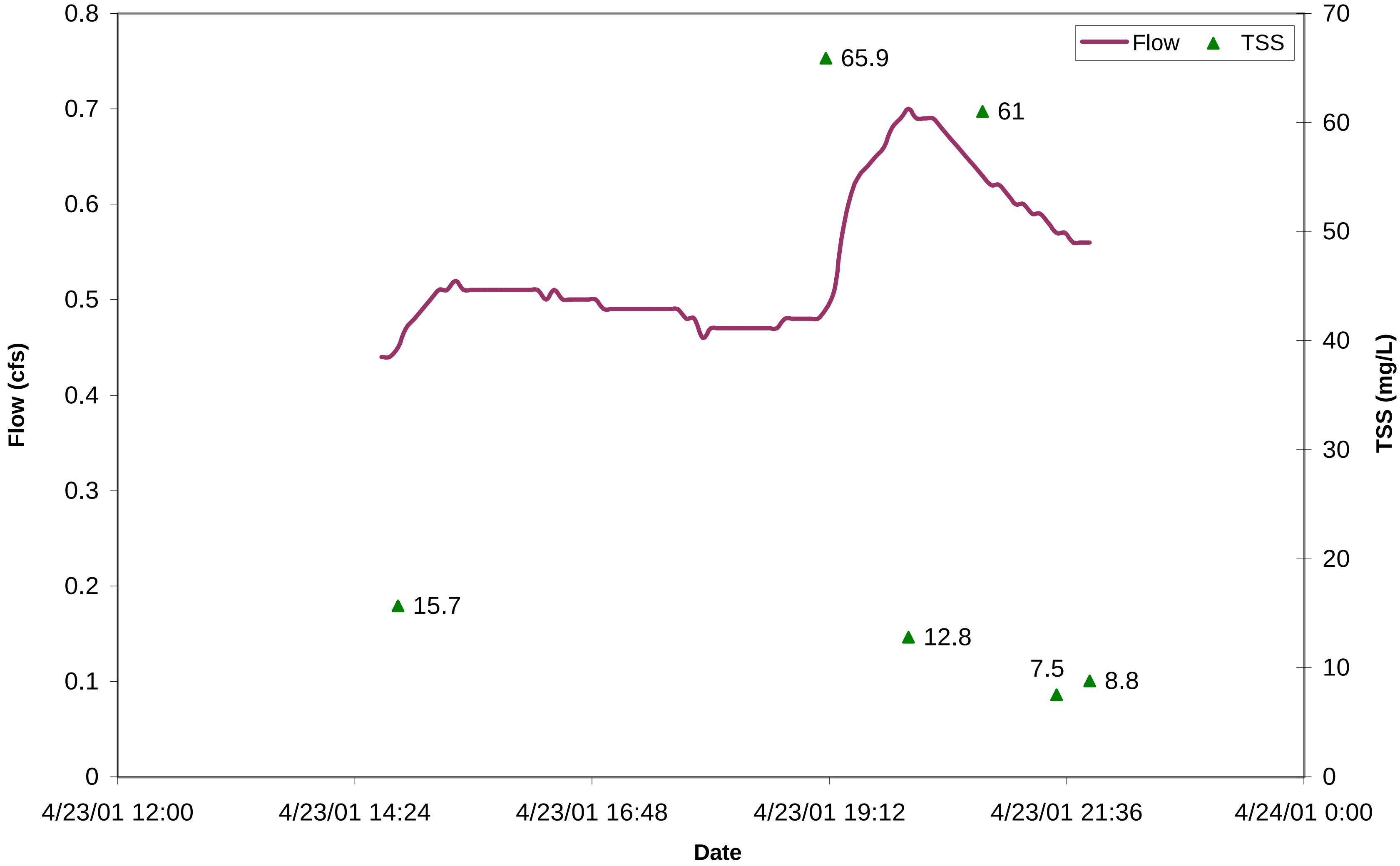


**Figure B-6. Flow and Total Phosphorus Concentrations at Location #3 for the May 7, 2001 Event.**

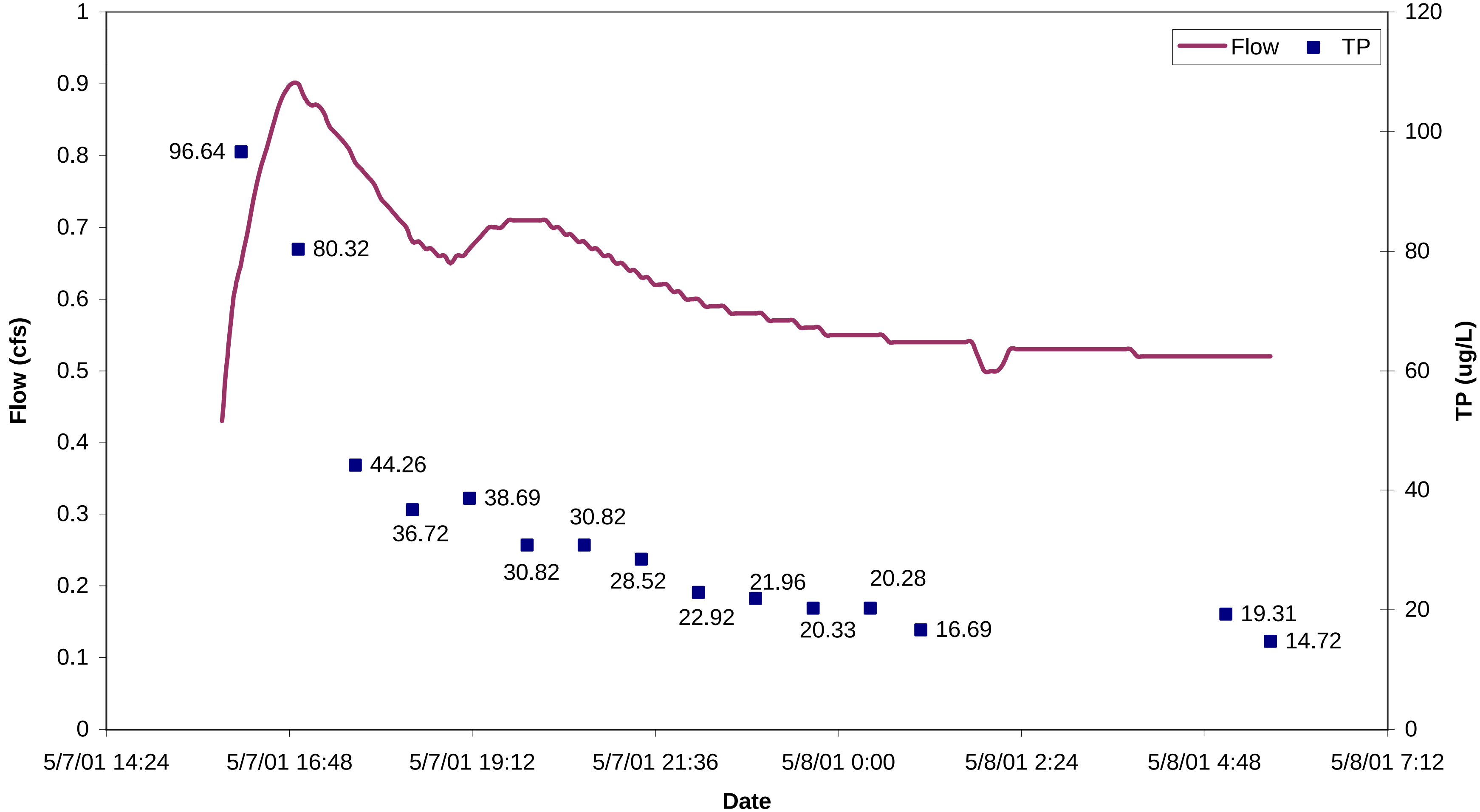


**Figure B-7. Flow and Soluble Reactive Phosphorus Concentrations at Locatin #3 for the May 7, 2001 Event.**

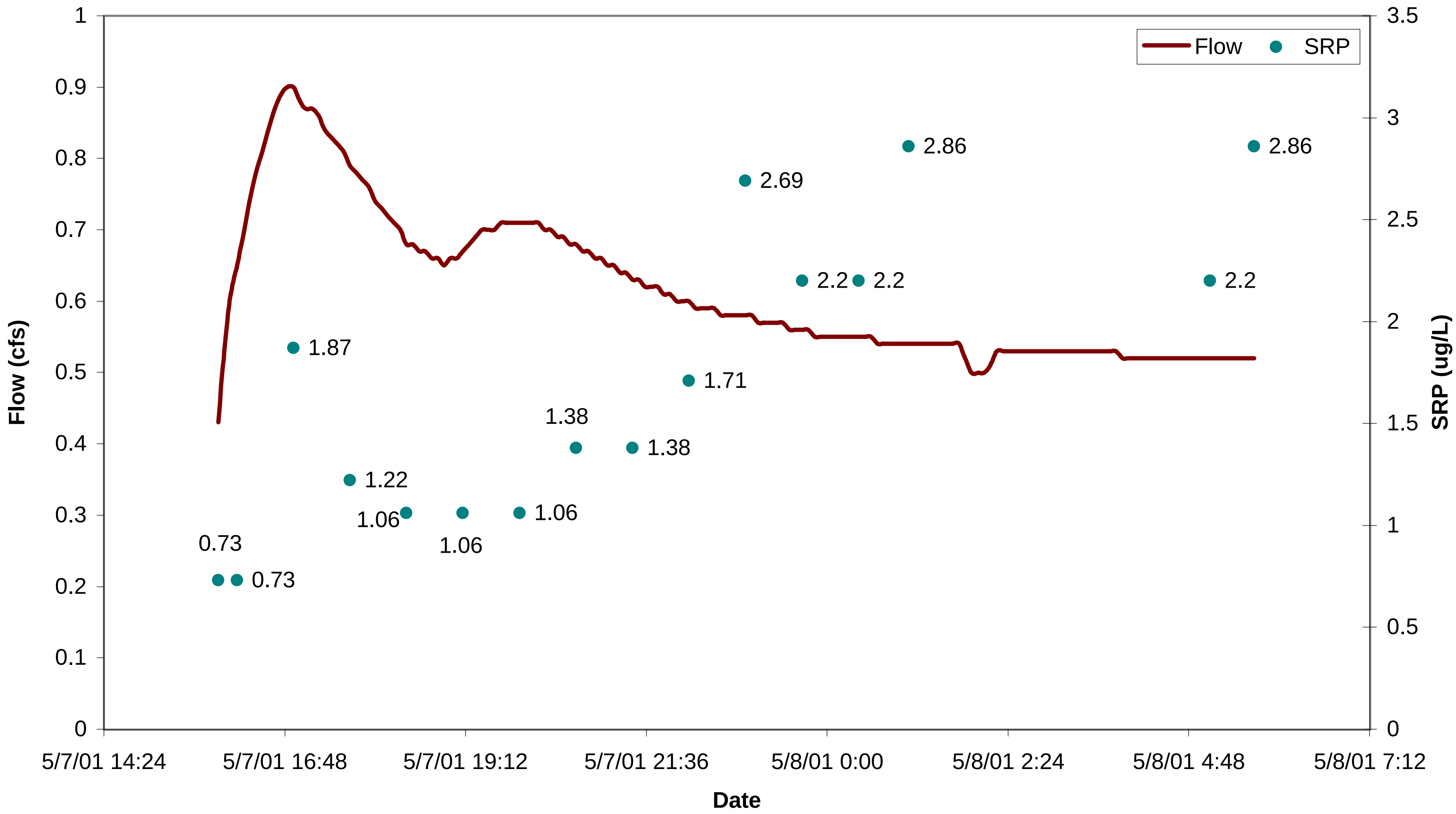


**Figure B-8. Flow and Total Suspended Solids Concentrations at Location #3 for the May 7, 2001 Event.**

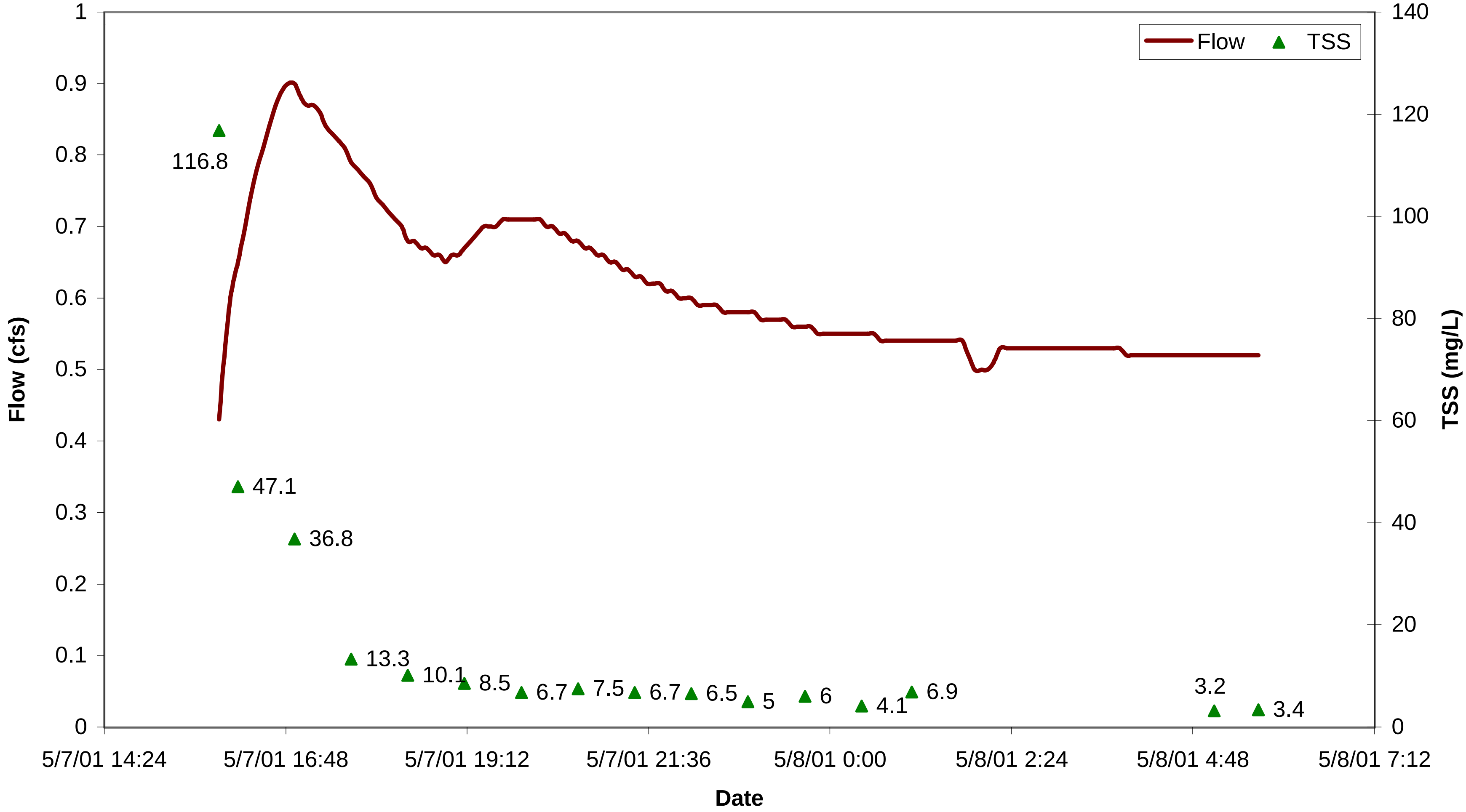


**Figure B-9. Flow and Total Phosphorus Concentrations at Location #3 for the May 10, 2001 Event.**

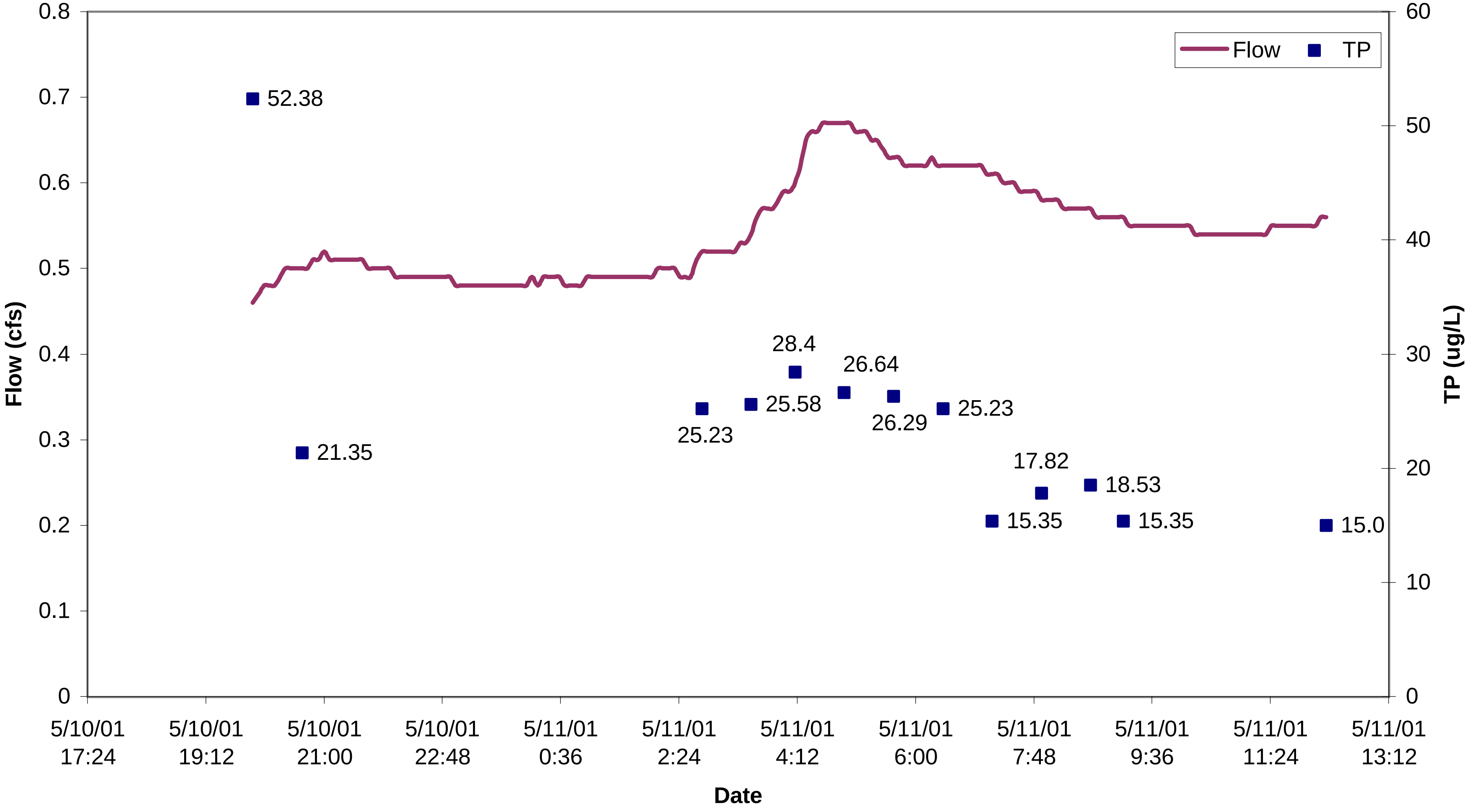


**Figure B-10. Flow and Total Suspended Solids Concentrations at Location #3 for the May 10, 2001 Event.**

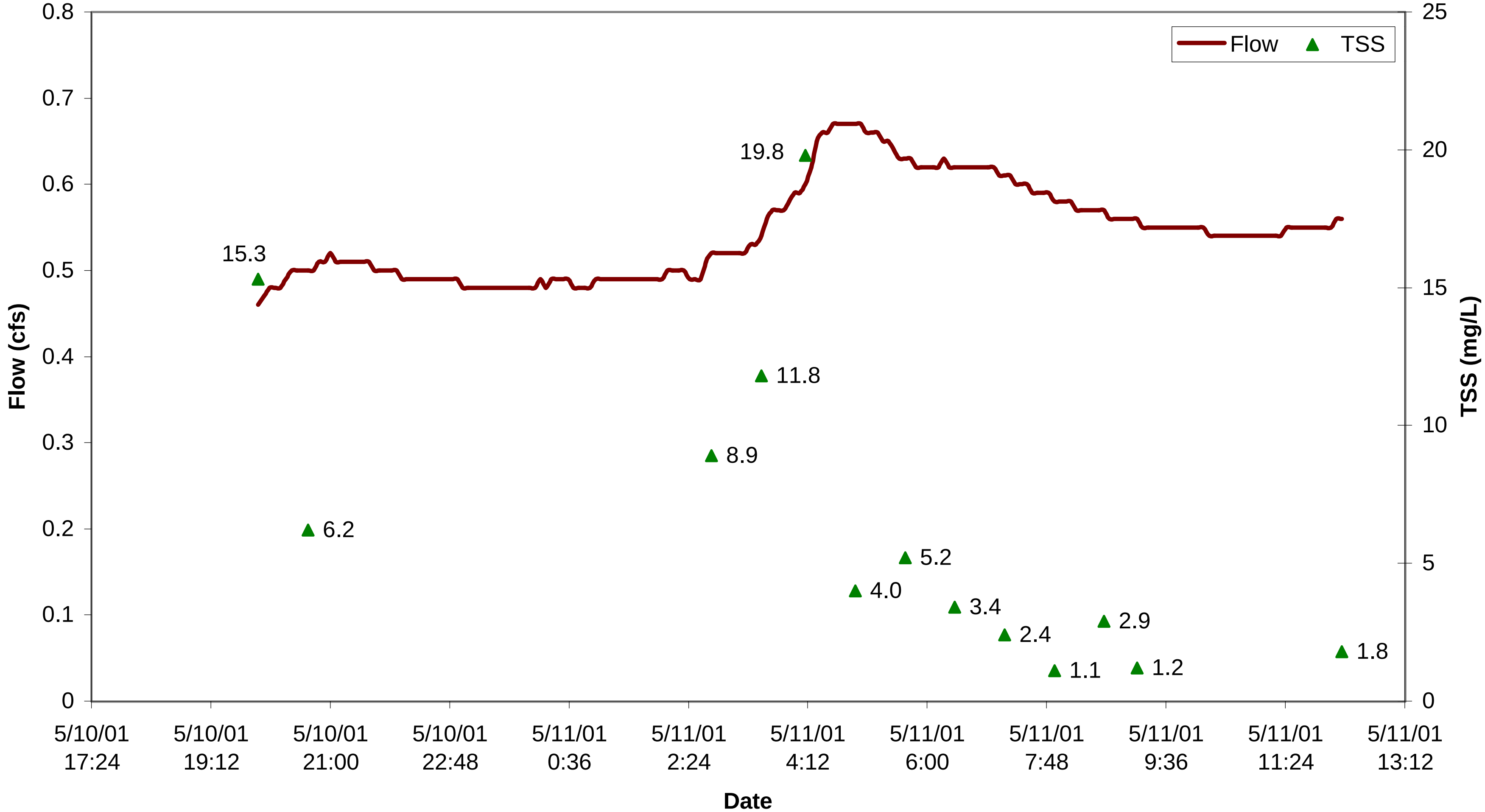


**Figure B-11. Flow and Total Phosphorus Concentrations at Location #3 for the May 31, 2001 Event.**

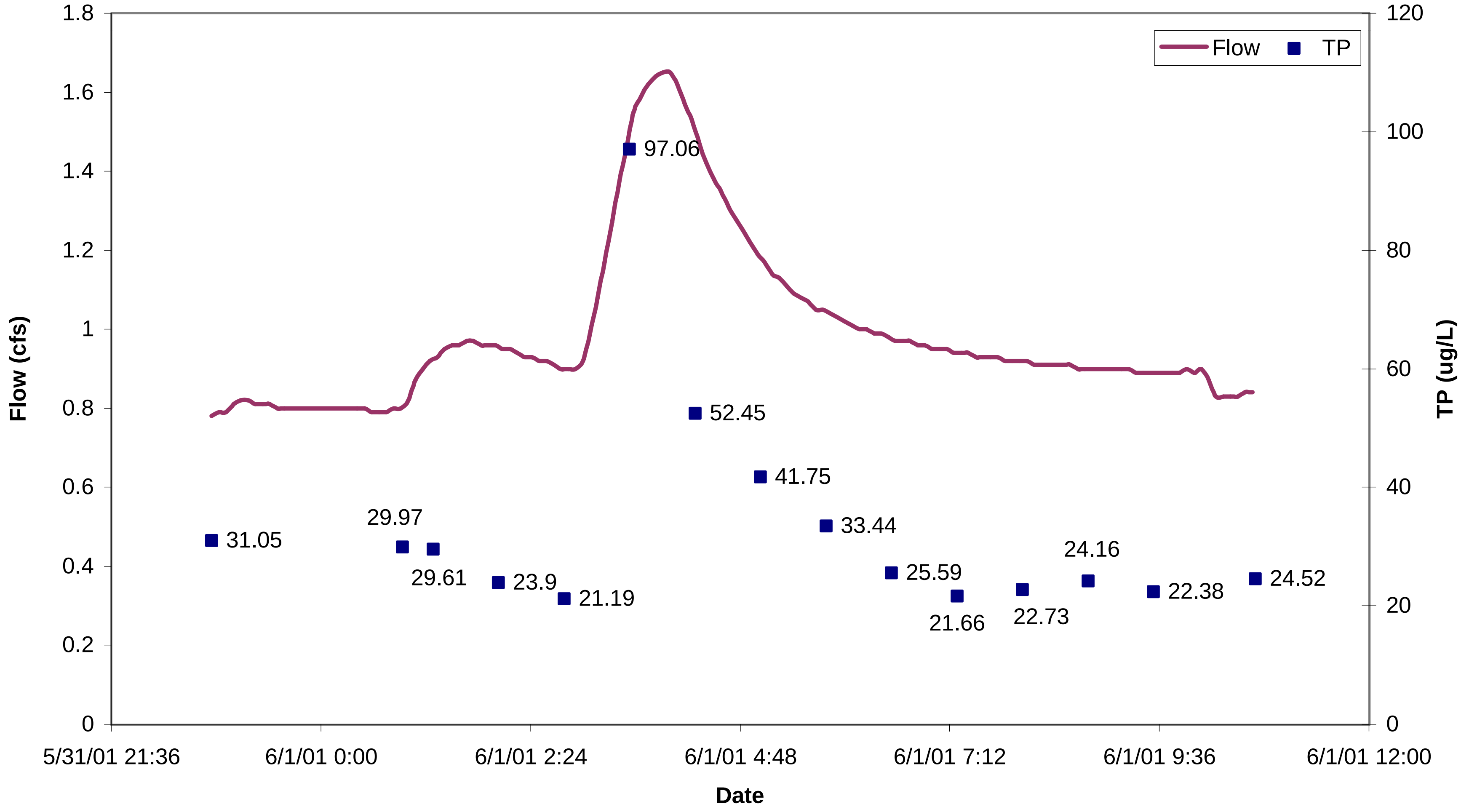


**Figure B-12. Flow and Total Suspended Solids Concentrations at Location #3 for the May 31, 2001 Event.**

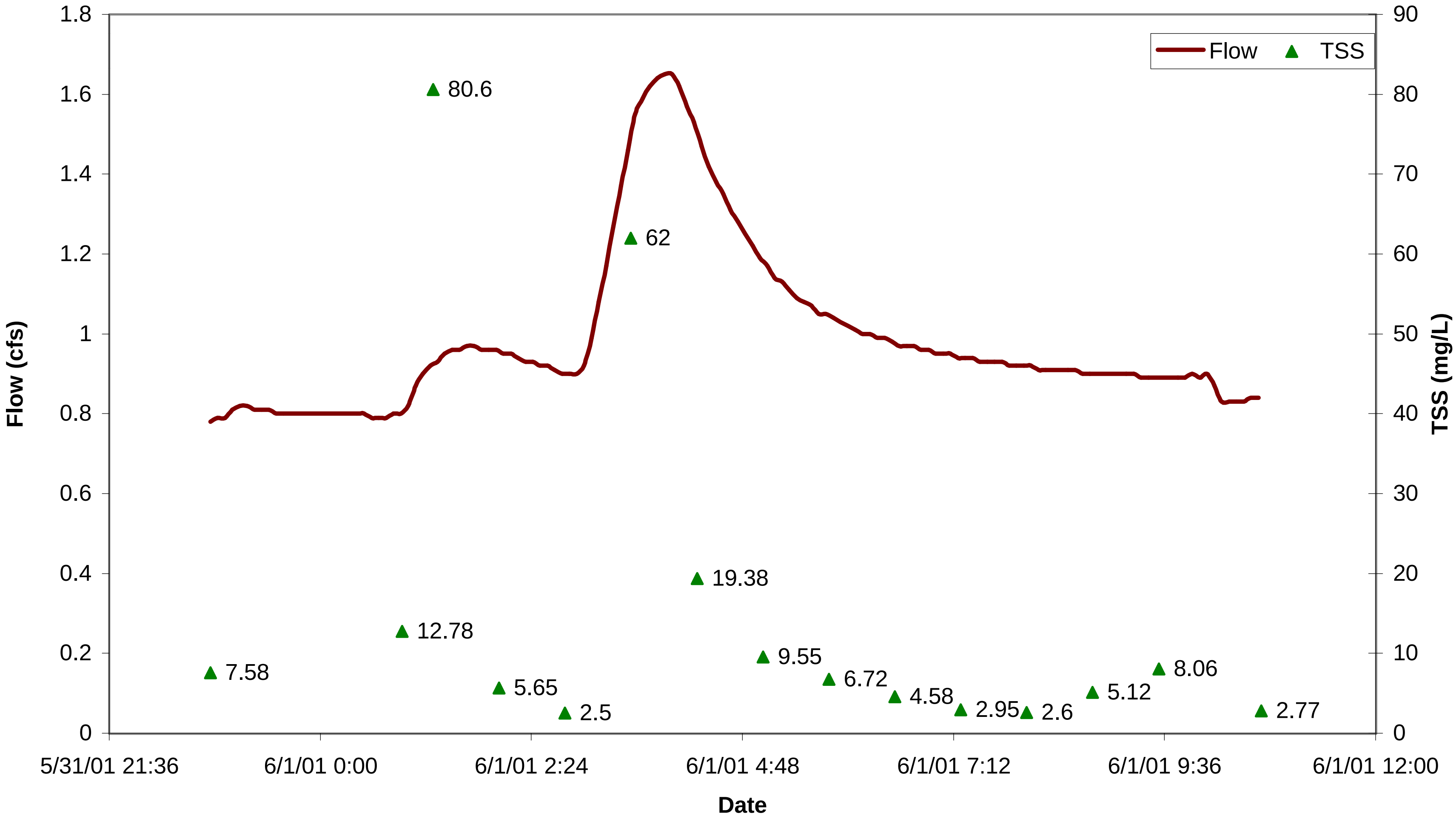


**Figure B-13. Flow and Total Phosphorus Concentrations at Location #3 for the June 12, 2001 Event.**

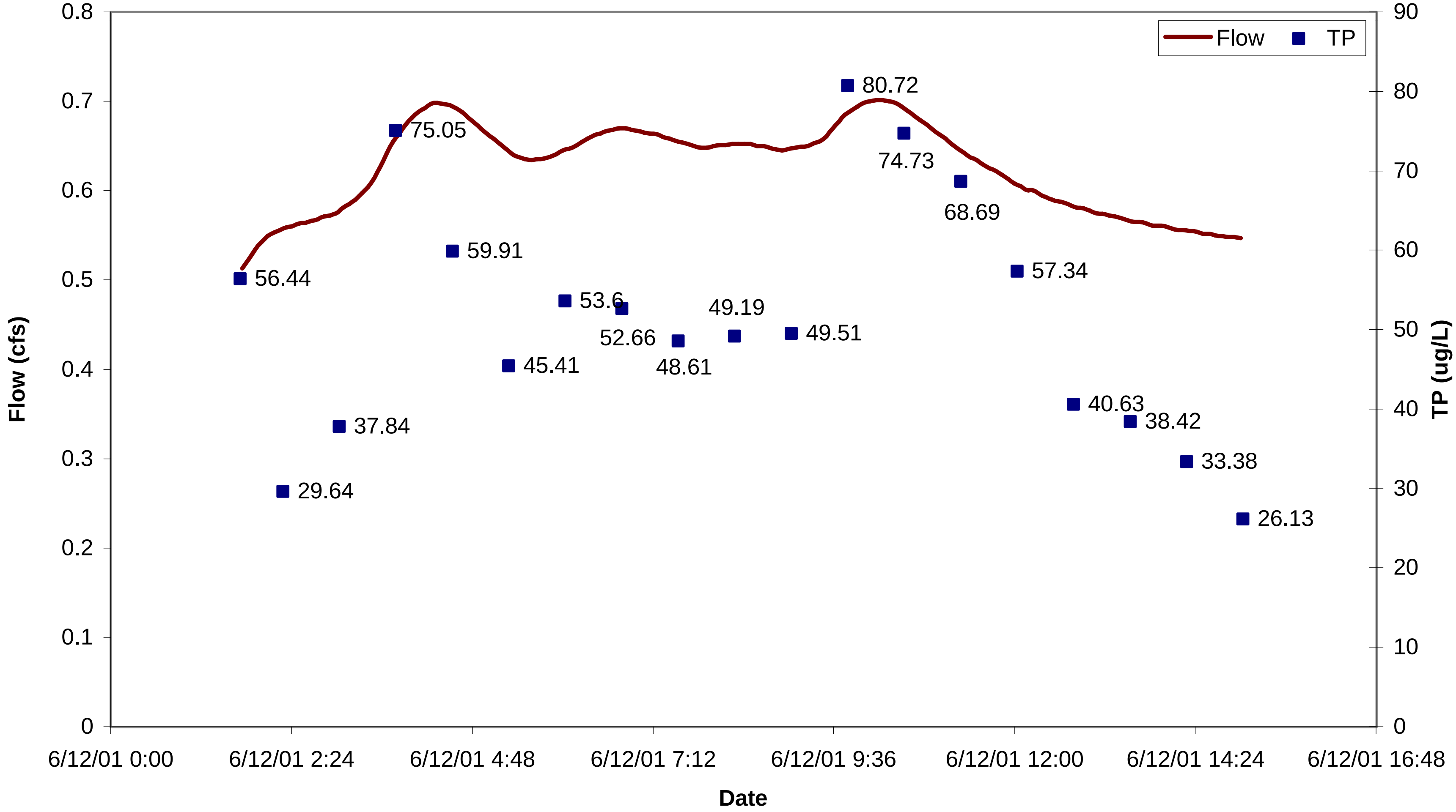


**Figure B-14. Flow and Total Suspended Solids Concentrations at Location #3 for the June 12, 2001 Event.**

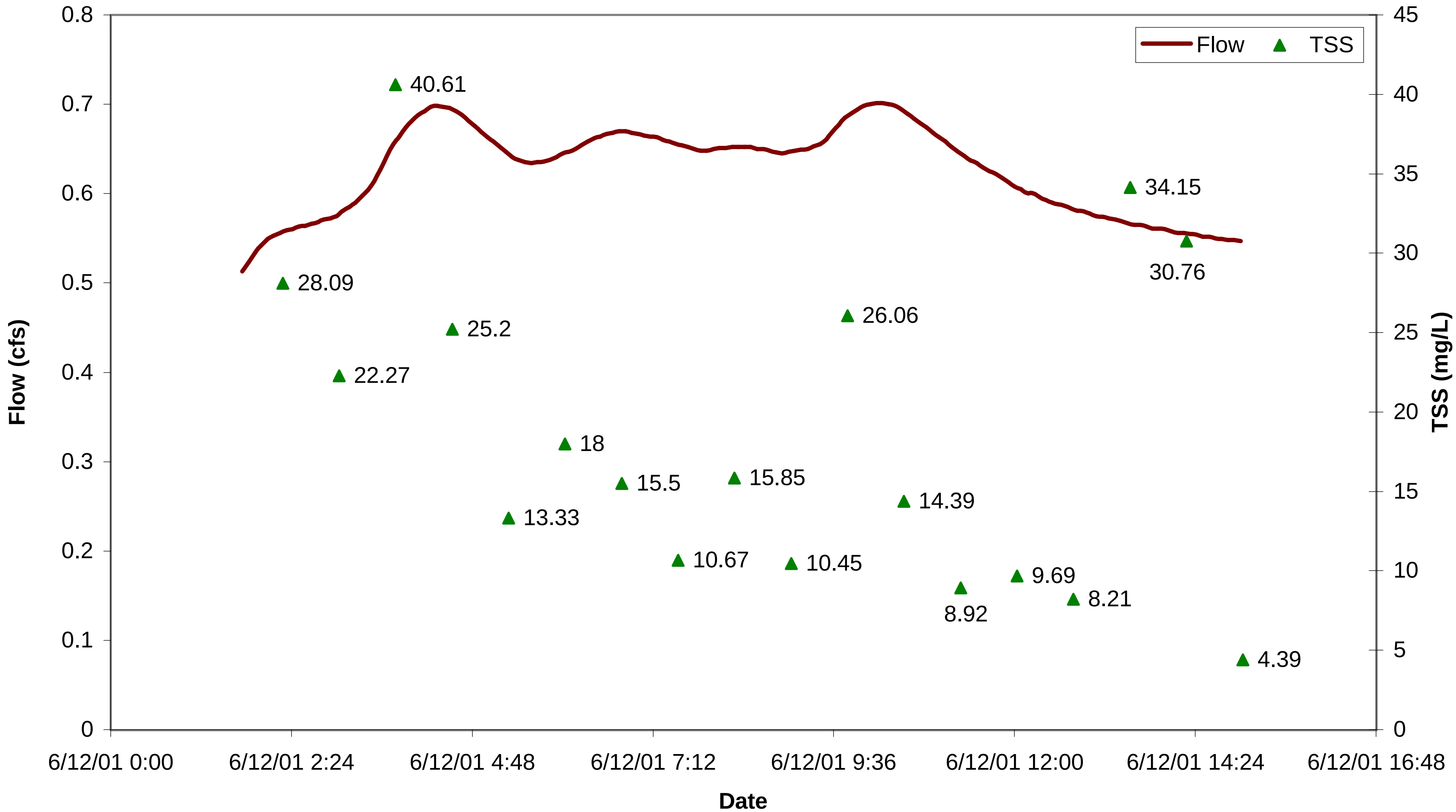


**Figure B-15. Flow and Total Phosphorus Concentrations at Location #1 for the June 12, 2001 Event.**

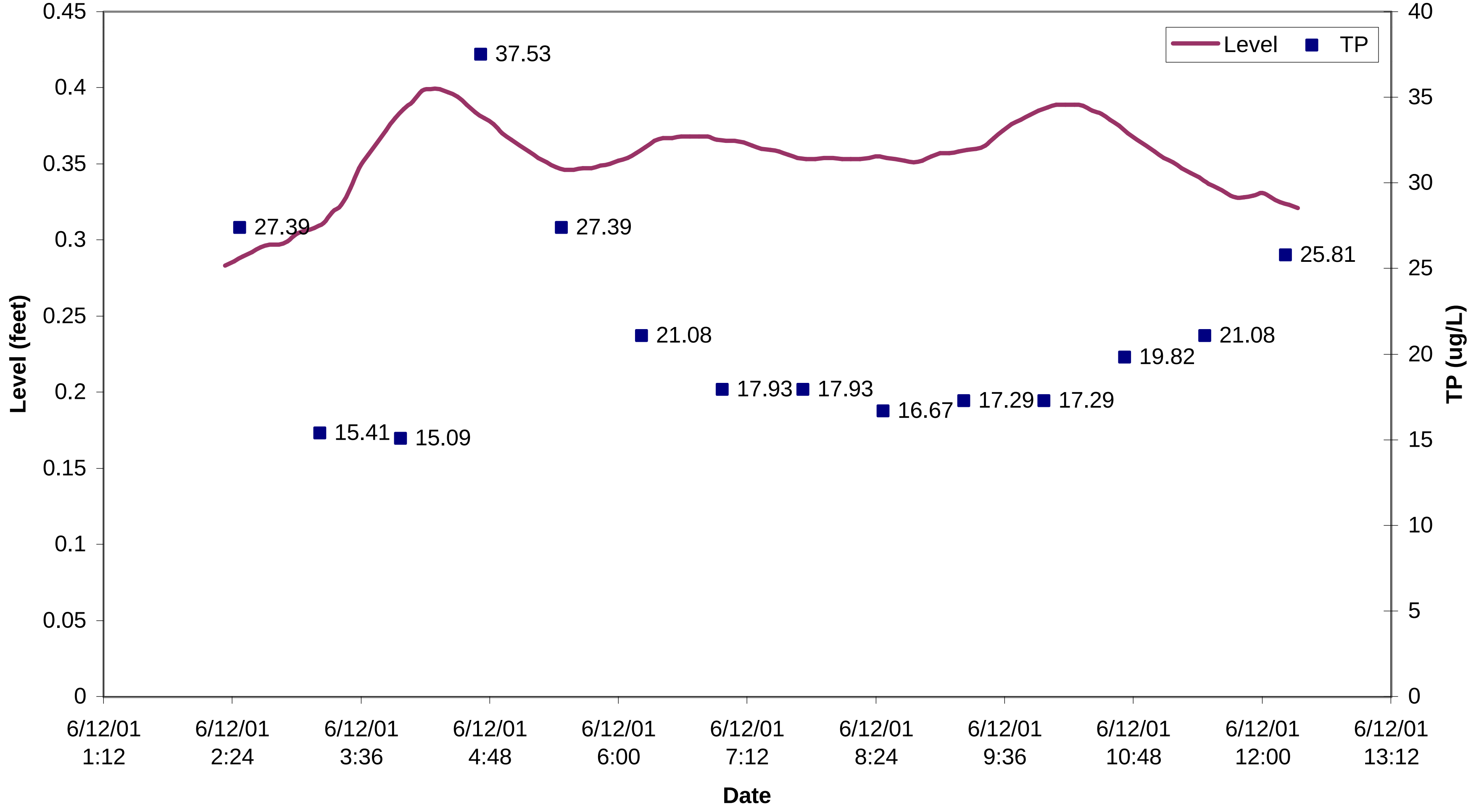


**Figure B-16. Flow and Total Suspended Solids Concentrations at Location #1 for the June 12, 2001 Event.**

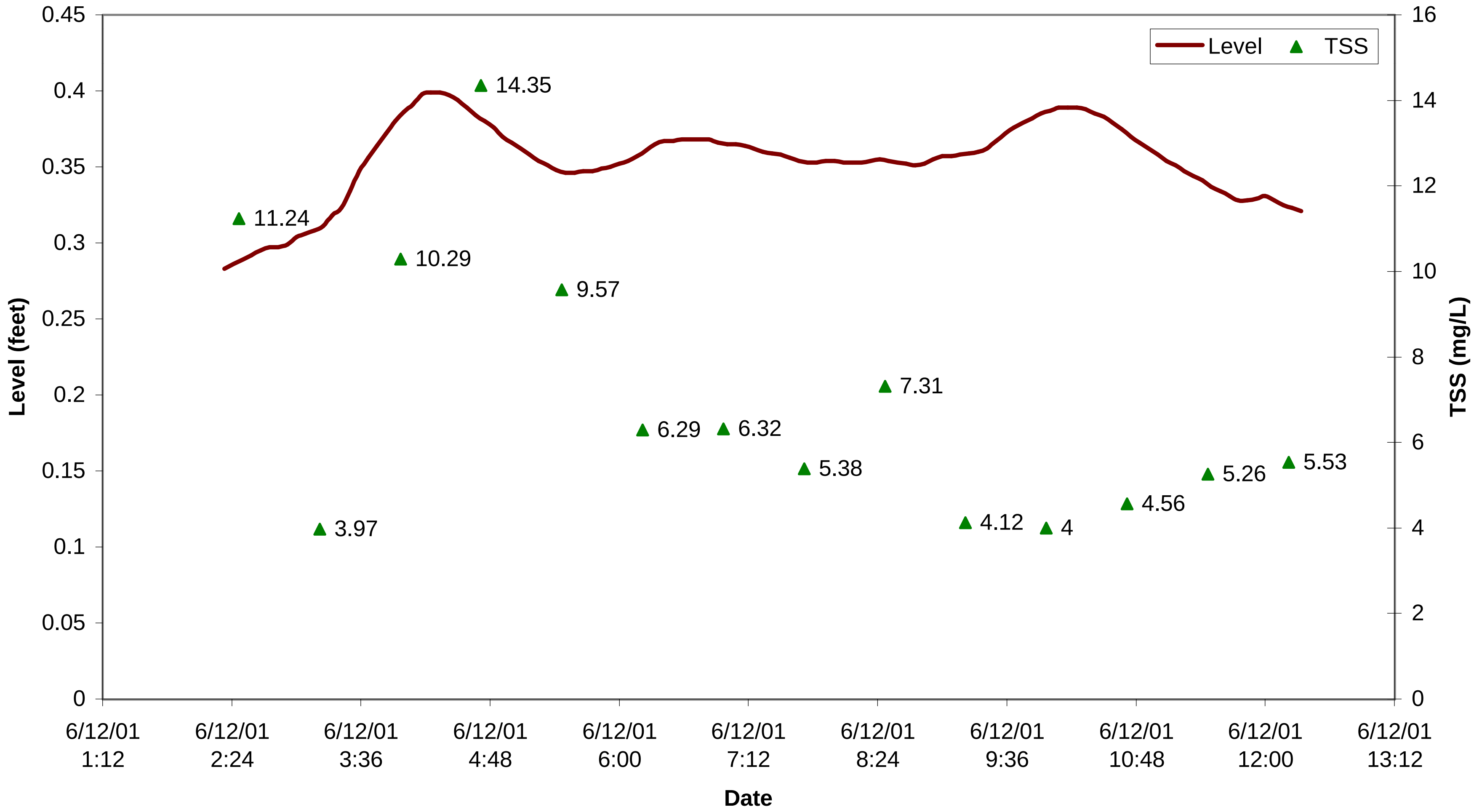


**Figure B-17. Flow and Total Phosphorus Concentrations at Location #3 for the August 18, 2001 Event.**

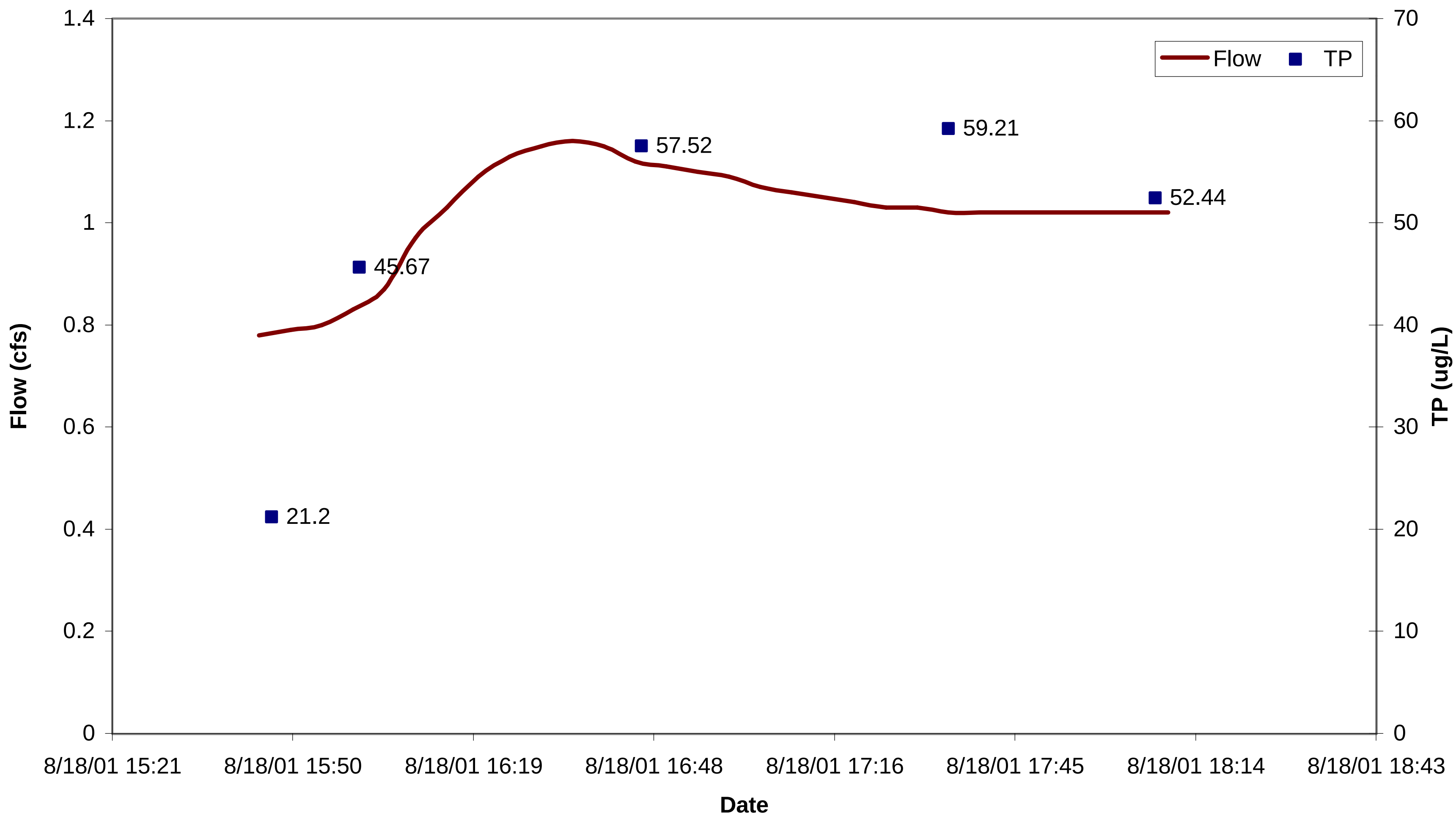


**Figure B-18. Flow and Total Suspended Solids Concentrations at Location #3 for the August 18, 2001 Event.**

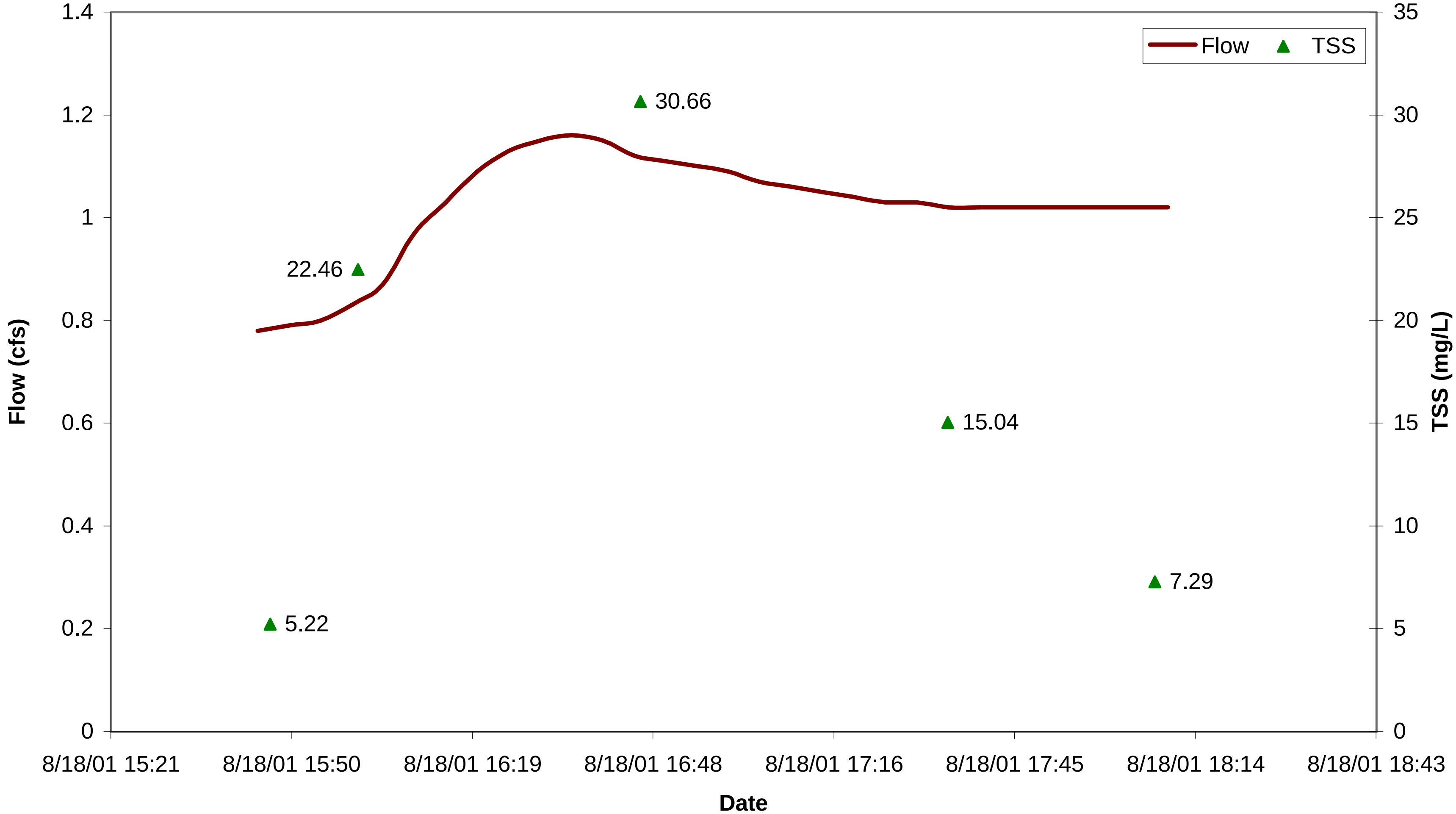


**Figure B-19. Flow and Total Phosphorus Concentrations at Location #1 for the August 18, 2001 Event.**

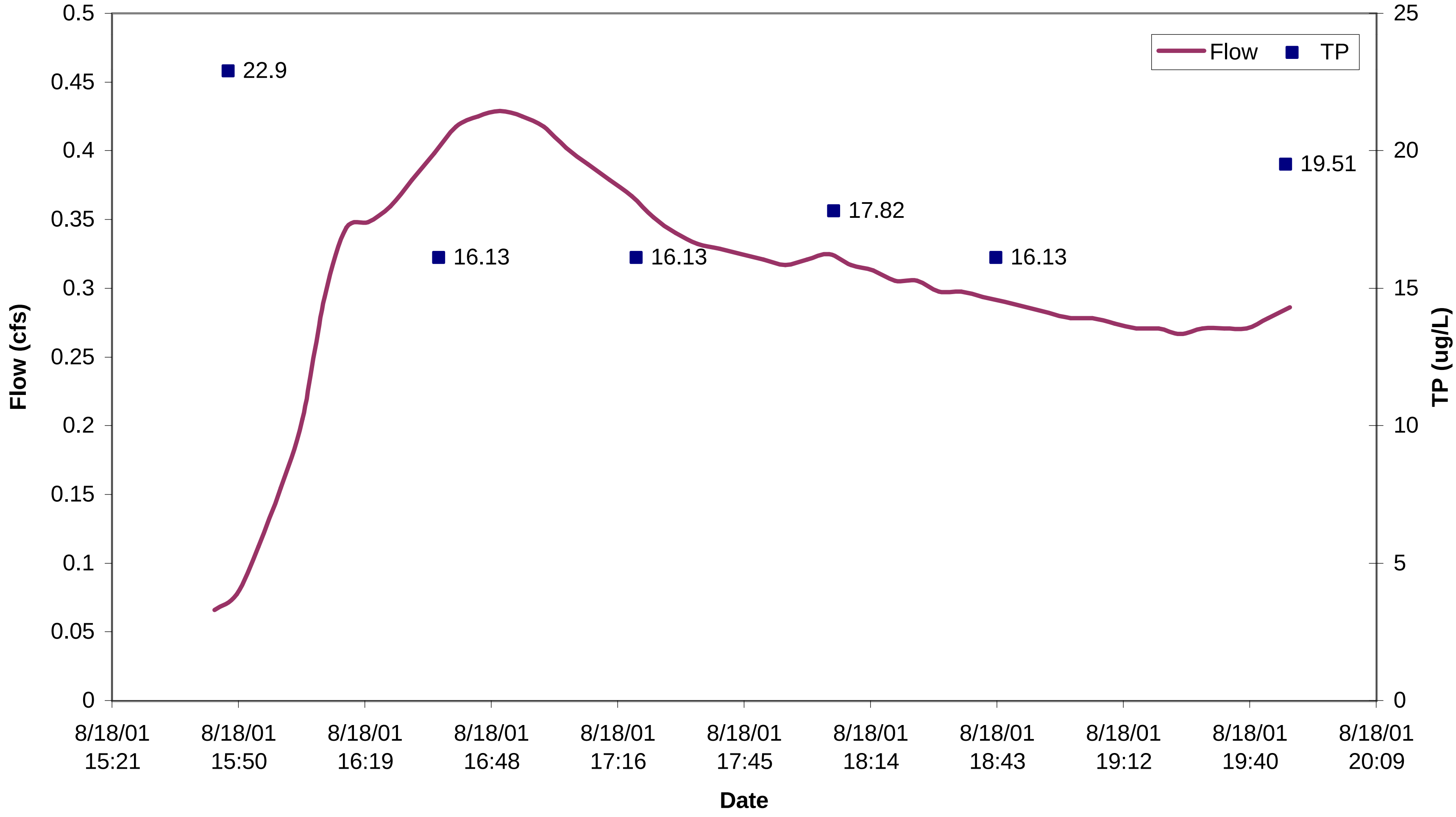


**Figure B-20. Flow and Total Suspended Solids Concentrations at Location #1 for the August 18, 2001 Event.**

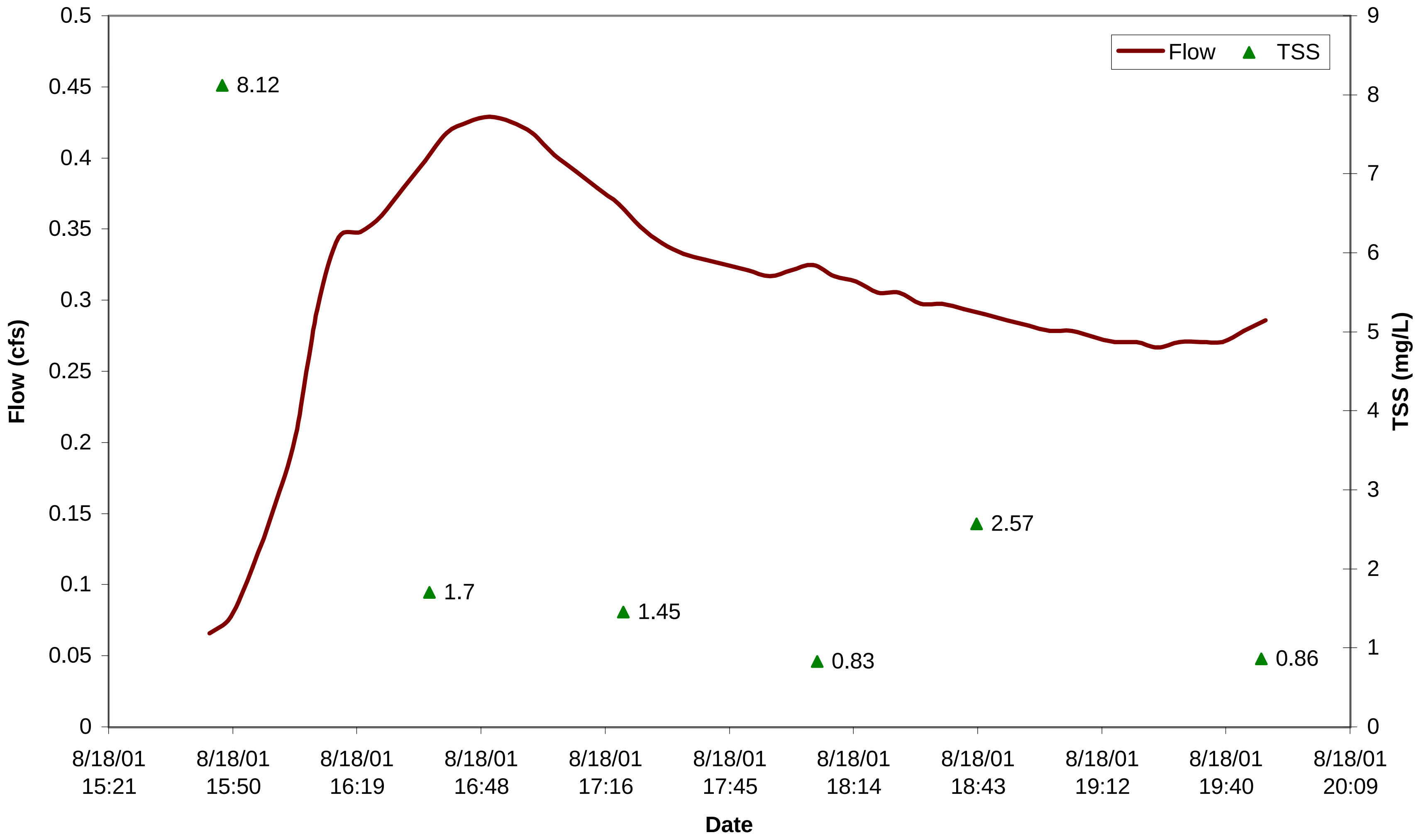


**Figure B-21. Flow and Total Phosphorus Concentrations at Location #3 for the August 19, 2001 Event.**

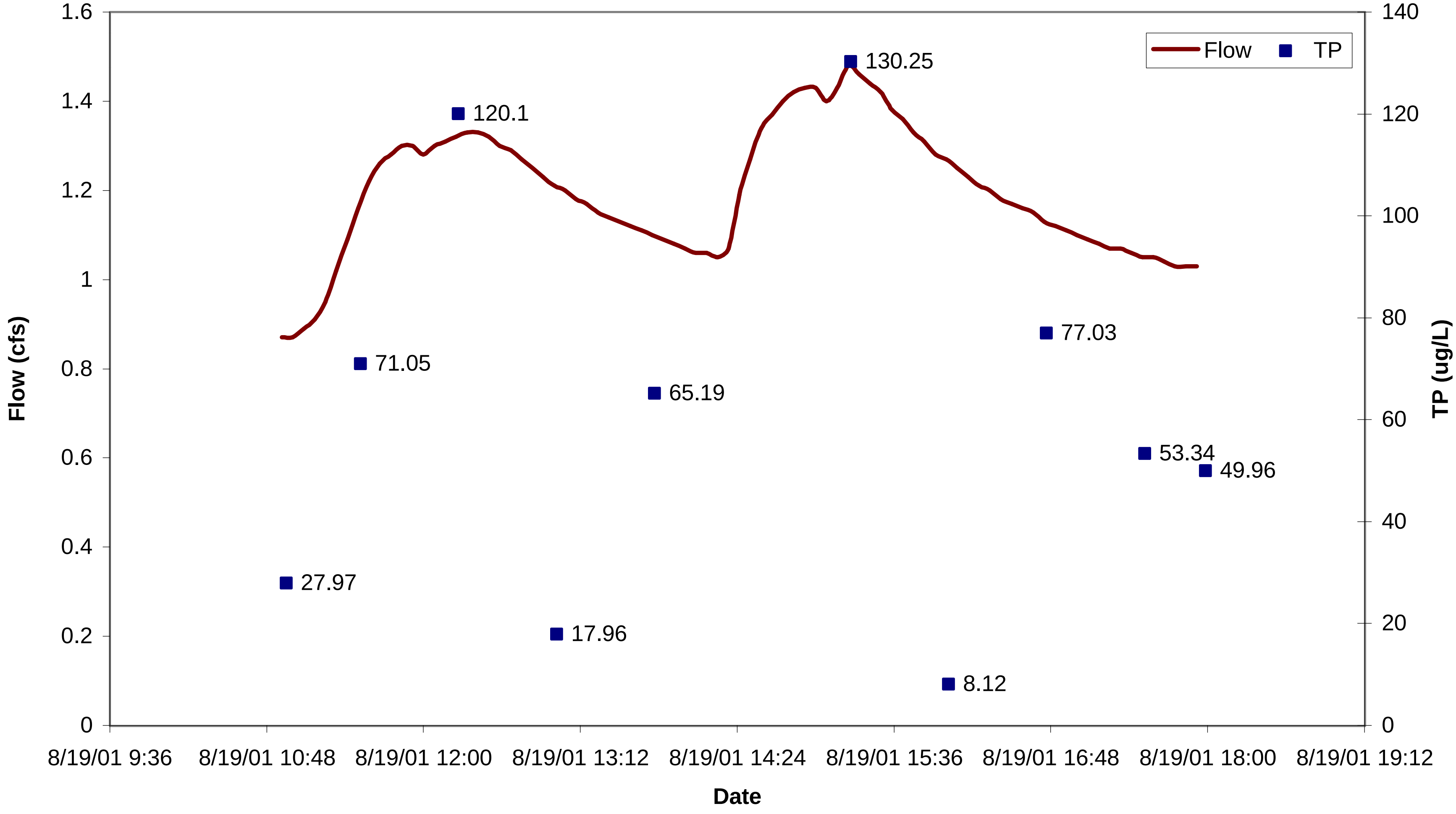


**Figure B-22. Flow and Total Suspended Solids Concentrations at Location #3 for the August 19, 2001 Event.**

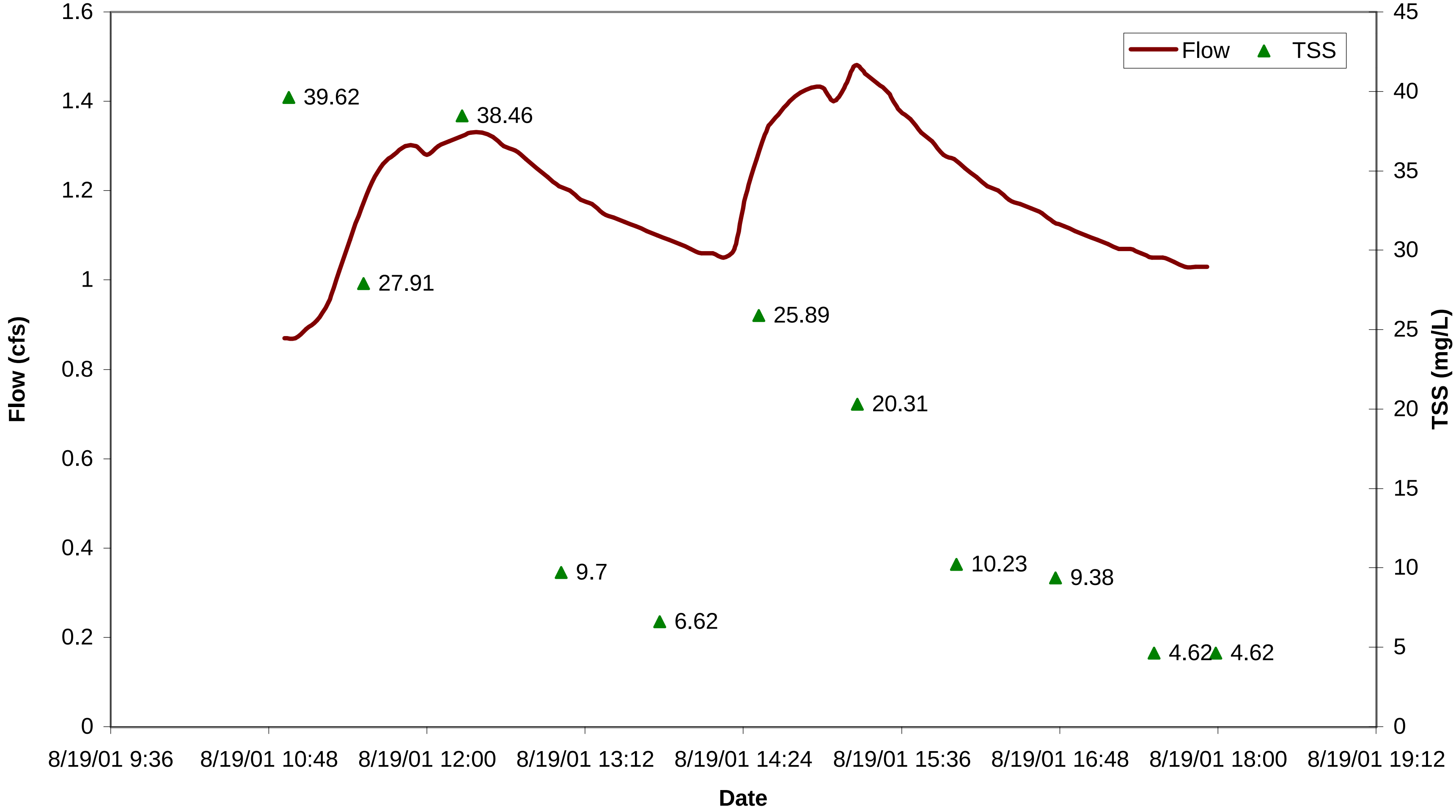


**Figure B-23. Flow and Total Phosphorus Concentrations at Location #1 for the August 19, 2001 Event.**

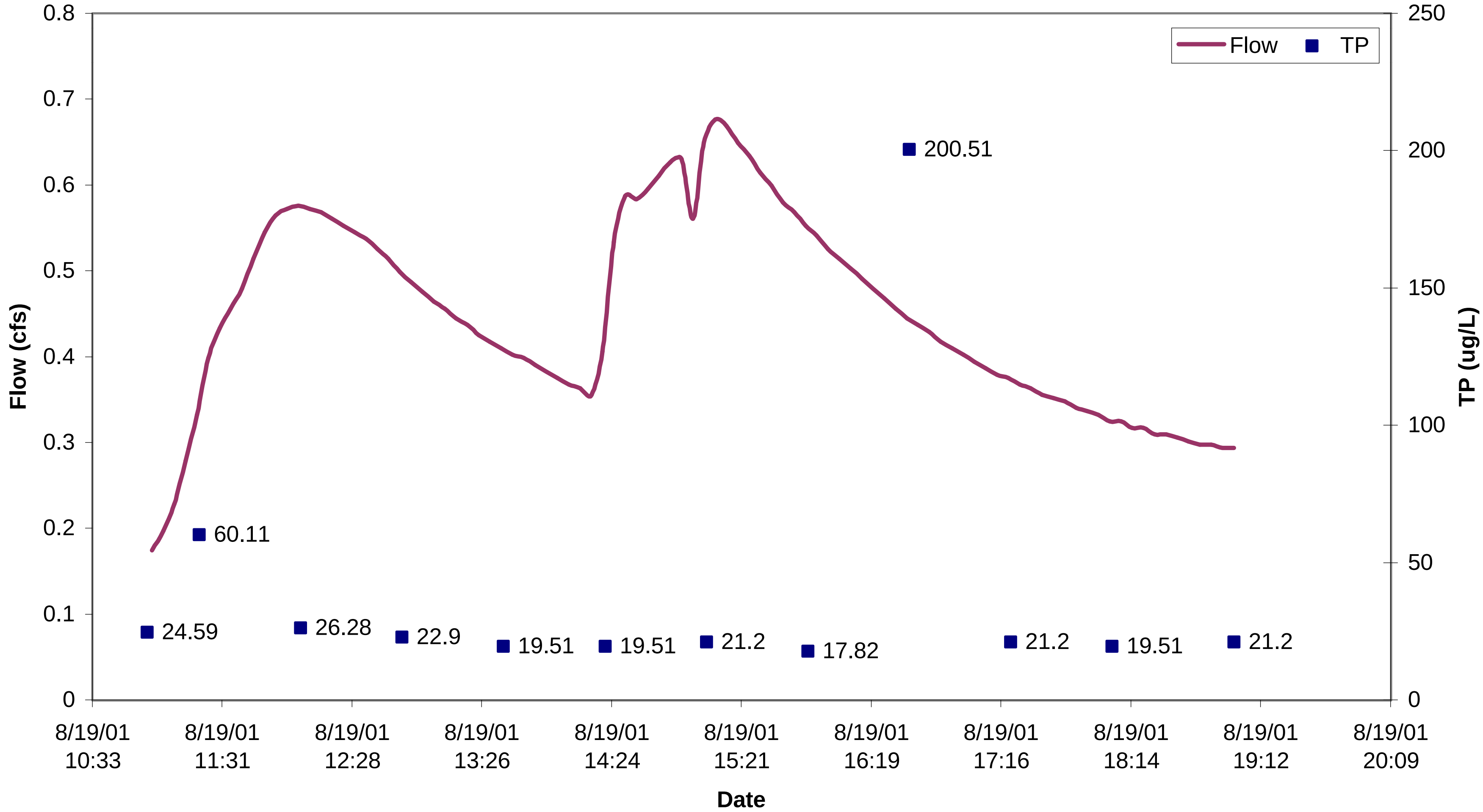


**Figure B-24. Flow and Total Suspended Solids Concentrations at Location #1 for the August 19, 2001 Event.**

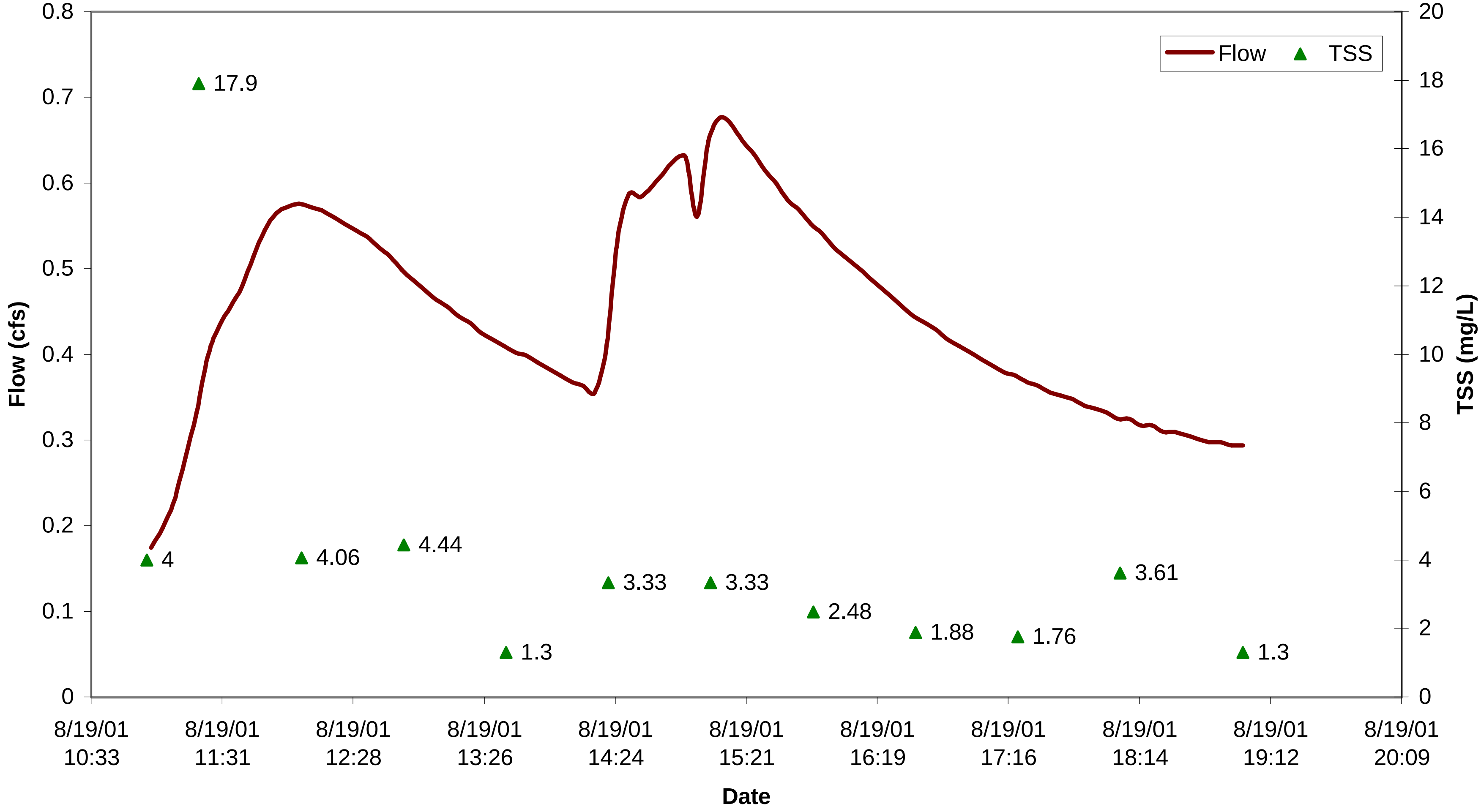


**Figure B-25. Flow and Total Phosphorus Concentrations at Location #3 for the August 22, 2001 Event.**

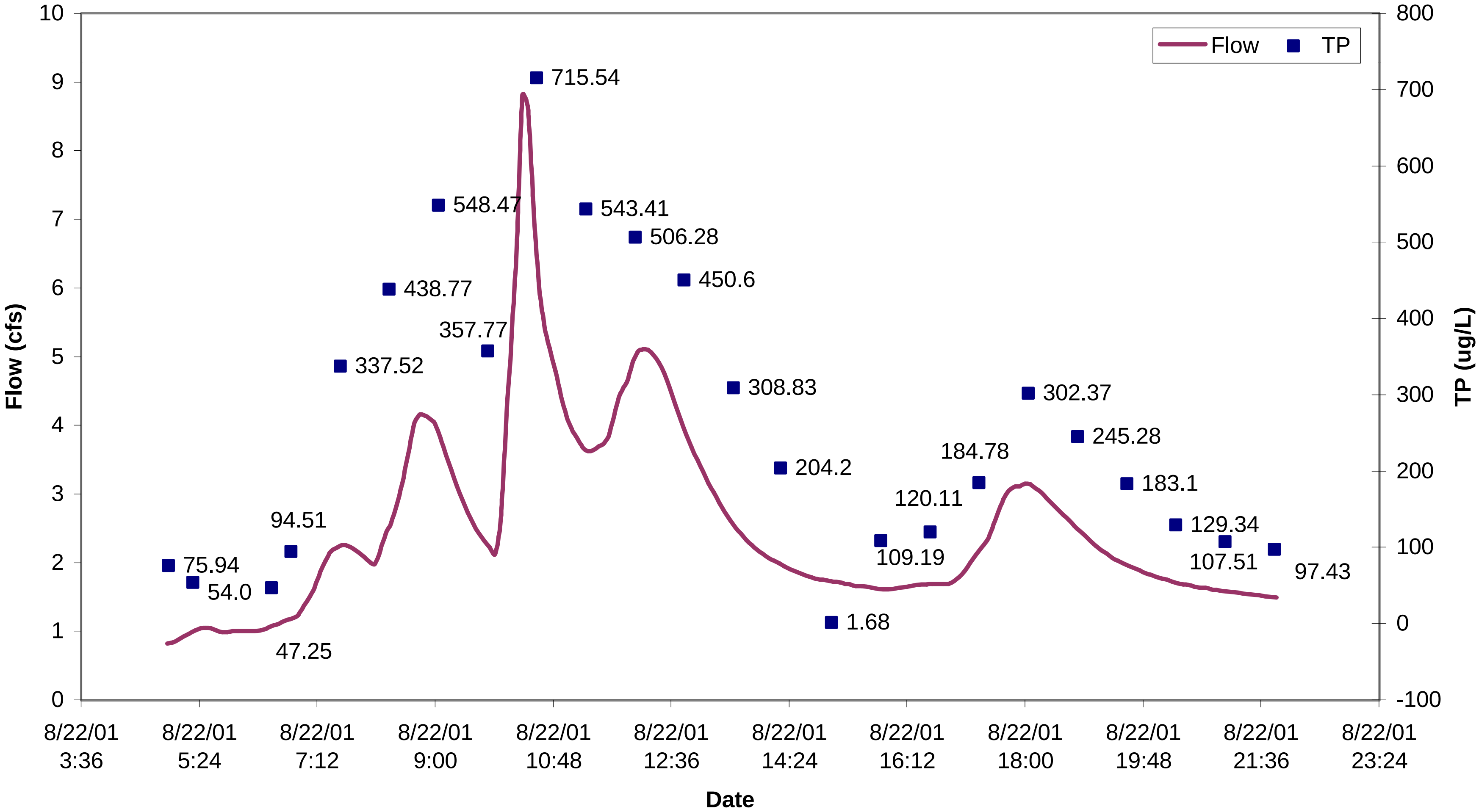


**Figure B-26. Flow and Soluble Reactive Phosphorus Concentrations at Location #3 for the August 22, 2001 Event.**

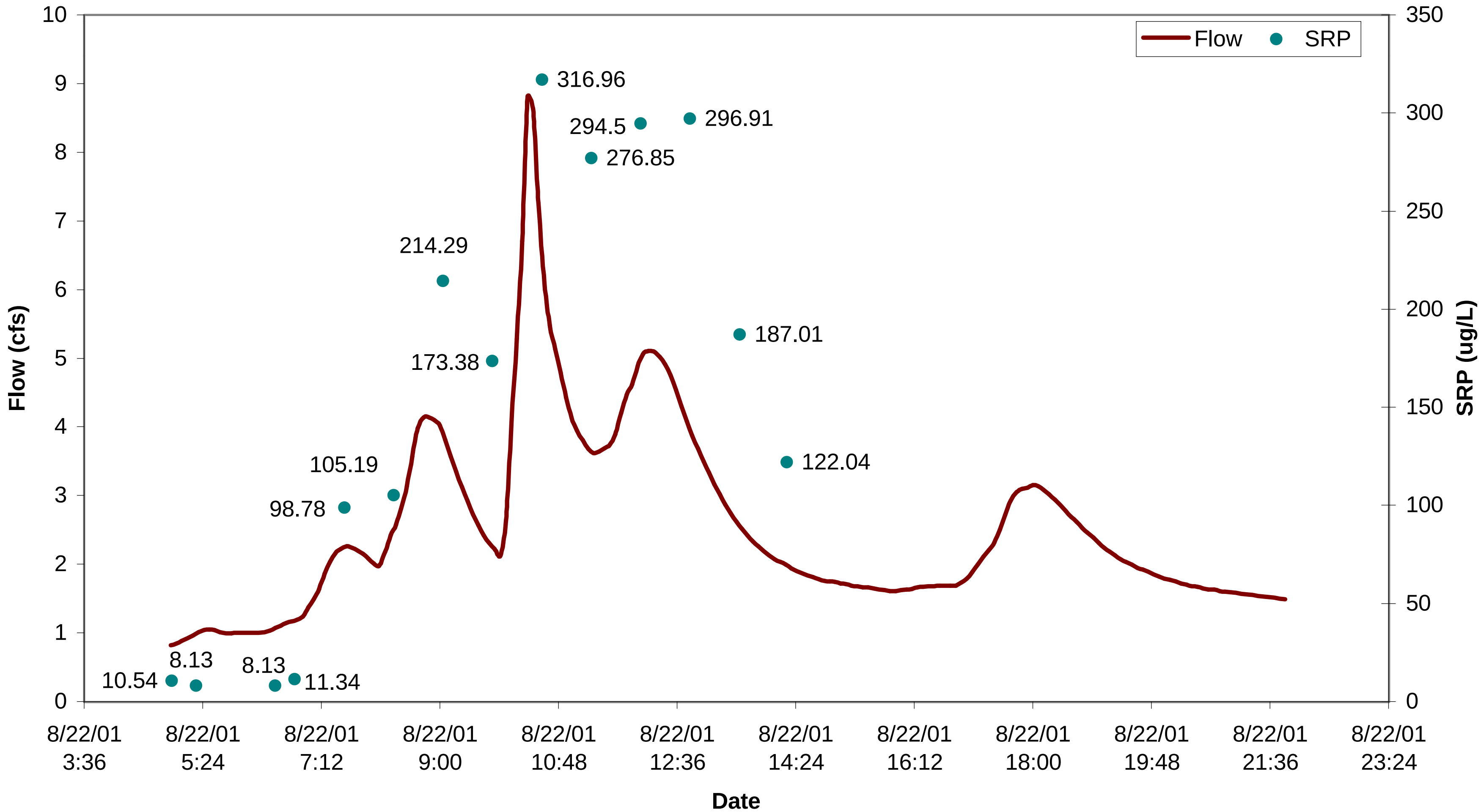


**Figure B-27. Flow and Total Suspended Solids Concentration at Location #3 for the August 22, 2001 Event.**

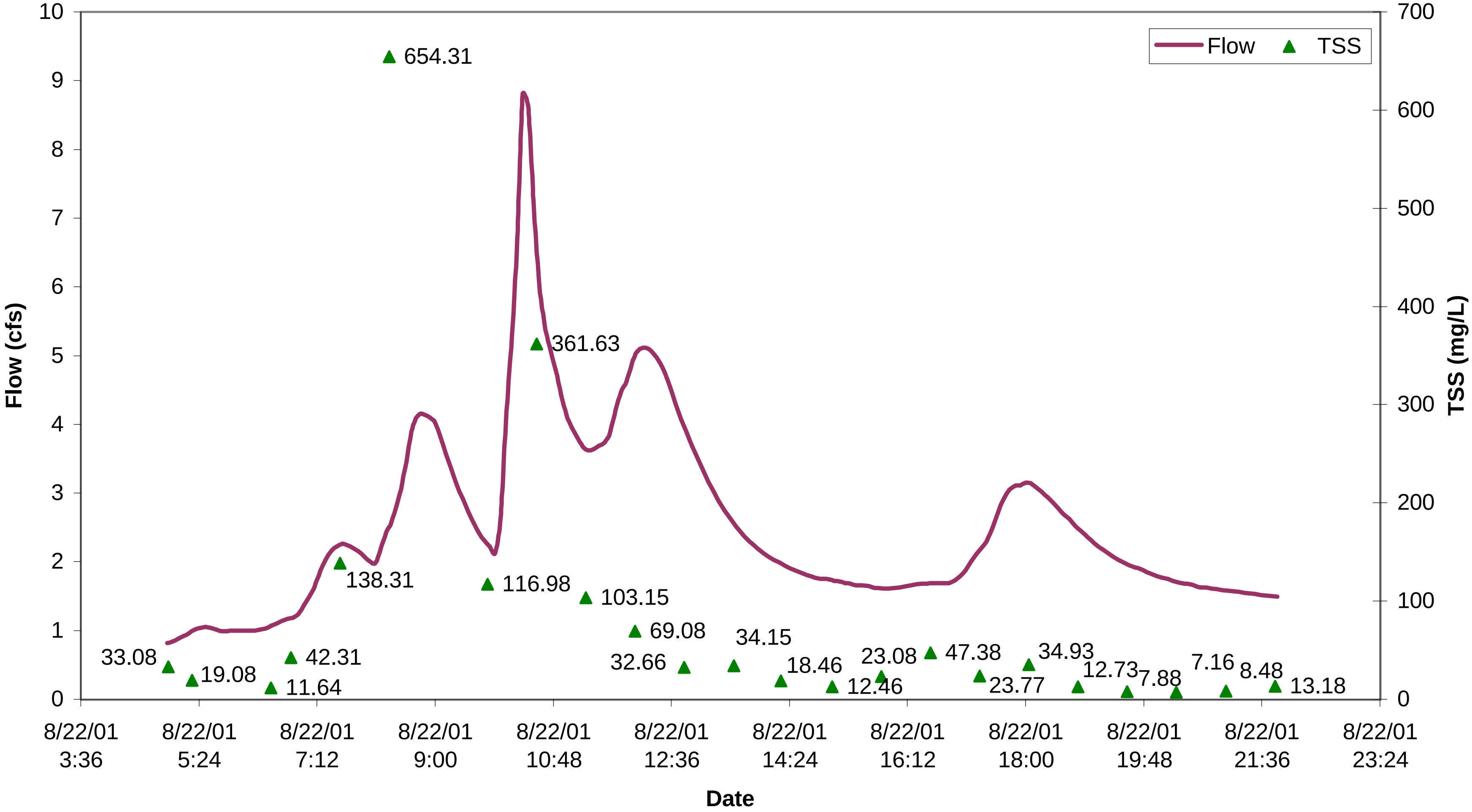


**Figure B-28. Flow and Total Phosphorus Concentrations at Location #1 for the August 22, 2001 Event.**

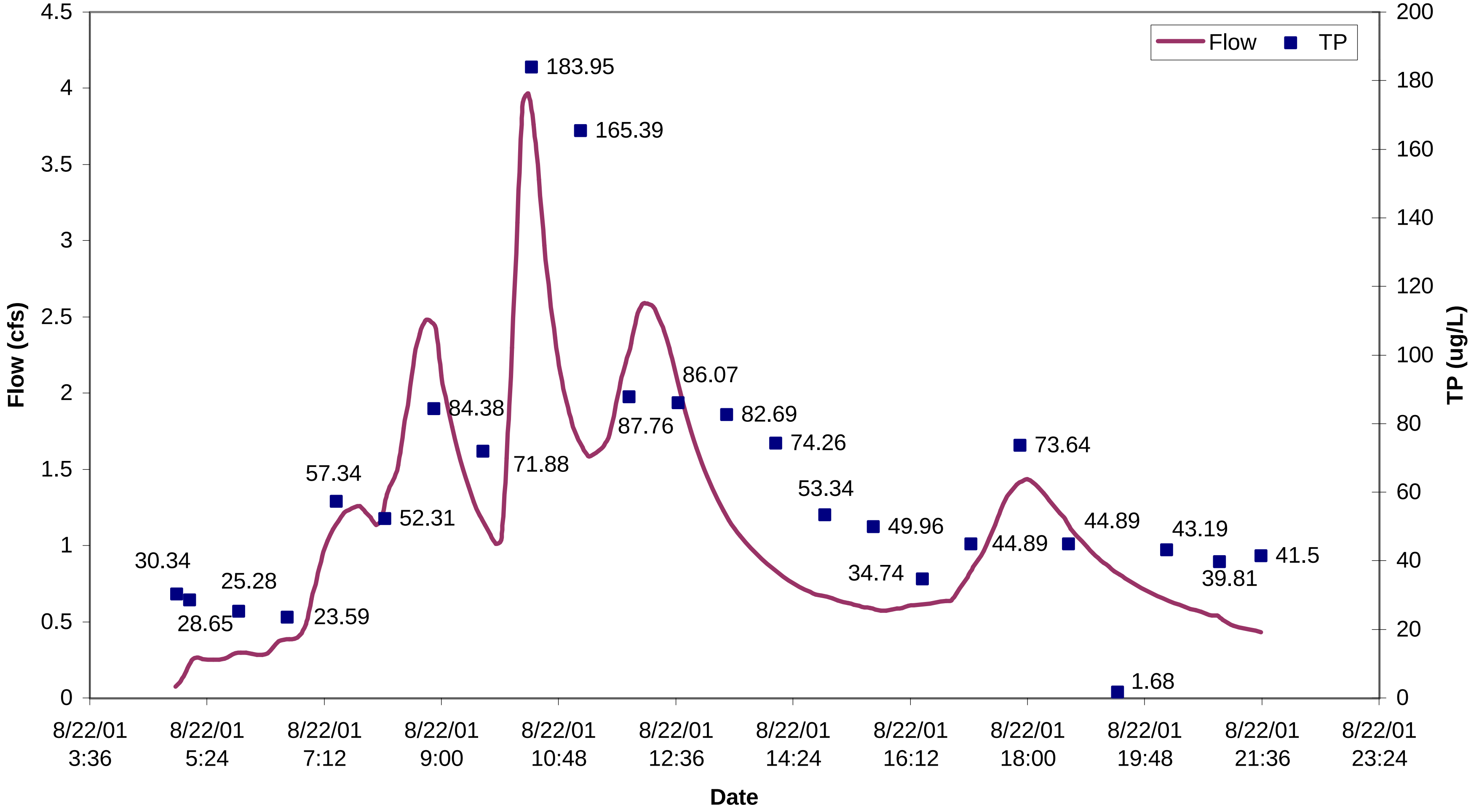


**Figure B-29. Flow and Soluble Reactive Phosphorus Concentrations at Location #1 for the August 22, 2001 Event.**

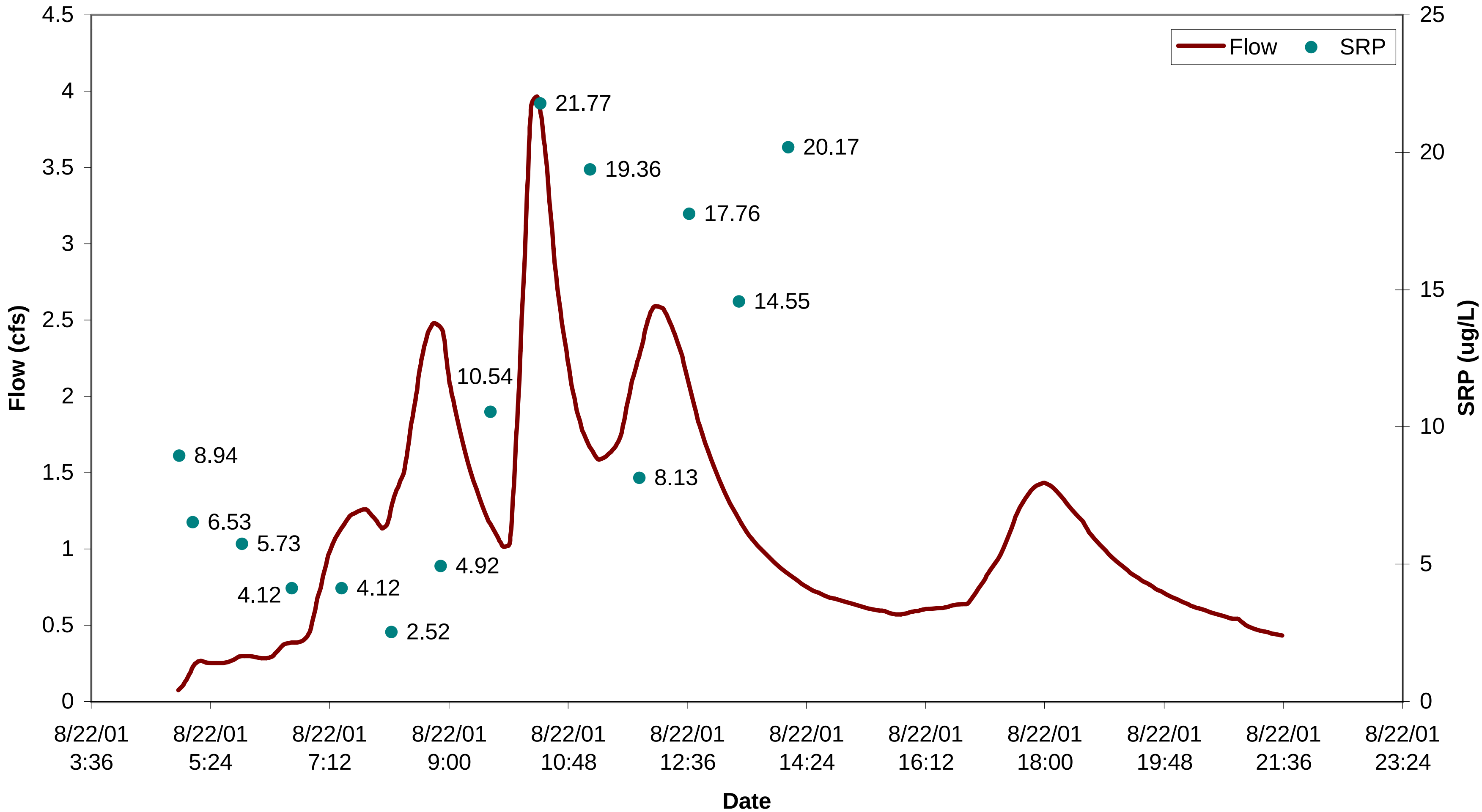
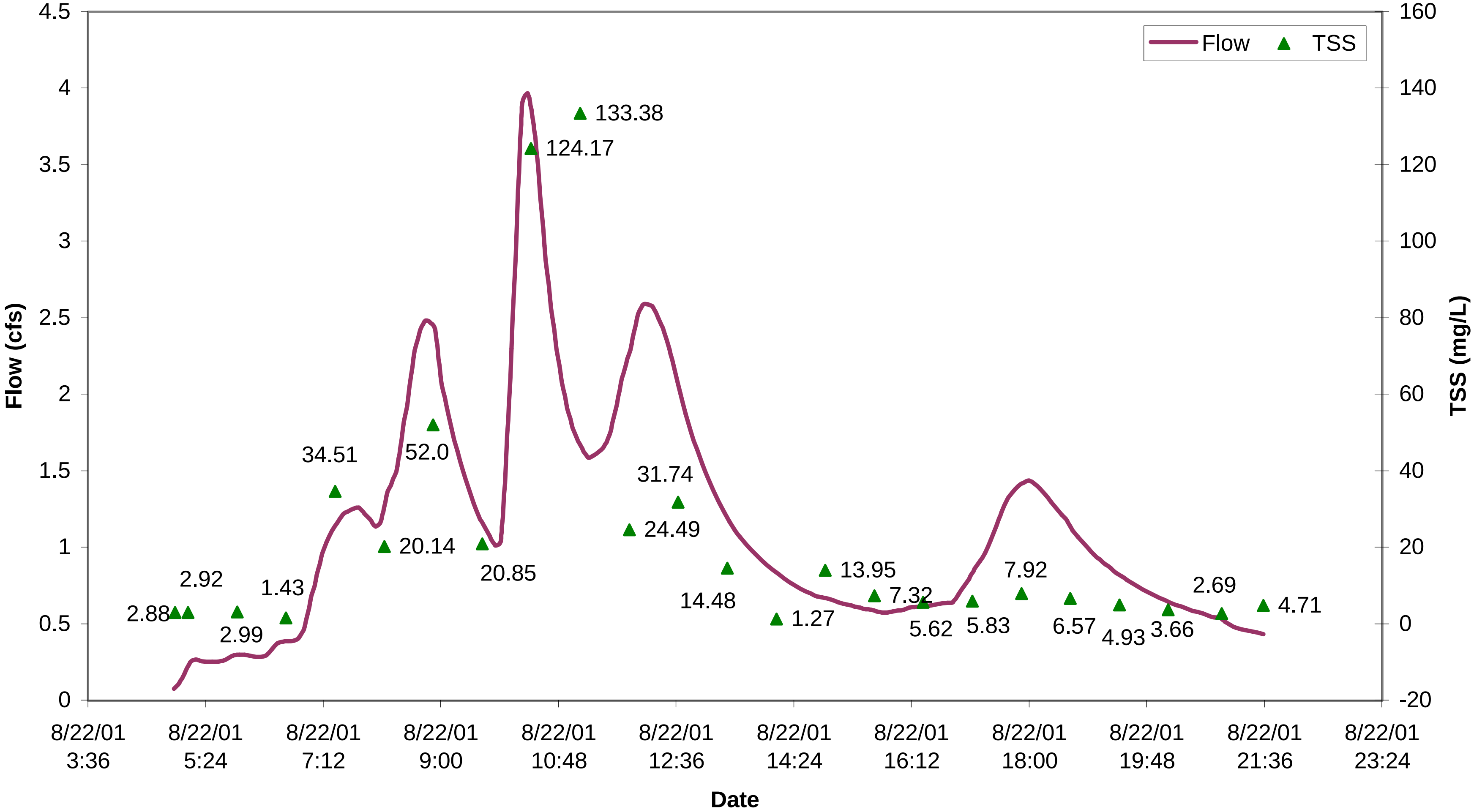


**Figure B-30. Flow and Total Suspended Solids Concentrations at Location #1 for the August 22, 2001 Event.**



# APPENDIX C

# Average Annual Rainfall Frequency for Kalamazoo, Michigan

## Appendix C. Average Annual Rainfall Frequency for Kalamazoo, MI

second column heading revised from pre-implementation report

| Average Annual Rainfall per 24-hour event (inches) | Frequency of Occurrence per Year (number of events/year) | Average Annual Rainfall (inches) | Average Annual Rainfall (%) | Cumulative Average Annual Rainfall (%) |
|---|---|---|---|---|
| 0.25 | 25.2 | 6.3 | 15.7 | 15.7 |
| .5 | 13.8 | 6.9 | 17.2 | 32.9 |
| .75 | 8.5 | 6.4 | 15.9 | 48.8 |
| 1 | 4.7 | 4.7 | 11.7 | 60.5 |
| 1.25 | 3.5 | 4.4 | 10.9 | 71.4 |
| 1.5 | 1.0 | 1.5 | 3.7 | 75.1 |
| 1.75 | 1.1 | 1.9 | 4.8 | 79.9 |
| 2 | 1.0 | 2.0 | 5.0 | 84.9 |
| 2.25 | 1.1 | 2.5 | 6.2 | 91.1 |
| 2.5 | .7 | 1.8 | 4.4 | 95.5 |
| 2.75 | .3 | 0.8 | 2.2 | 97.7 |
| 3 | .2 | 0.6 | 1.5 | 99.2 |
| 3.25 | .1 | 0.3 | 0.8 | 100 |