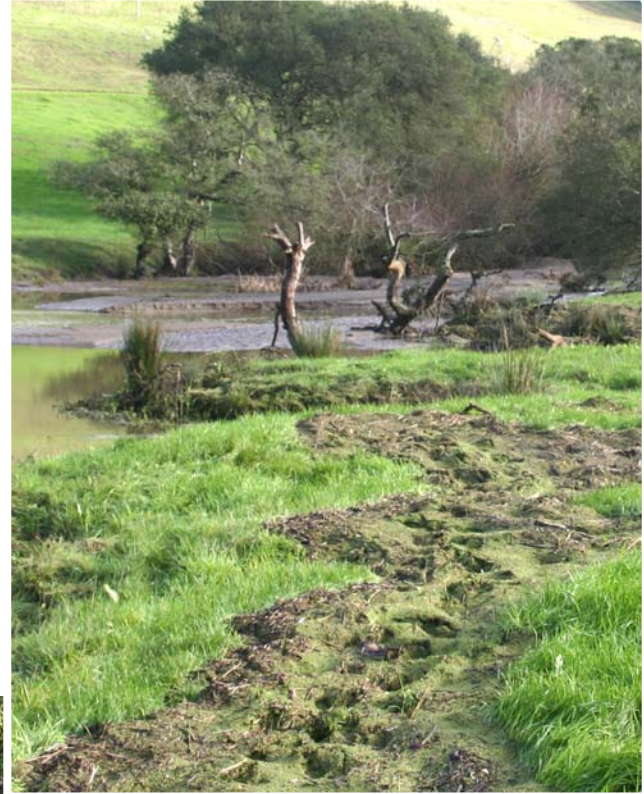


Stemple Creek Watershed Water Quality Analysis

prepared for

**USDA Conservation Effectiveness
Assessment Program**



prepared by

**University of California
Cooperative Extension,
County of Sonoma**

and

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Cover photos: Flotsam demarking stream stage height during the December 31, 2005 storm event (upper). Study site instrumentation with an ISCO auto sampler and YSI Data Sonde.

TABLE OF CONTENTS

Introduction	4
Methods	6
Site Description	6
Site Instrumentation.....	7
2004-2005.....	7
2005-5006.....	7
Sample Collection	7
2004-2005.....	7
2005-2006.....	8
Sample Analysis	8
Analytical Methods.....	9
QA/QC protocols.....	10
Results and Discussion	12
Precipitation and Stream Discharge	12
Laboratory Analysis	15
YSI Sondes.....	19
Loads	22
Summary	25
References	27
Appendix A.....	29
Appendix B.....	31
Appendix C.....	35
Appendix D.....	40
Appendix E.....	43

INTRODUCTION

Stemple Creek is a California coastal watershed approximately 40 miles northwest of San Francisco. The headwaters begin west of the City of Petaluma, flowing to the Estero de San Antonio and the Pacific Ocean. This estuary is included as part of the Gulf of the Farallones National Marine Sanctuary. Land-use history in the 52.5 square mile watershed included cereal crop and potato production from the 1850s to the early 1900s. This was in conjunction with and then replaced by livestock grazing and dairy production to the present.

Since the 1970s, water and habitat quality in Stemple Creek Watershed has received increased attention. In 1990, the North Coast Regional Water Quality Control Board (RWQCB) listed the watershed as impaired for nutrients and dissolved oxygen under Section 303 (d) of the United States of America Clean Water Act. This attention and designation have lead to water quality investigations, as well as delivery of educational, technical and financial resources to agricultural managers for improving water quality in the watershed.

Regional Board staff conducted water quality sampling and analysis for nutrients, pH, and dissolved oxygen in 1992 and 1993 at 12 sampling locations (Winchester et al., 1995). In general, results from this investigation indicated that nutrient concentrations decreased in a downstream direction. Staff concluded that un-ionized ammonia concentrations in Stemple Creek exceeded national criterion throughout the watershed at different times of the year. Specifically, acute toxic concentrations were documented during spring sampling rounds and were attributed to the interaction of nutrient loading from dairy manure and increased stream temperature. It was noted, however, that concentrations from this study were lower than results from 1988 to 1992 (Prunuske Chatham, Inc., 1994).

From 1991 to 2002, the California Department of Fish and Game (CDFG) conducted biweekly water quality monitoring during winter months (Rugg, 2003). Results from this program indicated that concentrations of un-ionized ammonia were initially above toxic values. Measured concentrations decreased during the monitoring program period. Results from this program were shared monthly at the Sonoma-Marin Animal Resources Committee which in turn worked with ranchers and farmers located above sampling sites to improve manure management and its potential impacts on Stemple Creek.

Water quality studies and monitoring for sediment within the watershed have been limited. There are, however, a few studies that identify trends in sedimentation and provide direction for implementation of practices to improve water quality. Underlying geology of the watershed includes marine sediments of the Franciscan and Wilson formations that result in fine sandy and silt loam soils (Miller, 1972; Kashiwagi, 1985). In 2002 and 2003, Ritchie et al. (2004) documented sedimentation rates from 1954 to the present. Their results indicate that rates from 1954 to 1967 are greater than those from 1968 to the present. Explanations for this change in rates include the transition from row crop agriculture to livestock agriculture in the 1930s and 1940s.

Local farmers and ranchers participated in water quality education programs during the 1980s and 1990s. These have been organized and implemented by University of California Cooperative Extension (UCCE), United States Department of Agriculture's

Natural Resources Conservation Service (NRCS), and both the Southern Sonoma and Marin Resource Conservation Districts (RCD). These included the Dairy Quality Assurance Program, Ranch Water Quality Planning Shortcourse (Rilla et al. 1995) and others. Producers participating in those programs are now cooperating with the two RCDs to implement water quality improving practices and measures through a program funded by State bond measures. In addition, the Petaluma Field and California State offices of the NRCS are shepherding an application for over five million dollars of implementation assistance for such efforts through the Public Law 566 process (NRCS, 2004). In addition, farmer and rancher application for technical and financial assistance through the NRCS' Environmental Quality Incentives Program (EQIP) continues annually.

The earlier water quality investigations, by RWQCB and CDFG, indicate that there has been some improvement to water quality as a result of the farmer and partnering agency conservation efforts. In order to meet water quality criteria this trend needs to continue including further implementation of beneficial practices and decreases in nutrient and sediment loading to the watershed. For this reason the RWQCB adopted the *Total Maximum Daily Load and Attainment Strategy for the Stemple Creek Watershed* in 1997 (Salisbury, 1997).

Evaluating the benefits and effects of implemented best management practices (BMP) to enhance water quality in the Stemple Creek Watershed requires a water quality sampling and analysis program that can account for the annual, seasonal, storm, and diurnal variability in nutrient and dissolved oxygen levels. In addition, the objective to evaluate BMP influence on water quality involves the establishment of a baseline or pre-implementation conditions from which trends can be developed.

The national need for documenting BMP effectiveness has recently been led by the NRCS' Conservation Effectiveness Assessment Program (CEAP). Stemple Creek Watershed was designated as one of 24 NRCS Special Emphasis Watersheds for the purposes of evaluating water quality benefits of dairy waste management systems, riparian restoration, and soil and water conservation practices.

In contribution to this evaluation, UCCE Sonoma County and the Departments of Land Air and Water Resources and Plant Sciences at the University of California, Davis conducted water quality analysis. This report provides an overview of the work completed, including steps taken to instrument sampling sites, number of samples collected per site for storm and 24-hour cycle sampling components, and methods of sample analyses. In addition, brief analysis and provisional summary graphs and tables are provided. A compact disc containing project raw data, also accompanies this report. This document finalizes the reporting requirements in the cooperative agreement (65-9104-4-417) between the University of California Division of Agriculture and Natural Resources and NRCS.

METHODS

Field work performed for the project began August 19, 2004 and ended June 6, 2006 (Appendix A). Laboratory sample processing and data analyses continued beyond that date to the writing of this report. Accordingly, activities and actions performed included site instrumentation, sample collection and analysis, and data analysis. In addition, the project team participated in a number of meetings with watershed landowners, Agricultural Research Service (ARS) researchers, and NRCS and RCD staff. The 2004-2005 water year field season began with instrument deployment in August 2004 and was completed on July 28, 2005 when samplers and instrumentation were removed from the field after stream sites had dried. Downstream ISCO samplers were redeployed for the 2005-2006 water year field season on November 2, 2005. Samplers were removed from the field on June 6, 2006 after downstream sites went dry.

Site Description

The four primary study sites included three mainstem sites - Sites 1, 2, and 3 from downstream to upstream. Site 4 is downstream of a holding area and upstream of a vegetative filter strip on a small tributary between Sites 2 and 3. Per instructions from NRCS Watershed Planning Geologist Vern Finney, Site 5 was added for the 2005-2006 water year several miles downstream of Site 1 and upstream of any tidal influence. Drainage area and location description for each site are provided in Table 1. Combined, these sites serve to represent the conditions of the entire watershed at large. This includes the scale and variability in hydrology, livestock agricultural activities, and implementation of conservation practices to improve water quality and habitat.

Table 1: Site drainage area and description.

Site #	Drainage Area acre (hectare)	Description
1	3,088 (1,250)	North Fork mainstem behind historical marker.
2	2,902 (1,174)	North Fork mainstem below conservation practices.
3	472 (191)	North Fork mainstem in upper watershed.
4	< 4 (<2)	Below holding area at dairy with 30+ head year round.
5	20,171 (8,163)	Stemple mainstem above tidal influence.

Site Instrumentation

Instrumentation of the five project sites consisted of installation of Teledyne ISCO, Inc. sampling equipment and Yellow Springs Instruments (YSI) 6820 data sondes. Working cooperatively with Vern Finney, we installed ISCO Model 6712 water quality samplers, with Model 730 bubblers to record stage height, and Model 674 tipping bucket rain gauges to measure wet precipitation at each site. All ISCO equipment installation was completed by the end of November each fall before any rainfall occurred (Appendix A). All sondes recorded data for nitrate, ammonium, turbidity, pH, temperature, electrical conductivity, and dissolved oxygen on a 15-minute interval.

2004-2005

We initiated calibration and deployment of the data sonde at Site 1 on December 21, 2004. We completed calibration and deployment of sondes at Sites 1, 2, and 3, including correct calibration of the ion specific electrodes for ammonium and nitrate with pH probes on February 4 and 8, 2005. Deployment of a sonde at Site 4 was not feasible because of the intermittent nature of stream flow that prevented the instrument from being continually submerged. The delay in sonde deployment resulted from the need to acquire the appropriate calibration fluids and pH probes that facilitated correct calibration and deployment of the nitrate-nitrogen and ammonium-nitrogen ion specific probes.

2005-2006

We initiated calibration and deployment of the YSI 6820 data sonde at Site 2 on November 28, 2005. We completed calibration and deployment of sondes at Sites 1, 2, and 3 on December 21, 2005. Site 5 was installed with a calibrated sonde on January 25, 2006. Similar to the previous winter, deployment of a sonde at Site 4 was not feasible because of the intermittent and shallow nature of stream flow that prevented the instrument from being continually submerged.

Sample Collection

2004-2005

We were prepared to begin sampling on October 1, 2004. Rain sufficient to generate runoff and allow for sampling did not occur until middle November for Site 4, late November for Site 3, and early December 2004 for Sites 1 and 2. Water quality samples were collected on a storm event basis at Sites 1 through 4 and a 24 – hour cycle basis at Sites 1 through 3. Sampling for the 24-hour cycle was not feasible at Site 4 because of the intermittent nature of flow in response to precipitation. Sample collection began on November 27, 2004, with initiation of in-stream flows, and continued into July 2005 until stream flow ceased. Site 3 continued to support base flow conditions all summer. As a result, the ISCO sampler remained deployed in the field until July 28, 2005 in order to monitor water level for stream flow calculations. A total of 468 samples were collected during the 2004-2005 water year (Table 2), including duplicates for quality control.

2005-2006

Similar to the previous year, water quality sampling required sufficient precipitation to generate stream flow. First opportunities for sampling occurred in early November 2005 for Sites 3 and 4, middle November for Sites 1 and 2, and early December for Site 5. Water quality samples were collected on a storm event basis at all sites until December 31, 2005, as agreed. One major revision to the work plan was the halting of 24-hour water quality sampling at Sites 1 through 3 to accommodate the addition of Site 5, at which storm sampling, continuous stage height, and water quality parameter recording were conducted. A total of 77 samples were collected for laboratory analysis from the four storms that occurred between October 1, 2005 and December 31, 2005, including duplicates for quality control (Table 2).

Table 2: Inventory of water quality samples collected at the five sites for CEAP water quality analysis on Stemple Creek Watershed in the 2004-2005 and 2005-2006 water years.

Site	Number of storms sampled	Number of storm samples collected	Number of 24 – hour cycles sampled	Number of 24 – hour cycle samples collected
<u>2004-2005</u>				
1	10	111	3	69
2	11	117	4	78
3	10	99	4	95
4	11	99	-	-
	subtotals	426		242
<u>2005-2006</u>				
1	3	17	-	-
2	3	18	-	-
3	2	13	-	-
4	2	15	-	-
5	2	14	-	-
	subtotals	77		

Sample Analysis

Collected water samples were preserved and transported at 4° C to the water quality laboratory at UC-Davis (Drs. Randy Dahlgren and Ken Tate's analytical laboratories). Samples were analyzed for pH, electrical conductivity, total suspended solids (organic and inorganic), volatile suspended solids (organic), turbidity, total nitrogen (TN), ammonium/ammonia (NH₄/NH₃), and nitrate (NO₃). Values of ammonium/ammonia combined with instream measurements of pH and temperature were used to calculate the respective concentration of un-ionized ammonia (Emerson et al.

1975). Particle size analysis was completed on a subset of the samples collected in the 2004-2005 water year field season. Analytical methods and quality control/quality assurance protocols are briefly described below.

Analytical Methods

1. Nitrate and Ammonium/Ammonia - Nitrate and ammonium/ammonia concentrations were determined on samples filtered through a 0.45 μm Nuclepore membrane filter (filters are pre-rinsed with sample). Nitrate and ammonium/ammonia were quantified simultaneously using an automated membrane diffusion/conductivity detection method (Carlson, 1978, 1986). The method allows for analysis of high ionic strength solutions without dilution of samples. This allowed us to obtain excellent detection limits. The stated method detection limit for the instrument is 1 ppb N. Under standard operating conditions for river waters from the Stemple Creek Watershed, we have determined a limit of detection of about 10 ppb calculated as three times the standard deviation of a distilled/deionized water blank. This limit of detection resulted in very few “less than detection” values for Stemple Creek water. Recovery of ammonium/ammonia and nitrate from spiked samples were >95% within the concentration range of Stemple Creek water. Repeated analyses of analytical standards had a coefficient of variation (CV) consistently <5%.
2. Total N - Total nitrogen was determined on non-filtered samples. Total nitrogen is determined conductimetrically (as described above) following persulfate oxidation (Yu et al., 1994). We used a 1% persulfate oxidant concentration, a sample:oxidant ratio of 1:1 (V/V), and heating in an autoclave. The limit of detection was a function of the nitrogen contamination content of the reagent chemicals. We used a high-purity potassium persulfate reagent that provides a limit of detection of about 50 ppb N. This detection level was low enough to quantify total nitrogen in all of the Stemple Creek waters. Recovery of total nitrogen was statistically identical to the Kjeldahl total nitrogen method that we have used in a comparison study utilizing several reagent grade, organic nitrogen compounds.
3. Suspended solids - Suspended solids were quantified by filtration of a known volume of water sample through a Gelman A/E glass fiber filter (about 0.45 μm) and weighing the filter before and after filtration. The glass fiber filters were preheated to 525° C for 1 hour to purge the filters of any volatile contaminants. The filters were stored in a desiccator prior to the filtration step. Following filtration, the filter, with suspended solids, was dried for 24 hours in a desiccator and then weighed again. Drying in a desiccator is preferred to oven drying because some organic compounds are unstable with heating resulting in some volatilization of the suspended solids. To determine volatile suspended solids (organic matter), we combust the filter at 525°C for 4 hours and subtract the lost in mass from the pre-combusted mass. We used a four-place balance (0.0001 g or 0.1 mg) for measurements. The detection limit was a function of the amount of water filtered through the filter. If a liter of river water was filtered, the limit of detection was about 0.5 mg/L given a plus/minus variation of 0.2

mg from the analytical balance and two weight determinations per sample (before and after filtration).

4. Particle size - Particle size distribution was analyzed by removing the organic solids (volatile) fraction from the samples and then analyzing the inorganic solids (nonvolatile) fraction using a Coulter® laser particle analyzer. Removal of the organic fraction was done by adapting the peroxide treatment for samples described by Klute (1986).

QA/QC protocols

Quality Assurance and Quality Control (QA/QC) measures consisted of our standard laboratory protocols including spikes, blind samples/duplicate samples, reference materials, setting of control limits, criteria for rejection and data validation methods.

1. Sondes – The 6820 data sondes were maintained by scheduled laboratory calibration and field cleaning. Due to particulates and algal growth, we determined regular maintenance of equipment in the field was essential in order to obtain accurate sonde data. We carefully cleaned all water quality probes on a weekly basis. Calibration of nutrient probes was especially important. We timed calibration of probes immediately prior to deploying sondes in the field.
2. Spikes – Our normal protocol was to run spiked samples at the onset of the project. Once we had established that we obtained a consistent and acceptable recovery from spiked samples, we periodically processed spiked samples for confirmation. Our frequency of running spiked samples was typically quarterly. We set an acceptable recovery at 85%.
3. Blind samples/duplicate samples – Approximately 5-10% of our unknown samples were run as duplicates. Because the individual who prepares the samples for analysis (filtering & pouring off samples) was different from the individual doing the analytical analysis, all duplicate samples were effectively blind samples. Within an analytical run, we reanalyzed all samples if duplicate samples were not within 10-20% of each other (20% if the value is less than 10 times the limit of detection; 10% if the value is greater than 10 times the limit of detection).
4. Reference materials – We utilized certified quality assurance standards for methods when commercially available. Certified “nutrient” and “mineral” standards containing nitrate and ammonium were used in this study. The reference standard was run immediately after instrument calibration to verify that our working standards were correct. We had a $\pm 10\%$ limit of acceptability from the certified value. For the total N, we digest reference standard to determine the recovery of the inorganic nutrient species. We were not aware of any reference standards available for total N that were based on organic forms of these nutrients.

5. Blanks, standards and standard curves – At the onset of an analytical run, we used a series of distilled-deionized and/or digested matrix blanks. Working standards were prepared fresh from dilution of a stock solution on at least a monthly basis. Standards were stored at 3° C and in the dark. All analytical standards were purchased from Fisher Scientific. A standard curve was then run from a series of standards which defines the working range of analysis. The standard curve was verified by running the certified reference standard. The standard curve was rejected if it did not determine the values of the certified reference standard within $\pm 10\%$. The standard curve was reanalyzed every 20-30 samples to verify that no instrument drift has occurred. Drift in excess of 10% resulted in rejection of all values determined since the previous standardization and re-analysis of those samples. Standards were also analyzed at the end of each analytical run to determine that the instrument remained stable through completion of all samples.
6. Sample handling – Upon receipt, samples were logged into a spreadsheet and verified against the chain of custody form. Each sample was assigned a laboratory number that serves to track the sample through the analytical analysis. Samples were stored at 3° C in the Water Quality Laboratory. A subsample of each sample was frozen and retained for up to six month or until the data had been examined by the contractor.
7. Data validation – Most data were collected electronically so that data transfer errors were minimized. For those methods requiring hand entry of data, data was verified by graphical and observation techniques to spot outliers. For complete chemistry analysis, we used charge balance and solute/EC relationships to validate concentrations. For long-term monitoring programs, temporal data were plotted to look for inconsistent relationships in the data record. Prior to releasing the data, the laboratory manager/principal investigator independently examined the data. All raw data were held for a minimum of one year.

RESULTS AND DISCUSSION

Precipitation and Stream Discharge

Results from ISCO instrumentation included wet precipitation and stage height or stream level recording on an event and 15-minute interval basis, respectively. We used the precipitation data to quantify 24-hour and annual cumulative rainfall at each site during the two water years. This is illustrated for Site 1 in Figure 1. Similar graphs for all sites are contained in Appendix B.

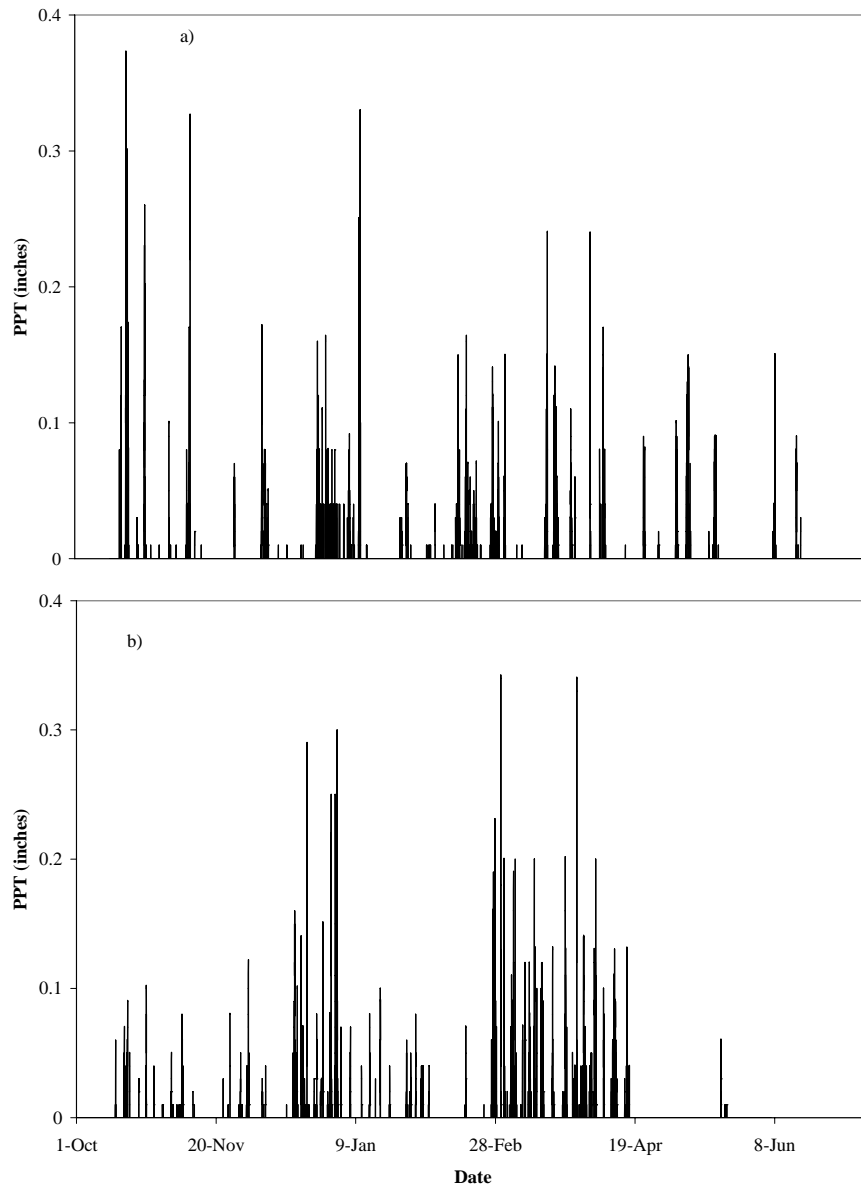


Figure 1: Corrected precipitation for Site 1 during the a) 2004-2005 and b) 2005-2006 water years.

We used the stage height data to calculate flow rate and volume. The measured cross-sectional area at each site, Manning's N of 0.045, and slope were input into the

Teledyne ISCO software (Flowlink Version 4.16) to make these calculations in conjunction with the recorded stage height. The calculations were then calibrated with field measurements of stage height and flow rate. We made these calculations for all sites in both water years to generate corrected discharge. This is demonstrated for Site 1 in Figure 2. A complete set of annual hydrographs is presented in Appendix C.

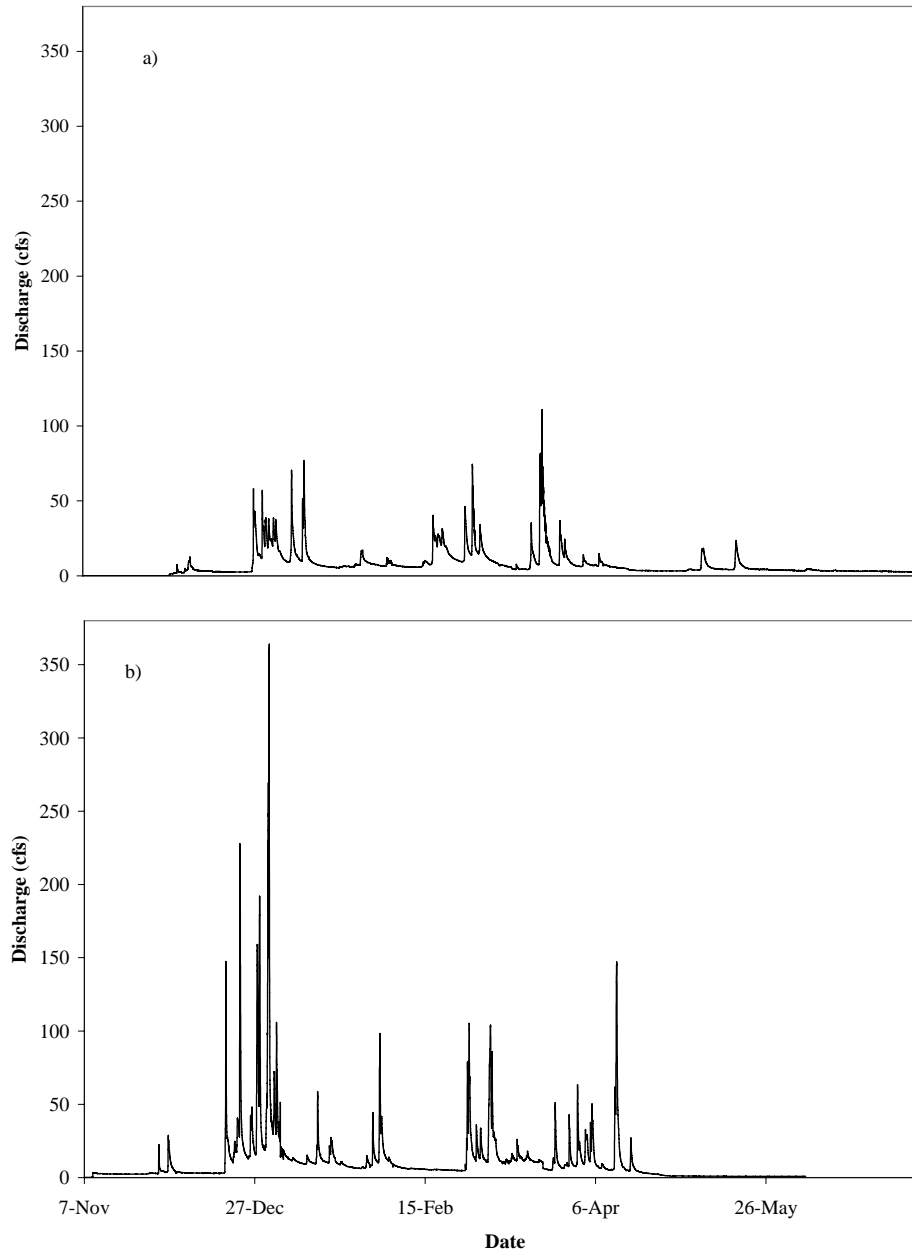


Figure 2: Corrected discharge for Site 1 during the a) 2004-2005 and b) 2005-2006 water years.

Comparing and contrasting the rainfall and stream flow in the 2004-2005 and 2005-2006 water years clearly demonstrates the annual and seasonal variability in hydrology that is common in California Mediterranean watersheds. Cumulative annual

rainfall for 2004-2005 ranged from 28 to 31.5 inches compared to a range of 33.5 to 38 inches in 2005-2006. This difference of 5 to 7 inches parallels a difference in annual cumulative stream flow between the two years. For example, a total of 3,674 acre-feet moved past Site 1 in 2004-2005 compared with 4,875 acre-feet in 2005-2006.

Seasonally, there are more subtle rainfall and stream flow similarities and differences between the two years. The onset of stream flow followed a similar pattern in both years. Generally, a few early storms of minimal rainfall amounts contributed to relatively small storm responses in stream flow, followed by a rapid return to low base flow stream discharge values. In both years, substantial and sustained stream flow was initiated in December after the preliminary storms primed the watershed. From the onset of stream flow in early December to approximately April in each water year, rainfall intensity and duration was greater in 2005-2006 than in 2004-2005. This translated to the 2005-2006 water year having the highest single storm discharge value (Figure 3), greatest number of stream flow storm responses, and elevated storm season base flow values relative 2004-2005. Conversely, 2004-2005 was marked by a protracted storm season that extended into late May and early June of 2005. This resulted in more elevated and extended baseflow and appreciable storm response in 2004-2005 than in 2005-2006.

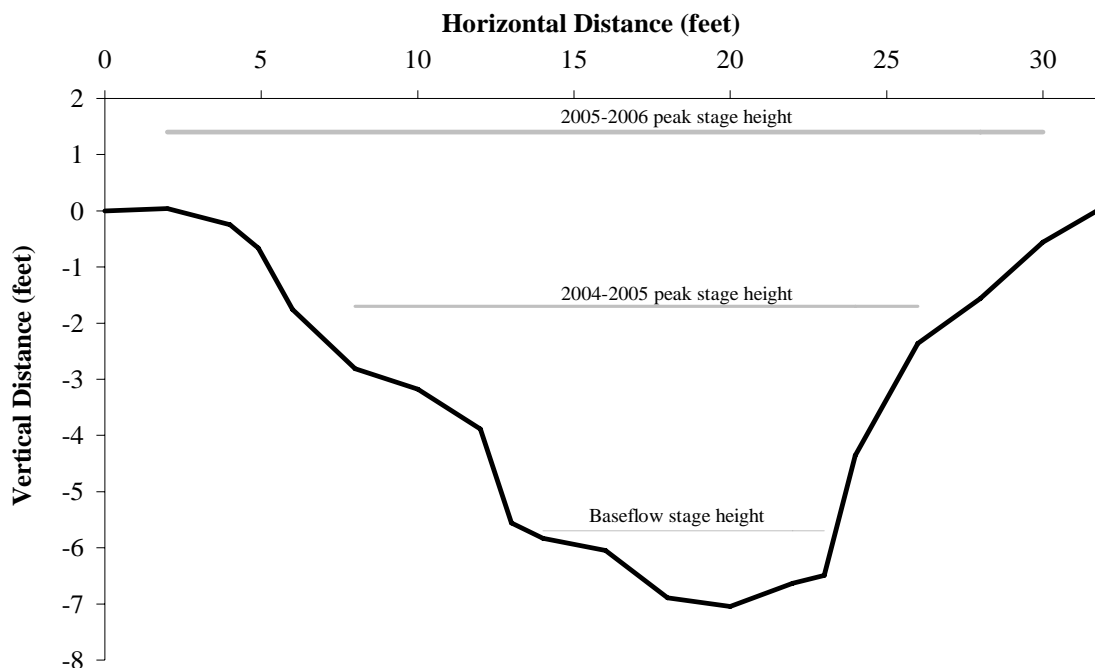


Figure 3: Channel cross section at Site 1 with peak stage height for both water years and baseflow stage height indicated.

Combined, these annual and seasonal observations illustrate that while annual cumulative rainfall is related to annual discharge, the timing, intensity, and duration of precipitation across seasons has a more significant effect on the release of water in the Stemple Creek Watershed. The implication of these results for water quality management are that seasonal and storm scale precipitation and stream flow characteristics derive the critical pollutant delivery paths, not annual totals.

Laboratory Analysis

Results from laboratory analysis for both years consistently indicate that runoff from Site 4 has higher levels of sediment, nutrients, and other water quality parameters than stream water from the other four sites (Appendix D). For example, concentrations of TSS and volatile-TSS are two to three orders of magnitude higher in Site 4 samples (Figure 4). Similarly, nutrient constituents such as TN and general chemistry constituents such as electrical conductivity were also orders of magnitude higher in Site 4 samples than in the other site samples (Figure 5). Additionally, the relationship between the two at Site 4 was direct compared with indirect at the other study sites.

These kinds of multiple constituent comparisons provide an illustrative method for comparing and identifying relationships in water quality at multiple sites. For example, volatile-TSS is on average 25 and 29 percent of TSS in samples from Sites 3 and 5, respectively. By comparison, volatile-TSS as a percentage of TSS in samples from Sites 1, 2, and 4 is 42, 43, and 46, respectively. This difference in sediment composition between the two groups indicates that the sources of sediment contributing to each are different. More specifically, high-use areas, like those represented by Site 4 may be delivering volatile-TSS and other constituents to reaches of the study area near Sites 1 and 2 but not sites 3 and 5. Site 3 is upstream of any holding areas and Site 5 is the site furthest downstream, with water quality conditions likely influenced by larger scale watershed sediment transport factors.

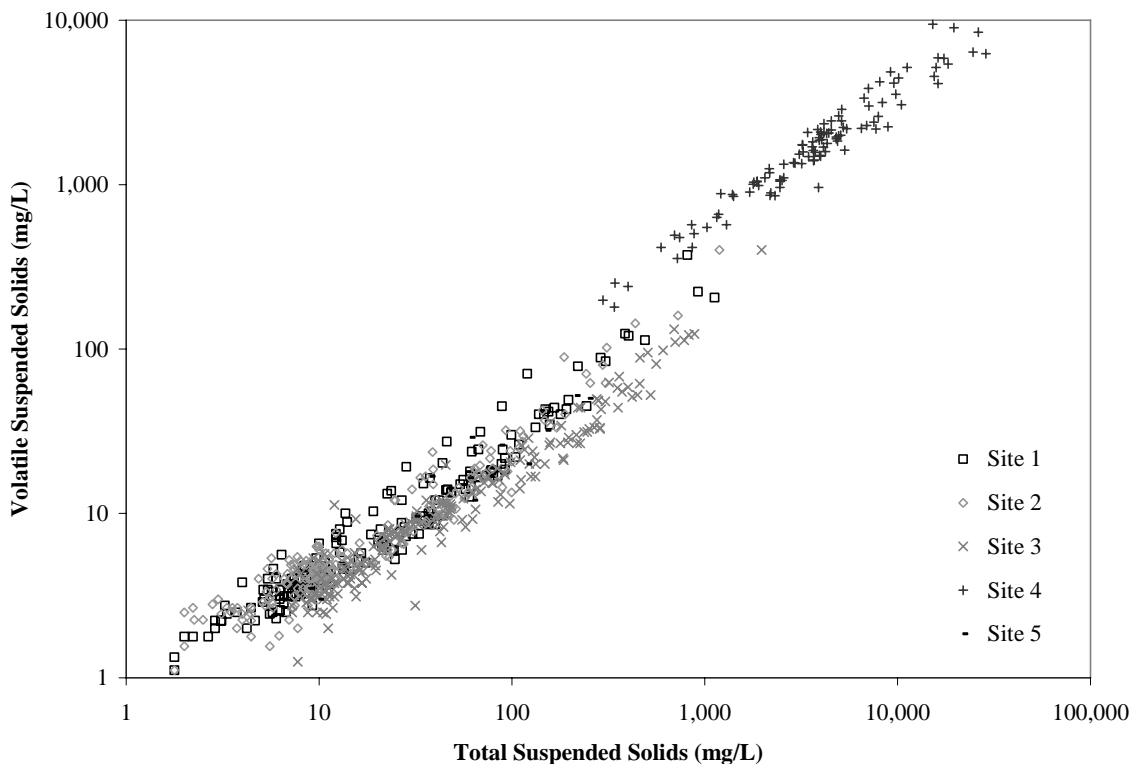


Figure 4: Volatile suspended solids as a function of total suspended solids by site for both water years.

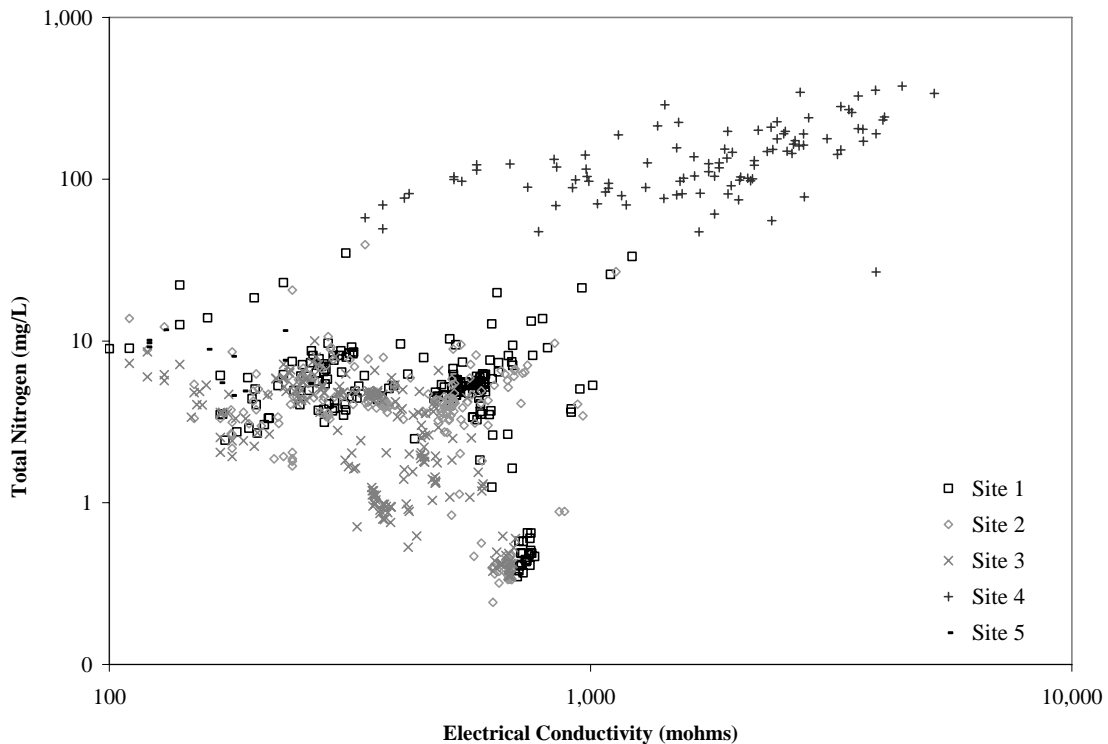


Figure 5: Total nitrogen as a function of electrical conductivity by site for both water years.

This delivery is constituent specific and dependent upon the implementation of management practices to reduce it. A useful and compelling example is un-ionized ammonia. As discussed, CDFG monitored the watershed for un-ionized ammonia during the 1990's (Rugg 2002). We compiled the data from that monitoring with results from this water quality analysis to identify any potential trends in water quality over time (Figure 6). An important distinction between the CDFG and CEAP data is the fundamental timing of sample collection. The CEAP samples were collected during storm events and peak flow, while CDFG samples were collected biweekly regardless of flow conditions. Additionally, all of the CDFG samples were collected from mainstem locations, compared to the small scale and close proximity to a potential source that Site 4 of the CEAP effort represents.

From 1991 to 2002 there is a decrease in the concentration of un-ionized ammonia. This is encouraging documentation that reductions in acute toxicity of this pollutant have been achieved in the watershed, through sharing monitoring results with local ranchers and farmers and corrective action being taken by these agriculturalists. This parallels an increase in knowledge, planning, and management measure implementation following water quality education delivered statewide to rangeland owners and operators (Larson et al. 2005).

Results from the CEAP study indicate that the gains made through 2001 have been at least maintained, if not furthered. There were 58 samples out of the total 441 collected over the two years of study that had concentrations of un-ionized ammonia

above the 0.025 mg/L criteria set by the U.S. Environmental Protection Agency. Of these, 36 were from Site 4 with the remaining 22 being mainstem samples. The maximum was 2.89 mg/L compared with the maximum of 2.66 mg/L identified by the RWQCB in 1995 (Winchester, 1995) and 9.89 determined by CDFG in 1991 (Rugg, 2002).

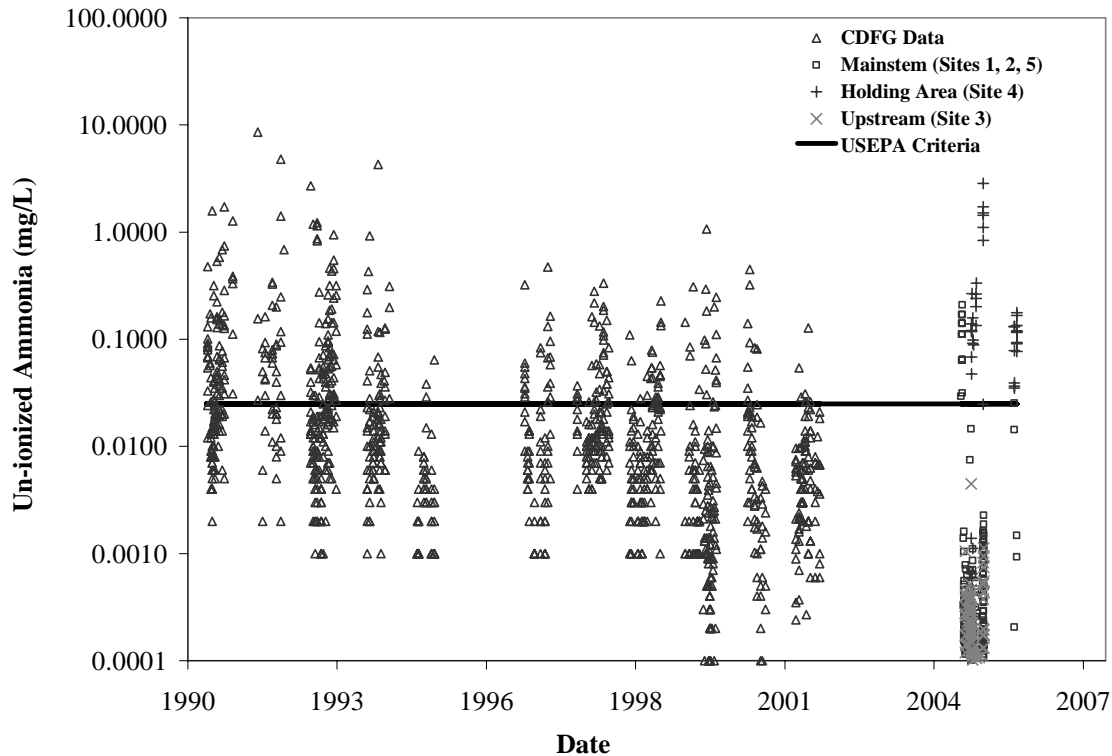


Figure 6: Un-ionized Ammonia (NH_3) concentration from 11-year dataset conducted by California Department of Fish Game in Stemple Creek Watershed combined with the two years of water quality analysis for this CEAP water quality analysis.

The effects of sample collection timing during storm events on water quality was discharge and parameter dependent. For example, a clear linear relationship between TSS and discharge exists at all sites except Site 4 (Figure 7). Similar but less pronounced relationships are demonstrated for ammonium (Figure 8) and nitrate (Figure 9). These figures also graphically illustrate that concentrations for the three constituents are greatest in samples from Site 4, which has the smallest drainage area of the five study sites.

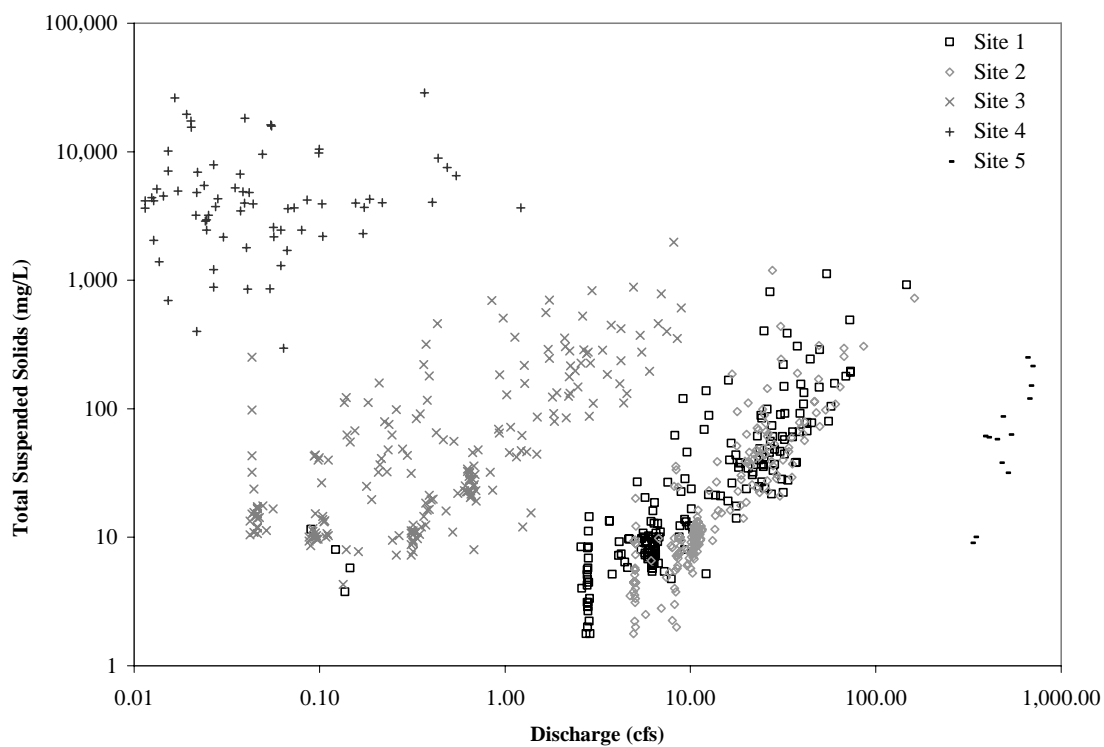


Figure 7: Total Suspended Solids concentration from laboratory analysis of water samples as a function of stream discharge from at all study sites in both water years.

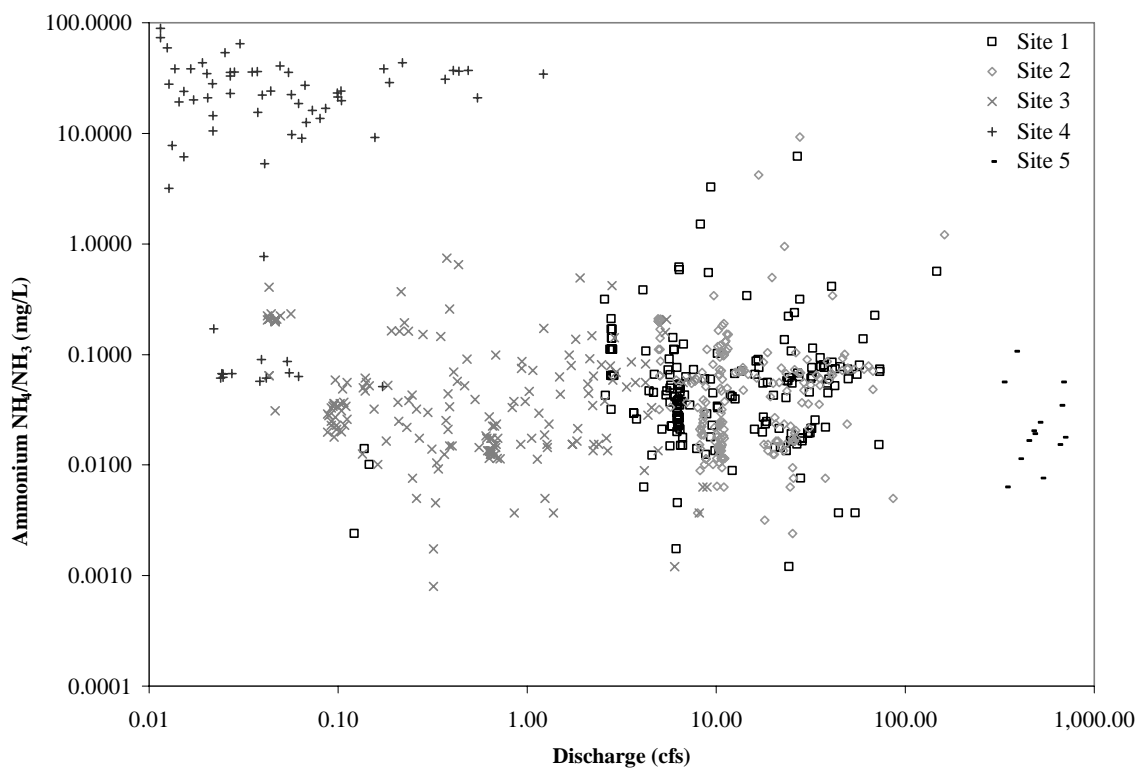


Figure 8: Ammonium (NH_4/NH_3) concentration from laboratory analysis of water samples as a function of flow collected at all sites over both water years.

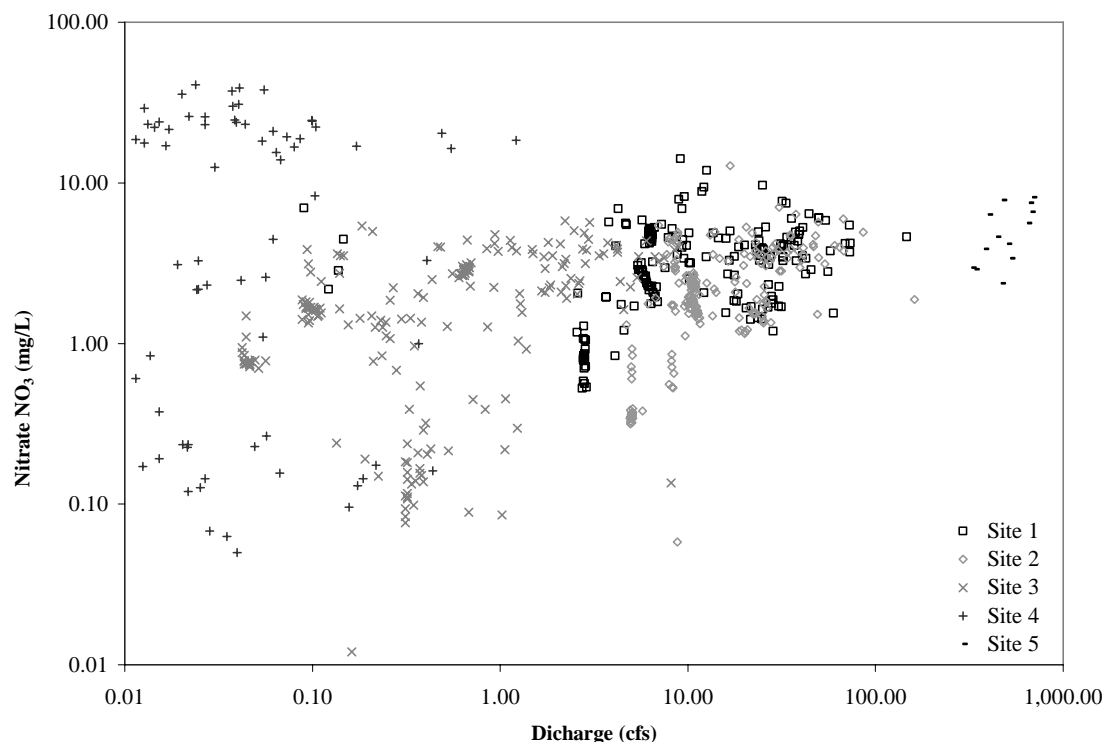


Figure 9: Nitrate (NO_3) concentration from laboratory analysis of water samples as a function of flow collected at all sites over both water years.

YSI Sondes

Calibration of the analytical laboratory and sonde values were conducted through linear regression for the parallel constituents. This included nitrate, ammonium, temperature, turbidity, conductivity, and pH for sites 1 through 3 for both years (Table 3). This was done as a quality control measure and to correlate water quality parameter values between the respective measurement methods. To reiterate, only Sites 1, 2, and 3 were instrumented in 2004-2005 and 2005-2006, with Site 5 added in the second year.

Use of the continual data recording sondes generated a more continuous data record for selected water quality constituents than was possible with the sampling and analysis conducted on a storm or 24-hour basis. This affords better documentation of the storm and seasonal variability that exists for the transport and delivery of water quality constituents. For example, values for both nitrate and ammonium demonstrate a seasonal flushing dynamic. They are highest early in the season and taper off through the water year (Figure 10a and b). In addition, they demonstrate a consistent rising and falling with discharge. It is interesting to note that the highest nitrate concentrations were documented during peak storm activity and flood conditions between December 18, 2005 and January 2, 2007. This flushing and storm response has been demonstrated in other California Mediterranean watersheds.

Table 3: Summary of statistical results for correlating Sonde data with analytical laboratory and temperature field data.

Site	Parameter	R ²	Correlation P-value	Regression Equation	P-value
1	Nitrate	0.54	<0.0001	Sonde = 2.2 + 0.9 * (Lab)	<0.0001
	Ammonium	0.03	0.0696	Sonde = 0.3 + 0.3 * (Lab)	<0.0001
	Temperature	0.99	<0.0001	Sonde = 0.1 + 1.0 * (Logger)	<0.0001
	Turbidity	0.02	0.0446	Sonde = 37.9 + 0. * (Lab)	<0.0001
	Conductivity	0.84	<0.0001	Sonde = 44.4 + 0.9 * (Lab)	0.0621
	pH	not significant			
2	Nitrate	0.27	<0.0001	Sonde = 5.0 + 1.3 * (Lab)	<0.0001
	Ammonium	0.23	<0.0001	Sonde = 0.4 + 5.8 * (Lab)	<0.0001
	Temperature	0.62	<0.0001	Sonde = 5.6 + 0.6 * (Logger)	<0.0001
	Turbidity	0.81	<0.0001	Sonde = 0.9 + 1.2 * (Lab)	0.6883
	Conductivity	0.93	<0.0001	Sonde = 5.7 + 1.0 * (Lab)	0.6545
	pH	not significant			
3	Nitrate	0.31	<0.0001	Sonde = -23.7 + 29.4 * (Lab)	0.0068
	Ammonium	0.02	0.0610	Sonde = 0.4 + 2.5 * (Lab)	<0.0001
	Temperature	0.72	<0.0001	Sonde = 2.6 + 0.8 * (Logger)	<0.0001
	Turbidity	0.92	<0.0001	Sonde = -6.4 + 1.3 * (Lab)	0.0490
	Conductivity	0.88	<0.0001	Sonde = -26.1 + 1.0 * (Lab)	0.0538
	pH	not significant			

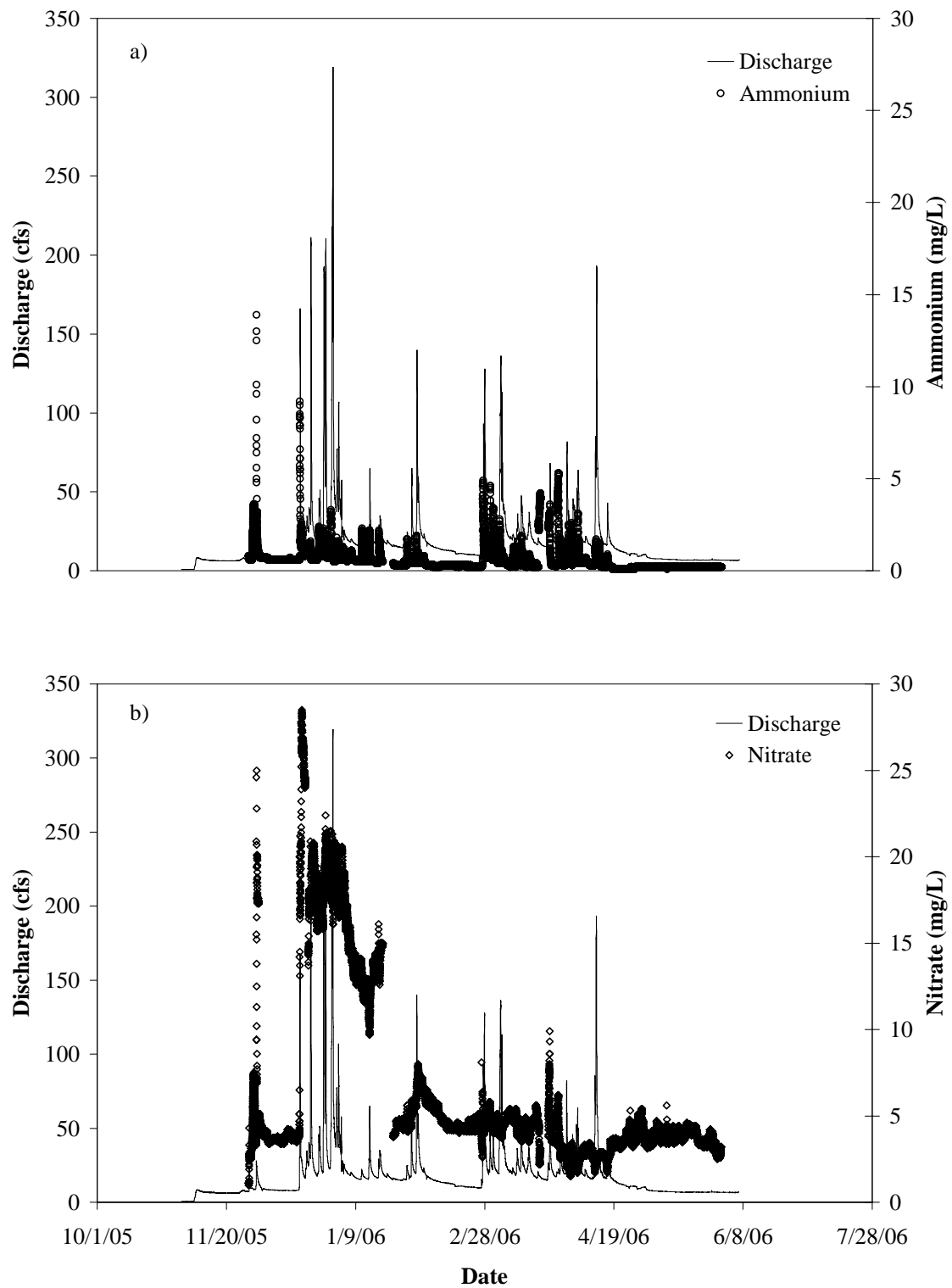


Figure 10: Discharge (cfs) and sonde measured ammonium (mg/L)(a) and nitrate (mg/L)(b) at Site 2 in 2005-2006 water year.

Loads

The combination of parameter concentration and discharge measurements provided us the opportunity to calculate total storm load or flux of specific water quality constituents. These loads were calculated for each site during the respective storms studied. A complete table of all storm load values for study Sites 1 through 5 is presented in Appendix E. These calculations were only possible for two storms at Site 5 during the second year of the study.

Similar to the discussion on parameter concentration, Site 4 consistently demonstrated the greatest total storm loads for the water quality parameters studied. This is compelling in that the area of Site 4 is three to four orders of magnitude smaller than the other four sites (Table 1). Also, on a standard comparison of unit area there is as much as three to four orders of magnitude greater flux of selected suspended solids or nutrients moving past Site 4 than the other study sites (Figure 11). This is particularly true for Ammonium and Ammonia. Another interesting observation is that values for many constituents at Site 1 are consistently lower than for those upstream at Site 2.

While the difference between Site 4 and the other sites is clear, it is important to recognize the variability in storm loads at each site because of individual storm intensity and precipitation volume (Figure 12). For example, the greatest storm loads at all sites were consistently experienced on January 11 and 12, 2005 and December 18, 2005, compared with lowest the storm loads experienced on November 15, 2005 (Appendix E).

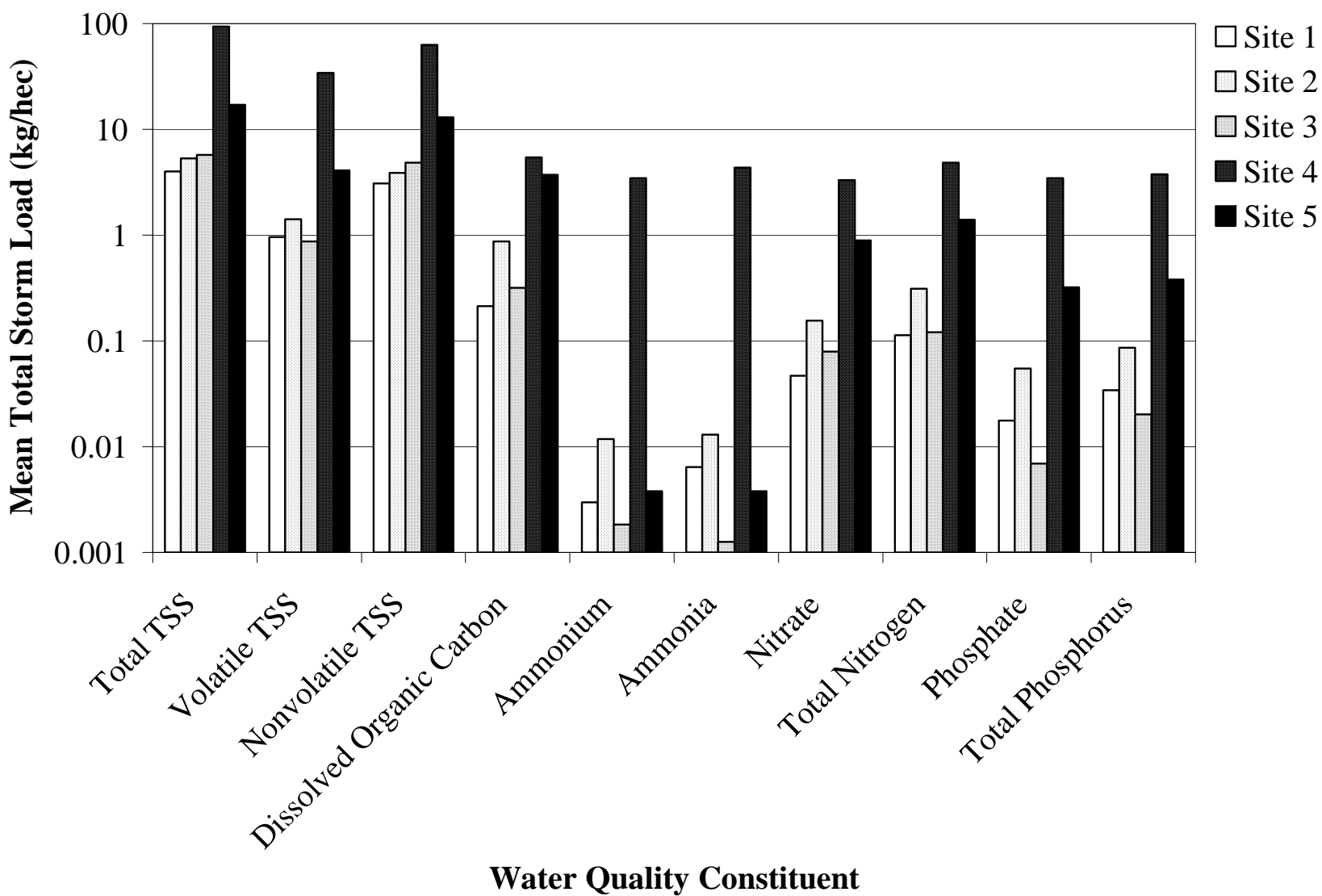


Figure 11: Mean total storm loads for studied water quality constituents on a per unit area basis. The units of kilograms per hectare convert approximately to pounds per acre. For example 100 kilograms/hectare equates roughly to 100 pounds/acre.

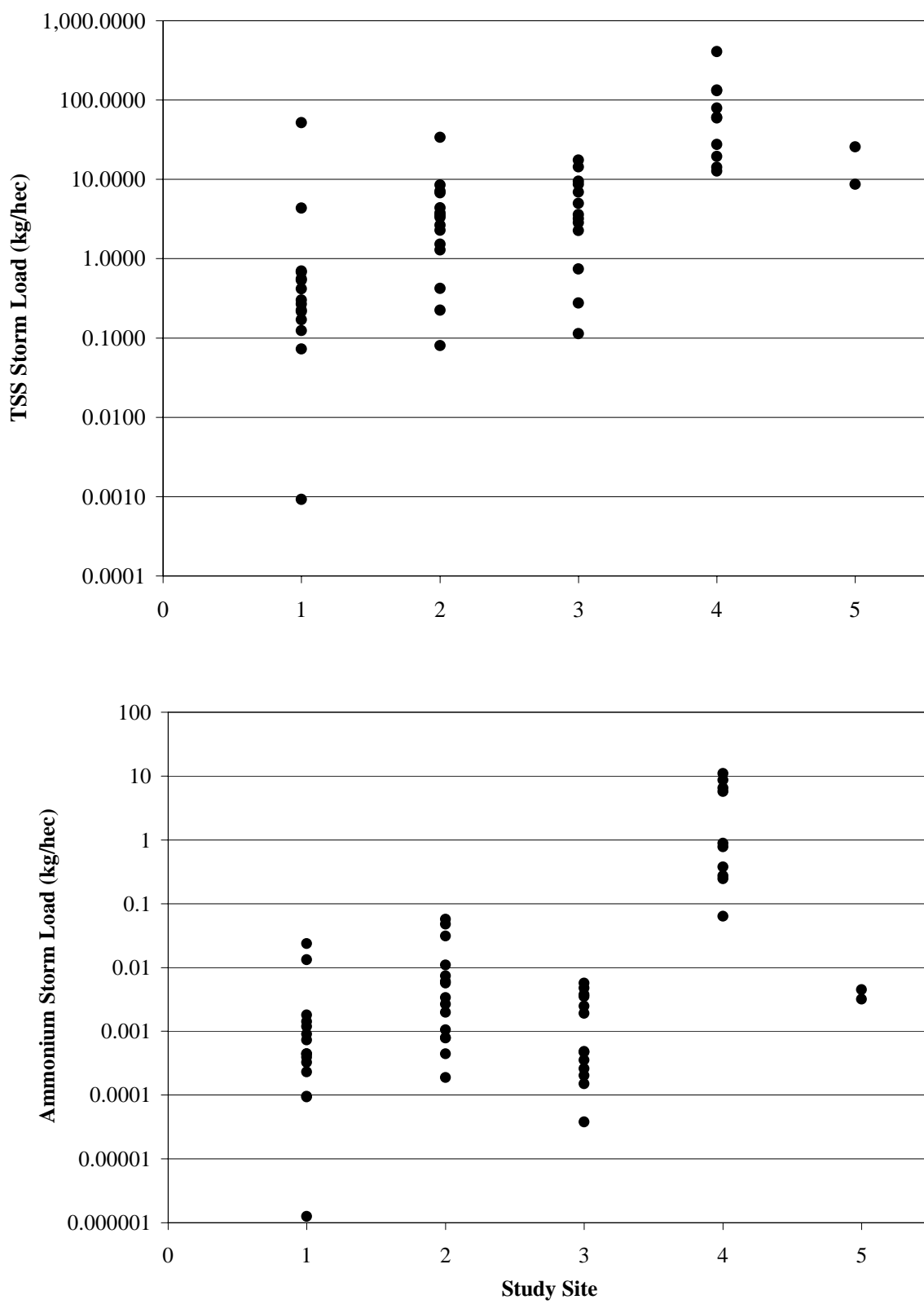


Figure 12: Storm loads for TSS (upper) and ammonium (lower) at all five study sites.

SUMMARY

The combined results of hydrology, precipitation and water quality from this endeavor provide the data to model water quality and the role BMP implementation can have in reducing agricultural, and specifically livestock agriculture, impacts on water quality. Complimentary to any modeling, the results of this water quality analysis document the annual, seasonal, and storm scale variability in stream flow generation and water quality. They also facilitate prioritization of efforts to assist agriculture in its use of management measures to improve water quality and maintain the viability of its operations.

Stream discharge generation at the study sites was typical of California's Mediterranean climate. In both study years, an initial volume of rainfall was required to prime the watershed prior to the initiation of stream flow. From that point in the water year, discharge at each sample site rose and fell with each subsequent storm, until the end of the season. The time period from early fall up to and including the watershed priming period represents an important opportunity for the management of livestock and manure to reduce potential water quality impacts. Ranchers and farmers can take actions, such as herd rotation or manure spreading and incorporation, in advance of stream flow generation and the delivery of any sediment or nutrients from the uplands to area streams. Inevitably, there will be storms and storm series that exceed management capacity to reduce the transport of sediment and nutrients. Such conditions were experienced during the last week of December 2005 and first week in January 2006. In this saturated state, the watershed is fully connected hydrologically.

Water quality samples from Site 4 had concentrations of nutrients and sediment that were orders of magnitudes greater than those at Sites 1, 2, 3, and 5. Conversely, stream flow volumes were at a minimum an order of magnitude less at Site 4 than the other sites. This is not unexpected. As noted, this site represents a high use area needed by dairy farms and ranches for concentrating and handling livestock during some portion of the year. These areas have many common names including exercise lots, sick pens, calving pens, calf corrals, feeding areas, and loafing areas and are important production components for area dairies and ranches. They contribute to herd health by providing lactating animals a place to exercise that is near to milking facilities. They facilitate supplemental feeding in a cost-effective way. Producers, alternatively, use these areas as nurseries or sick pens, allowing them to monitor groups of animals that require direct and timely attention. Admittedly, the use of these areas results in surfaces where vegetation may be absent or slow to regenerate. This increases the susceptibility of these areas to erosion and subsequent transport of nutrients and sediment in runoff from these sites during winter storms.

The resulting management challenge for these areas is how to maintain animal productivity, health and welfare while reducing impacts to water quality. And given the relatively high concentrations and low flow volumes measured at Site 4, the question is raised as to the loading potential of sites like Site 4 for the studied constituents. In the actual case of Site 4, runoff from the area is directed through a grassed waterway prior to entering an intermittent tributary of the main stem of Stemple Creek. Because the objective of this water quality analysis was to generate data at differing scales for modeling purposes, we did not conduct above and below water quality monitoring to

determine the effectiveness of this specific measure. Additional analysis of the data and further study designed to investigate this specific question are required to achieve that objective. However, the preliminary analysis presented in this report indicates that there is potential loading from high use areas and other intensive agricultural operations like Site 4. For example, similar and higher values for volatile-TSS as a percent of TSS in samples from Sites 1, 2, and 4 relative to Sites 3 and 5 indicate that there may be loading of fine solids from high use areas like Site 4 upstream of Sites 1 and 2. And consistently the concentrations and loads for all studied parameters were lowest in Site 3 samples, the study site furthest upstream and above intensive agricultural operations such as high use areas and pastures receiving spread manure.

This is not to say that Site 4 is the source of increased nutrient and sediment concentrations at Sites 1, 2, and 5. There are spatial scales and multiple activities between these study sites, including the implemented management measure described above, that prevent any differentiation or association to be made. More generally, the results and this preliminary analysis offer indications that water quality is changing from upstream to downstream and that loading from intensive agricultural operations is a potential source for these changes. Accordingly, these areas and locations on the farms and ranches within the watershed should be the first point of intervention for further soil and water conservation measure implementation. Previous water quality monitoring data combined with the results from this water quality analysis confirm a downward trend in ammonia concentrations in the Stemple Creek Watershed. This record parallels previous and ongoing collaboration with watershed farmers and ranches to improve water quality. They should serve as the motivation that continuation of these conservation programs and actions will be effective in achieving that resource goal.

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APPENDIX A

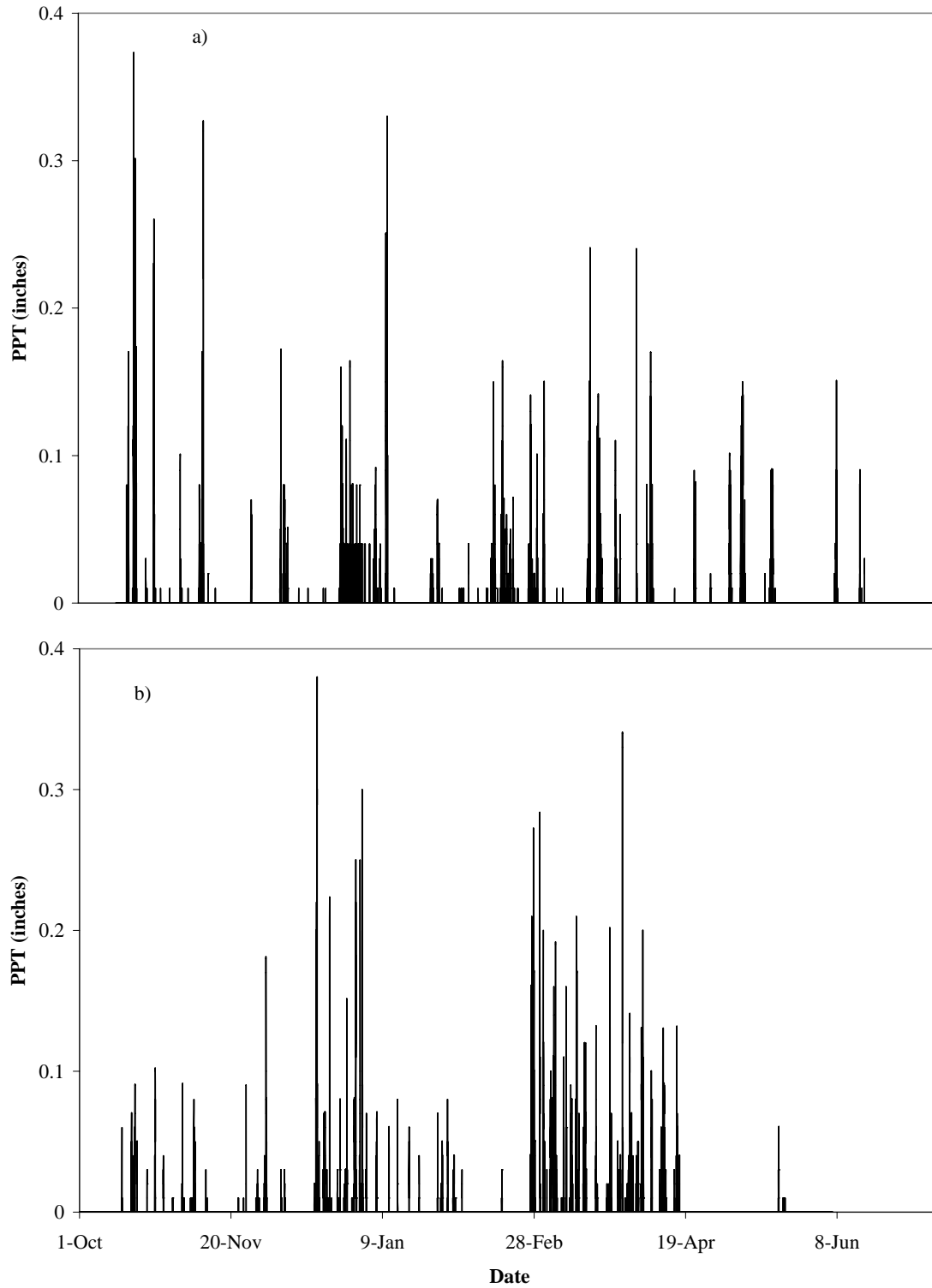
Activities and actions performed to conduct CEAP water quality analysis on Stemple Creek Watershed.

Date	Activity and Action
8/19/04	Meeting with Stemple Creek Watershed landowners to introduce the project.
9/13-24/04	Installation of water quality samplers, stage height recorders, and rain gauges at four project sites.
11/10/04	Measured project sites cross-sectional areas.
12/2/04 - ongoing	Water samples collected and analyzed. ISCO and YSI instrument data collected.
12/2-3/04	Field tour and meeting to coordinate with AGNPS researchers.
12/21/04	Sonde deployed at Site 1 without pH probe and correct calibration of ammonium and nitrate probes.
1/6/05	Sondes deployed at Sites 2 and 3 without pH probes and correct calibration of ammonium and nitrate probes.
1/21/05	Sondes removed for correct calibration of ammonium and nitrate probes with pH probes.
1/28/05	Field tour with UC Davis researchers.
2/4/05	Sonde programmed and deployed at Site 2 with correct calibration of ammonium, nitrate, and pH probes.
2/8/05	Sondes programmed and deployed at Sites 1 and 3 with correct calibration of ammonium, nitrate, and pH probes.
4/11/05	Sonde removed from all 3 sites for calibration.
4/21/05	Sondes redeployed to all 3 sites.
6/22/05	Sondes removed for calibration and storage over summer.
7/28/05	ISCO samplers removed from field Sites 1,2 and 3 for cleaning, maintenance and storage.

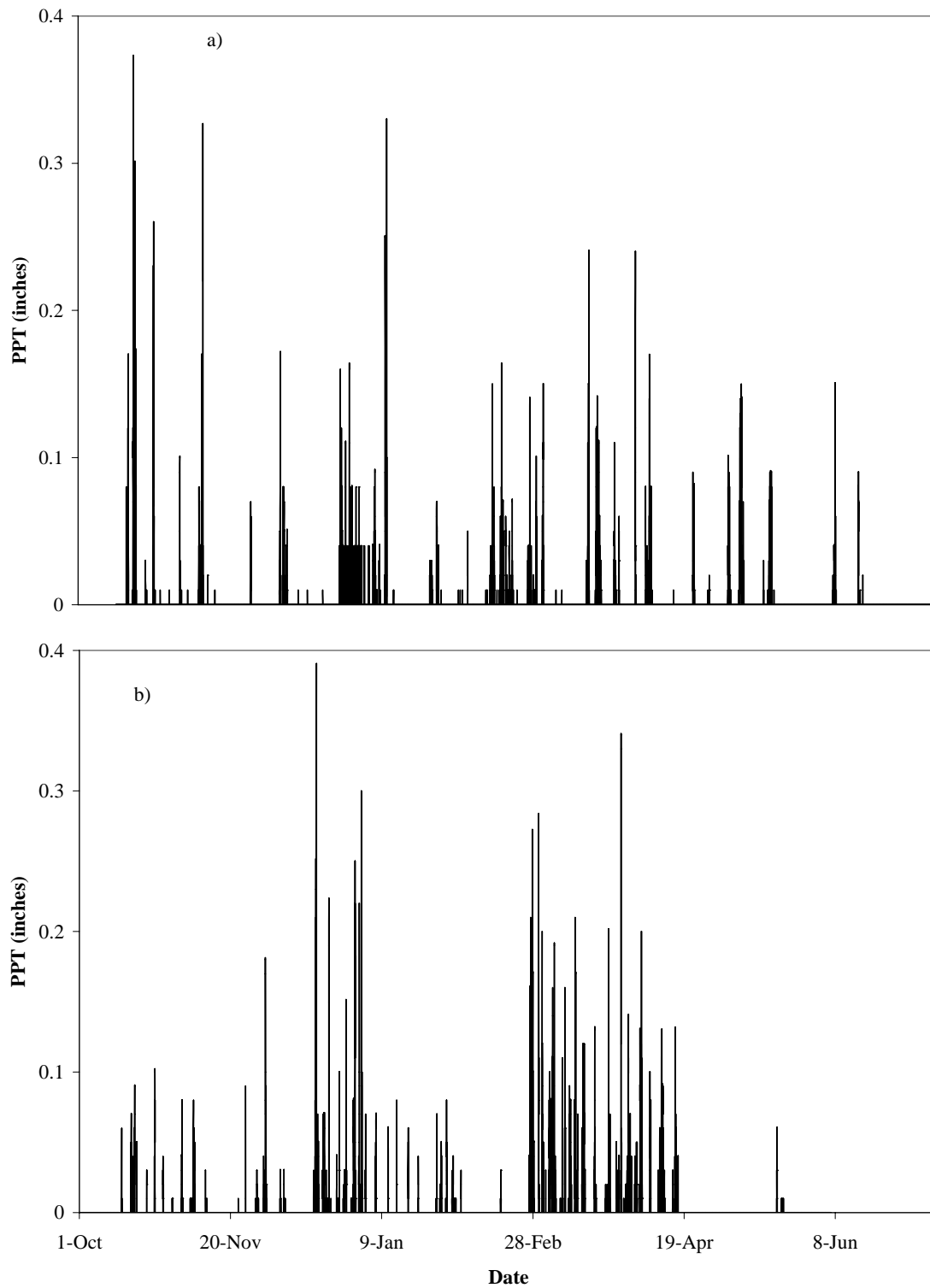
10/31/05	Groundwater wells near stream sites were sampled.
11/2/05	ISCO samplers were deployed at the four project sites.
11/22/05	ISCO sampler deployed at new Site 5.
11/28/05	Sonde installed at Site 2.
12/1/05 - ongoing	Water samples collected and analyzed. ISCO and YSI instrument data collected.
12/21/05	Sondes installed at Sites 1 and 3. Sonde replaced at Site 2.
1/19/05	Sondes removed from Sites 1, 2 and 3 for calibration.
1/23/05	Sondes redeployed to Sites 1, 2 and 3.
1/25/05	Sonde deployed at Site 5.
2/10/05	Sonde removed from Site 5.
2/15/05	Groundwater wells near stream sites were sampled.
2/16/05	Sonde redeployed to Site 5.
3/21/06	Sondes removed from all 5 sites for calibration.
3/24/06	Sondes redeployed to all 5 sites.
5/30/06	Sondes removed from all 5 sites.
6/6/06	ISCO samplers removed from all five sites.
6/27/06	Tour sites with state and federal NRCS staff.
5/1/07	Meeting with Stemple Creek Watershed landowners to share preliminary project results.

APPENDIX B

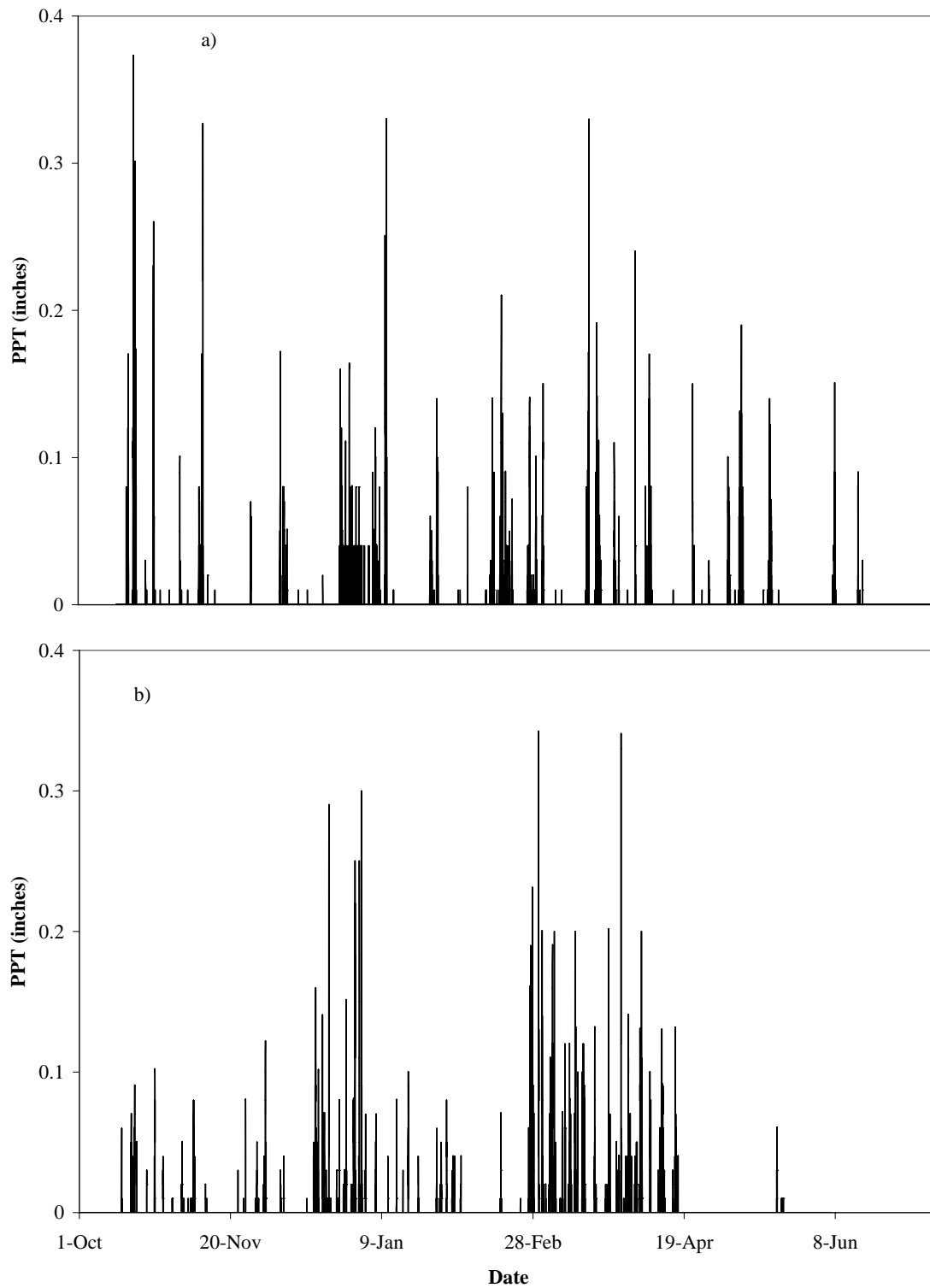
Annual precipitation for Site 1 over both water years - 2004-2005 (a) and 2005-2006 (b).



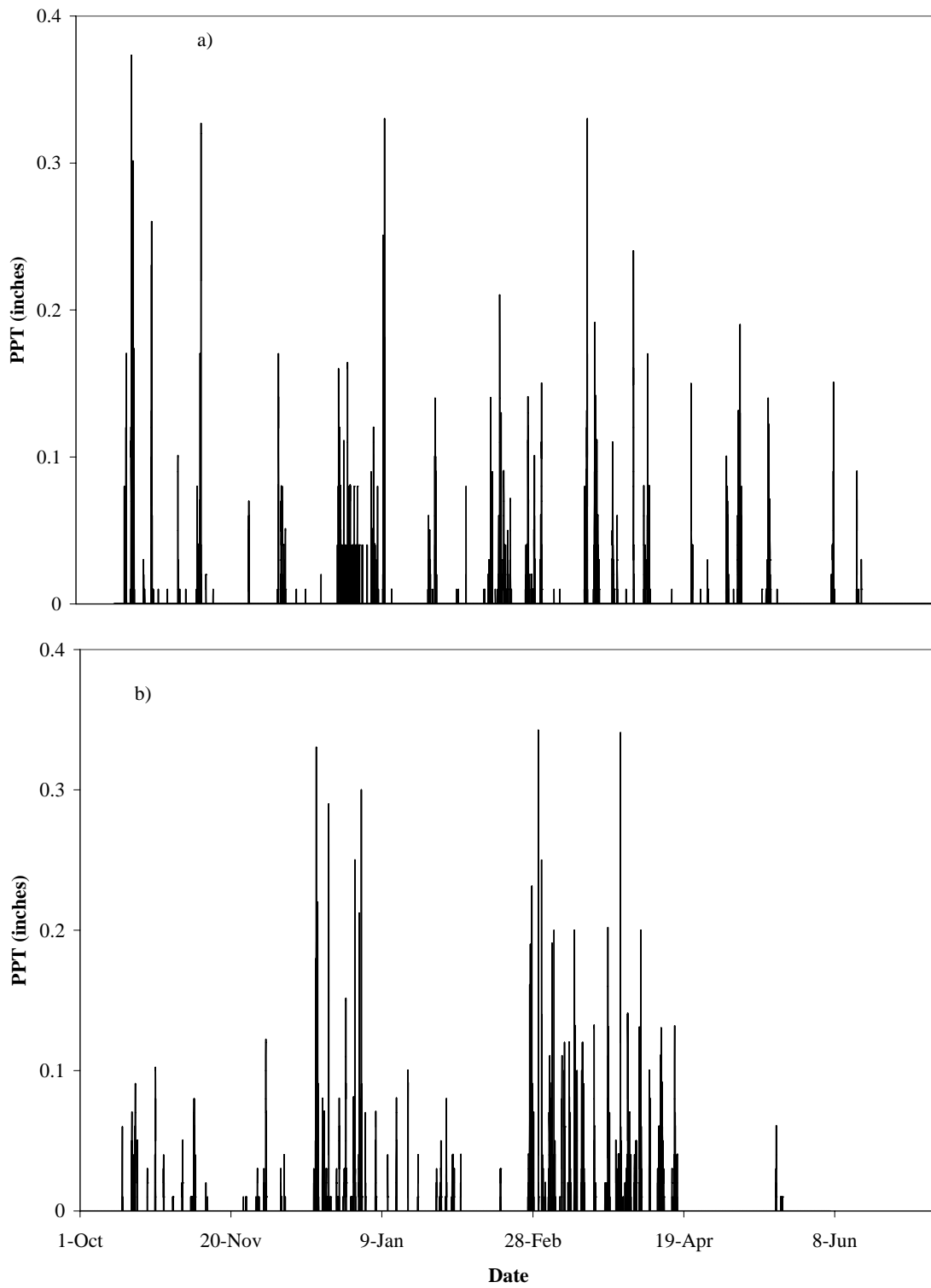
Annual precipitation for Site 2 over both water years - 2004-2005 (a) and 2005-2006 (b).



Annual precipitation for Site 3 over both water years - 2004-2005 (a) and 2005-2006 (b).

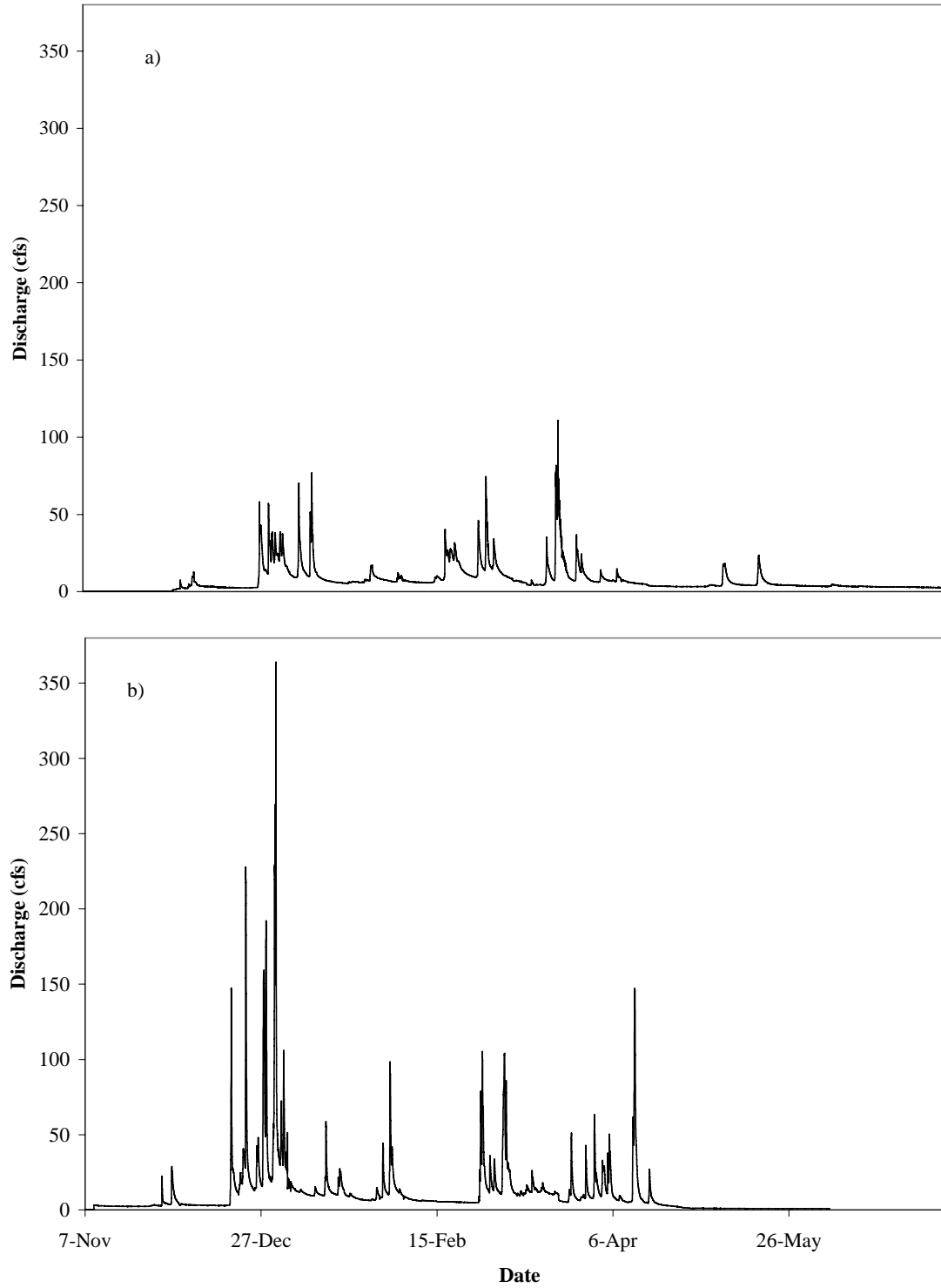


Annual precipitation for Site 4 over both water years - 2004-2005 (a) and 2005-2006 (b).

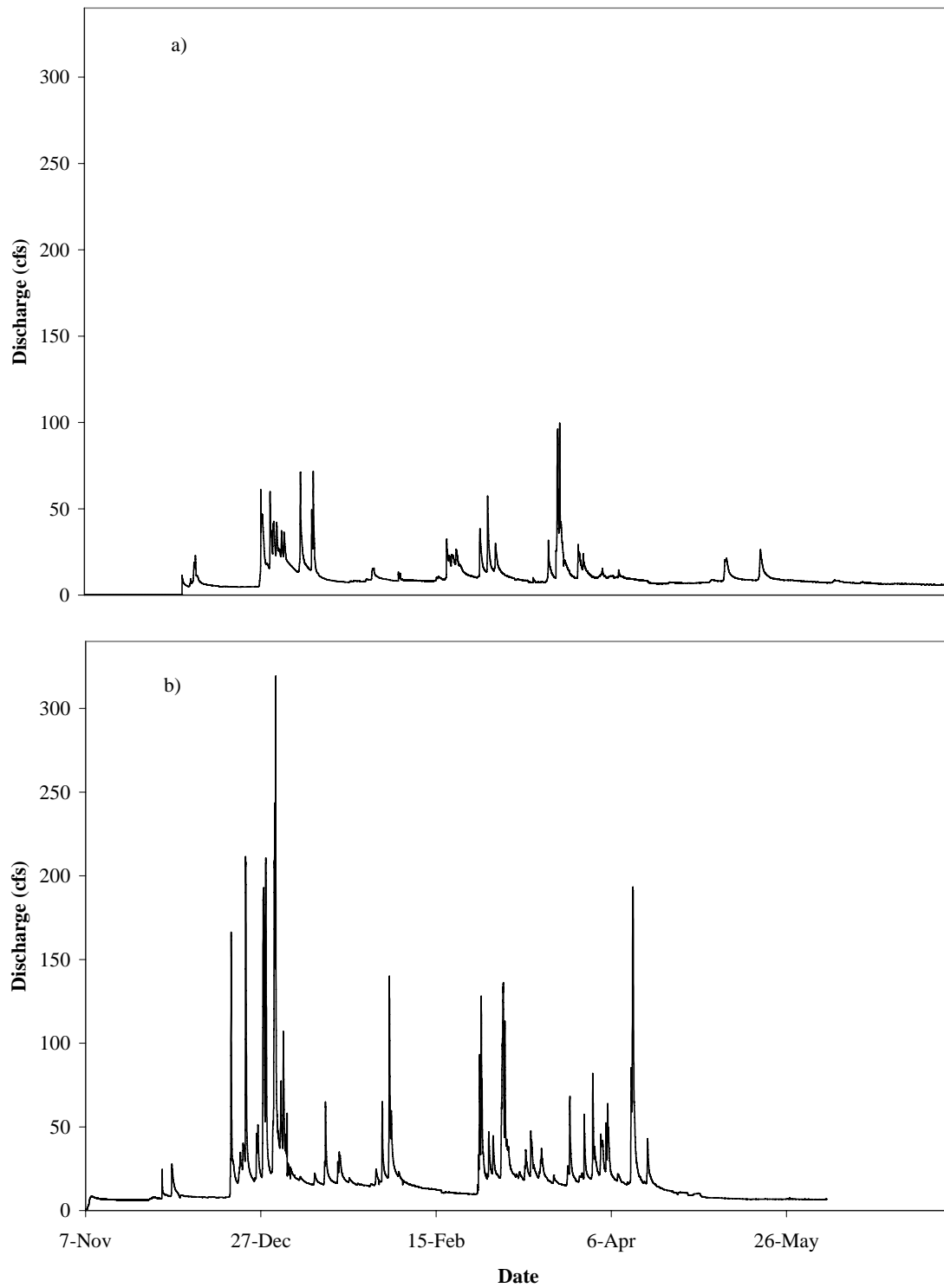


APPENDIX C

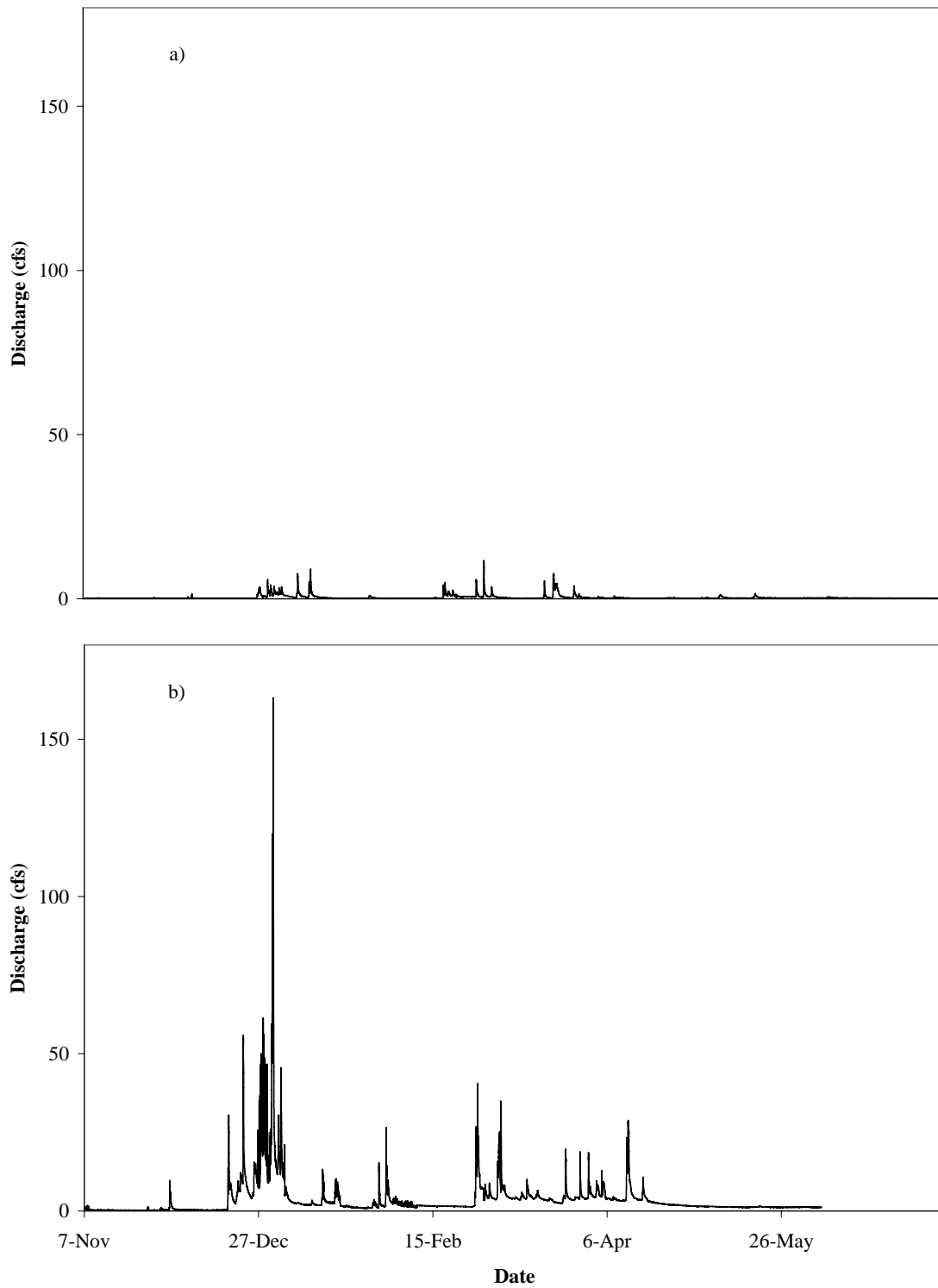
Annual hydrographs for Site 1 over both water years - 2004-2005 (a) and 2005-2006 (b).



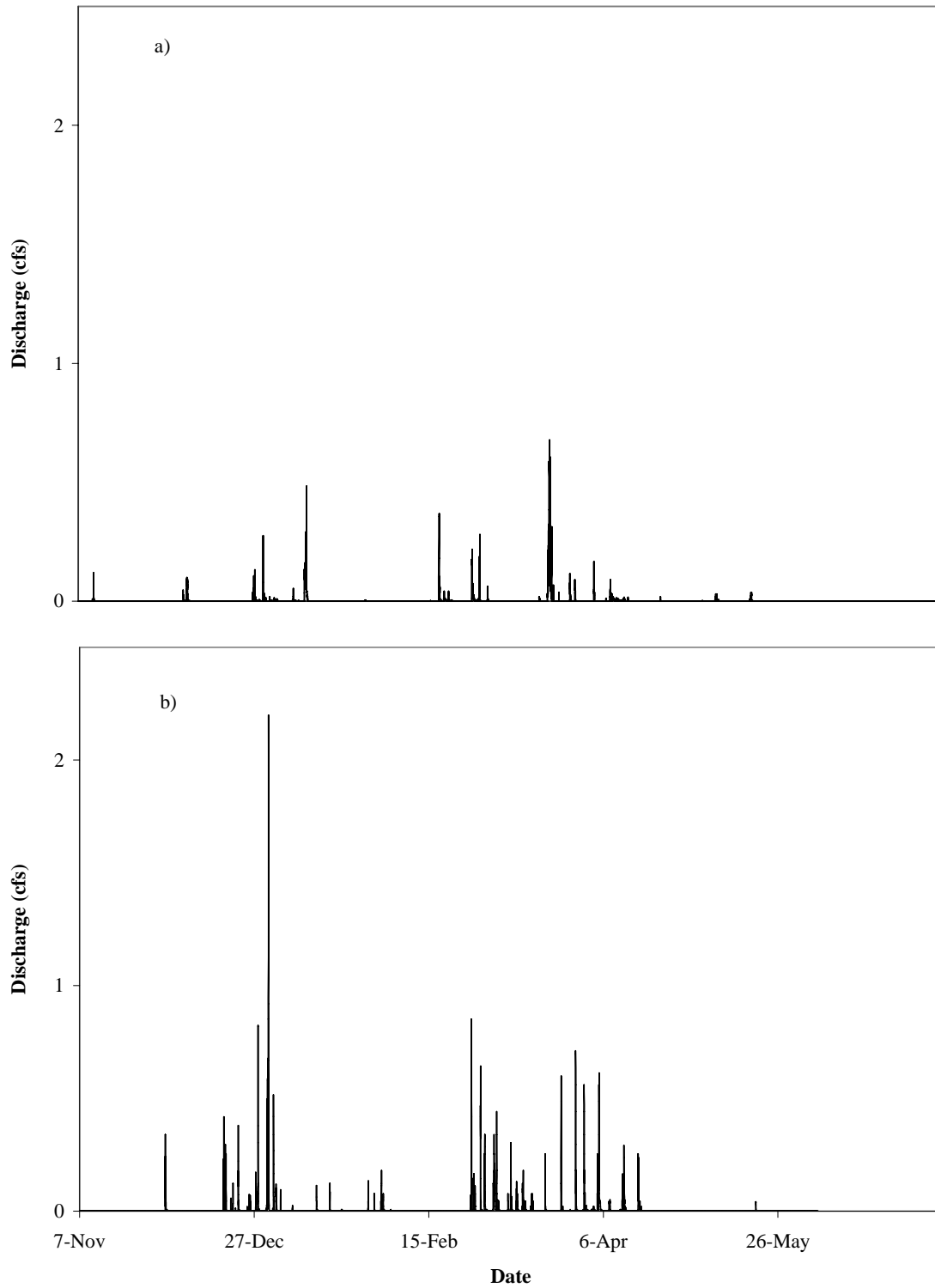
Annual hydrographs for Site 2 over both water years - 2004-2005 (a) and 2005-2006 (b).



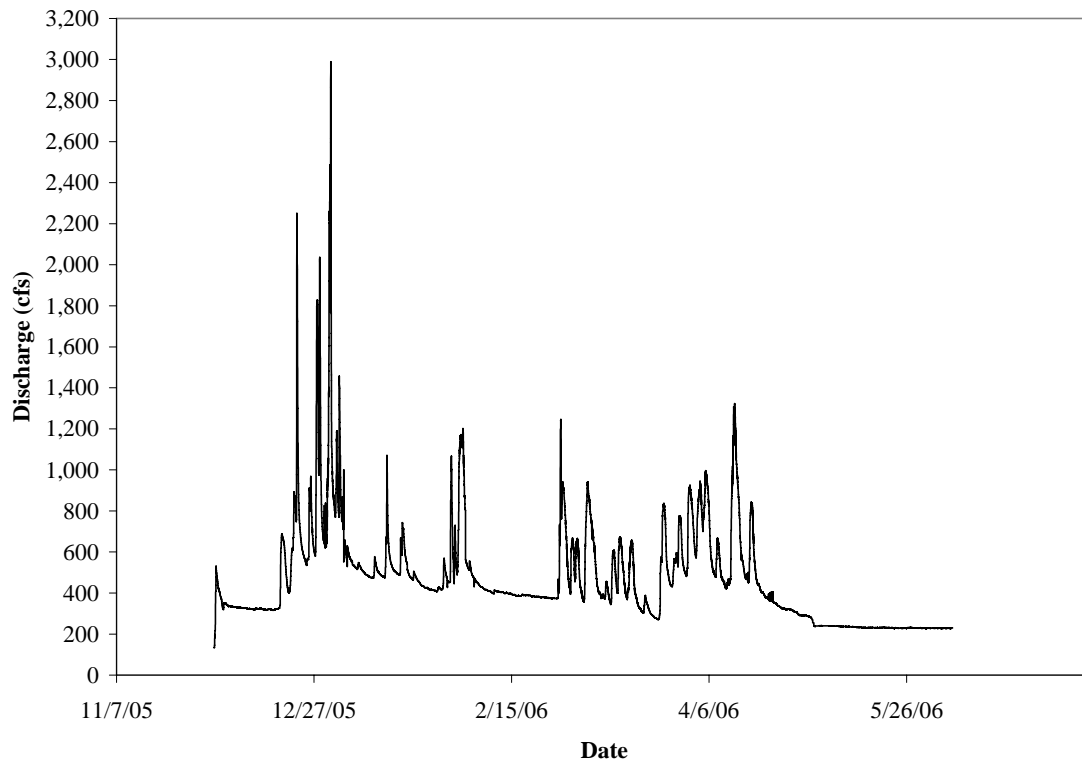
Annual hydrographs for Site 3 over both water years - 2004-2005 (a) and 2005-2006 (B).



Annual hydrographs for Site 4 over both water years - 2004-2005 (a) and 2005-2006 (b).



Annual hydrograph for Site 5 over the 2005-2006 water year.



APPENDIX D

Basic statistics for chemistry, turbidity and suspended sediment concentrations by year and site.

Water Year	Site	pH					Electrical Conductivity (uS/cm)					Turbidity (mg/L)				
		Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.
2004-2005	1	7.5	0.015	7.5	7.0	7.8	502	15.2	530	26	1,100	31	3.8	9.6	1.4	493
2004-2005	2	7.5	0.014	7.5	6.9	7.9	465	13.0	488	179	1,130	24	2.2	9.9	1.2	195
2004-2005	3	7.5	0.019	7.5	6.7	8.0	391	10.3	365	148	698	66	6.3	27.0	4.2	527
2004-2005	4	7.8	0.043	7.8	7.0	9.0	2,212	106.2	2,040	114	5,180	281	11.9	275.5	12.6	474
2005-2006	1	7.0	0.040	7.0	6.7	7.3	282	62.7	320	100	1,220	117	31.3	51.2	1.5	332
2005-2006	2	7.1	0.047	7.2	6.8	7.5	197	13.5	185	110	340	71	24.9	13.2	0.8	352
2005-2006	3	7.1	0.068	7.2	6.7	7.3	153	9.1	155	110	200	103	37.9	48.9	4.8	418
2005-2006	4	7.4	0.036	7.4	7.2	7.7	569	44.9	540	340	850	127	23.0	105.0	12.6	306
2005-2006	5	7.5	0.015	7.0	7.0	7.8	182	15.0	180	120	280	75	16.1	51.7	12.7	197

Water Year	Site	Total Suspended Solids TSS (mg/L)					Volatile TSS (mg/L)					Non-volatile TSS (mg/L)				
		Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.
2004-2005	1	36	3.9	13	1.8	307	11.5	1.1	5.8	1.1	89	25	2.8	7.0	0.2	223
2004-2005	2	32	3.5	11	1.8	310	9.8	1.0	5.1	0.7	102	22	2.6	6.6	0.0	216
2004-2005	3	105	11.7	32	4.3	884	17.9	1.7	8.6	1.3	132	87	10.0	24.0	1.7	760
2004-2005	4	5,385	615.6	3,712	296.4	33,120	2,211.6	209.6	1,695.0	180.0	10,820	3,174	426.4	1,980.0	90.7	22,410
2005-2006	1	276	88.3	84	3.3	1,123	75.9	25.8	16.9	0	373	200	66.2	67.6	0.5	917
2005-2006	2	179	74.9	28	2.3	1,190	50.5	23.4	6.9	2.0	400	128	52.2	20.9	0.0	790
2005-2006	3	289	161.6	67	7.3	1,970	55.0	32.4	12.7	2.8	400	234	129.4	56.2	0.8	1,570
2005-2006	4	7,886	1,690.6	5,320	400.0	24,600	2,639.3	443.6	2,050.0	240.0	6,400	5,247	1,278.9	3,700.0	160.0	18,200
2005-2006	5	89	20.9	61	9.0	250	22.2	4.3	17.9	3.0	52	66	17.0	43.4	5.5	200

Basic statistics for chemistry, turbidity and suspended sediment concentrations by year and site.

Water Year	Site	Dissolved Organic Carbon (mg/L)					Total Nitrogen (mg/L)					Ammonium NH ₄ /NH ₃ (mg/L)				
		Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.
2004-2005	1	15.9	0.41	16	5.8	50	5.265	0.260	5.187	0.348	25.787	0.103	0.022	0.053	0.002	3.26
2004-2005	2	14.8	0.36	14	7.6	59	4.186	0.198	4.099	0.242	26.865	0.098	0.023	0.056	0.003	4.196
2004-2005	3	11.6	0.15	12	7.9	18	3.088	0.153	2.801	0.349	10.016	0.075	0.008	0.035	0.000	0.741
2004-2005	4	192.1	7.95	182	13.6	623	151.547	7.571	139.420	26.677	376.640	23.545	2.002	22.950	0.051	89.263
2005-2006	1	19.9	3.31	14	11.6	62	12.917	2.442	8.941	3.138	34.939	0.407	0.362	0.010	0.000	6.174
2005-2006	2	19.7	2.81	15	7.9	58	7.527	2.246	3.320	1.686	39.358	0.591	0.516	0.007	0.000	9.289
2005-2006	3	11.8	0.42	12	9.6	14	4.537	0.719	4.112	1.928	8.572	0.004	0.001	0.004	0.000	0.009
2005-2006	4	169.0	43.49	126	40.5	682	92.252	7.205	97.081	47.373	132.765	21.721	2.898	20.925	9.177	43.534
2005-2006	5	22.7	2.10	22	13.2	40	8.045	0.675	8.042	4.595	11.722	0.030	0.008	0.019	0.006	0.106

Water Year	Site	Nitrate NO ₃ (mg/L)					Ammonia NH ₃ (mg/L)				
		Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.
2004-2005	1	3.41	0.15	3.3	0.526	14.1	0.013	0.003	0.0002	0.00001	0.210
2004-2005	2	2.37	0.11	2.2	0.058	12.8	0.0004	0.00005	0.0002	0.00003	0.002
2004-2005	3	1.95	0.10	1.7	0.012	5.8	0.00025	0.00004	0.0002	0.00001	0.004
2004-2005	4	17.92	1.76	18.0	0.050	103.8	0.339	0.108	0.092	0.001	2.839
2005-2006	1	6.34	1.34	4.6	1.967	25.8	0.0009	0.0008	0.00002	0.00001	0.014
2005-2006	2	2.37	0.49	1.5	0.530	7.1	0.0015	0.0014	0.00002	0.00001	0.025
2005-2006	3	2.40	0.53	1.3	0.136	5.7	0.00001	0.00001	0.00001	0.00001	0.00005
2005-2006	4	0.18	0.01	0.2	0.096	0.3	0.103	0.011	0.115	0.035	0.177
2005-2006	5	5.09	0.56	4.6	2.370	8.1	0.00005	0.00001	0.00003	0.00001	0.0002

Basic statistics for chemistry, turbidity and suspended sediment concentrations by year and site.

Water Year	Site	Total Phosphorus (mg/L)					Ortho Phosphate PO ₄ (mg/L)				
		Mean	Std. Error	Median	Min.	Max.	Mean	Std. Error	Median	Min.	Max.
2004-2005	1	1.1	0.080	0.8	0.094	7.485	0.834	0.056	0.6	0.184	6.4
2004-2005	2	0.9	0.064	0.7	0.043	8.789	0.701	0.044	0.6	0.143	6.5
2004-2005	3	0.5	0.031	0.3	0.020	3.498	0.170	0.014	0.1	-0.957	1.9
2004-2005	4	41.7	2.354	34.0	5.989	108.454	23.764	0.695	23.0	5.520	42.4
2005-2006	1	3.5	0.895	1.8	0.765	14.451	2.026	0.541	1.0	0.488	9.0
2005-2006	2	2.7	0.990	0.9	0.479	17.682	1.500	0.611	0.6	0.301	11.2
2005-2006	3	1.1	0.348	0.6	0.469	4.718	0.223	0.026	0.2	0.030	0.4
2005-2006	4	54.6	4.855	49.5	27.240	97.525	28.823	3.366	26.2	17.792	71.8
2005-2006	5	2.1	0.282	1.8	0.818	3.915	1.831	0.261	1.7	0.210	3.3

APPENDIX E

Total storm loads for Site 1.

Date	Total TSS Storm Load (kg)	Volatile TSS Storm Load (kg)	Nonvolatile TSS Storm Load (kg)	Dissolved Organic Carbon Storm Load (kg)	Ammonium Storm Load (kg)	Nitrate Storm Load (kg)	Total Phosphorus Storm Load (kg)	Total Nitrogen (kg)	Phosphate Storm Load (kg)	Ammonia Storm Load (kg)
12/8/04	1,291.3	671.1	620.2	645.2	7.8	163.8	86.4	296.6	63.0	
12/27/04	9,348.1	2,312.5	7,035.7	1,502.6	15.7	371.9	171.4	678.3	132.8	0.058
12/31/04	3,662.4	858.2	2,804.2	1,096.8	5.2	290.3	88.6	482.3	71.7	0.024
1/2/05	2,896.9	746.7	2,150.2	1,546.8	4.9	399.7	120.4	677.4	90.7	0.022
1/3/05	1,876.9	496.1	1,380.8	1,197.2	4.3	283.0	88.2	452.6	68.4	0.024
1/8/05	7,631.0	1,970.3	5,660.7	1,866.6	11.0	401.4	143.5	510.3	111.3	0.029
1/11/05	5,509.1	1,504.4	4,004.8	845.5	2.9	184.8	82.9	245.6	65.1	0.009
1/12/05	9,855.7	2,347.5	7,508.2	2,045.6	8.9	388.5	150.7	431.6	121.2	0.027
2/16/05	419.6	263.2	156.4	384.7	9.8	136.1	18.0	161.2	14.2	0.044
2/19/05	6,854.3	2,009.0	4,845.3	1,214.7	1.1	156.8	116.5	443.6	78.1	0.004
2/21/05	2,472.0	679.6	1,792.3	1,074.1	1.1	93.2	58.2	249.9	50.7	0.008
5/8/05	1,006.9	468.9	537.9	721.2	2.3	93.8	64.7	228.3	41.2	0.008
11/9/05	1.1	0.5	0.6	2.2	0.002	0.7	0.2	0.9	0.2	0.00001
12/1/05	5,391.1	2,199.6	3,191.5	284.3	29.5	64.6	97.7	260.9	62.7	0.068
12/18/05	64,682.8	14,212.8	50,469.7	2,087.8	16.5	465.7	409.7	1,293.7	167.3	0.027

Total storm loads for Site 2.

Date	Total TSS Storm Load (kg)	Volatile TSS Storm Load (kg)	Nonvolatile TSS Storm Load (kg)	Dissolved Organic Carbon Storm Load (kg)	Ammonium Storm Load (kg)	Nitrate Storm Load (kg)	Total Phosphorus Storm Load (kg)	Total Nitrogen (kg)	Phosphate Storm Load (kg)	Ammonia Storm Load (kg)
12/8/04	3,118.5	1,443.9	1,674.7	1,199.4	55.6	231.5	151.9	465.2	106.7	
12/27/04	4,410.9	1,215.5	3,195.4	905.4	12.8	193.6	109.8	367.5	78.2	
12/31/04	3,910.7	872.3	3,038.5	1,097.3	8.7	262.2	75.3	477.4	56.4	
1/2/05	1,780.2	438.0	1,342.2	836.0	2.3	201.0	66.9	339.1	41.2	
1/3/05	1,502.8	398.0	1,104.8	906.6	3.9	223.9	58.2	354.0	50.1	
1/8/05	8,311.9	2,149.5	6,162.4	1,770.2	7.1	398.6	137.1	511.2	111.8	
1/11/05	4,120.2	1,295.4	2,824.8	751.0	3.1	163.4	72.1	228.8	56.5	
1/12/05	7,949.4	1,881.0	6,068.4	1,454.9	6.7	276.4	105.1	385.9	81.2	
2/16/05	262.8	163.1	99.8	362.2	0.5	63.8	14.4	113.2	10.9	0.003
2/19/05	5,131.7	1,450.6	3,681.1	994.5	0.9	110.1	74.3	331.8	55.3	0.004
2/21/05	2,688.7	641.9	2,046.8	837.4	0.9	82.0	33.9	147.5	36.9	0.007
5/8/05	493.9	235.1	258.8	375.0	1.2	59.6	30.7	126.1	20.0	0.016
11/9/05	94.3	59.6	34.7	280.1	0.2	17.5	19.3	45.3	13.5	0.001
12/1/05	9,914.7	3,188.2	6,726.5	435.3	66.7	61.4	153.5	370.2	97.5	0.182
12/18/05	39,555.7	9,363.6	30,192.0	3,113.0	36.4	395.5	410.0	1,201.2	149.7	0.045

Total storm loads for Site 3.

Date	Total TSS Storm Load (kg)	Volatile TSS Storm Load (kg)	Nonvolatile TSS Storm Load (kg)	Dissolved Organic Carbon Storm Load (kg)	Ammonium Storm Load (kg)	Nitrate Storm Load (kg)	Total Phosphorus Storm Load (kg)	Total Nitrogen (kg)	Phosphate Storm Load (kg)	Ammonia Storm Load (kg)
12/8/04	430.9	82.2	348.7	14.5	0.1	4.2	1.9	5.7	0.3	
12/27/04	1,321.4	193.1	1,128.3	67.4	0.7	19.8	4.8	33.2	3.5	
12/31/04	948.9	119.7	829.2	58.7	0.4	17.0	4.0	28.2	1.3	
1/2/05	683.5	115.1	568.5	133.7	1.1	38.9	6.7	58.8	2.7	
1/3/05	607.3	78.2	529.0	65.8	0.5	17.4	3.2	28.4	1.3	
1/8/05	1,796.3	243.9	1,552.4	96.9	0.9	24.2	5.3	23.4	1.8	0.0022
1/11/05	3,335.2	485.4	2,849.8	113.1	0.7	32.3	7.2	33.7	2.5	0.0021
2/16/05	52.5	12.4	40.1	10.2	0.04	1.3	0.3	2.3	0.1	0.0003
2/19/05	1,650.2	251.5	1,398.7	68.2	0.1	10.1	5.2	26.3	1.2	0.0003
2/21/05	539.6	72.2	467.4	37.6	0.05	5.6	1.2	11.2	0.7	0.0003
5/8/05	140.6	31.3	109.3	23.7	0.1	0.6	0.9	4.2	0.3	0.0011
11/9/05	21.6	11.4	10.2	19.8	0.007	1.9	1.1	3.9	0.5	0.00004
12/1/05	2,723.9	478.2	2,245.7	79.5	0.03	24.1	8.4	40.6	1.0	0.00005

Total storm loads for Site 4.

Date	Total TSS Storm Load (kg)	Volatile TSS Storm Load (kg)	Nonvolatile TSS Storm Load (kg)	Dissolved Organic Carbon Storm Load (kg)	Ammonium Storm Load (kg)	Nitrate Storm Load (kg)	Total Phosphorus Storm Load (kg)	Total Nitrogen (kg)	Phosphate Storm Load (kg)	Ammonia Storm Load (kg)
12/8/04	161.3	64.3	97.0	6.0	0.6	0.9	2.3	4.5	1.0	
12/27/04	25.3	13.5	11.8	1.0	0.1	0.2	0.2	0.9	0.2	
12/31/04	28.4	15.9	14.2	2.2	1.8	1.8	1.9	2.4	1.8	
1/8/05	118.6	51.1	80.4	15.5	13.2	13.0	13.4	14.6	13.2	
1/11/05	262.3	89.7	172.7	7.5	0.8	0.8	1.4	5.1	0.9	
2/19/05	813.0	238.3	590.4	26.5	17.1	16.6	18.8	26.5	17.0	15.710
2/21/05	54.8	35.6	40.9	23.1	21.9	21.8	22.1	22.8	22.0	21.803
5/8/05	38.8	25.5	24.4	12.9	11.4	11.2	11.4	12.7	11.2	11.102
12/1/05	121.5	42.6	78.9	8.5	0.5	0.007	1.5	2.4	1.0	0.004
12/18/05	266.5	112.2	154.3	6.0	1.6	0.008	2.6	5.4	1.1	0.006

Total storm loads for Site 5.

Date	Total TSS Storm Load (kg)	Volatile TSS Storm Load (kg)	Nonvolatile TSS Storm Load (kg)	Dissolved Organic Carbon Storm Load (kg)	Ammonium Storm Load (kg)	Nitrate Storm Load (kg)	Total Phosphorus Storm Load (kg)	Total Nitrogen (kg)	Phosphate Storm Load (kg)	Ammonia Storm Load (kg)
12/3/05	70,523.7	22,198.0	48,325.8	27,014.3	25.8	6,380.1	3,093.3	10,394.8	2,302.3	0.044
12/18/05	208,402.7	44,433.1	163,969.6	33,518.1	36.5	8,230.3	3,115.7	12,409.8	2,948.0	0.058