Floodwater Chemistry in the Yolo Bypass during Winter and Spring 1998

Open-File Report 2007–1025

U.S. Department of the Interior
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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
liter (L)	61.02	cubic inch (in^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
	Flow rate	
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Floodwater Chemistry in the Yolo Bypass during Winter and Spring 1998

Laurence E. Schemel and Marisa H. Cox

Abstract

A preliminary investigation of temporal and spatial variations in floodwater chemistry was conducted during winter and spring 1998 in the Yolo Bypass floodplain of the Sacramento River system. Samples were collected at locations along the eastern margin of the floodplain over the duration of the study and across the floodplain during major periods of inundation. Specific conductance and dissolved organic carbon concentrations along the eastern margin of the Yolo Bypass varied inversely with discharge. The Sacramento River was the greatest source of discharge to the floodplain during major periods of inundation. Increases in specific conductance and dissolved organic carbon were observed along the eastern margin during periods of lower discharge, when local streams accounted for a significant fraction of the total discharge through the Yolo Bypass. Apparent influences of local stream discharges also were observed in surface waters near the western margin of the floodplain during major periods of inundation. Although river and local stream sources of suspended particulate matter appeared important, in-floodplain processes were likely contributors to temporal and spatial variability in concentrations. Values for the C:N ratio of the particulate matter were lowest during periods of decreasing and low discharge through the floodplain, indicating production of phytoplankton in floodplain waters or supply to the floodplain by local stream sources. Phytoplankton discharged from the Yolo Bypass was detected by chlorophyll *a* monitors downstream in the Sacramento River during this study.

Introduction

The Yolo Bypass is the largest engineered floodplain in the Sacramento River system (Fig. 1). This floodplain is part of a large and complex system of floodplains and levees that was developed in the early 1900's to prevent large-scale flooding in the Sacramento Valley that frequently occurred during winter and spring (Kelley, 1989). The Yolo Bypass specifically protects the Sacramento metropolitan area and surrounding agricultural lands. In order to provide this protection, the floodplain was designed to accommodate discharges of nearly five times the capacity of the adjacent Sacramento River channel. Floodwaters from the Yolo Bypass flow to the Sacramento-San Joaquin Delta, which drains directly to San Francisco Bay estuary.

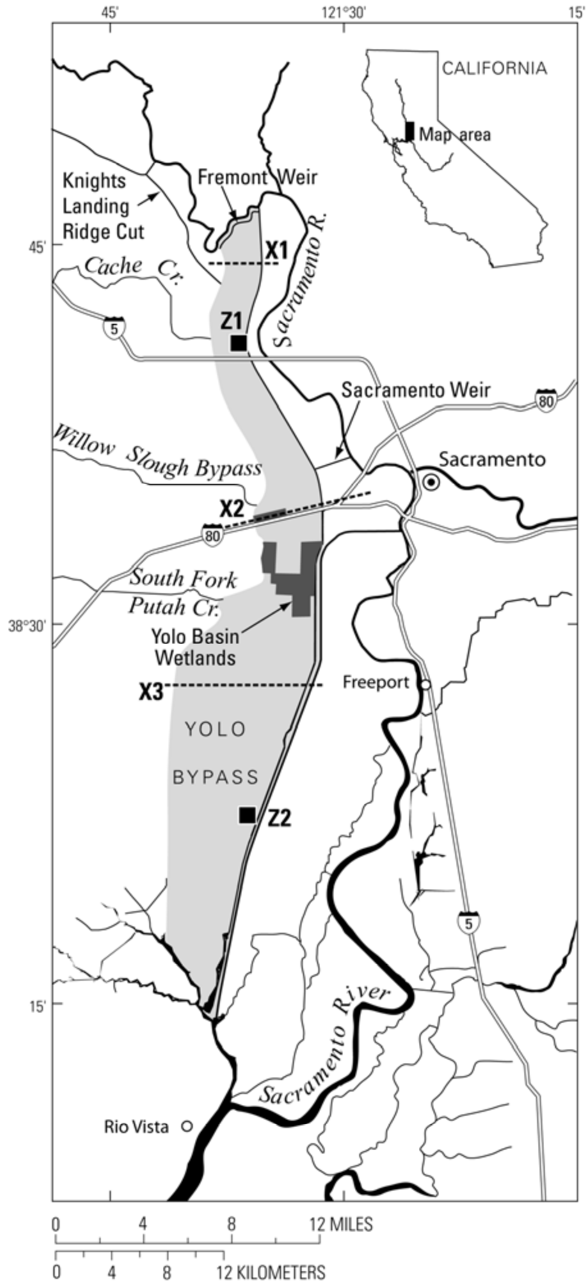

Fig. 1. Map showing the Yolo Bypass floodplain, locations of inflows from tributaries of the Sacramento River system and local streams, and sampling sites along the eastern margin (Z1, Z2) and across the floodplain (X1, X2, X3).

Studies of fisheries have recognized ecological benefits of the seasonally high river discharge to the Delta and estuary for many years (Bennett and Moyle, 1996). More recently, the importance of floodplain inundation and particularly the Yolo Bypass to migratory fishes and a variety of other aquatic species has become apparent (Sommer and others, 2001). Tributaries and upstream bypasses in the Sacramento River system are the major sources of discharge to the Yolo Bypass (Schemel and others, 1996), but local sources that directly supply runoff and wastewater to the floodplain potentially affect water chemistry and habitat quality for aquatic species particularly as the floodplain drains. Discharge plumes from these local sources are visible in aerial photographs of the flooded Yolo Bypass (Sommer and others, 2001). Although water quality data are collected in the Sacramento River and in some local streams, few measurements of floodwater chemistry have been made within the flooded Yolo Bypass. This report summarizes results from the first of two studies conducted by the U.S. Geological Survey that sampled floodwaters in the Yolo Bypass in order to determine how concentrations of dissolved and particulate constituents vary over time and space during inundation. Observations during this first study (1998) primarily were used to design a comprehensive sampling strategy for the second study (2000); however, the results from 1998 are valuable in themselves because of the unusual hydrographic characteristics of floodplain inundation over that winter and spring.

The (aerial) extent of inundation in the Yolo Bypass is directly related to the total discharge to the floodplain. When discharge in the Yolo Bypass exceeds about 100 m^3/s, flooding extends from the channel along the eastern margin towards the levee along the western margin, creating a broad, shallow-water area that increases in depth with increasing discharge. Discharge through the Yolo Bypass is estimated by the California Department of Water Resources accounting program, DAYFLOW (available at http://www.iep.ca.gov/dayflow/index.html). At the time this report was prepared, computed values were available for fifty water years (October 1955 through September 2005). Over that period, large-scale inundations that exceeded two-thirds of the capacity of the Yolo Bypass had occurred in only two water years, 1986 and 1997. The 1998 water year, which immediately followed this extreme event, ranked eleventh in terms of peak discharge, but the number of days of floodplain inundation ranked fourth and flooding extended later into spring than in any of the fifty years. The 100 m^3/s threshold value (for flooding beyond the eastern-margin channel) was exceeded for ninety-nine days in 1998 and the floodplain was inundated from January 16 through June 7. Inundations later than May 12 occurred in only three of the fifty years and the median value for days inundated per year was thirty. Discharge in the Yolo Bypass exceeded discharge in the adjacent Sacramento River channel for a month during winter 1998, but discharges did not exceed the Sacramento River values during the study in 2000. A comparison of discharges and floodplain inundation characteristics for 1998 and 2000 can be found in Sommer and others (2004).

The sequence of storms during winter and spring typically produces substantial variability in flow and the extent of floodplain inundation. In late April 1998, discharge fell below the 100 m^3/s threshold value for about two weeks before runoff from the next storm increased discharge and the flooded area in the Yolo Bypass. The Yolo Bypass hydrograph also indicated several episodes of flooding and partial draining with flows still exceeding 100 m^3/s during winter and spring 1998. These flooding-draining sequences coincided with variations in chlorophyll *a* concentrations in the Sacramento River downstream from the location where discharge from the Yolo Bypass enters the Delta (Rio Vista; Fig. 1), indicating that drainage from the Yolo Bypass was enriched in phytoplankton (Sommer and others, 2004). The 1998 study measured organic matter in the Yolo Bypass, but primary production was confirmed by measurements of chlorophyll *a* in the floodplain as it drained during the study in 2000. Primary production in the Delta and estuary is limited by many environmental factors and increased grazing by recently introduced (exotic) species. Therefore, seasonal flooding of the Yolo Bypass is important because it enhances food resources in the Delta in addition to providing floodplain habitat for aquatic species (Schemel and others, 2004). Restoration projects within the Yolo Bypass (for example, the Yolo Basin Wetlands; Fig. 1) are enhancing floodplain habitats while providing controlled environments for floodplain research.

Two publications present the results of the USGS 2000 study and provide interpretations of both hydrologic and chemical variability (Schemel and others, 2002 and 2004). The study in 2000 linked chemical variability in floodwaters of the Yolo Bypass to the chemistry of discharges to the floodplain, primarily the Sacramento River and four local creeks and drainage canals. Although the effect of discharge from the Sacramento River was recognized in the 1998 results, the roles of the other sources could not be specifically identified. Therefore, the scope of this report is limited to descriptions of the 1998 methods and results and presentation of the numerical data without further interpretation.

Acknowledgments

This study would not have been possible without encouragement from T.R. Sommer of the California Department of Water Resouces and the field support of his staff members. In particular, we thank Kurt Malchow and W.C. Harrell for collecting most of the samples. Funding for this study was provided by the U.S. Geological Survey National Research Program and Toxic Substances Hydrology Program and the Interagency Program for the Sacramento-San Joaquin Estuary.

Methods

Samples were collected along the eastern margin of the floodplain (Z1, Z2; Fig. 1) and at (non-specific) sites along three transects across the floodplain (X1, X2, X3). Most of the flow occurs in the deeper water on the eastern side of the floodplain. Samples from the eastern-margin sites (Z1 and Z2) were collected by wading into the water and allowing the sample bottle to fill at a depth of approximately 0.3m. Samples collected on transects across the floodplain were intended to identify variations in surface water quality attributable to local stream and canal discharges. Sample bottles were allowed to fill at a depth of approximately 0.3m at three locations while transect sites were occupied by boat. Samples were collected along the transects near the eastern (E) and western (W) margins of the floodplain and at a half-way point (center, C). The E, C, and W sites do not necessarily correspond to the same locations on different dates because of variations in flooding and boat navigation and safety considerations.

Each sample was collected in a 1-liter, pre-combusted, amber glass bottle with teflon cap. An aliquot was decanted into a small polyethylene bottle for specific conductance analysis, and the remainder of the sample was refrigerated until processing. Some samples were processed on the day following collection, but most of the samples were refrigerated for up to one week before processing in the laboratory.

The laboratory procedures and apparatus were similar to those described in detail by Schemel and others (2002) for the study in 2000, but fewer analytes were measured in 1998. Pre-weighed silver rather than cellulose ester membrane filters were used to collect suspended particulate matter (SPM) in 1998. These filters were dried in a desiccator for several weeks before sediment weights were measured on an analytical balance. Particulate matter samples for C and N (PC, PN) measurements were collected on pre-combusted glass fiber filters, which were dried in a desiccator before analysis with a Carlo Erba Instruments Model NA 1500NC analyzer. Requirements of this analyzer limited the sample size to only 15-20 milliliters. Consequently, some differences between duplicate samples were large, in part because of the difficulty in preparing identical sub-samples. Duplicate filters from each sample were analyzed in two separate runs.

Glass fiber filters in an all-stainless filtration apparatus were used to prepare filtrate for dissolved organic carbon (DOC) analysis. Samples were refrigerated until analysis with a MQ1001 TOC analyzer. Each DOC sample was analyzed twice during separate analytical runs.

Specific conductance was measured on each sample in a thermostated bath (25C) using a Pt-electrode cell and meter standardized with commercially prepared KCl solutions.

Results

Numerical values for single and duplicate samples are shown in Table 1 (refer to separate Table1.xls file). Descriptions of the data in the following text primarily refer to graphs that in most cases present the data with respect to time. Graphs of the results from duplicate samples show the mean values with error bars representing the range of the original results. Discharge hydrographs are included on most of the graphs to show associations between discharge variations and concentrations. Even though discharge varies with location in the Yolo Bypass, most of the discharge comes from the Sacramento River via Fremont Weir and to a much lesser extent Sacramento Weir (Fig. 1). Local sources of discharge (streams and canals) are important primarily during periods of lower discharge. We begin with a description of the results from Z2, the lower (southern) bypass site along the eastern margin of the floodplain, which was the only site where samples were collected over the entire duration of the study.

Specific conductance is a measure of the dissolved electrolyte content that typically varies among stream sources, in part because of differences in drainage basin characteristics. Consequently, sources of surface waters and mixing processes often can be identified by differences in specific conductance. Results from 1998 at Z2 showed an inverse relationship between specific conductance and discharge throughout the study (Fig. 2). Lowest values for specific conductance corresponded to times when the Sacramento River supplied most of the discharge to the floodplain. Discharge from local streams is represented on the graph by the total from Cache and Putah creeks, the two gauged streams of the four major local sources. It is likely that this substantially underestimates total local stream discharge because Knights Landing Ridge Cut canal, which was not gauged, was probably a major source. Specific conductance increased as discharge from local sources represented an appreciable fraction of the total discharge through the Yolo Bypass. For example, specific conductance increased near (calendar) day 70 when floodplain discharge decreased to levels similar to that from the local streams. The pulse in discharge (from the Sacramento River) near day 90 reduced specific conductance, which then increased following this pulse. Highest specific conductance coincided with lowest flows in spring, but another flow pulse from the Sacramento River near day 150 coincided with a large, although brief, reduction in specific conductance. Results from Z1 (the upper bypass site along the eastern-margin channel; Table 1) also showed this inverse relationship between specific conductance and discharge. Specific conductance values at the two sites were similar during periods of high discharge, but values at Z1 tended to be higher than those at Z2 during low discharge.

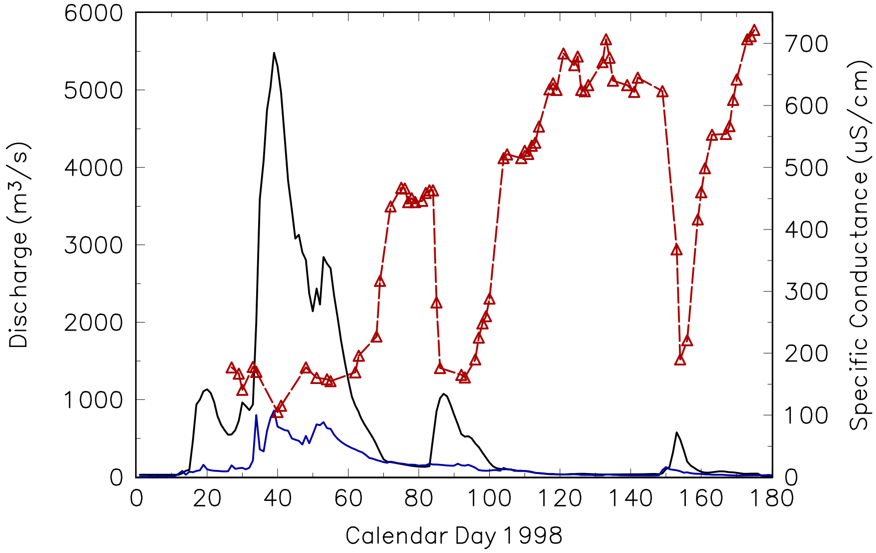

Fig. 2. Sacramento River (black line) and local stream (blue line) discharges to the Yolo Bypass and specific conductance at Z2 (red symbols) during winter and spring 1998.

In general, DOC concentrations also showed an inverse relationship with discharge at Z2 (Fig. 3). There were, however, differences in comparison to specific conductance. DOC concentrations decreased over the period of high discharge (days 30-60). Concentrations were high during periods when the local streams were significant contributors to the total discharge, and a distinct decrease in DOC coincided with the pulse of discharge from the Sacramento River near day 90. Highest concentrations were measured at the end of the study period when discharge was low, but this was preceded by a small decrease in concentration coinciding with the discharge pulse near day 150.

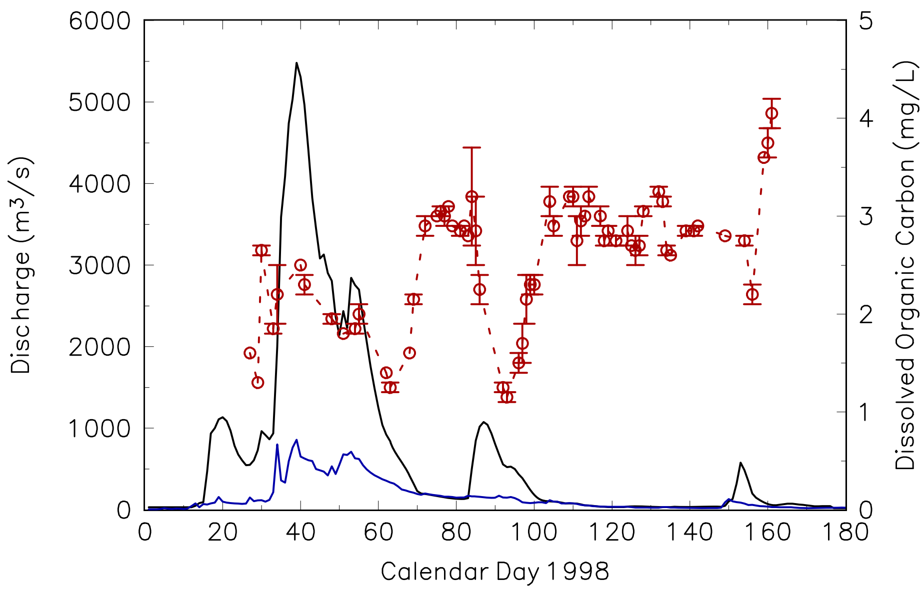

Fig. 3. Sacramento River (black line) and local stream (blue line) discharges to the Yolo Bypass and dissolved organic carbon concentrations at Z2 (red symbols) during winter and spring 1998.

SPM concentrations in the Yolo Bypass can be affected by supply from the Sacramento River and local sources and by erosion/deposition processes in the floodplain. Most of the floodplain is shallow, and particles from the substrate can be suspended by turbulence induced by winds and currents. Particles can also be deposited as water travels the approximately 60 km length of the floodplain. In addition, the growth of aquatic species, particularly phytoplankton, can increase SPM concentrations in the water column. As a likely consequence of these many processes, concentrations of SPM did not exhibit a simple relationship with discharge and varied greatly among sites sampled on the same day. In general, concentrations of SPM were highest during periods of high discharge through the floodplain (Fig. 4 and Table 1). At Z2, however, concentrations of SPM also tended to increase as the floodplain drained over periods of low discharge. Highest SPM concentrations during the greatest discharges were measured at transect sites. SPM variability across the floodplain is examined below in descriptions of results from the transects.

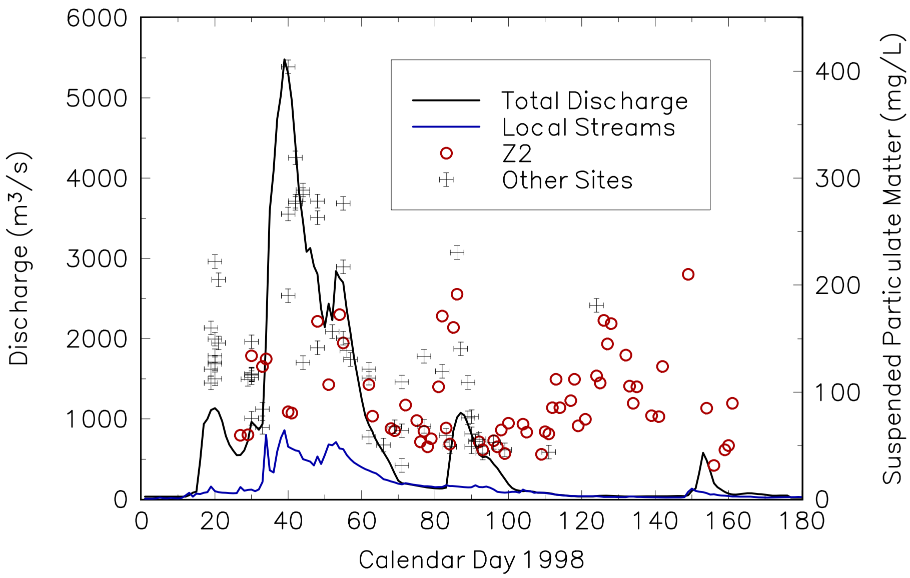

Fig. 4. Sacramento River (black line) and local stream (blue line) discharges to the Yolo Bypass and suspended particulate matter concentrations at Z2 (red symbols) and other locations (black symbols) during winter and spring 1998.

PC, which is presumably dominated by organic detritus, typically constitutes a few percent of the total SPM in the Sacramento River during winter and spring (Schemel and others, 1996). Therefore, the concentration of PC is likely to depend, in part, on the concentration of SPM. This is illustrated in Fig. 5, which also shows that PC concentrations in the Yolo Bypass were within one-to-three percent of the SPM over a wide range of SPM concentration. The organic matter component of SPM that is most useful as food (largely phytoplankton, which contain chlorophyll *a*) typically has a low carbon to nitrogen ratio (C:N ratio) relative to more-refractory, vascular-plant fragments. C:N ratios were lowest during periods of low discharge, when the floodplain was draining and local streams were supplying a substantial fraction of the discharge (Fig. 6). Discharge pulses (e.g., near days 90 and 150) coincided with increased C:N ratios, but proved important in transporting organic matter from the floodplain to the river. This was shown in records from the monitoring station in the downstream Sacramento River as increases in concentrations of chlorophyll *a* during these discharge events (Sommer and others, 2004).

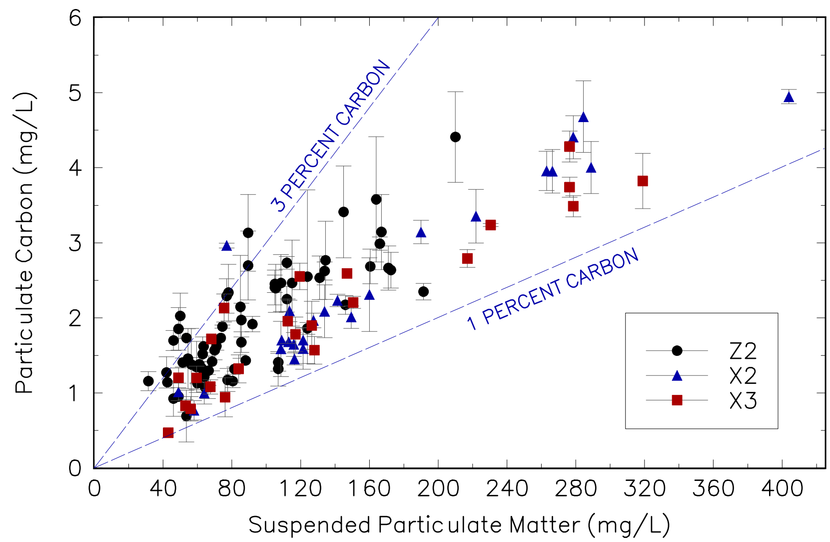

Fig. 5. Relation between particulate carbon and suspended particulate matter concentrations at Z2 (black symbols) and across the X2 (blue symbols), and X3 (red symbols) transects during winter and spring 1998.

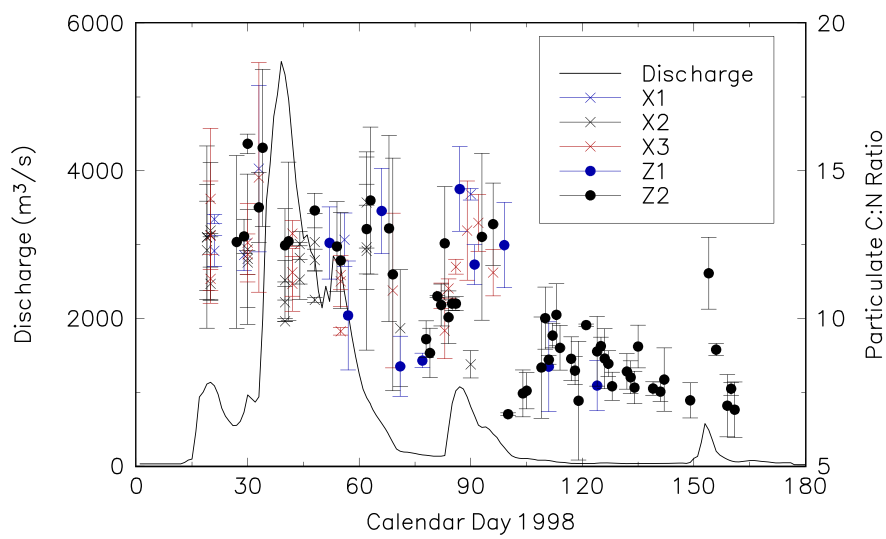

Fig. 6. Sacramento River discharge (black line) particulate C:N ratios at all sites during winter and spring 1998.

Aerial photographs of the flooded Yolo Bypass frequently show bands of flow extending most of the length of the floodplain, which appear to originate from local discharge sources (Sommer and others, 2004). An objective of the 1998 study was to examine the chemistry of surface waters along three transects across the floodplain for differences that could be attributable to the local sources. These transects could be sampled only during periods of high discharge that inundated the floodplain beyond the eastern-margin channel. Transect X1 was upstream from major local sources, and the data in Table 1 primarily represent variations in chemistry associated with the discharge across Fremont Weir from the Sacramento River tributaries and upstream bypasses. Only one attempt (January 21) was made to sample across this transect. Those two samples (E and C) had similar specific conductance, but DOC and particle concentrations were greater in the C sample.

Transects X2 and X3 were located downstream from potentially important local sources of discharge (Fig. 1). Cache Creek and Knights Landing Ridge Cut (canal) were expected to be greater dischargers than Putah Creek and Willow Slough Bypass (Fig. 1). Results from X2 are shown with the total discharge hydrograph in Fig. 7. In general, concentrations (of all analytes) near the eastern margin of the floodplain (E) were lower than concentrations near the center of the floodplain (C) and near the western margin (W), where influences from local sources were more likely. During the highest discharge (near day 40), specific conductance and DOC were similar at the E and C sites, but results were higher at the W site. This might be expected because of the overwhelming level of discharge from the Sacramento River, even though discharges from the two upstream local sources were presumably high. SPM and POC, however, showed a gradient across the transect with highest concentrations at the W site. Samples collected at X2 during the short discharge pulse near day 90 showed that specific conductance, DOC and PC at the W site were substantially higher than at the E site (Table 1).

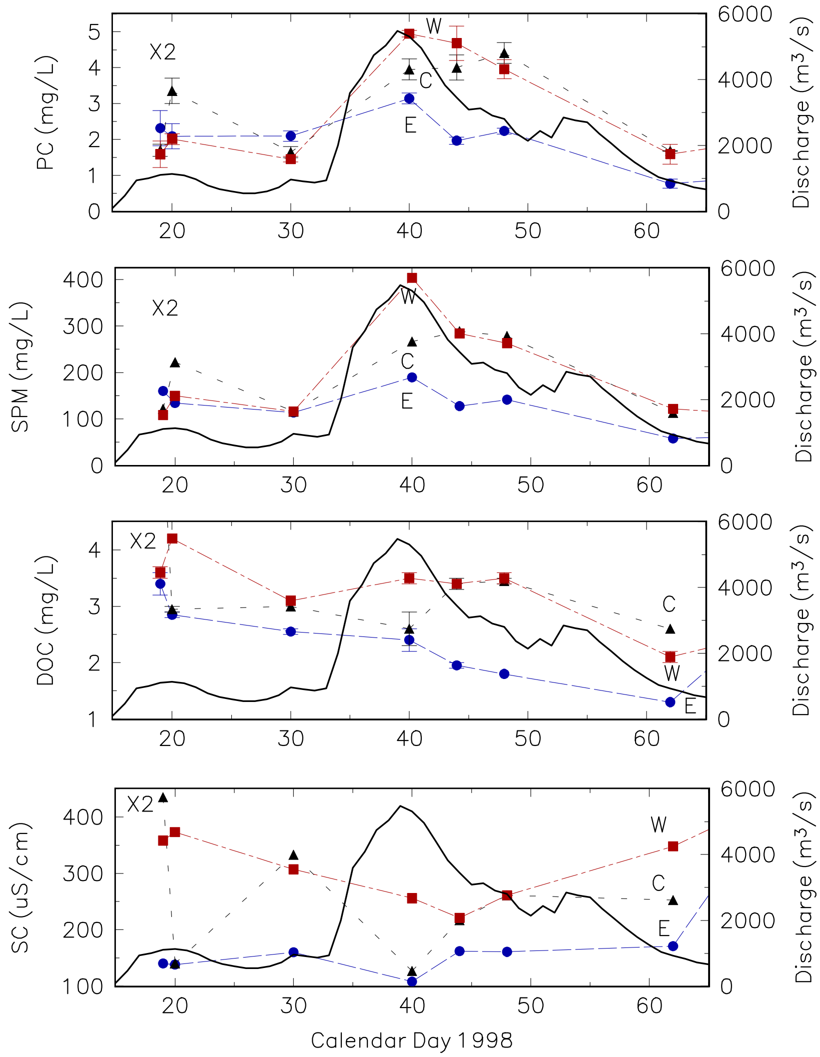

Fig. 7. Sacramento River discharge (black line) and results from transect X2 located near the eastern margin (E, blue), center (C, black), and western margin (W, red) of the inundated floodplain during winter 1998. Abbreviations used in this figure are: PC for particulate carbon, SPM for suspended particulate matter, DOC for dissolved organic carbon, and SC for specific conductance.

Most of the samples from X3 were collected on different days than those at X2, so a direct comparison is not possible. General features of specific conductance are comparable between the two transects in that results from the E and C sites were similar during the highest discharge and highest values were typically seen at the W sites (Fig. 8). Concentrations of DOC, SPM, and PC from X3 were similar among the sites during the highest discharge (day 42), but distinct differences among the sites were observed during the subsequent period of lower discharge (day 55). Highest concentrations of all three analytes on day 55 were measured near the center of the floodplain (site C), rather than along the western margin.

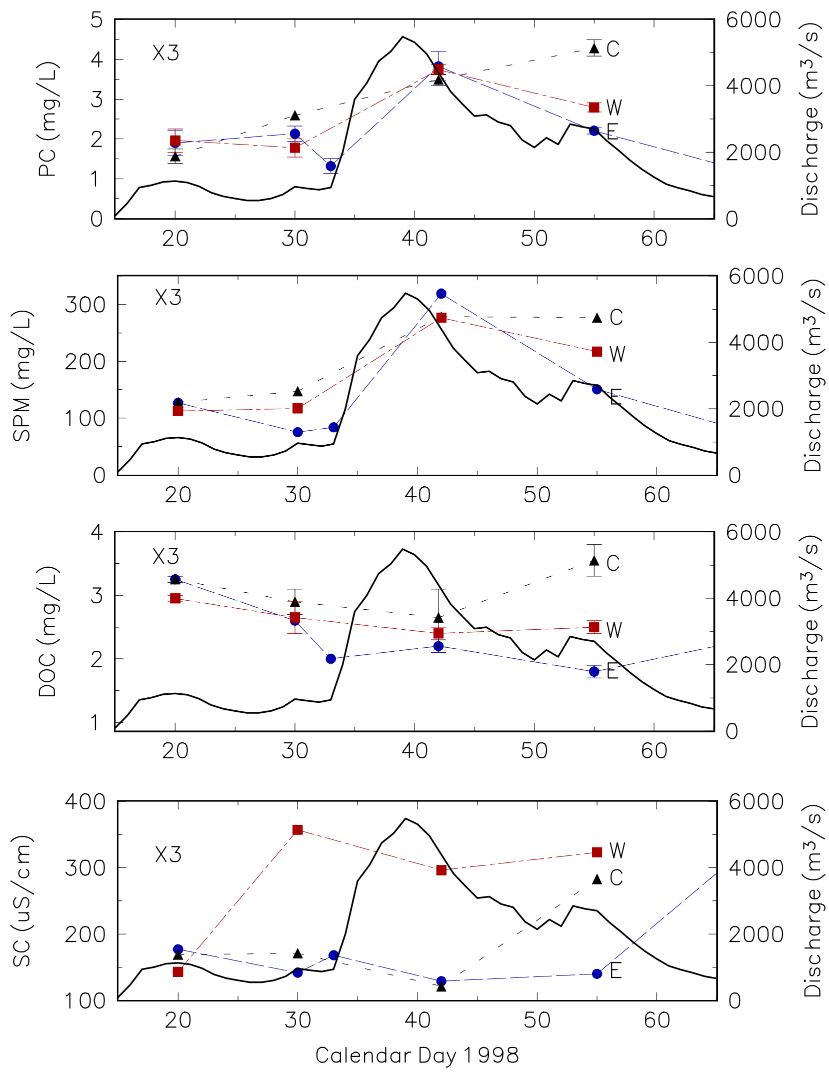

Fig. 8. Sacramento River discharge (black line) and results from transect X3 located near the eastern margin (E, blue), center (C, black), and western margin (W, red) of the inundated floodplain during winter 1998. Abbreviations used in this figure are: PC for particulate carbon, SPM for suspended particulate matter, DOC for dissolved organic carbon, and SC for specific conductance.

Summary

Results from this study show that variations in concentrations of dissolved analytes (specific conductance and DOC) were related to discharge levels and presumably sources of discharge. In general, concentrations in the discharge over Fremont Weir were lower than what appeared to be supplied by the local streams. Results from the transects indicate that inflows from individual local streams might be identifiable by differences in dissolved analyte concentrations. Analysis for additional major ions that might show greater differences in concentrations among the freshwater sources is suggested. Although the Sacramento River is undoubtedly a major source of particulate matter to the Yolo Bypass, the potential importance of local sources and in-floodplain processes cannot be ignored. Quality of the particles, in particular the C:N ratio, has been linked to the supply of phytoplankton (as indicated by chlorophyll *a*) from the Yolo Bypass to the Delta. Results from 1998, however, could not determine if phytoplankton (indicated by low C:N ratios) were primarily supplied by local streams or produced in the floodplain during periods of decreasing and low discharge. Understanding of autotrophic processes has important implications for the management of floodplain and Delta resources.

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