State of California
The Resources Agency
Department of Water Resources
Division of Environmental Services

The Municipal Water Quality Investigations Program

Summary and Findings of Data Collected from the Sacramento-San Joaquin Delta Region, October 2005 through September 2007

June 2008

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Governor
State of California

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The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected August 1998 through September 2001.* (Printed by DWR July 2003)

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected October 2001 through September 2003.* (Printed by DWR June 2005)

The Municipal Water Quality Investigations Program *Summary and Findings of Data Collected from the Sacramento-San Joaquin Delta Region, October 2003 through September 2005.* (Printed by DWR December 2006)

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Foreword

The Sacramento-San Joaquin Delta (Delta) is a major source of drinking water for two-thirds of the population in the State of California. The quality of Delta waters, however, may be degraded by a variety of sources and environmental factors. Close monitoring of Delta waters is necessary to ensure delivery of high quality source waters to urban water suppliers and users of the State.

The Municipal Water Quality Investigations (MWQI) Program of the Division of Environmental Services in the Department of Water Resources is charged with monitoring and research of water quality in the Delta. Among all State and local agencies monitoring the Delta and its tributaries, MWQI conducts the only monitoring program mandated to investigate the quality of source waters in the Delta with respect to its suitability for production of drinking water.

Since 1982, MWQI has been conducting comprehensive and systematic source water monitoring in the Delta region, and regularly prepares biennial or multi-year data summary reports. The previous two-year report (December 2006) summarized data collected October 2003 through September 2005. The current report summarizes and interprets monitoring data collected from October 1, 2005 through September 30, 2007, from 11 MWQI sampling sites. Presented are data and findings for major water quality constituents, including organic carbon, bromide, salinity, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of current interest.

This and other MWQI reports are available online at the MWQI website: www.wq.water.ca.gov/mwqi/mwqi_index.cfm. For further information about the MWQI Program, please visit its website; contact Cindy Messer, Chief of the Municipal Water Quality Investigations Program, (916) 651-9687; or send your request to: MWQI Program, P.O. Box 942836, Sacramento, CA 94236-0001.

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Appendix A Current State and Federal Drinking Water Standards .... available online and CD*
Appendix B Data Files .... available online and CD*

* Data are available on the CD that accompanies the printed version of this report or online where it is posted with the report at DWR's Office of Water Quality Web site: http://www.wq.water.ca.gov/index.cfm .

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State Water Project Contractors:

Alameda County Flood Control and Water Conservation District Zone 7
Alameda County Water District
Antelope Valley-East Kern Water Agency
Castaic Lake Water Agency
Central Coast Water Authority
Crestline-Lake Arrowhead Water Agency
Kern County Water Agency
Metropolitan Water District of Southern California
Mojave Water Agency
Napa County Flood Control and Water Conservation District
Palmdale Water District
San Bernardino Valley Municipal Water District
San Gabriel Valley Municipal Water District
San Gorgonio Pass Water Agency
San Luis Obispo County Flood Control and Water Conservation District
Santa Clara Valley Water District
Solano County Water Agency

MWQI Program Participant:

Contra Costa Water District

Executive Summary

Purpose and Scope

The Municipal Water Quality Investigations (MWQI) Program monitors surface water in the Sacramento-San Joaquin Delta (Delta) region and reports its findings to the State Water Contractors and the public through annual or multiyear reports. In this report, we summarize the results of MWQI discrete (grab) sampling data collected from October 2005 through September 2007. This reporting period represents two extreme water year types; 2006 being a very wet year and 2007 being a very dry year in both the San Joaquin and Sacramento valley watersheds. Two previous reports presented data from August 2001 through September 2005.

Presented are data from 11 MWQI stations. MWQI monitors water quality at 4 locations on the San Joaquin River (SJR), the Sacramento River, and the American River near the edge of the Delta. Three of these 4 stations are on the American and Sacramento rivers at or near the north end of the Delta—American River at E.A. Fairbairn Water Treatment Plant (WTP), Sacramento River at West Sacramento WTP Intake, and Sacramento River at Hood. The E.A. Fairbairn WTP represents water quality of the American River, which is a major tributary of the Sacramento River. West Sacramento WTP Intake represents water quality of the Sacramento River before mixing with water of the American River, and the Sacramento River at Hood reflects the quality of water from the Sacramento River shortly after it enters the Delta. The SJR near Vernalis location represents SJR water quality as it enters the Delta. In addition, MWQI monitored an urban drainage site—Natomas East Main Drainage Canal (NEMDC), which is just upstream of the northern boundary of the Delta.

The 6 remaining stations are within the Delta or at diversion points in the Delta. Three of the stations—Old River at Station 9, Old River at Bacon Island and Middle River at Union Point —are Delta channel stations representing quality of mixed waters primarily from the SJR and Sacramento River. Water is diverted near Old River at Station 9 at a pumping station belonging to the Contra Costa Water District (CCWD). Two of the stations—Banks Pumping Plant and Contra Costa Pumping Plant #1—are diversion points that reflect the quality of water being diverted from the Delta at these points. The last station— the Sacramento River at Mallard Island—in the west Delta is most susceptible to seawater influence due to its proximity to the San Francisco and Suisun bays.

Water quality constituents in Delta source waters are presented according to current regulatory priorities with organic carbon, bromide, salinity, and nutrients addressed in individual chapters. For each constituent at each station, descriptive plots in the form of temporal graphs show general seasonal patterns. Summary statistics that include range, mean, and median describe general data characteristics. Additionally, this is the first summary report to include a section on volumetric fingerprinting which is used to determine the source waters at key points in the Delta. Understanding the contribution of different source waters at a site is a useful tool in understanding water quality.

Summary of Findings

Organic Carbon

Organic carbon at 11 MWQI stations in the Delta and its tributaries differed spatially with north Delta stations generally having lower total organic carbon (TOC) concentrations than southern Delta and channel stations. American River water had the lowest median TOC of 1.7 milligrams per liter (mg/L). Median TOC at the Sacramento River at the West Sacramento WTP was 2.0 mg/L. Median TOC at Sacramento River at Hood was 2.1 mg/L, which represents organic carbon levels of northern Delta inflows. In contrast, median TOC for the SJR near Vernalis was 3.3 mg/L, which was about 60% higher than the TOC concentration in the northern inflows. Despite lower organic carbon concentration in northern inflows, median TOC at the 3 Delta channel stations and the 2 diversion stations ranged from 3.0 to 3.4 mg/L, comparable to that of the SJR near Vernalis suggesting considerable in-Delta sources of organic carbon. Agricultural drainage and in-channel production are probable in-Delta sources of organic carbon. Compared with the previous 4 water years, median TOC concentrations increased slightly at Hood, decreased slightly at Vernalis and remained the approximately the same at Banks. Seasonal patterns of organic carbon concentrations differed between tributary and channel stations. Seasonal patterns at the Delta channel and diversion stations differed from those at SJR and the Sacramento River stations, further indicating in-Delta loads of organic carbon.

Bromide

As expected, bromide concentrations were higher at those stations closer to seawater influence. Of the 11 stations, the Mallard Island station is the closest to the Suisun and San Francisco bays and had the highest median bromide (3.10 mg/L). The SJR near Vernalis had the second highest bromide concentrations with a median of 0.18 mg/L. Elevated bromide in the SJR may be attributable to agricultural drainage returns, which are indirectly influenced by seawater. Agricultural lands in the San Joaquin Valley have been irrigated with water diverted from the Delta through the Delta Mendota Canal (DMC), which contains considerable bromide. Soils in some areas developed from old marine deposits with high levels of bromide, which may be concentrated on the soil surface, and were washed into the river during wet months of low to moderate rainfall. In some areas, shallow groundwater carries high levels of bromide and moves into the SJR through seepage. Therefore, bromide levels in the SJR and Delta channels were elevated.

Median bromide concentrations at Banks Pumping Plant and Contra Costa Pumping Plant #1, the 2 diversion stations, were 0.12 mg/L and 0.14 mg/L, respectively. Stations at the north edge of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below the reporting limit of 0.01 mg/L.

The data provides additional evidence that the source of bromide is primarily seawater. The ratio of bromide to chloride in seawater is 0.0034. The ratio of bromide to chloride for the 6 central and western Delta stations and the Mallard Island station was 0.0036. Excluding the Mallard Island station, which has the closest proximity to seawater, the ratio was 0.0033.

Salinity

Among the 11 MWQI stations, the lowest electrical conductivity (EC) was found in the American River at E.A. Fairbairn WTP with a median of 56 µS/cm. Median EC at NEMDC was 314 µS/cm, but median flow at NEMDC was less than 3% of the combined flows from Sacramento and American rivers. Median EC at Sacramento River at Hood was 147 µS/cm, which represented salinity in northern Delta inflows. EC of the SJR was much higher than those found in the American or Sacramento rivers. Median EC at SJR near Vernalis (492 µS/cm) was the second highest of the 11 monitored stations. High levels of salts in irrigation returns from the San Joaquin Valley and recirculation of salts from the Delta ultimately increased EC levels in this area. EC was significantly lower in the Delta channel and diversion stations than in the SJR due to the dilution effects of water from the Sacramento River. Median EC at the Delta channel stations was 304 µS/cm for Old River at Station 9, 262 µS/cm for Old River at Bacon Island and 318 µS/cm for Middle River at Union Point. EC was higher at one of the diversion stations, the Contra Costa Pumping Plant #1, where the median was 428 µS/cm. Of all 11 MWQI sampling stations, Mallard Island had the highest salinity because of its proximity to Suisun Bay, where tides bring seawater in to the western Delta. Seawater was the primary source of salinity throughout the western Delta as indicated by the high median EC of 3374 µS/cm at Mallard Island. From the northern rivers to the SJR and throughout the Delta, salinity is affected by watershed runoff, urban discharges, and agricultural drainage. Seasonal precipitation during wet months and reservoir releases during dry months decrease salinity by diluting this water with low mineral content. However, salinity loads from the watersheds were significant during the wet months, especially following the first few major rain events.

Nutrients

Nitrogen and phosphorus are critical nutrients to aquatic life, but in high concentrations can cause water quality problems. Of the 11 MWQI stations, median inorganic and total nitrogen concentrations ranged from 0.04 to 1.41 mg/L and 0.14 to 1.90 mg/L, respectively; median total phosphorus and orthophosphates ranged from 0.01 to 0.35 mg/L and 0.01 to 0.22 mg/L, respectively. Concentrations of nitrogen and phosphorus were lowest in the American River at E.A. Fairbairn WTP, the West Sacramento WTP Intake and at the Contra Costa Pumping Plant #1. The highest nutrient concentrations were found at the NEMDC station and the San Joaquin River near Vernalis. Although the Hood station receives high quality American River water, it had higher concentrations of nitrogen and phosphorus. This is likely due to urban loads and wastewater discharges downstream of E.A. Fairbairn WTP and West Sacramento WTP and upstream of Hood.

Other Constituents

Also monitored were other constituents known to cause adverse effects on human health. The 9 constituents with primary standards monitored were: arsenic, beryllium, barium, cadmium, chromium, lead, mercury, nickel, and selenium. Beryllium, barium, cadmium, lead and mercury were not detected in Delta waters. Chromium, nickel and selenium were detected, but well below the maximum contaminant level (MCL). Of the constituents with secondary standards, those that can adversely affect taste, odor, or appearance of the water, aluminum, copper, iron, manganese, silver and zinc were monitored. Silver and zinc were never detected. Concentrations of copper, iron and manganese detected were well below their MCLs. It should be noted that these federal or State maximum contaminant MCLs are applicable to treated drinking water, not source waters in the Delta. In many cases, treatment removes or reduces concentrations of regulated substances in finished drinking water.

Volumetric and EC Fingerprinting

Volumetric fingerprinting was done for the west side of Bacon Island and Clifton Court Forebay. Overall in 2006, 54% of the water on the west side of Bacon Island was from the Sacramento River and 36% was from the San Joaquin River. At Clifton Court Forebay, 37% of the water was from the Sacramento River and 54% was from the San Joaquin River in the 2006 WY. Shortly after the high runoff in the winter of 2006, there was a shift in source waters from primarily Sacramento River water to primarily San Joaquin River water at both locations. Overall in 2007, the primary source of water at both sites was the Sacramento River with the San Joaquin River making up only 4% of the water on the west side of Bacon Island and 15% of the water at Clifton Court Forebay. Unlike the 2006 WY, the San Joaquin River in the 2007 WY did not dominate winter runoff.

EC fingerprinting was done for the same 2 sites as the volumetric fingerprinting. The EC fingerprints demonstrated that the San Joaquin River had a stronger influence throughout the year at Clifton Court than it did further north along the Old River. However, comparisons at both stations between the EC fingerprints and the volumetric fingerprints demonstrated that saltwater from Martinez greatly influenced EC. An increased percentage of Martinez water resulted in elevating EC significantly.

Acronyms and Abbreviations

AL(s)	action level(s)
CCPP	Contra Costa Pumping Plant #1
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CVP	Central Valley Project
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DPH	California Department of Public Health
DWR	California Department of Water Resources
EC	electrical conductivity
EPA	US Environmental Protection Agency
FLIMS	Field and Laboratory Information Management System
HORB	Temporary barrier constructed at the head of Old River
ICP	Inductively Coupled Plasma Optical Emission Spectroscopy
L	liters
LCS	laboratory control sample
MCL	maximum contaminant level
MDL	method detection limit
mg/L	milligrams per liter
MTBE	methyl tertiary-butyl ether
MWQI	DWR Municipal Water Quality Investigations
NEMDC	Natomas East Main Drainage Canal
nm	nanometers
NTU(s)	nephelometric turbidity unit(s)
O&M	DWR Division of Operations and Maintenance
pH	negative log of the hydrogen ion activity
QA/QC	quality assurance/quality control
RPD(s)	relative percent difference(s)
SJR	San Joaquin River
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
US EPA	see EPA
UVA_{254}	ultraviolet absorbance measured at a wavelength of 254 nanometers
VAMP	Vernalis Adaptive Management Plan
WDL	Water Data Library
WOMT	Water Operations Management Team
WTP	water treatment plant
WY	water year
µg/L	micrograms per liter
µm	micrometers
µS/cm	microsiemens per centimeter

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	Meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	Square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	Square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	Square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	Pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	Meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	Degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

Chapter 1 Introduction

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Chapter 1 Introduction

Scope

This report summarizes and interprets discrete water quality sampling data collected by the Municipal Water Quality Investigations Program (MWQI) of the Department of Water Resources (DWR) from October 1, 2005, to September 30, 2007. This report is the third such report produced within the last five years. The last MWQI report was completed in December 2006 and summarized data collected from October 2003 through September 2005 (DWR 2006).

Data presented in this report were collected from 11 MWQI stations in or near the Sacramento-San Joaquin Delta (the Delta). An extensive range of water quality constituents were analyzed for each sample and this report presents the constituents that are of most concern to drinking water quality. The selection of constituents is based on findings from previous reports and feedback from the MWQI steering committee represented by urban State Water Contractors (SWCs). Water quality constituents of lesser concern to the SWCs are discussed only for selected stations.

Major water quality constituents examined in this report include organic carbon, bromide, salinity, nutrients, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of interest.

Statistical data analyses were limited to simple statistics and illustrations of seasonal patterns. Brief discussions on sources and temporal and spatial patterns of some constituents are presented. All raw data (including hydrologic) are available both online and on a CD-ROM accompanying this report (see Appendix A for URL).

This report primarily summarizes data in sufficient detail to demonstrate general source water quality conditions in the Delta. Because source waters are not regulated to meet standards for finished drinking water, this report does not discuss water quality in the context of drinking water standards or make specific management recommendations. Maximum Contaminant Levels (MCLs) are the maximum permissible levels in finished drinking water to protect human health. Since source waters in the State Water Project (SWP) are not required to meet MCL standards, comparisons are made with data collected at some diversion stations to provide a relative indication of source water quality. Water quality objectives specified in the long-term water supply contracts between DWR and each SWC were also implemented. This report does not present the details of the regulations, standards, or provisions; the regulations and standards may be found at the Web sites of the US Environmental Protection Agency and the California Department of Health Services (EPA 2008; DPH 2007). The Standard Provisions for Water Supply Contracts between DWR and the SWCs are available from the Project Water Contracts Unit (Web site: http://www.swpao.water.ca.gov/wsc/index.cfm) in the State Water Project Analysis Office of DWR.

Interpretations in this report are primarily based on monthly or biweekly (every 2 weeks) grab sampled data. Given the Delta's complex hydrology, results and interpretations from grab sampled data, especially monthly data, have limitations in explaining spatial and seasonal patterns in the Delta. MWQI collects real-time data at 3 stations to enable model-assisted forecasting of water quality conditions. This report includes a section on the modeled volumetric contributions of source waters at key points in the Delta. Understanding the volumetric proportions of source water at a given site can provide insights to the observed water quality. Whenever possible, water quality was related back to modeled results to help interpret the results. Available models may be found at the Web site of the Modeling Support Branch, Bay-Delta Office of DWR (DWR 2006; Web site: http://baydeltaoffice.water.ca.gov/modeling/index.cfm). MWQI provides a weekly update for contractors, water agencies, and other interested parties about the real-time data at http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm The project releases its data through an electronic weekly update to the SWCs and the public.

Monitoring Stations and Sampling Frequency

Geographic locations of the 11 monitoring stations are presented in Figure 1-1. During the reporting period, MWQI collected samples at 10 stations; Division of Operations and Maintenance (O&M) collected samples for MWQI at the Banks Pumping Plant station.

Figure 1-1 MWQI discrete sampling stations, October 1, 2005, to September 30, 2007

Samples were generally collected either monthly or biweekly (Table 1-1). Biweekly samples were collected at 2 key stations, the Sacramento River at Hood and the San Joaquin River (SJR) near Vernalis. These biweekly samples were scheduled with the real-time equipment maintenance trips to both stations. Samples at all other stations were collected monthly.

Table 1-1 Summary of organic carbon at 11 MWQI stations

For discussion purposes in this report, the 11 sampling stations were divided into 5 groups. These are: stations north of the Delta, the Sacramento River at Hood, the San Joaquin River at Vernalis, channel and diversion stations, and Mallard Island (Table 1-1). With the exception of the Natomas East Main Drainage Canal (NEMDC) and Mallard Island stations, stations within each group were either geographically or hydrologically related. The NEMDC and Mallard Island stations were considered separately because NEMDC is an urban drainage tributary to the Sacramento River and Mallard Island shows the most seawater influence of all the Delta stations. Water quality at NEMDC was also the subject of an MWQI special study (DWR 2008).

Modeled volumetric fingerprinting of electrical conductivity (EC) and flow was calculated for Banks Pumping Plant and Bacon Island. (Fingerprinting presents the proportion of each variable, EC or water volume, that contribute to a total at a particular point in the Delta.) These locations were chosen because they are representative of the central and south Delta. No modeling was done for north Delta stations because source waters for these sites come primarily from snowmelt and the Sacramento and American rivers.

Program Changes

Monthly sampling began at the Union Point station in July 2006. This station is on the Middle River on the north side of Union Island and is one of the main channels leading to Clifton Court Forebay. The addition of this station resulted in more complete coverage of the Delta.

In October 2006, sampling was modified at the Contra Costa Pumping Plant. Prior to this date, sampling was conducted on the pump outflow side. Currently, samples are taken on the Rock Slough intake side of the pumping plant. This change was made at CCWD's request to provide source water quality data regardless of the district's pumping rate.

Sample Collection and Laboratory Analysis

Sample collection and laboratory analysis methods were the same as those used for the last MWQI data report. Detailed sample collection procedures and laboratory methods can be found in the MWQI summary report covering October 2001 through October 2003 (DWR 2005). Sample methods are listed in Table 1-2.

Table 1-2 Analytical methods and reporting limits for included constituents

Data Quality

After the analyses were completed, the remaining sample was kept in storage for 30 to 60 days before being discarded. Sample retention is necessary for evaluating and ensuring acceptable results. Bryte Laboratory follows a set of internal quality assurance and quality control (QA/QC) audit procedures, which include evaluation of blanks data (laboratory and field), calibration standards, laboratory control samples, etc. The detailed QA/QC procedures and corrective actions have been described in Bryte Laboratory's latest QA technical documentation (Fong and Aylesworth 2006). The QA/QC Unit of the Office of Water Quality performs data quality checks routinely on data in DWR's Water Data Library (WDL). Results of data quality evaluations for constituents included in this report are presented in Chapter 8.

In this report, constituents at concentrations below their reporting limits are treated as a "nondetect" and are not included in the summary statistics (discussed below). During the reporting period, occasional method changes occurred for some constituents due to adoption of improved techniques, equipment failures, or staff limitations. Constituents that may be analyzed by more than 1 method are shown in Table 1-2. To minimize the discrepancy of data resulting from method changes, this report includes analysis results from a single method for each constituent.

Statistical Analysis

The following summary statistics are presented in tabular forms for each constituent:

- Data range: data between the minimum and the maximum concentrations.
- Mean: presented mostly for historical reasons. Skewed data of wide variability, such as water quality data, should not be averaged because the mean is usually strongly influenced by data at both ends and is often misleading. Non-detects were not included in mean calculations.
- Median: more resistant measure for water quality data, thus it is a generally preferred measure over the mean. Non-detects were included in median calculations.

Much of the water quality data was not normally distributed, therefore the parametric the Mann-Whitney test (also called the Wilcoxon Rank-sum test) was used for comparisons of medians among stations or among different time periods. The Kruskal-Wallis test (followed by a Dunn's Multiple Comparison test) was also used for multiple station or time period comparisons.

Most data are presented in descriptive graphics. Summary statistics were computed using Microsoft Excel. Nonparametric statistical comparisons were calculated using Minitab, Release 14.

Descriptive Plots

Monthly or biweekly data are plotted with time to demonstrate general pattern of the data during the reporting period. Non-detects were not graphed.

Data interpretations are illustrated with bar or scatter plots for seasonal differences, which demonstrate the influences of constituent sources during a given time period.

Box plots are used to illustrate summary statistics of 6 concurrent water years. In the box plot, the boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicates the 90th and 10th percentile. The outliers plot the 5th and 95th percentiles as symbols (Figure 1-2).

Figure 1-2 Illustrative box plot

Fingerprinting

Modeled fingerprinting uses the Delta Simulation Model 2 (DSM2) to estimate the concentrations of a tracer constituent at a specific time and location in the Delta as a function of its source (e.g., tributary rivers, seawater from the west at Martinez, or in-Delta island agricultural drainage returns). (A tracer is a measurable constituent or characteristic of a water parcel that can be used to track flow. A conservative tracer remains constant as it moves with the water parcel, whereas a reactive tracer, such as a chemical reacting with its surroundings, may grow or decay over time.) Volumetric contributions from different sources are determined by simulating transport of conservative tracer constituents. These volumetric contributions can be useful in estimating concentrations of conservative constituents (Anderson 2002). Historical volumetric and EC fingerprinting were modeled in this report.

Frequently Used Terms and Abbreviations

This report uses specialized terms, acronyms, and abbreviations. A complete list is at the front of this report. Some frequently used terms and abbreviations are defined here:

Water year or WY: The period from October 1 of one calendar year to September 30 of the following calendar year is called a water year. The year number is the latter of the 2 calendar years; for example, 2005 WY runs from October 1, 2001 to September 30, 2005.

Wet months: November 1 to April 30 of each water year

Dry months: May 1 to October 31 of each calendar year

Critical Year, Dry Year, Below Normal Year, Above Normal Year, and Wet Year: Runoff year types indicating very low, low, moderately low, moderately high, and high total unimpaired runoff in a watershed, respectively, as defined in http://cdec.water.ca.gov/cgi-progs/iodir/wsihist. The Sacramento and San Joaquin basins are defined independently.

NEMDC: Natomas East Main Drainage Canal

SJR: San Joaquin River

Banks Pumping Plant: Harvey O. Banks Pumping Plant Headworks monitoring station at the start of the California Aqueduct

Contra Costa Pumping Plant (CCPP): Contra Costa Water District Pumping Plant #1

Reporting period/Summary period: The period from October 1, 2005, to September 30, 2007, which spans 2 water years. Thus, “the reporting period” or “the summary period” may also be referred to as “the 2 water years” throughout the report.

VAMP: The Vernalis Adaptive Management Plan is mandated by State Water Resources Control Board Decision 1641. From April 15 to May 15, reservoir releases to the SJR are increased, and temporary barriers are installed to increase the survival of juvenile Chinook salmon in their migration to the ocean.

p-value and statistical significance: In this report, the p-value, or p in short, is reported whenever a statistical comparison is made. The p-value is a computed probability value used in combination with a prescribed level of significance (α) to declare if a test is statistically significant. The p-value is a measure of the likelihood that the observed pattern is the result of random chance, rather than a genuine effect. The smaller the p-value, the stronger is the evidence supporting statistical significance. This report uses a commonly accepted α value of 5%, or $\alpha = 0.05$. If the p-value is < 0.05, the statistical test is declared significant; otherwise, the test is declared not statistically significant.

TKN: Total Kjeldahl nitrogen is total digestible organic nitrogen and it excludes the inorganic nitrogen species, such as ammonia, nitrate, and nitrite.

Chapter 1 Introduction

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Figure 1-1 MWQI discrete sampling stations, October 1, 2005, to September 30, 2007

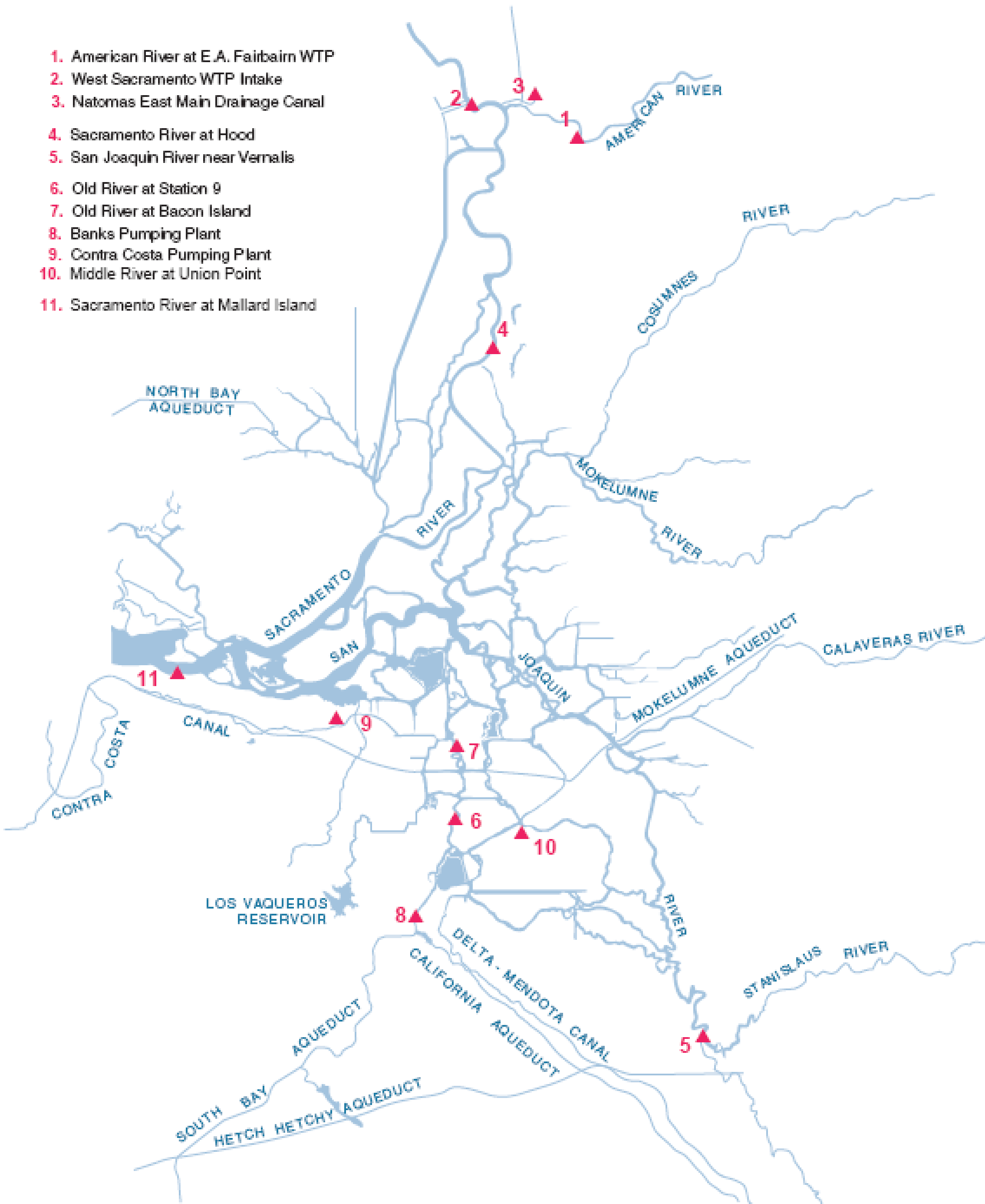

Figure 1-2 Illustrative box plot

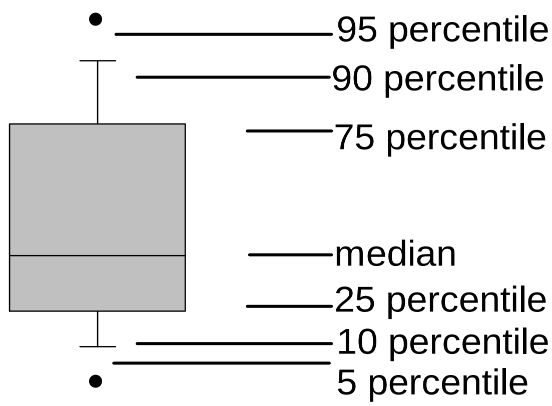

Table 1-1 Summary of organic carbon at 11 MWQI stations

Station	DWR Station Number	Monitoring Frequency
Stations north of the Delta		
American River at E.A. Fairbairn WTP[a]	A0714010	Monthly
West Sacramento WTP Intake	A0210451	Monthly
Natomas East Main Drainage Canal	A0V83671280	Monthly
Sacramento River at Hood	B9D82211312	Biweekly
San Joaquin River near Vernalis	B0702000	Biweekly
Channel and diversion stations		
Old River at Station 9	B9D75351342	Monthly
Old River at Bacon Island	B9D75811344	Monthly
Banks Pumping Plant	KA000331	Monthly
Contra Costa Pumping Plant	B9591000	Monthly
Middle River at Union Point	B9D75351292	Monthly
Mallard Island	E0B80261551	Monthly

a. WTP = water treatment plant

Table 1-2 Analytical methods and reporting limits for included constituents

Constituent	Method source [a]	Method number	Reporting limit [b]
Total organic carbon (TOC)	Std Methods	5310-D, Wet oxidation, IR, automated	0.5
	EPA	415.1 Wet oxidation, IR, automated	0.5
Dissolved organic carbon (DOC)	EPA	415.1 Wet oxidation, IR, automated	0.5
UV absorbance at 254 nm	Std Methods	5910-B UV-absorbing organics	0.001 cm^{-1}
Bromide		300.0 ion chromatography	0.01
Electrical conductivity (EC)	Std Methods	2310-B Wheatstone Bridge	1 µS/cm
	EPA	120.1 Wheatstone Bridge	1 µS/cm
Total dissolved solids (TDS)	Std Methods	2540-C Gravimetric, dried at 180° C	1
	EPA	160.1 Gravimetric, dried at 180° C	1
Total Suspended Solids (TSS)	EPA	160.2	1
THFMP	DWR	THFMP Buffered	10
Chloride	Std Methods	4500-Cl-E Colorimetric, Ferricyanide	1
Sulfate		375.2 Colorimetric, Methythymol Blue	1
		300.0 Ion Chromatography	1
Calcium	EPA	215.1AA Flame	1
		200.7 ICP	1
Magnesium		242.1 AA Flame	1
		200.7 ICP	1
Potassium	EPA	200.7 ICP	0.5
Sodium		273.1 AA Flame	1
		200.7 ICP	1
pH	Std Methods	2320-B Electrometric	0.1 pH unit
	EPA	150.1 Electrometric	0.1 pH unit
Alkalinity	Std Methods	2320-B Titrimetric	1
	EPA	310.1 Titrimetric	1
Hardness	Std Methods	2340 B total by calculation	1
Turbidity		2130-B Nephelometric	1 NTU
	EPA	180.1 Nephelometric	1 NTU

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

a. Std Methods = “Standard Methods for the Examination of Water and Wastewater,” 1995. 19th ed. Eaton AD, Clesceri LS, Greenberg AE, Franson MAH, editors. Prepared and published jointly by American Public Health Association, American Water Works Association, and Water Environment Federation. Washington, DC: American Public Health

b. Unit is mg/L unless otherwise indicated.

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Table 1-2 continued

Constituent	Method source [a]	Method number	Reporting limit [b]
Aluminum	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.01
		200.9 GFAA	0.01
Antimony	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
Arsenic	Std Methods	3114 (4d), AA gaseous hydride	0.001
	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
Barium	EPA	200.7 ICP	0.01
		200.8 ICP/MS	0.05
		200.9 GFAA	0.05
		208.2 GFAA	0.05
Boron	USGS	I-2115-85 Colorimetric, Azomethine	0.1
Cadmium	EPA	200.7 ICP	0.01
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		213.2 GFAA	0.005
Total chromium (all valencies)	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		218.2 GFAA	0.005
Cobalt	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		219.2 GFAA	0.005
Copper	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		220.1 AA Flame	0.1
		220.2 GFAA	0.005

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

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b. Unit is mg/L unless otherwise indicated.

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Table 1-2 continued

Constituent	Method source[a]	Method number	Reporting limit[b]
Iron	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		236.1 AA Flame	0.1
		236.2 GFAA	0.005
Lead	EPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		239.2 GFAA	0.005
Manganese	EPA	200.7 ICP	0.01
		200.9 GFAA	0.005
		243.1 AA Flame	0.1
		243.2 GFAA	0.005
Mercury	EPA	245.1 AA, Flameless, cold vapor	0.001
Molybdenum	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		246.2 GFAA	0.005
Nickel	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		249.1 AA Flame	0.1
		249.2 GFAA	0.005
Selenium	Std Methods	3114B AA gaseous hydride	0.001
	EPA	200.8 ICP/MS	0.001
Silver	EPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		272.2 GFAA	0.005

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

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b. Unit is mg/L unless otherwise indicated.

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Table 1-2 continued

Constituent	Method source [a]	Method number	Reporting limit [b]
Zinc	EPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		289.1 AA Flame, Direct	0.1
		289.2 GFAA	0.005
Ammonia	Std Methods	4500-NH_3 B, G Automated Phenate	0.01
	EPA	350.1 Automated Phenate	0.01
Total Kjeldahl nitrogen	EPA	351.2 Colorimetric, semi-automated	0.1
Nitrate	Std Methods	4500-NO_3-F Cd-Reduction	0.01
	EPA	353.2 Cd-Reduction, Automated	0.01
Nitrite + nitrate	EPA	353.2, Cd-Reduction, Automated	0.01
Orthophosphate	Std Methods	4500-P-E Colorimetric, Ascorbic Acid	0.01
	EPA	365.1 Colorimetric, Ascorbic Acid	0.01
Phosphorus, total	EPA	365.4 Colorimetric, semi-automated	0.01

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth 2006).

a. Std Methods = "Standard Methods for the Examination of Water and Wastewater," 1995. 19th ed. Eaton AD, Clesceri LS, Greenberg AE, Franson MAH, editors. Prepared and published jointly by American Public Health Association, American Water Works Association, Water Environment Federation. Washington, DC: American Public Health

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Chapter 2 Watershed and Delta Hydrology

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Chapter 2 Watershed and Delta Hydrology

Water quality in the Delta is affected by the hydrology of the Delta as well as the hydrologic conditions of the watersheds that contribute water to it. Data presented in this chapter include inflows from the 2 major rivers, releases from the larger reservoirs, precipitation in the watersheds, and the calculated total Delta outflow. Hydrologic classification indexes are also presented for both watersheds for water years (WYs) 2002 through 2007.

Sacramento River Basin

The Sacramento River watershed is greater than 26,000 square miles and is the largest in the state. The major tributaries are the Pit, McCloud, Feather, Yuba, and American rivers. Although it is not a tributary nor is it in the Sacramento River watershed, some of the Trinity River flow is diverted to the Sacramento River.

Flow in the Sacramento River originates as runoff from 6 major areas. These are the Sacramento Valley and the Modoc Plateau, plus the mountainous areas of the Coast Range, Klamath Mountains, Cascade Range, and Sierra Nevada. Most of the population in this watershed, as well as the majority of agricultural land, is in the Sacramento Valley; therefore, the greatest use of water for domestic supply and agricultural purposes is in this area.

The major reservoirs in the watershed have a total capacity of approximately 10 million acre-feet. Precipitation in the Central Valley occurs primarily in the winter and spring. Because demand for water is greater in the summer and fall, it is fortunate that much of the precipitation at higher elevations occurs as snow. In this way, these areas act as natural reservoirs holding the water for later use.

San Joaquin River Basin

The San Joaquin River (SJR) is the second largest river in the state with a watershed of approximately 15,200 square miles. The major tributaries are the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes rivers. The San Joaquin and its major tributaries have their origin in the Sierra Nevada, and they all have reservoirs. There are 9 reservoirs with a capacity equal to or greater than 100,000 acre-feet, and their total capacity is 7.44 million acre-feet.

Precipitation in the Sacramento and San Joaquin Valleys

Data from 3 weather stations in each valley are presented in this chapter, and the locations of these stations are shown in Figure 2-1. Stations used in the

Figure 2-1 Location of selected weather stations

Sacramento Valley are Redding Fire Station, Durham, and California State University at Sacramento (CSUS). Stations used in the San Joaquin Valley are Brentwood, Stockton Fire Station, and Madera.

Data for these stations were obtained from 2 sources: the California Data Exchange Center (CDEC) and California Irrigation Management Information System (CIMIS). CDEC provided data for the Redding Fire Station, Stockton Fire Station, and CSUS stations. CIMIS provided data for the Durham, Brentwood, and Madera stations.

In water years 2006 and 2007, precipitation was higher in the Sacramento River watershed than in the San Joaquin (Table 2-1 and Figure 2-2). In both years, precipitation for the 3 stations in the Sacramento watershed was more than twice that of the San Joaquin watershed. The seasonal rainfall patterns were typical for the state, with most occurring during the late fall through early spring and little to none in the summer.

Table 2-1 Summary of monthly precipitation (inches) at six weather stations

Figure 2-2 Cumulated monthly precipitation at six stations

In the Sacramento River watershed, the Redding Fire Station had the greatest annual rainfall, with 69.76 inches in WY 2006 and 31.00 inches in WY 2007. It was also the only station with daily totals greater than 4 inches. In the SJR watershed, the total annual precipitation at the Stockton Fire Station was similar to the Brentwood station in both water years (Table 2-1).

At all stations, the annual total precipitation was greater in WY 2006 than in WY 2007. The maximum difference occurred at the Madera station where precipitation for the total WY 2006 was 297% higher than in WY 2007. The minimum difference was at the Durham station where precipitation for the total WY 2006 was 173% higher than the WY 2007 total. In WY 2006, wet conditions from WY 2005, which was above normal, combined with significant precipitation around January 2006 and again throughout March and into the early April resulted in very high flow conditions and increased in reservoir releases for both the Sacramento and San Joaquin valleys. WY 2007 had relatively little precipitation, resulting in lower flows and reservoir releases in both watersheds.

Water Year Classification

The classification of water years is done using a system developed by the State Water Resources Control Board (SWRCB). The method is found in Water Rights Decision 1641, revised March 15, 2000 (SWRCB 2000), and is based on the amount of unimpaired runoff at key stream stations in the Sacramento River and SJR watersheds. Under this system there are 5 water year types: wet, above normal, below normal, dry, and critical.

The Sacramento Valley water year types were wet in WY 2006 and dry in WY 2007 (Table 2-2). The water year types for the San Joaquin Valley were wet in WY 2006 and critical in WY 2007 (Table 2-2).

Table 2-2 Hydrologic index classification based on measured unimpaired runoff at selected rivers

Releases from Reservoirs

Central Valley reservoirs furnish water for agricultural, municipal, industrial, recreational and environmental uses. Millions of people in California receive a high percentage of their household water from these reservoirs, and approximately 4-million acres of cropland are irrigated with water from these sources. Because most of the precipitation occurs in a 6-month period, these reservoirs are needed to supply water year-round.

Sacramento Valley

Major reservoir releases provide water to the Sacramento River (Figure 2-3). Shasta Reservoir release data include water imported from the Trinity River. Reservoir releases for the combined WYs 2006 and 2007 were more than 38 million acre-feet. WY 2006 was classified as a wet year and Shasta Reservoir released more than 26 million acre-feet. Increased reservoir release can be attributed to the combination of WY 2005 being above normal and the wet WY 2006 (Figure 2-3 and Table 2-2).WY 2007 was classified as a dry year. During WY 2007, reservoir releases of less than 12 million acre-feet reflected the lack of snowmelt and precipitation.

Figure 2-3 Sacramento River watershed reservoir releases

San Joaquin Valley

Release data from 6 major reservoirs in the SJR watershed are presented in Figure 2-4. Total releases from these reservoirs for the 2 water years were much lower than those from reservoirs in the Sacramento River watershed. The total release for WY 2006 was approximately 11 million acre-feet, and the total for WY 2007 was approximately 4 million acre-feet. Total reservoir releases for the San Joaquin Valley for WYs 2006 and 2007 were approximately 15 million acre-feet.

Figure 2-4 San Joaquin River watershed reservoir releases

Delta Outflows

The Sacramento River, the SJR, and their tributaries provide fresh water inflow to the Delta. Within the Delta, diversions of water reduce the amount of fresh water that flows out of the Delta and into the Suisun and San Francisco bays. Besides water used locally for irrigation, the major diversions that take water out of the Delta are the State Water Project (SWP) and the Central Valley Project (CVP).

Water that is not diverted or does not evaporate from the channels flows out of the Delta and into the bays. The lower the outflow, the more the tides increase the salinity of Delta waters. It is difficult to measure Delta outflow directly; instead, Delta outflows are determined mathematically. The calculated outflows and the inflows of the Sacramento and San Joaquin rivers are presented in Figure 2-5. The outflows tend to be lowest in the late summer and early autumn.

Figure 2-5 Delta total outflow and major river inflows, 2006 and 2007 WYs

Due to the sharp population decline in the endangered delta smelt, DWR and the United States Bureau of Reclamation (USBR) substantially reduced pumping during the spring of 2007 at the request of the state and federal fishery agencies. From May 31 through June 8, DWR voluntarily shut down pumps at Banks Pumping Plant (Figure 2-6) to protect the endangered fish species. SWP pumping was curtailed until the delta smelt moved away from the immediate vicinity of the pumping plant (SWC 2007).

Figure 2-6 Delta outflow and major river inflows from April 30 through July 31. 2007

Vernalis Adaptive Management Plan

The Vernalis Adaptive Management Plan (VAMP) is an annual experimental program that is conducted to evaluate the effect of SJR flow and export pumping with the head of Old River barrier on survival of migrating juvenile Chinook salmon smolts in their travel down the SJR to the ocean. The normal VAMP period is from April 15 through May 15, but it can be a different 31-day period based on the time of the migration. In years of lower flows, releases from the major reservoirs in the San Joaquin watershed are increased. At the same time, combined pumping at the Banks and Tracy pumping plants are reduced to 1,500 cubic feet per second (cfs). In years of higher flows, the combined pumping can be higher. Because the VAMP program is adaptively managed and adjusted based on the hydrology in the particular year, specific levels of pumping corresponding to various levels of flow cannot be forecast until the spring of that year. In addition to the limited pumping during VAMP, a temporary barrier is constructed at the head of Old River (HORB). This barrier causes the migrating smolts to follow the SJR through the Delta, and it considerably reduces the number lost as a result of SWP and CVP diversions.

Due to high flows, the HORB was not installed for WYs 2005 and 2006. Actions associated with VAMP to protect the juvenile Chinook salmon and evaluate the relationship between the SJR flows and SWP and CVP pumping rates were implemented May 1 through May 31 for WY 2006. In WY 2007, lower flows allowed the installation of the HORB and pumping rates were decreased between April 22 and May 22.

In 2006 mean daily flow in the SJR below the Stanislaus River exceeded 10,000 cfs in early March and increased to 15,000 cfs by the end of March. April flow exceeded 34,000 cfs and remained above 30,000 cfs until the beginning of May. By the end of May the flow was reduced to 20,000 cfs. Because the flow in early April was significantly above the allowable installation flow threshold of 5,000 cfs, DWR was unable to install the temporary HORB.

San Joaquin River flow for 2007 was approximately 3,000 cfs at the beginning of March and it decreased to 2,000 cfs by the end of March (roughly a 12,000 cfs decrease from the previous year). By the start of the VAMP period on April 22, flow in the SJR was above 3,500 cfs, but decreased to 3,000 cfs by the end of the VAMP period.

The HORB was installed in 2007 to improve the survival of the SJR fall run of the Chinook salmon and smolts. The barrier remained closed for the duration of the VAMP period in accordance with the Water Operations Management Team’s (WOMT) decision (FishBio 2007).

Volumetric Fingerprinting

Volumetric fingerprinting of water at the west side of Bacon Island and Clifton Court Forebay is shown in Figures 2-7 and 2-8, respectively. These figures identify the percentage of source water over a 2-year period by tracking the relative volumetric contributions of various sources in the column of water at a specified location in the Delta. The methodology and applications of volumetric fingerprinting using the Delta Simulation Model 2 (DSM2) can be found in Anderson 2002, Anderson and Wilde 2005, and Mierzwa and Wilde 2004. Fingerprinting locations were chosen to facilitate explanations between observed water quality in the central and south Delta and the volumetric sources of water. Modeled fingerprints of source water are also valuable in interpreting changes in electrical conductance (EC) and explaining how hydrology affected the movement of water.

Figure 2-7 Total volumetric contributions at the west side of Bacon Island

Figure 2-8 Total volumetric contributions at the west side of Clifton Court Forebay

One of the most important aspects shown by the fingerprints is how the San Joaquin River dominated spring runoff during WY 2006. While Sacramento River is most often the dominant source water at the pumps, under certain circumstances SJR water can make up the majority of the volume of water observed at the pumps. As discussed in the following chapters, this phenomenon can have significant consequence for water quality.

In WY 2006, 54% of the water on the west side of Bacon Island was Sacramento River source water and 36% was San Joaquin River source water (Figure 2-7 and Figure 2-8). At Clifton Court Forebay 37% of the water was Sacramento River source water and 54% was from the San Joaquin River (Figures 2-9 and 2-10). The observed pattern of shifting between the Sacramento and San Joaquin rivers as the main source of water between the 2 locations in WY 2006 was not repeated in WY 2007.

Figure 2-9 Volumetric fingerprint at Old River

Figure 2-10 Volumetric fingerprint at Clifton Court Forebay

More than 70% of the water at Bacon Island and the Clifton Court Forebay throughout WY 2007 came from the Sacramento River (Figures 2-7 through 2-10). On the west side of Bacon Island, the San Joaquin River accounted for only 4% of the total volume; however, the San Joaquin River accounted for approximately 15% of the total volume at Clifton Court Forebay (Figures 2-7 through 2-10).

Modeled fingerprints of source water are also valuable in interpreting changes in EC and explaining the movement of water due to hydrology. In Chapter 6, volumetric and EC fingerprints of source water are analyzed for correlations to EC variability.

Chapter 2 Watershed and Delta Hydrology

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Figure 2-1 Location of selected weather stations

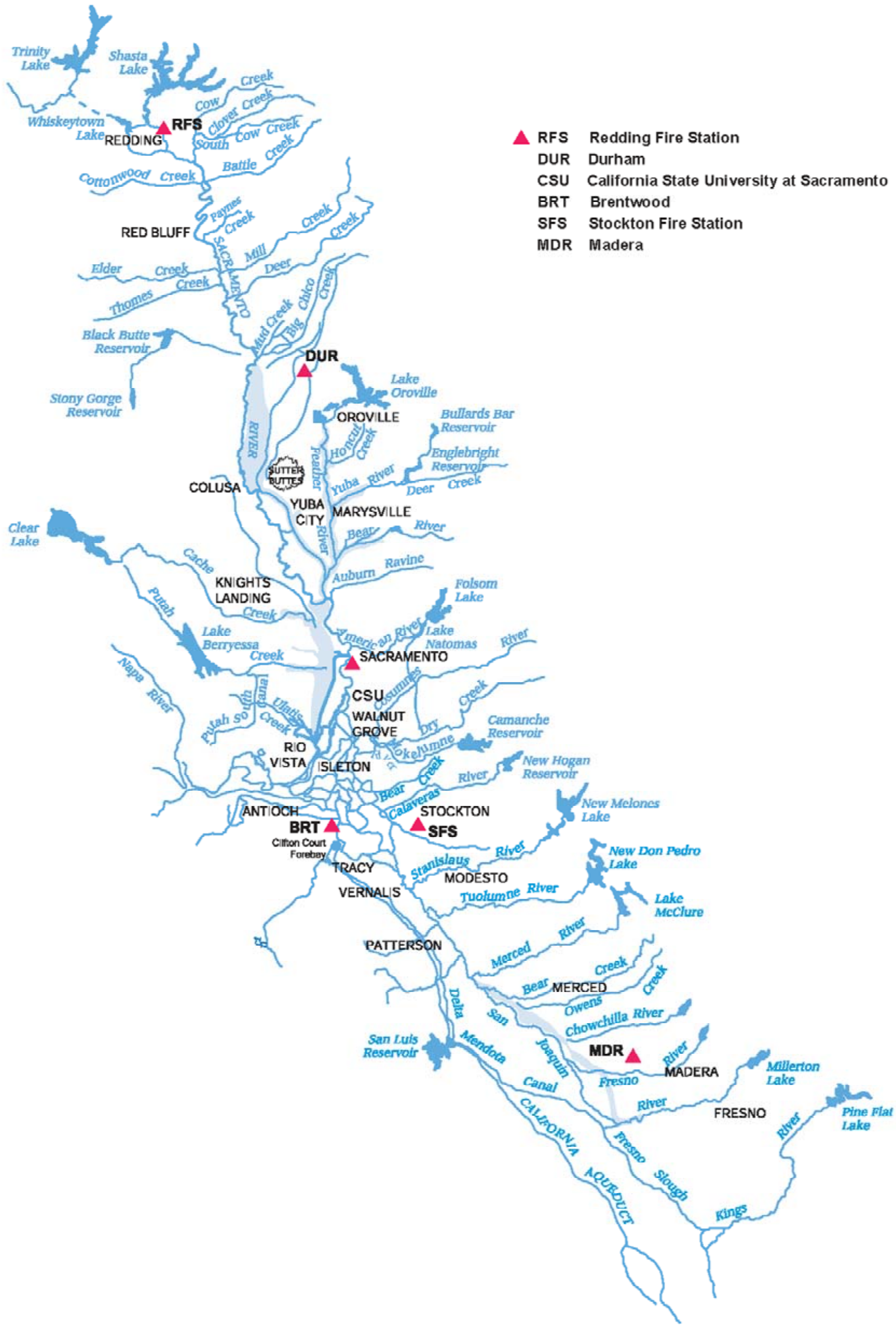
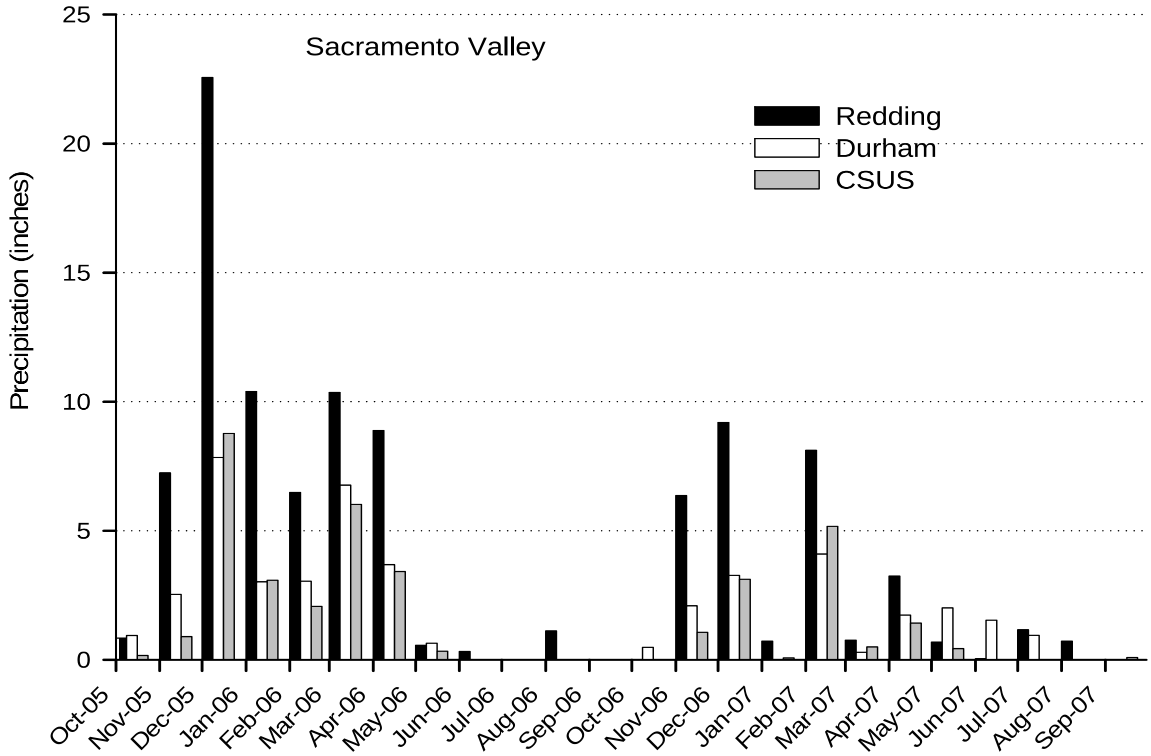


Figure 2-2 Monthly precipitation at 6 stations in the Sacramento-San Joaquin River watersheds



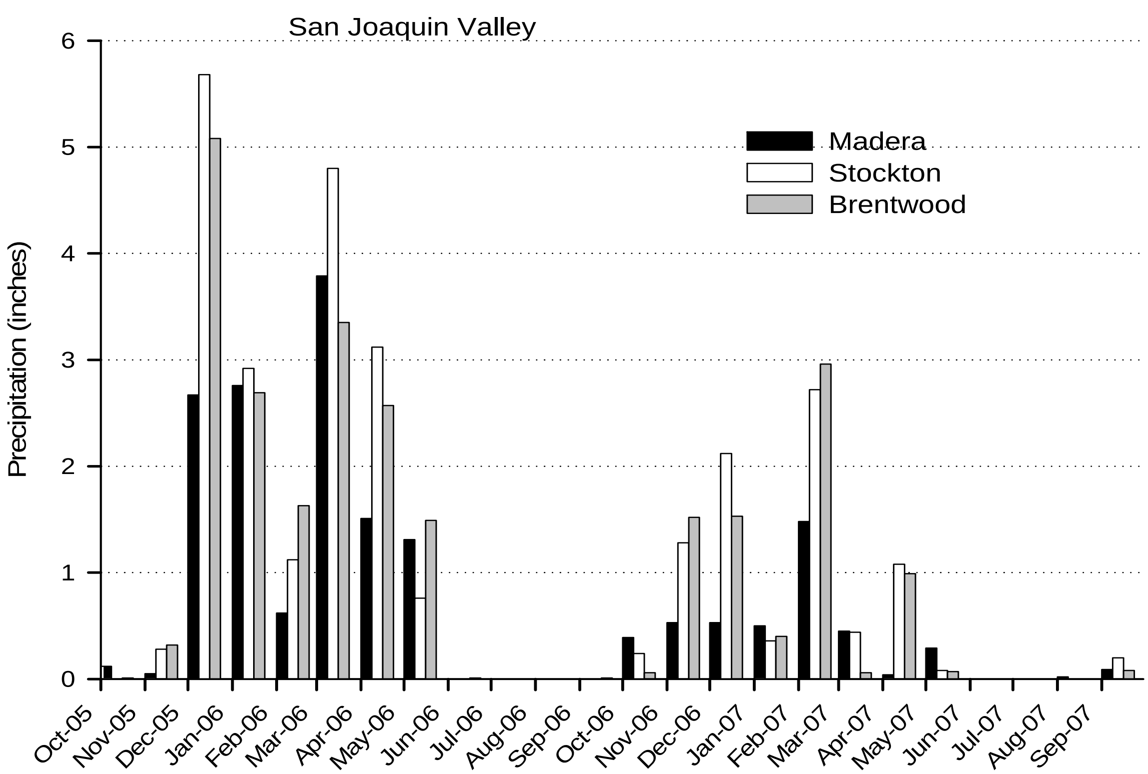


Figure 2-3 Sacramento River watershed reservoir releases

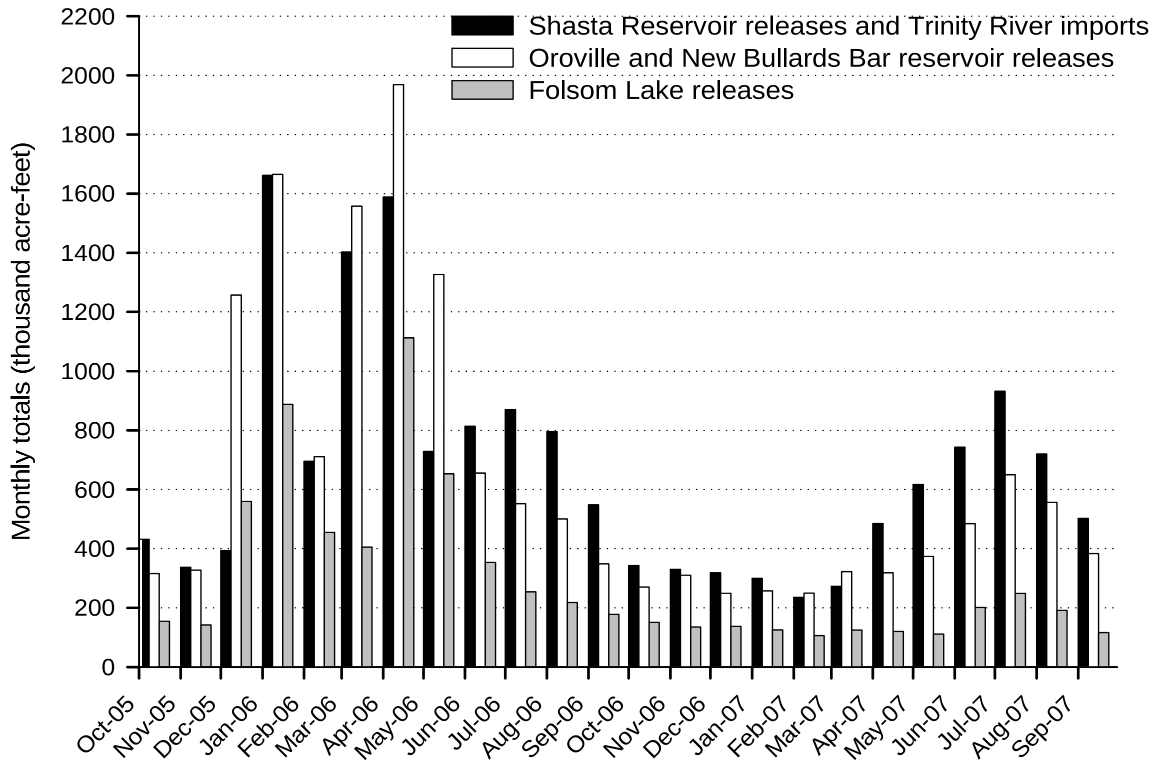


Figure 2-4 San Joaquin River watershed reservoir releases

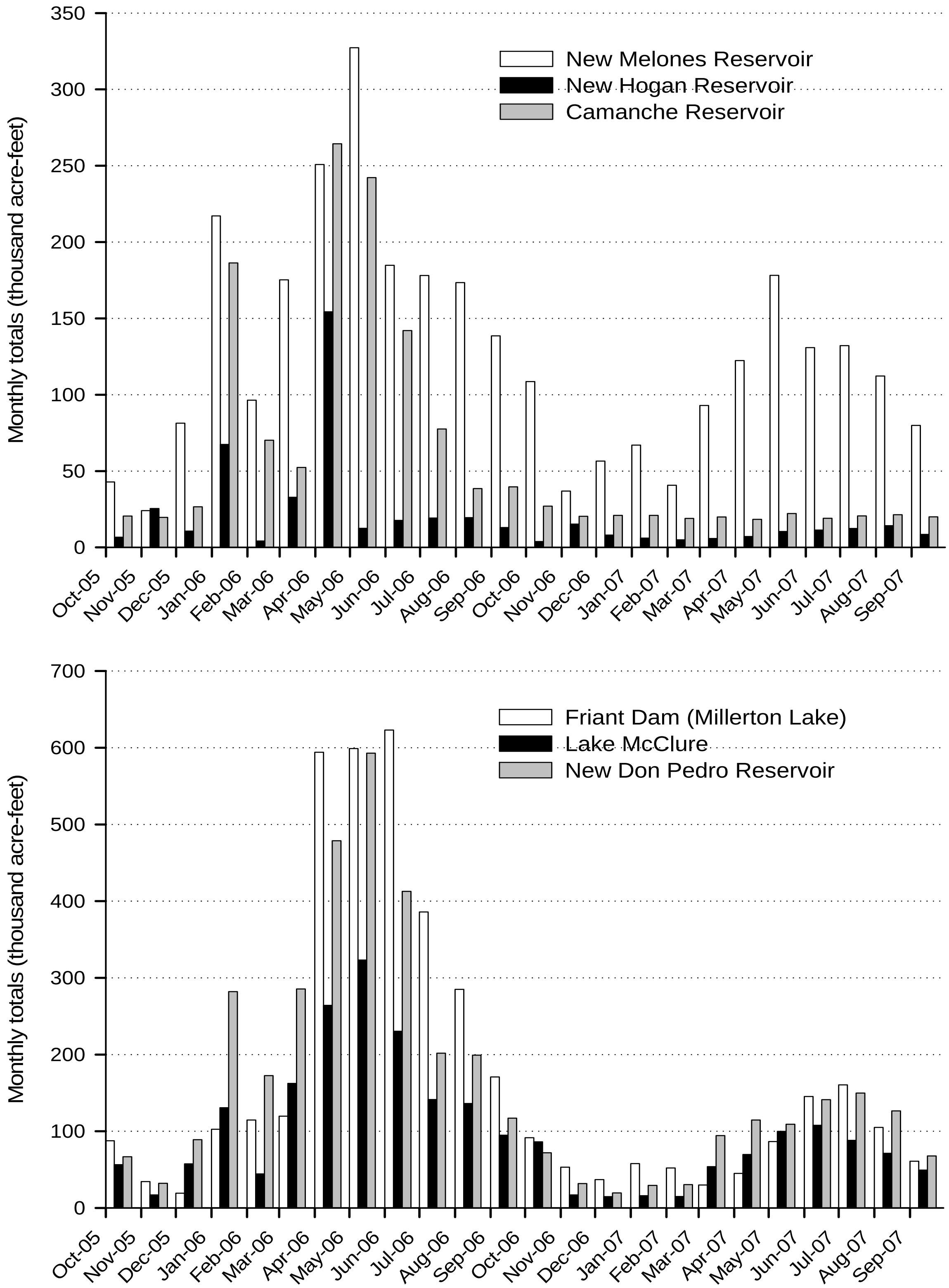


Figure 2-5 Delta total outflow and major river inflows (WYs 2006 and 2007)

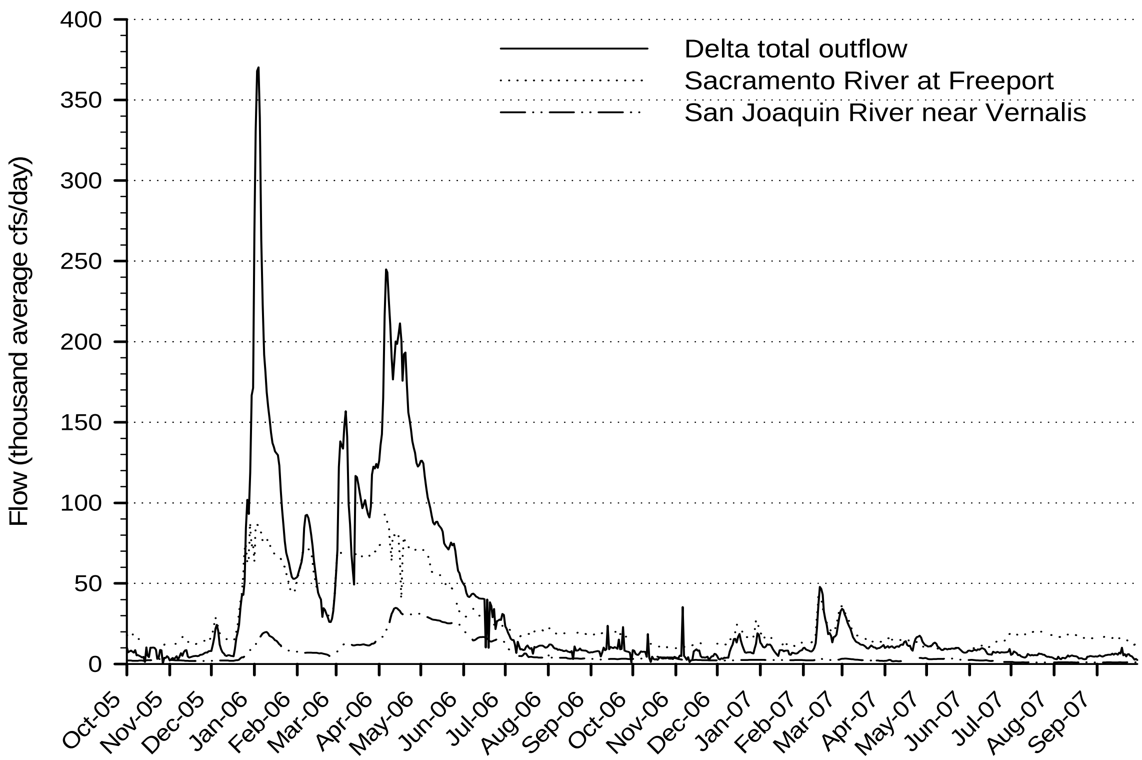


Figure 2-6 Delta outflow, major river inflows and pumping at Banks Pumping Plant (April 30-July 31, 2007)

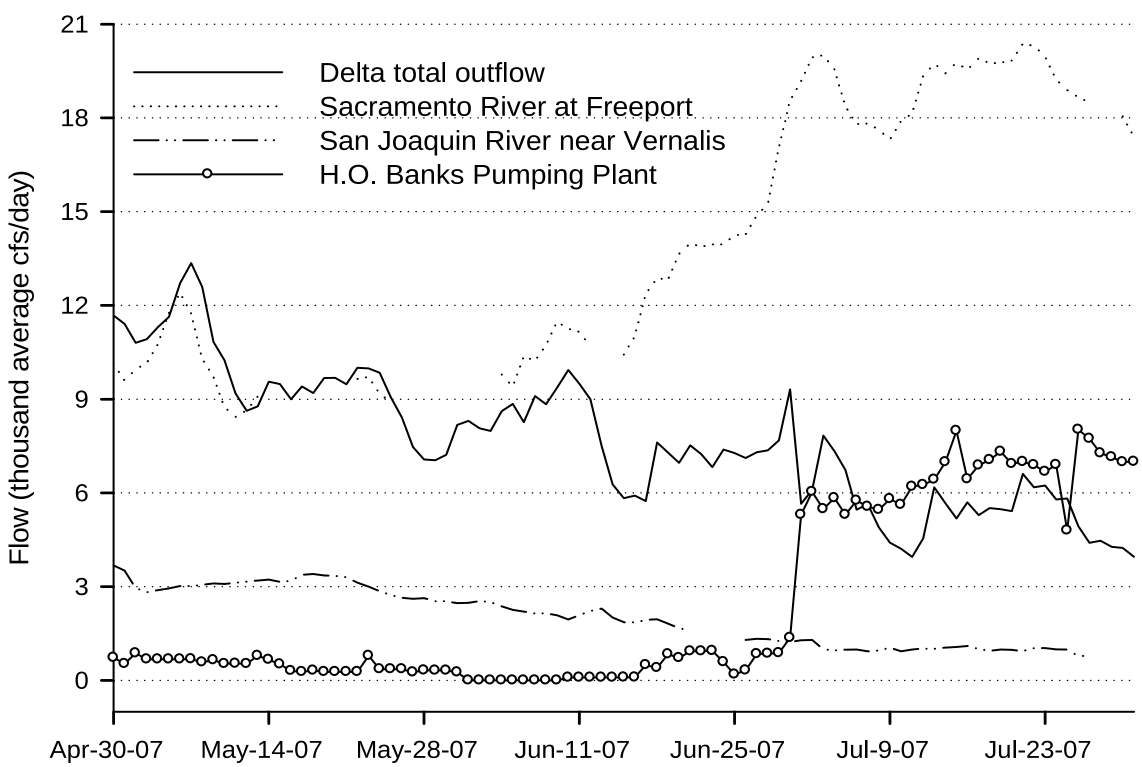


Figure 2-7 Total volumetric contributions at Old River

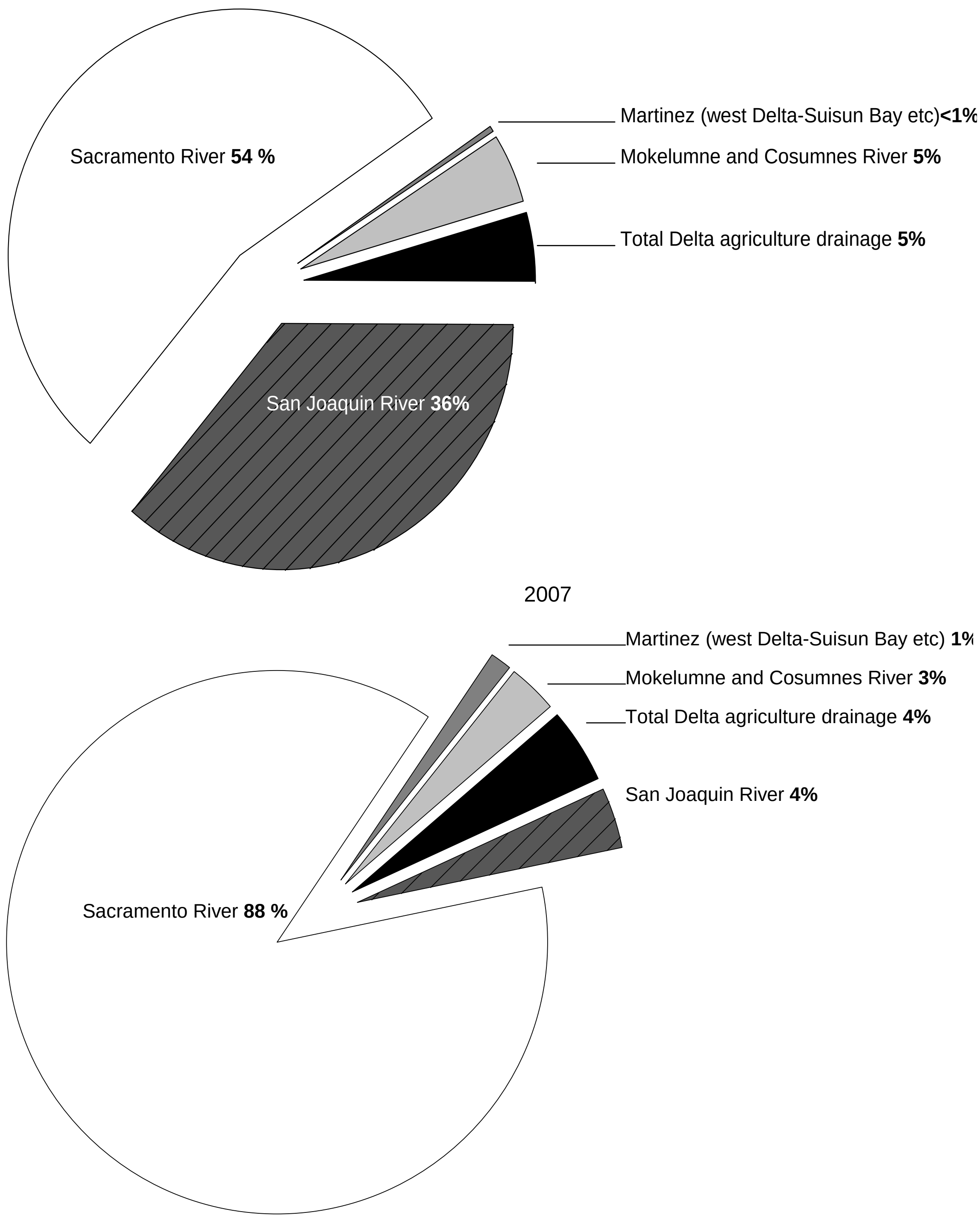
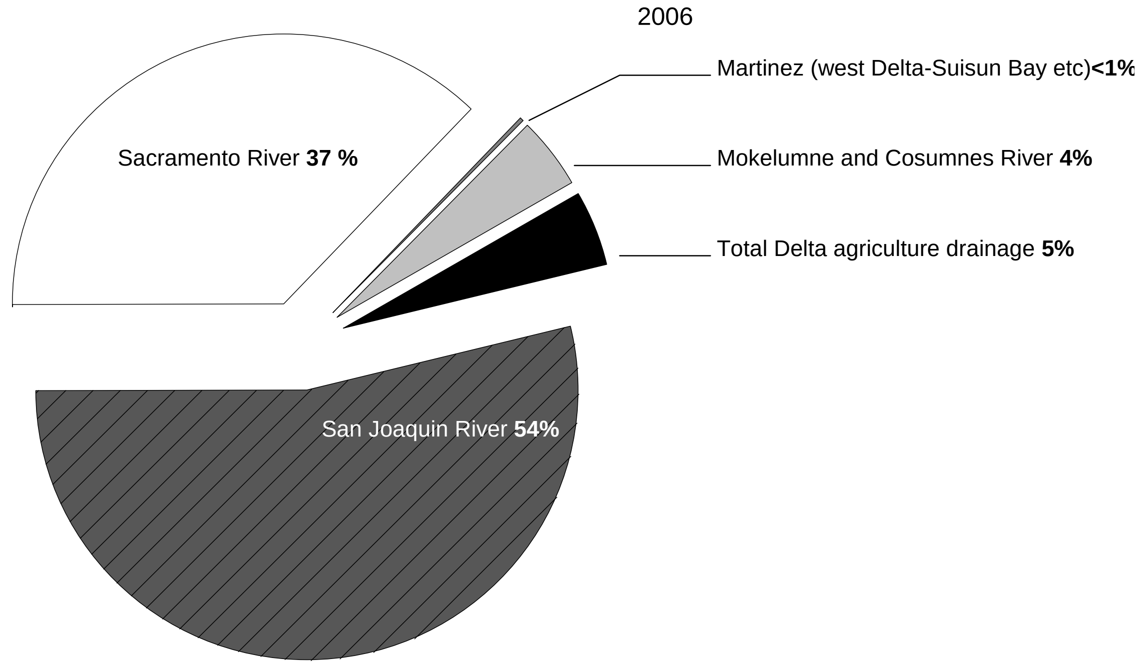


Figure 2-8 Total volumetric contributions at Clifton Court Forebay



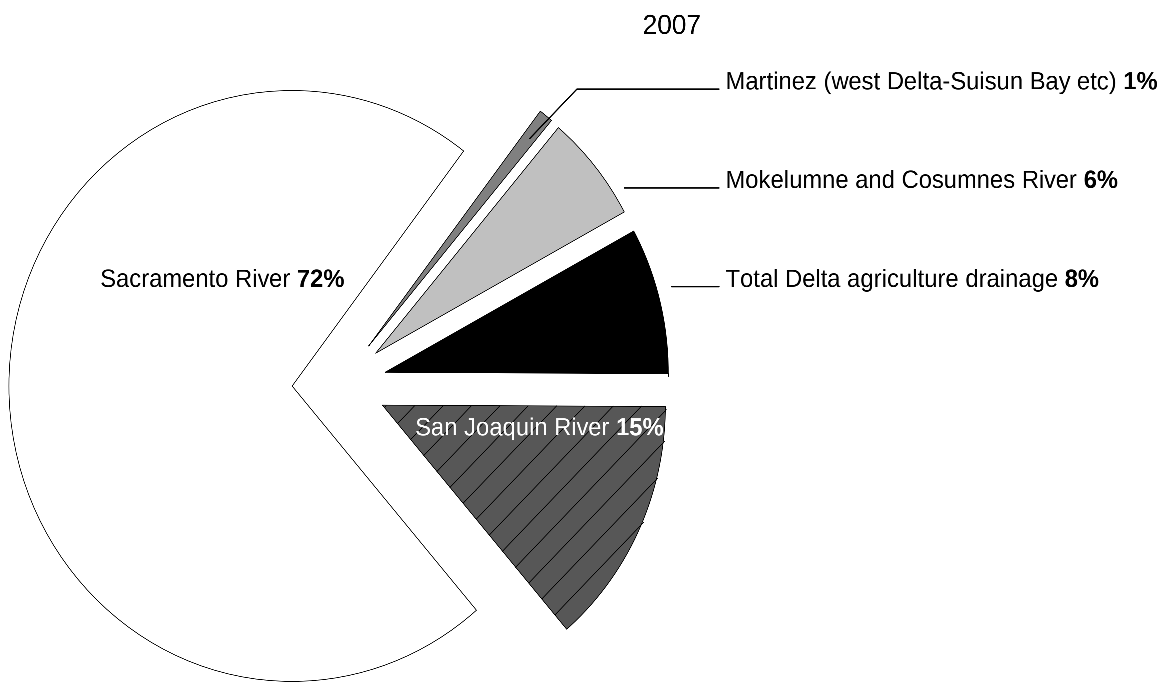


Figure 2-9 Volumetric fingerprint at Old River

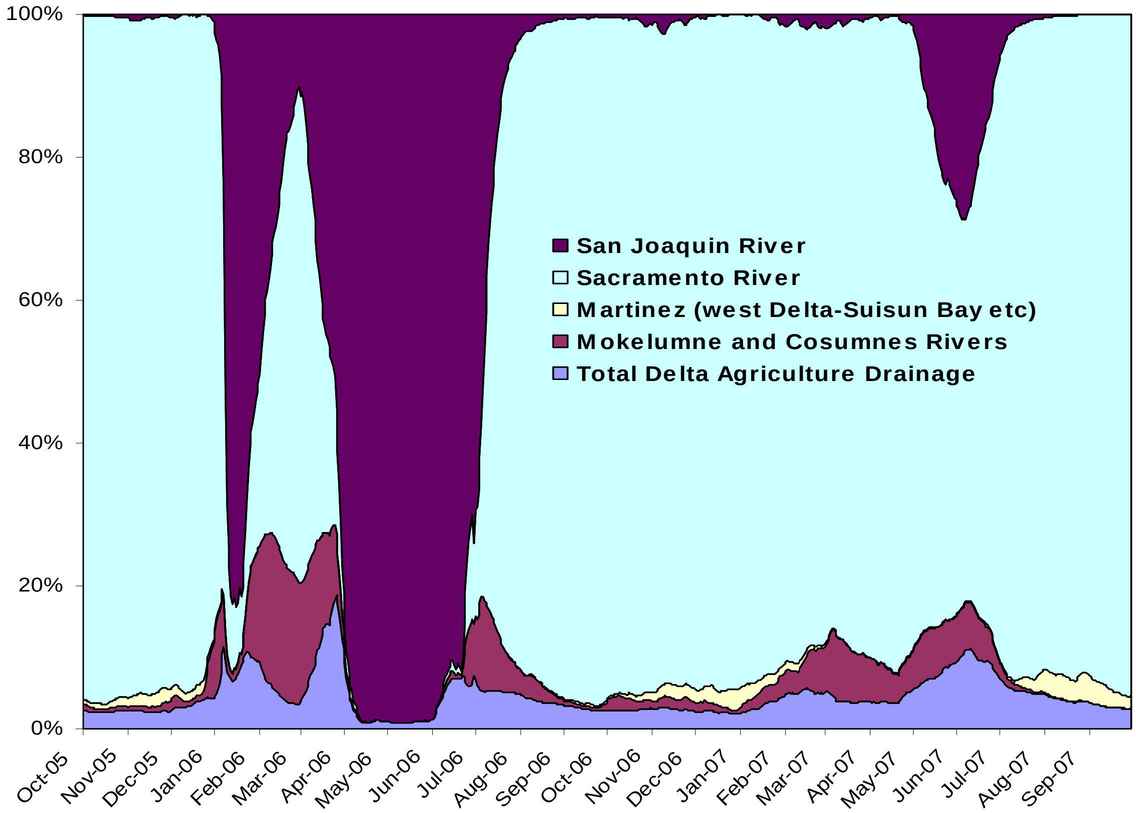


Figure 2-10 Volumetric fingerprint at Clifton Court Forebay

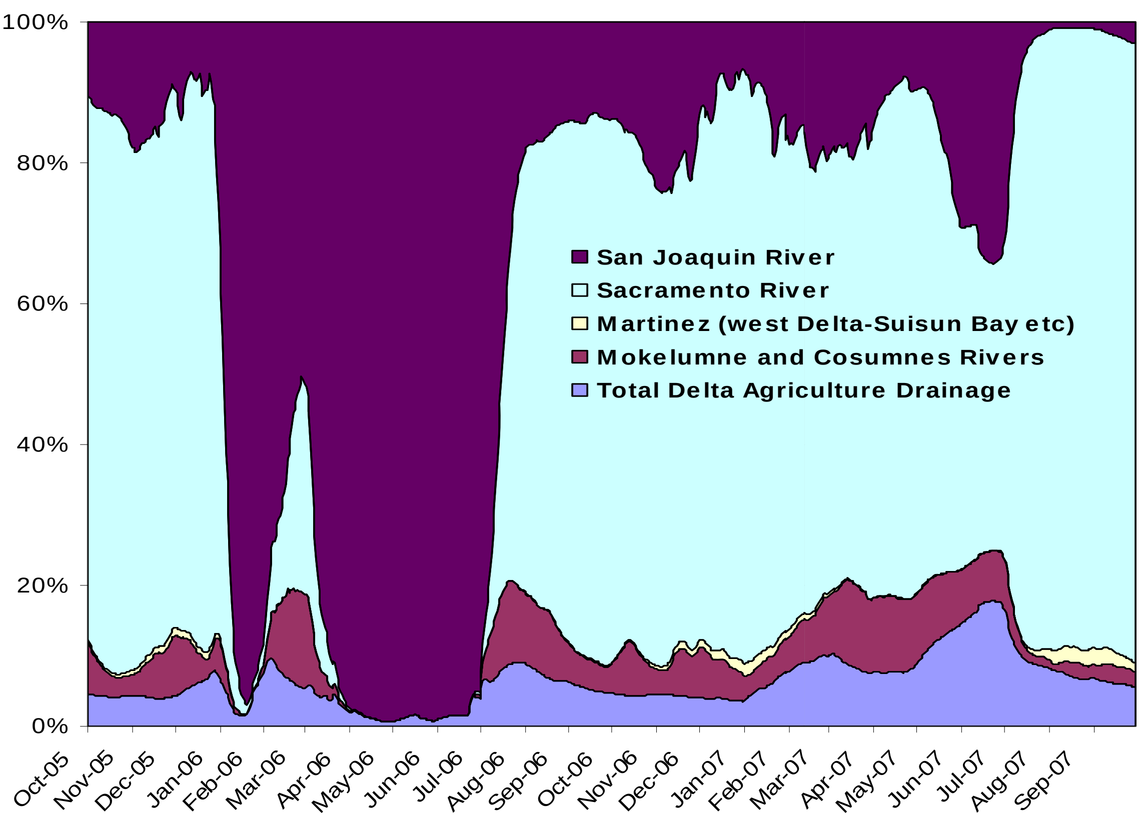


Table 2-1 Summary of monthly precipitation (inches) at 6 weather stations

Station	Reporting months	Months rained	Monthly precipitation			Cumulated precipitation in water year [b]	
			Range[a]	Mean[a]	Median[a]	2006	2007
Sacramento Valley							
Redding Fire Station	24	20	0.04 – 22.56	4.16	0.98	68.76	31.00
Durham	24	17	0.29 – 7.83	1.87	1.24	28.46	16.45
Sacramento State University	24	17	0.01 – 8.77	1.53	0.38	24.75	11.86
San Joaquin Valley							
Stockton Fire Station	24	18	0.08 – 5.68	1.13	0.32	18.68	8.52
Brentwood	24	16	0.01 – 5.08	1.03	0.20	17.16	7.67
Madera	24	19	0.02 – 3.79	0.71	0.34	12.83	4.32

a. Calculated with data from months with rain.

b. Water year runs from October 1 to September 30; for example, the 2006 water year runs from October 2005 through September 2007.

Table 2-2 Hydrologic index classification based on measured unimpaired runoff at selected rivers

Water year	Sacramento Valley	San Joaquin Valley
Previous summary period		
2002	Dry	Dry
2003	Above Normal	Below Normal
2004	Below Normal	Dry
2005	Above Normal	Wet
Current Summary Period		
2006	Wet	Wet
2007	Dry	Critical

Chapter 3 Organic Carbon

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Chapter 3 Organic Carbon

Dissolved organic carbon (DOC) reacts with disinfectants in the water treatment process to form disinfection bi-products such as haloacetic acids and trihalomethanes. Haloacetic acids potentially increase the risk of cancer and trihalomethanes may cause liver, kidney or central nervous system problems and increase the risk of cancer (EPA 2008). There is no maximum contaminant level (MCL) for dissolved organic carbon although there are regulations for total organic carbon (TOC) in finished drinking water dependent on source water alkalinity (EPA 1998a). For finished drinking water, the MCL for haloacetic acid is 0.060 and the MCL for total trihalomethanes is 0.080 (EPA 2008).

This chapter summarizes grab sample data for organic carbon collected at 11 stations in the Sacramento-San Joaquin Delta (Delta) from October 1, 2005, to September 30, 2007. Samples were collected twice a month for the Sacramento River at Hood and the San Joaquin River near Vernalis. At the remainder of the stations, samples were collected monthly. For the Banks Pumping Plant, Hood, and Vernalis stations, additional weekly or biweekly samples were collected during the entire reporting period. These 3 stations have real-time monitoring equipment installed, and weekly or biweekly quality assurance/quality control (QA/QC) visits were necessary. During these QA/QC trips, additional discrete samples were collected.

Organic carbon data were acquired by 2 analytical methods. One method, commonly referred to as the combustion method, oxidizes organic carbon with high temperature; the other method, commonly referred to as the wet oxidation method, oxidizes organic carbon with chemical oxidants. During the current reporting period, total organic carbon (TOC) and dissolved organic carbon (DOC) at Hood, Vernalis, Natomas East Main Drainage Canal (NEMDC) and some samples at Banks were determined by both the combustion and wet oxidation methods. The remainder of the stations used only the wet oxidation method. This report only summarizes TOC and DOC data by wet oxidation. Basic summary statistics, including range, median, and averages, are presented. Brief discussions on seasonality at individual stations and some limited spatial comparisons are made.

Stations North of the Delta

MWQI sampled 3 stations near the northern boundary of the Delta. These stations are the American River at the E. A. Fairbairn Water Treatment Plant (WTP) intake, the Sacramento River at the West Sacramento WTP intake, and NEMDC (Figure 3-10). Water quality at these stations represents inflows to the Delta from the American and Sacramento rivers, as well as urban drainage from a heavily populated urban watershed.

American River at the E. A. Fairbairn Water Treatment Plant

With the exception of each rainy season, organic carbon concentrations were generally below 2 milligrams per liter (mg/L) (Figure 3-1). During the rainy season, heavy rains in the watershed brought additional organic carbon into the American River, increasing carbon levels to between 2 and 3 mg/L.

Figure 3-1 Organic carbon at the American River and West Sacramento WTP

Both TOC and DOC ranges were similar, while median and average TOC and DOC concentrations were different by only 0.1 and 0.2 mg/L, respectively (Table 3-1). Such small differences suggest that organic carbon was mostly in a dissolved form. American River water is low in turbidity (see "Chapter 7 Other Water Quality Constituents"), thus the differences between TOC and DOC were small.

Table 3-1 Summary of organic carbon at 11 MWQI stations

Organic carbon fluctuations were generally small, except at the beginning of the wet months (Figure 3-1). In response to stormwater runoff and dam releases, organic carbon increased between January and April 2006 and in January 2007, but elevated organic carbon levels did not persist (Figure 3-1). During June and July 2006, TOC concentrations were elevated but unrelated to rainfall or dam releases. Elevated TOC measurements at the American River station are generally strongly correlated to elevated turbidities, but during this period turbidities were low. This period of high TOC cannot be explained by weather-induced watershed events. Despite the differences in precipitation between the wet WY 2006 and the dry WY 2007, median TOC and DOC between the 2 water years were not statistically different (Mann-Whitney, $p = 0.1683$ and 0.6974 for TOC and DOC, respectively).

Sacramento River at the West Sacramento WTP intake

The West Sacramento WTP intake is about 2.5 miles upstream of the confluence of the American and the Sacramento rivers (Figure 3-10). Water quality at this station reflects the quality of the Sacramento River before it mixes with inflows from the American River and NEMDC and before entering the Delta. Organic carbon concentrations were generally between 1 and 3 mg/L, with organic carbon concentrations increasing to above 3 mg/L during periods of high rainfall (Figure 2-2, Figure 3-1). The median levels of TOC and DOC for the reporting period were 2.0 and 1.9 mg/L, respectively (Table 3-1). There were no statistical differences between carbon types (Mann-Whitney, $p=0.3414$). The lack of differences in ranges and medians between TOC and DOC indicated that organic carbon was mostly in the dissolved form.

Figure 3-10 Total organic carbon: Range, median (mg/L)

Like the American River, TOC and DOC were higher in the Sacramento River during the wet months than during the dry months. Both TOC and DOC showed less fluctuation during the dry months of the 2 water years (Figure 3-1). Although WY 2006 was much wetter than WY 2007 in the watershed, median TOC and DOC concentrations between the water years were not significantly different (Mann-Whitney, $p=0.3094$ and 0.3689 for TOC and DOC, respectively).

Natomas East Main Drainage Canal

NEMDC at El Camino Avenue in north Sacramento is an urban drainage canal that discharges water to the Sacramento River. It collects drainage waters from one of the rapidly urbanizing and highly populated watersheds in the Sacramento Valley. NEMDC was the subject of a Municipal Water Quality Investigations (MWQI) special study that monitored loads, seasonality of organic carbon, coliform bacteria, and other constituents of concern (DWR 2008).

Figure 3-2 Natomas East Main Drainage Canal at El Camino Blvd

Among the 3 MWQI stations north of the Delta, organic carbon concentrations at NEMDC were 2 to 4 times greater than those at the American and Sacramento rivers at the West Sacramento WTP intake and higher than at any other MWQI station (Table 3-1). Carbon concentrations were generally higher during the wet months than during the dry months, but this was only true during periods of moderate to high stormwater runoff. During a dry year, such as 2007, concentrations did not increase with the onset of the wet season (Figure 3-2). In previous years, after initial heavy rainfall events in the watershed, organic carbon reached as high as 25 to 35 mg/L (Table 3-1). Concentrations this high have occurred only after the first significant rainfall event following a long dry period (DWR 2005). During the dry months, organic carbon ranged between 4 and 6 mg/L.

During the 2-year period covered in this report, median TOC and DOC were not significantly different (Mann-Whitney, p=0.3540). These results suggest that organic carbon was primarily in the dissolved form. Unlike the upper Sacramento and American rivers, concentrations of TOC and DOC at NEMDC differed by year type (Mann-Whitney, p=0.0012 and 0.0088, TOC and DOC, respectively), reflecting the differences between runoff in wet and dry years. More than 3 times as much water flowed down NEMDC in WY 2006 than in WY 2007.

Although organic carbon concentrations at NEMDC were much higher than those in the nearby Sacramento and American rivers, NEMDC inflows were generally small relative to flows in both rivers. During the reporting period, daily flows at NEMDC ranged from 414 to 13,332 cubic feet per second (cfs), whereas combined flows of the Sacramento River at Verona and the American River at Lake Natoma ranged from 8,990 to 120,008 cfs (Figure 3-2). Median flow at NEMDC (487 cfs) was less than 3% of the combined daily median flows from the Sacramento and American rivers (18,232 cfs), but TOC loads at NEMDC can be significant. For example, in early January 2006, NEMDC accounted for only 8% of flows in the lower Sacramento River, but 20% of the TOC.

Sacramento River at Hood

Water at the Hood station is on the Sacramento River shortly after the river enters the Delta from the north. Because of its key location, water quality at Hood is monitored on a weekly or biweekly basis. During the reporting period, organic carbon concentrations ranged from 1.5 to 4.3 mg/L for TOC and 1.4 to 4.0 mg/L for DOC (Table 3-1). These ranges were less variable than previous years. This is of interest given how wet WY 2006 was compared to the previous 4 years. Median concentrations of TOC and DOC (2.1 and 1.9 mg/L, respectively) were statistically different (Mann-Whitney, p=0.0097); thus, unlike other northern stations, more carbon was in the particulate form.

A clear rainfall-driven seasonal pattern was observed at the Hood station. Organic carbon was elevated during the wet months and generally ranged between 2 and 4 mg/L; whereas during the dry months, organic carbon was between 1.0 and 2.5 mg/L with only small fluctuations (Figure 3-3). Taking into account the wet-and-dry-month seasonal patterns, there was no evidence of an increase in organic carbon between water years (Figure 3-3). Organic carbon medians were not significantly different between WY 2006 and WY 2007 (TOC: p=0.3677 and DOC: p=0.4408).

Figure 3-3 Organic carbon at the Hood Station on the Sacramento River

San Joaquin River near Vernalis

The San Joaquin River (SJR) near Vernalis is where the SJR enters the Delta from the south. Like the Hood station on the Sacramento River, water quality near Vernalis was monitored either weekly or biweekly during the reporting period. Organic carbon concentrations generally varied between 2 and 4 mg/L, but were as high as 5.9 mg/L during January 2006 (Figure 3-4). Median concentrations of TOC and DOC were 3.3 and 3.0 mg/L, respectively (Table 3-1). Differences were significant (Mann Whitney, $p < 0.0001$) indicating the presence of particulate organic carbon in the water.

Figure 3-4 Organic carbon at the San Joaquin River near Vernalis

As with north Delta stations, organic carbon concentrations generally reached their peak during the wet season (Figure 3-4). However, unlike northern Delta stations, where organic carbon fluctuations during the dry months were generally small, organic carbon levels at Vernalis were often elevated during the dry months due to irrigation discharge. This was especially noticeable during dry runoff years. Conversely, organic carbon concentrations were generally lowest between April and May of each year due to the higher flows during the Vernalis Adaptive Management Plan (VAMP). During dry runoff water years, as soon as VAMP releases stopped, organic carbon increased (Figure 3-4). During the current reporting period, WY 2007 was a critical runoff year in the watershed. Both TOC and DOC increased from June to September to levels greater than those seen during the winter runoff period (Figure 3-4). This pattern was not as evident during wet and above-normal years such as WY 2006 (Figure 3-4).

The higher organic carbon concentrations during the dry months were likely due to agricultural drainage returns into the SJR. Agricultural drainage enters the SJR during the May to October growing season, resulting in increased organic carbon concentrations in the river (Figure 3-4). Low organic carbon levels in October 2007 were probably due to decreased agricultural drainage entering the SJR at the end of the growing season.

Channel and Diversion Stations

Old River Stations

Two stations were sampled along Old River: one at Bacon Island (Bacon) and the other at Pumping Station 9 near Highway 4 (Station 9) (Figure 3-10). These stations are approximately 9 river miles apart. Ten agricultural return sites from 5 islands or tracts—Holland, Bacon, Orwood, Woodward, and Victoria—drain to this section of Old River. In addition, the Woodward and North Victoria canals and Indian Slough merge with this section of the river.

As reported in previous MWQI reports (DWR 2003, 2005, 2006), the temporal patterns of TOC and DOC at both stations were identical. Organic carbon data collected during the current reporting period were no exception (Figure 3-5). At both sites, little difference was found between TOC and DOC, suggesting that organic carbon was mostly in the dissolved form.

Figure 3-5 Organic carbon at two Old River stations

Organic carbon at Old River stations comes from multiple sources, including waters from the San Joaquin River, the Sacramento River, and Delta island drainage. Seasonal patterns of organic carbon at these stations were similar to those at other stations, with the exception of SJR near Vernalis. Most elevated TOC and DOC concentrations were observed during the wet months when most precipitation occurred. Unlike the Vernalis station on the SJR, organic carbon concentrations were much lower during dry months than during wet months (Figures 3-4 and 3-5).

The seasonal patterns of TOC and DOC at the 2 Old River stations were similar to seasonal patterns of the 2 major river systems and Delta island drainage (Figure 3-5). Organic carbon concentrations in waters of both the SJR and the Sacramento River were elevated during wet months (Figures 3-3 and 3-4). Organic carbon levels in drainage waters were also higher during this period. When inflows of high organic carbon water from these sources reached Old River, organic carbon concentrations increased. Aside from the organic carbon levels of river waters, another factor was the quantity or ratio of river basin water that was available at Old River. Based on volumetric fingerprinting, the lower the percentage of Sacramento River water moving through Old River, the higher the organic carbon levels tended to be (Figure 2-9). At the Old River stations, both factors resulted in the observed seasonal organic carbon levels (Figure 3-5).

Middle River at Union Point

The Middle River at Union Point station is a new addition to MWQI's monthly monitoring (Figure 3-10). It was added in July 2006 due to concerns that Middle River waters, by way of Victoria Canal, could be affecting water quality at the State Water Project (SWP) pumps. Monitoring at this location helps provide data to model Middle River inputs to the SWP.

The temporal patterns and concentrations of organic carbon on Middle River were quite similar to the Old River stations. Concentrations peaked during the wet season before trending downward through summer and mid-autumn.

Figure 3-6 Organic carbon at Middle River at Union Point

Dry season concentrations ranged between 2 and 3 mg/L (Figure 3-6). Over the 15-month sampling period, median TOC and DOC were 3.4 mg/L and 3.2 mg/L, respectively (Table 3-1). TOC and DOC concentrations did not differ significantly (Mann-Whitney, p=0.5194), suggesting that the majority of organic carbon in the river was in the dissolved form.

Banks Pumping Plant

Samples were collected at the State Water Project's Banks Pumping Plant. Organic carbon concentrations at this station represent the quality of Delta water that is diverted into the California Aqueduct. TOC and DOC ranges at Banks were similar to other channel and diversion stations (Table 3-1). Higher concentrations were found mostly during the wet months, but a secondary peak in concentrations occurred during early summer in both water years (Figure 3-7). Organic carbon concentrations varied between 3 and 5 mg/L during the wet months. During the dry months, concentrations were less variable than in the winter and were generally near 3 mg/L (Figure 3-7). The increase in organic carbon during the wet months was attributable to increased loads from contributing watersheds. Median TOC and DOC concentrations were 3.2 and 3.1 mg/L (Table 3-1), respectively, which were not statistically different (Mann-Whitney, p= 0.2237). This indicates that particulate organic carbon was limited in the water at Banks.

At many stations, TOC concentrations tend to increase with flow. However, this is not necessarily true at Banks because flow rate is determined by pumping and is not a result of a watershed event such as rainfall or dam releases. Therefore, increased pumping does not lead to higher organic carbon concentrations unless pumping occurs at a time when high organic carbon concentrations are present in Clifton Court Forebay. Over the period covered in this report, high pumping generally occurred only when TOC concentrations were at or below 4 mg/L (Figure 3-8).

Figure 3-8 Banks Pumping Plant average monthly discharge rate compared to TOC concentrations

For both water years, organic carbon decreased during the dry season (Figure 3-7). The decrease in organic carbon during this period was probably due to a combination of factors, including the opening of the Delta Cross Channel gates, implementation of VAMP in the San Joaquin Valley, increased reservoir releases into the Sacramento and San Joaquin rivers, and the absence of storm water runoff. Releases from reservoirs in both watersheds were generally highest from May to August, although the intense rains of January 2006 also brought about greater releases (Figures 2-3 and 2-4). In the San Joaquin River system, the intense rains of winter and spring 2006 led to elevated and extended releases from reservoirs (Figures 2-2 and 2-4). This kept the south Delta rock barriers from being installed, which, coupled with high runoff, created a situation where up to 98% of waters moving past the export pumps came from the San Joaquin River (Figure 2-9). SJR source water caused a secondary peak in TOC concentrations that occurred at the export pumps during spring 2006 (Figure 3-7). Based on the volumetric fingerprint (Figure 2-9), a similar secondary peak that occurred in WY 2007 was also likely due to an increase in SJR water at the export pumps (Figure 3-7).

Contra Costa Pumping Plant

Samples at the Contra Costa Pumping Plant were collected from 2 separate locations during the 2-year period of the report. From October 2005 to September 2006, samples were collected from the canal (pumping plant outflow). Because pumping is not continuous, samples collected from the canal did not necessarily reflect the quality of the water available for pumping. Beginning in October 2006, samples were collected from Rock Slough (the inlet to the pumping plant) to better characterize the quality of water actually diverted into the canal. Regardless of sample location, MWQI staff kept a record of pumping activities during each sample collection.

The median values for TOC and DOC were 3.4 mg/L and 3.0 mg/L, respectively. The highest concentrations of organic carbon occurred during the wet months and varied from 3.0 to 5.5 mg/L depending on water year (Figure 3-7). Like the Banks station, TOC and DOC concentrations at the Contra Costa Pumping plant were not significantly different (Mann-Whitney, p =0.3067), suggesting low particulate organic carbon in the water. Seasonal patterns at the Contra Costa Pumping Plant were similar to those at Banks Pumping Plant (Figure 3-7) and those at Old River Station 9 and Bacon Island (Figure 3-5). Like these sites, organic carbon concentrations at Contra Costa were influenced by the ratio of Sacramento River water present in Old River (Figures 2-9 and 3-7).

Figure 3-7 Organic carbon at two Delta diversion stations

Mallard Island Station

Water at the Mallard Island station comes from several sources, including the San Joaquin River, the Sacramento River, the San Francisco Bay, drainage from Delta islands, and numerous municipal and industrial discharges. Because of dilution from bay waters that have low organic carbon, organic carbon concentrations at Mallard Island were lower than they were at Delta channel and diversion stations (Table 3-1). Median TOC and DOC concentrations were 2.4 and 2.1 mg/L, respectively, which was approximately 25% to 35% less than those found at channel and diversion stations (Table 3-1). The difference between TOC and DOC was not significant (Mann-Whitney, p=0.1393), which indicated that most organic carbon was in the dissolved form. Likewise, the organic carbon concentrations did not differ significantly between water years (TOC, p=0.4014 and DOC, p=0.4331).

Like the other stations, organic carbon concentrations were elevated during wet months, with concentrations varying from 2.5 to 4 mg/L (Figure 3-9). These variations were smaller than those at the river and channel stations because of the diluting effects of the multiple sources mentioned above.

Figure 3-9 Organic carbon at Mallard Island

Comparisons Between the Current Reporting Period and Previous Periods

Stations North of the Delta

At the American River and West Sacramento intakes, the range and median concentrations during the current reporting period were comparable to those found during the previous 4 water years (Table 3-1). At NEMDC, median TOC and DOC values were slightly lower than those during the previous 4 water years (Table 3-1), but in line with medians from 1998 through 2003 (DWR 2006). Minimum values decreased somewhat, while the maximum values declined considerably (Table 3-1).

Sacramento River at Hood Station

Table 3-2 Summary of organic carbon during three consecutive sampling periods

Over the last 6 water years, median organic carbon concentrations have increased slightly. The range for the 2005-2007 reporting period was smaller than the ranges of the prior reporting periods (Table 3-2). This is of interest given how wet WY 2006 was compared to the previous 4 years. According to the Kruskall-Wallis test, the median organic carbon concentrations for WY 2006 were statistically higher than both WY 2002 (TOC, p=0.0009 and DOC, p=0.0005) and WY 2003 (TOC, p=0.0058 and DOC, p=0.0025). All other comparisons between water years were statistically insignificant.

Taking into account the comparisons of the years described above, the data from 2001 to 2007 suggest an increasing trend in organic carbon (Figure 3-3). For organic carbon data affected by precipitation, the median is a good indicator of baseline water quality conditions. If the median is taken as a measure of baseline organic carbon conditions, then the TOC and DOC baseline levels of 1.9 and 1.7 mg/L over the previous 4 water years (WY 2002 to WY 2005) were similar to the median TOC and DOC concentrations of 1.9 and 1.8 mg/L over the past 6 water years (WY 2002 to WY 2007) (Table 3-2).

San Joaquin River near Vernalis Station

Over the last 6 water years, median organic carbon concentrations decreased slightly. The 2005-2007 reporting period had the lowest median of all 3 reporting periods, and it was lower than the median for all 6 water years (Table 3-2). This difference was likely related to greater summer reservoir releases into the San Joaquin River made possible by 2 consecutive wet years in 2005 and 2006. TOC was statistically lower in WY 2006 than WY 2004 (p=0.0001) and WY 2005 (p=0.0089). Also, TOC in WY 2007 was statistically lower than in WY 2004 (p=0.0012). DOC in WY 2005 was statistically higher than in WY 2002 (p=0.0029), WY 2003 (p=0.0099), and WY 2007 (p=0.0007). The remaining comparisons of organic carbon concentrations between water years were not statistically different.

Channel and Diversion Stations

At the Station 9 and Bacon Island stations, the ranges and medians from the current period differed only slightly from those found during the previous 4 water years (Table 3-1). No comparison data was available for the Middle River at Union Point station due to its recent addition to the monitoring program.

Median TOC concentrations have held steady over the past 6 years at Banks, while median DOCs have increased slightly. For the 2005 to 2007 reporting period, TOC and DOC ranges were narrower than in previous periods (Table 3-2). From 2001 to 2007, there were no statistical differences in organic carbon concentrations between any of the water years.

At the Contra Costa Pumping Plant, the ranges for both TOC and DOC were similar and were comparable to those found during the previous 4 water years (Table 3-1). Over the same period, median DOC values decreased by 0.1 mg/L, while TOC values increased by 0.3 mg/L.

Mallard Island

Median organic carbon levels were slightly higher during the current period than during the previous 4 water years (Table 3-1). Compared to previous years, a slight increase in dry season baseline concentrations was observed (Figure 3-9). WY 2007 was a dry year in the Sacramento watershed and a critical year in the San Joaquin watershed. The ramifications of such a dry year can be seen in these elevated dry season medians. Less fresh water was available to be released from reservoirs over the summer months, which led to less dilution of the waters reaching Mallard Island and an increase in median concentrations.

Summary

Organic carbon at 11 MWQI stations in the Delta and its tributaries differed spatially, with north Delta stations generally having lower TOC concentrations than south Delta and channel stations (Figure 3-10 and Table 3-1). The American River station had the lowest median TOC of 1.7 mg/L. Median TOC at the Sacramento River at the West Sacramento WTP intake was 2.0 mg/L. Median TOC at Sacramento River at Hood was 2.1 mg/L. In contrast, median TOC for the SJR near Vernalis was 3.3 mg/L, which was about 60% higher than the TOC concentration at the Sacramento and American river stations. The median TOC at Mallard Island was 2.4 mg/L, which, when compared to the median TOC concentrations at Hood and Vernalis, reflected the multiple sources of water at this station.

The 5 Delta channel and diversion stations—Old River at Station 9, Old River at Bacon Island, Middle River at Union Point, Banks Pumping Plant, and Contra Costa Pumping Plant #1—receive water from both the San Joaquin and Sacramento rivers. Despite the dilution effects of water from the Sacramento River, median TOC concentrations for these stations ranged from 3.0 to 3.4 mg/L; these concentrations were comparable to the SJR near Vernalis. These results suggested a considerable in-Delta influence, as well as the influence from the SJR. Drainage from Delta islands and in-channel production were probable sources of in-Delta organic carbon. Compared with the previous 4 water years (Table 3-1), median TOC concentrations of most stations did not show large changes. Seasonal patterns of organic carbon concentrations were similar between tributary and channel stations. Seasonal patterns at the 5 Delta channel and diversion stations were also similar to those at the San Joaquin and Sacramento rivers. In general, stations experienced elevated carbon levels during the rainy season, which trended downward through the early summer months before reaching their seasonal low during the late summer to early fall.

Chapter 3 Organic Carbon

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Figure 3-1 Organic carbon at the American River and West Sacramento WTP intakes

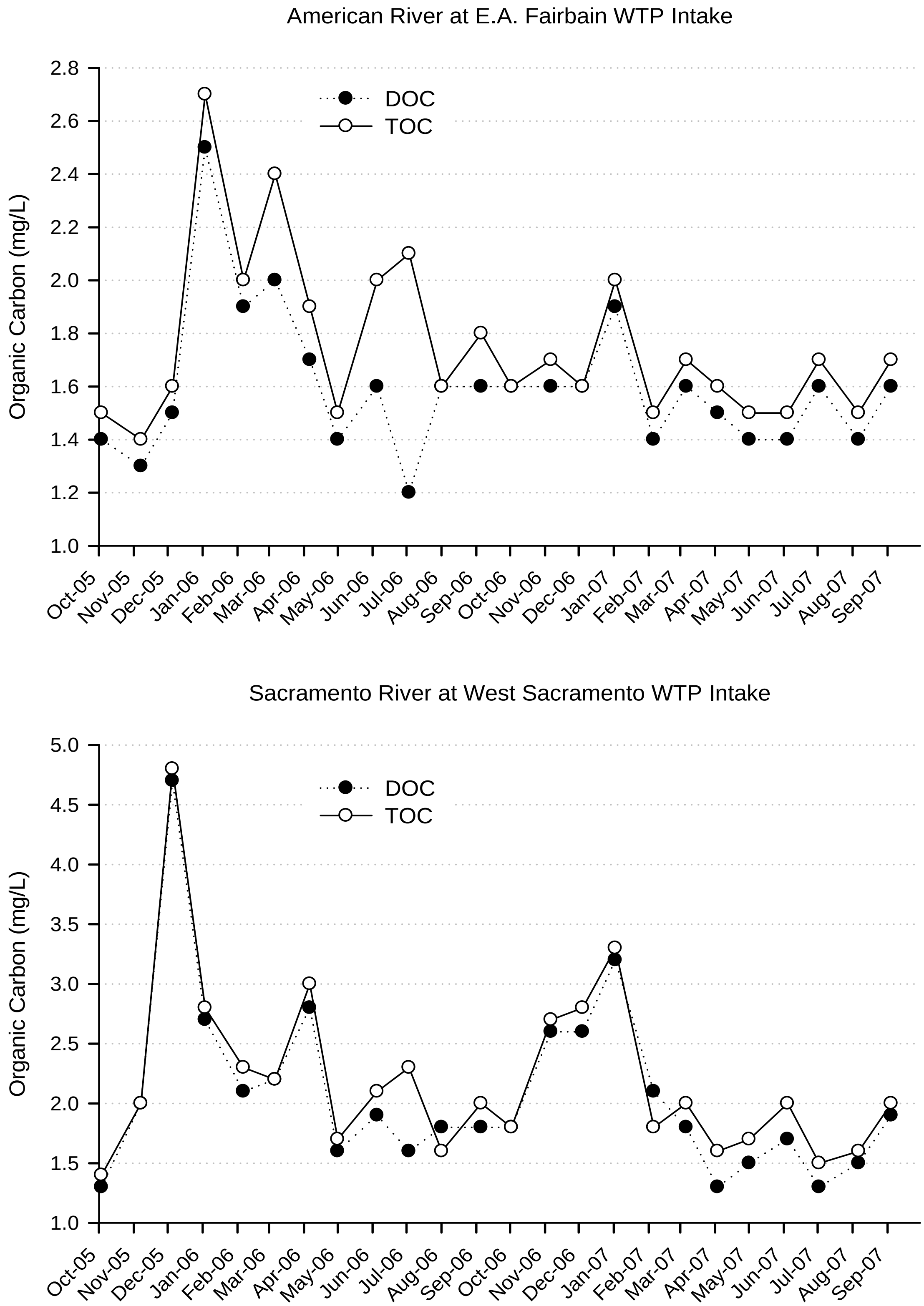


Figure 3-2 Organic carbon from NEMDC at El Camino Blvd. and northern Delta inflows

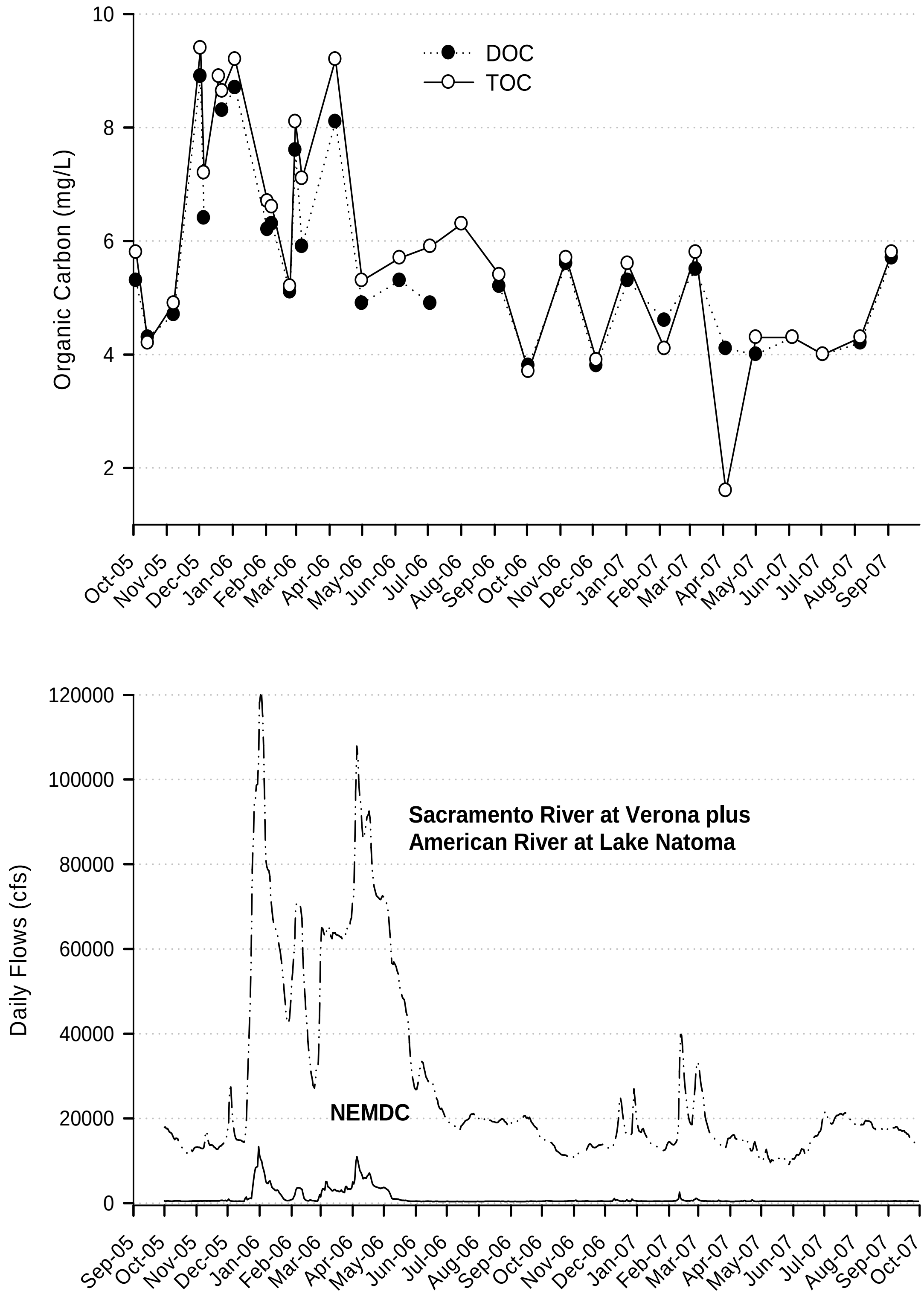
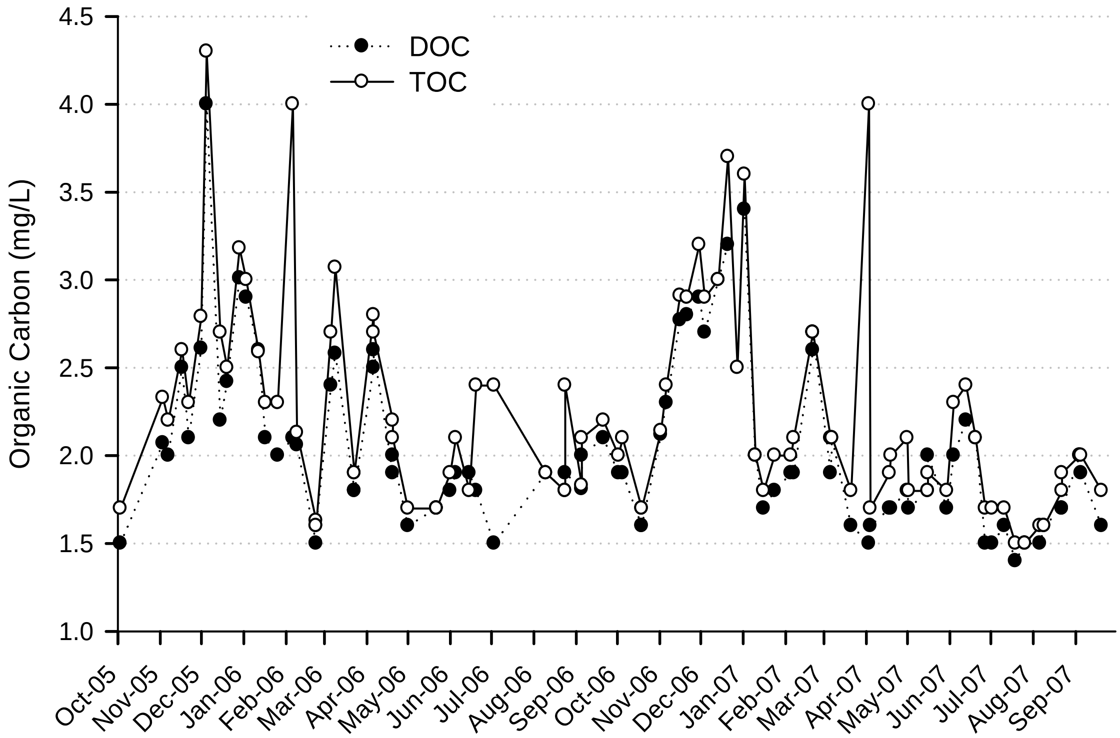


Figure 3-3 Organic carbon at the Hood Station on the Sacramento River



Sacramento River at Hood: 2002 WY to 2007 WY

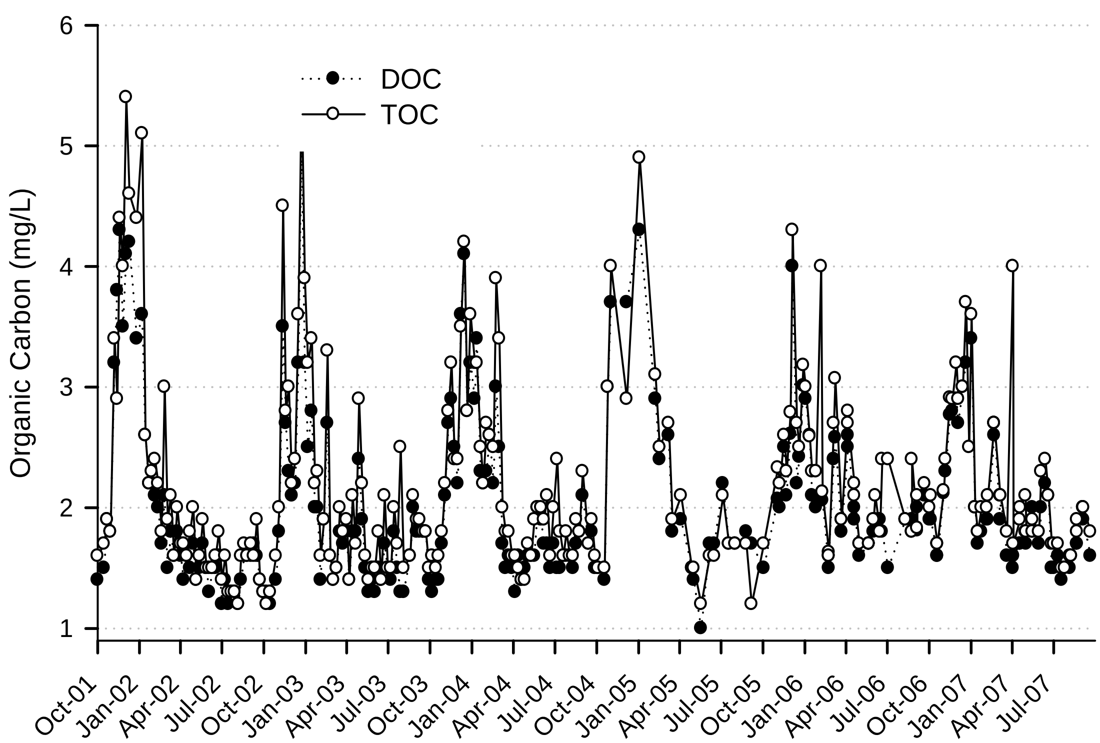
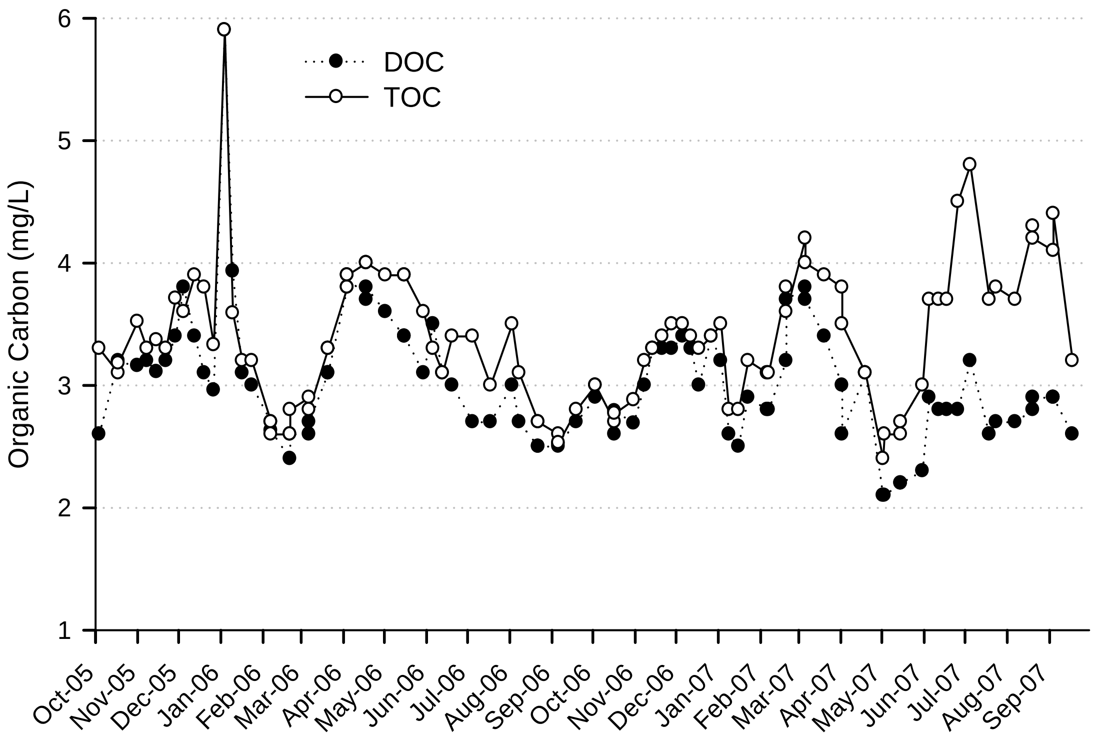


Figure 3-4 Organic carbon at the San Joaquin River near Vernalis



San Joaquin River near Vernalis: 2002 WY to 2007 WY

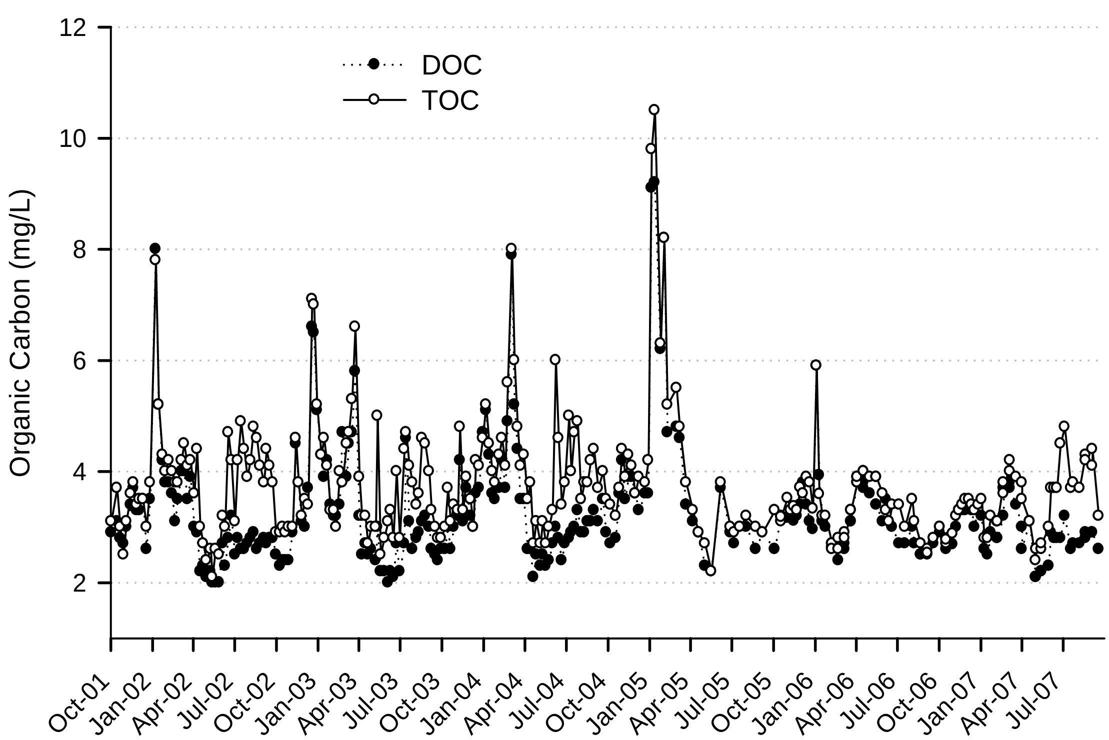
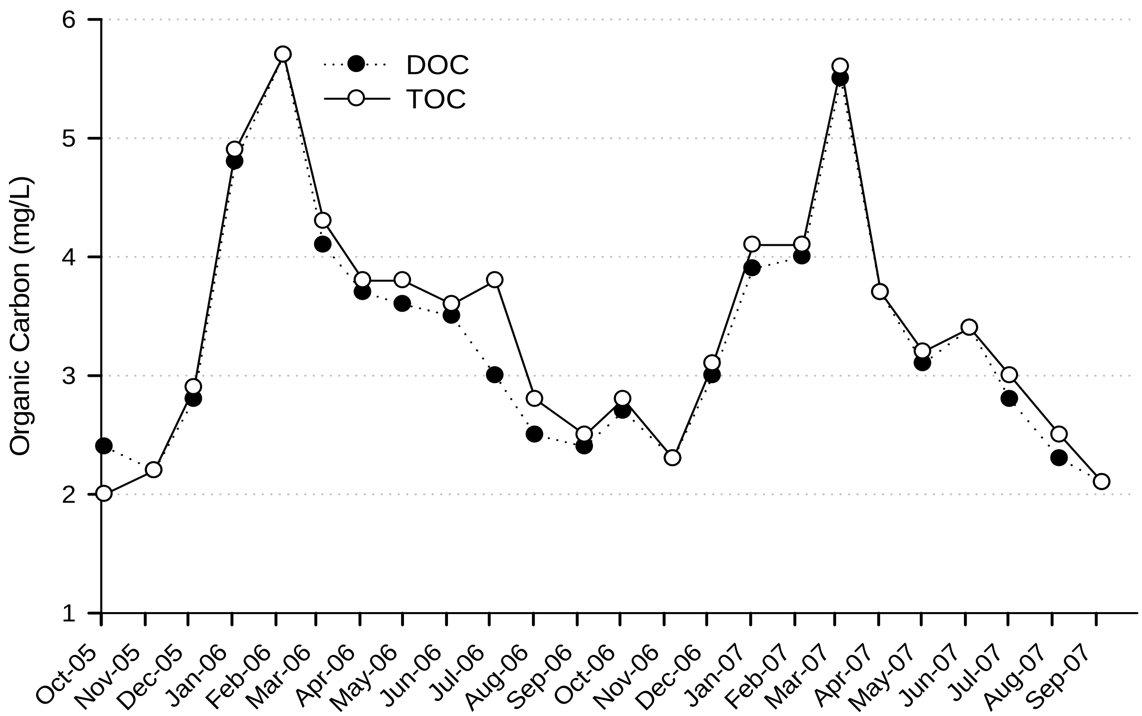


Figure 3-5 Organic carbon at 2 Old River stations

Old River at Station 9



Old River at Bacon Island

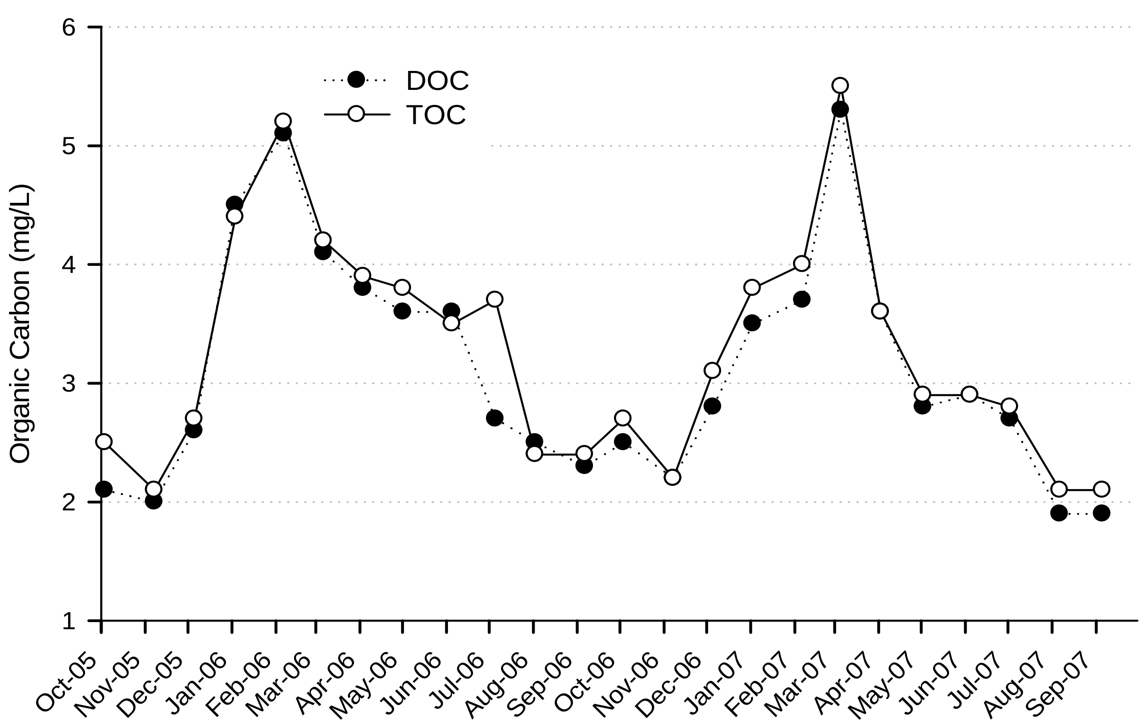


Figure 3-6 Organic carbon at Middle River at Union Point

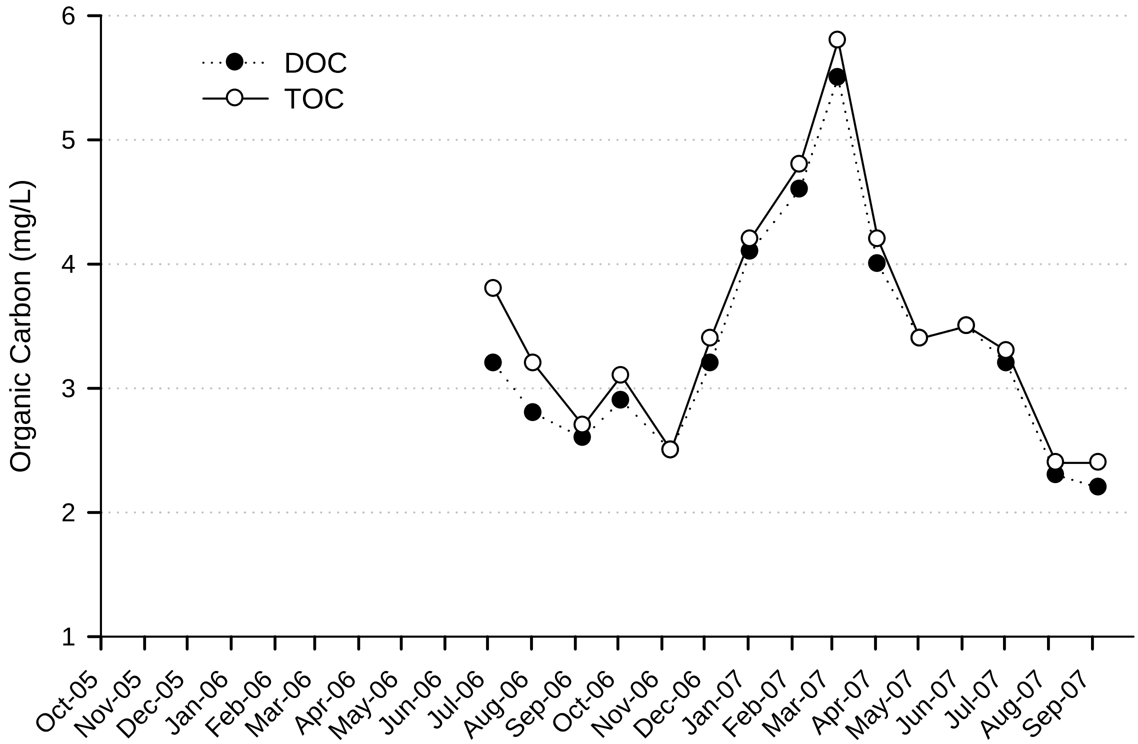
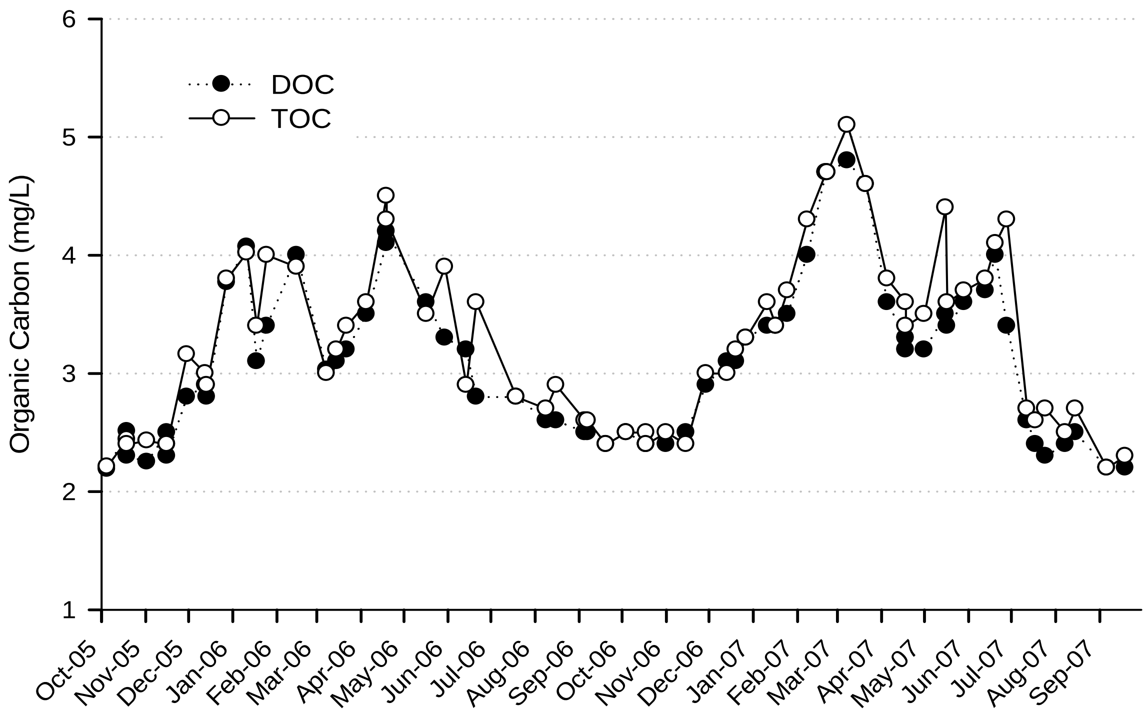


Figure 3-7 Organic carbon at 2 Delta diversion stations

Banks Pumping Plant



Contra Costa Pumping Plant

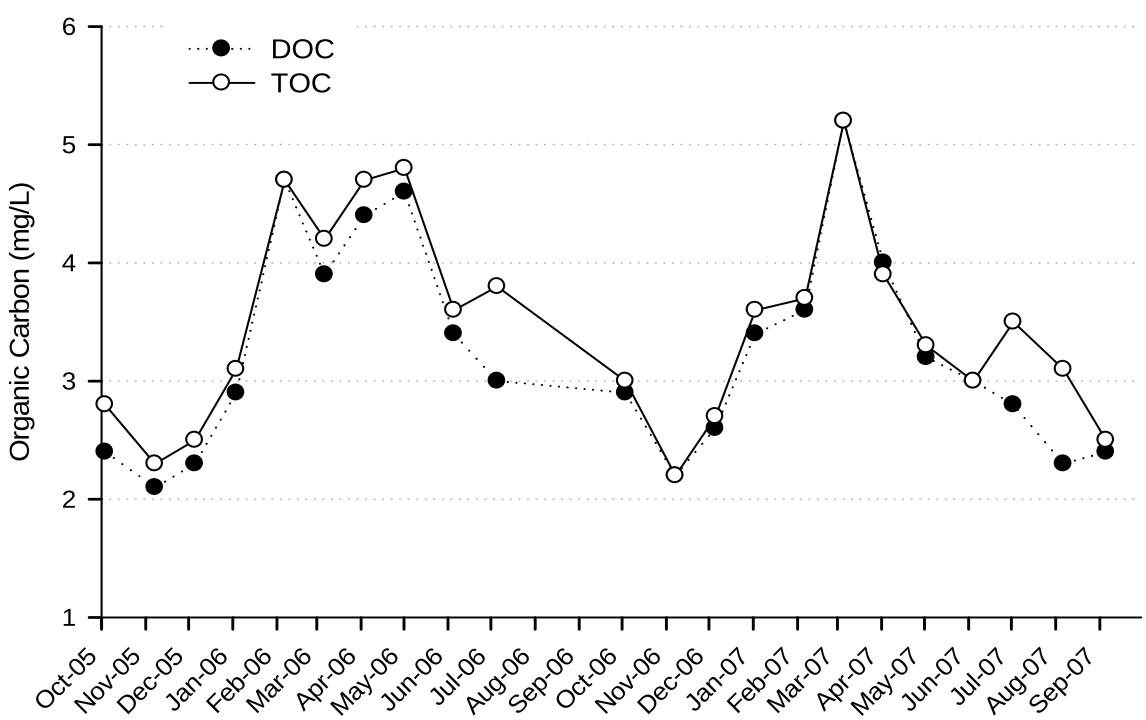


Figure 3-8 Banks Pumping Plant average monthly discharge rate compared to TOC concentrations

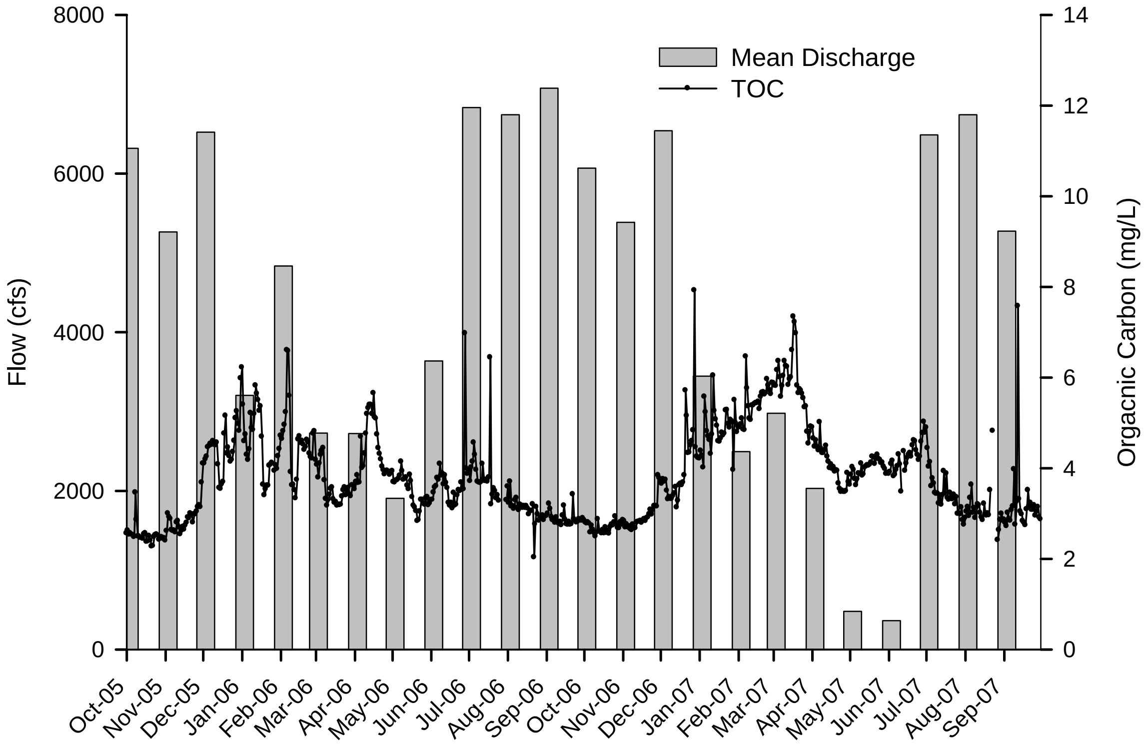
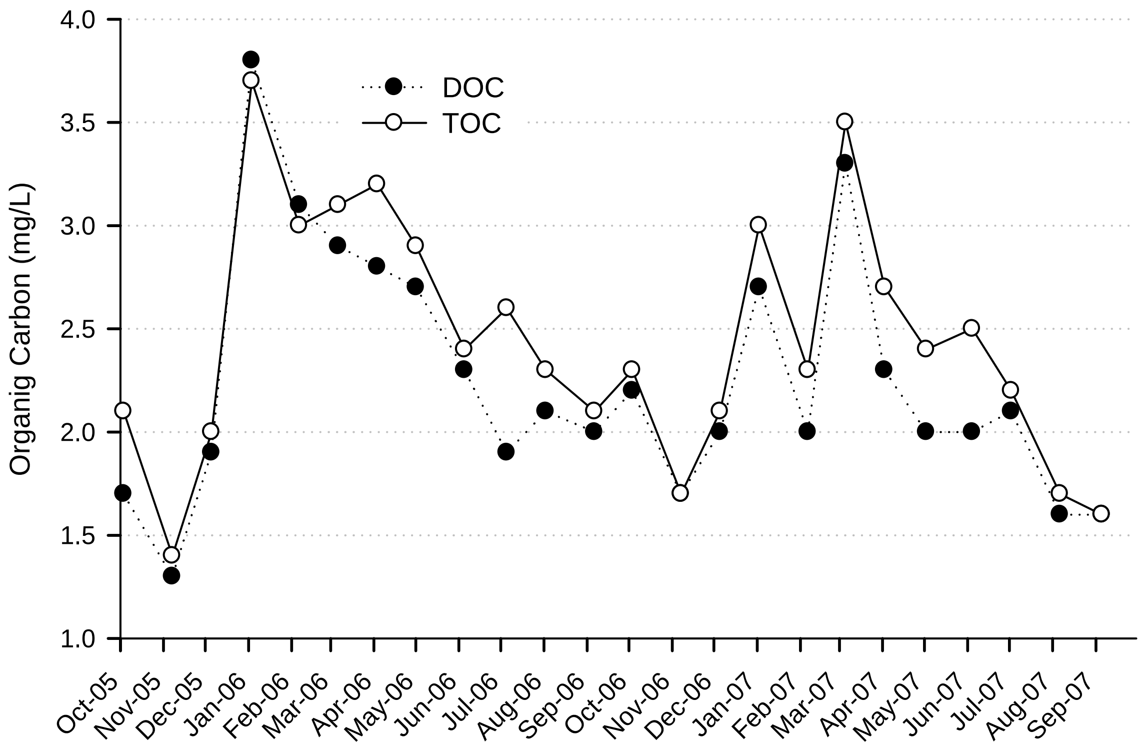


Figure 3-9 Organic carbon at Mallard Island



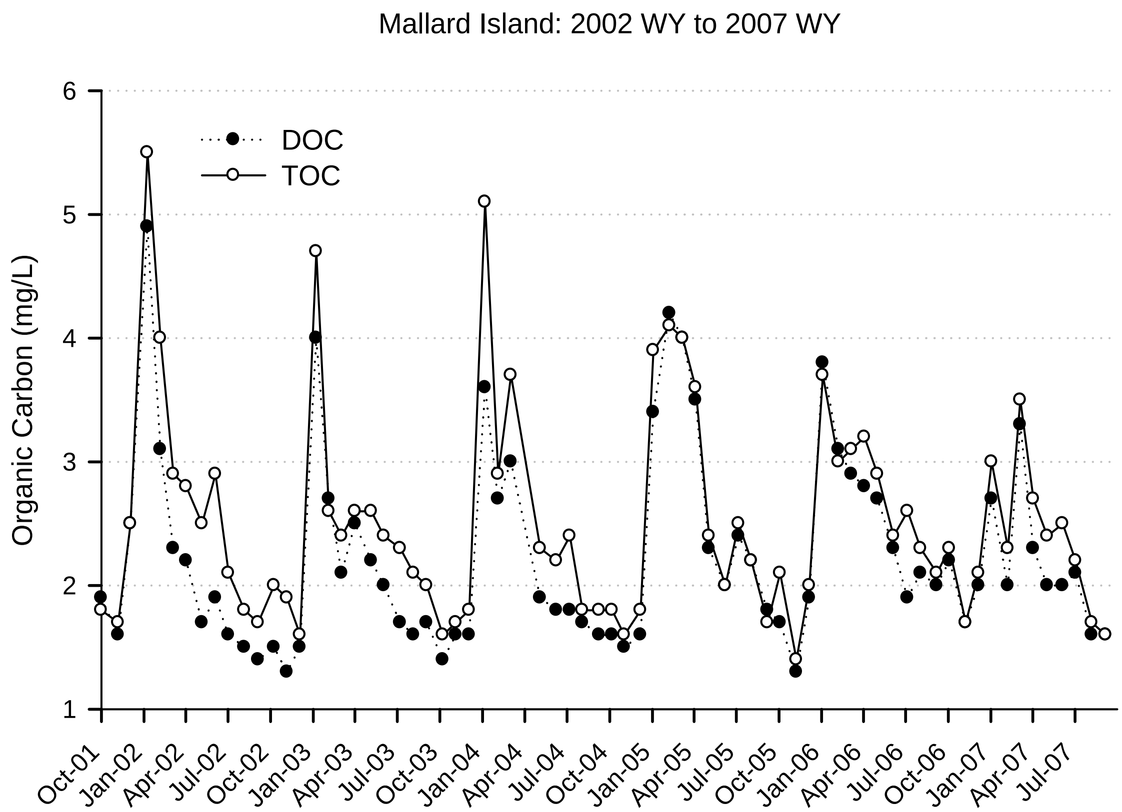


Figure 3-10 Total organic carbon: Range (median) in mg/L

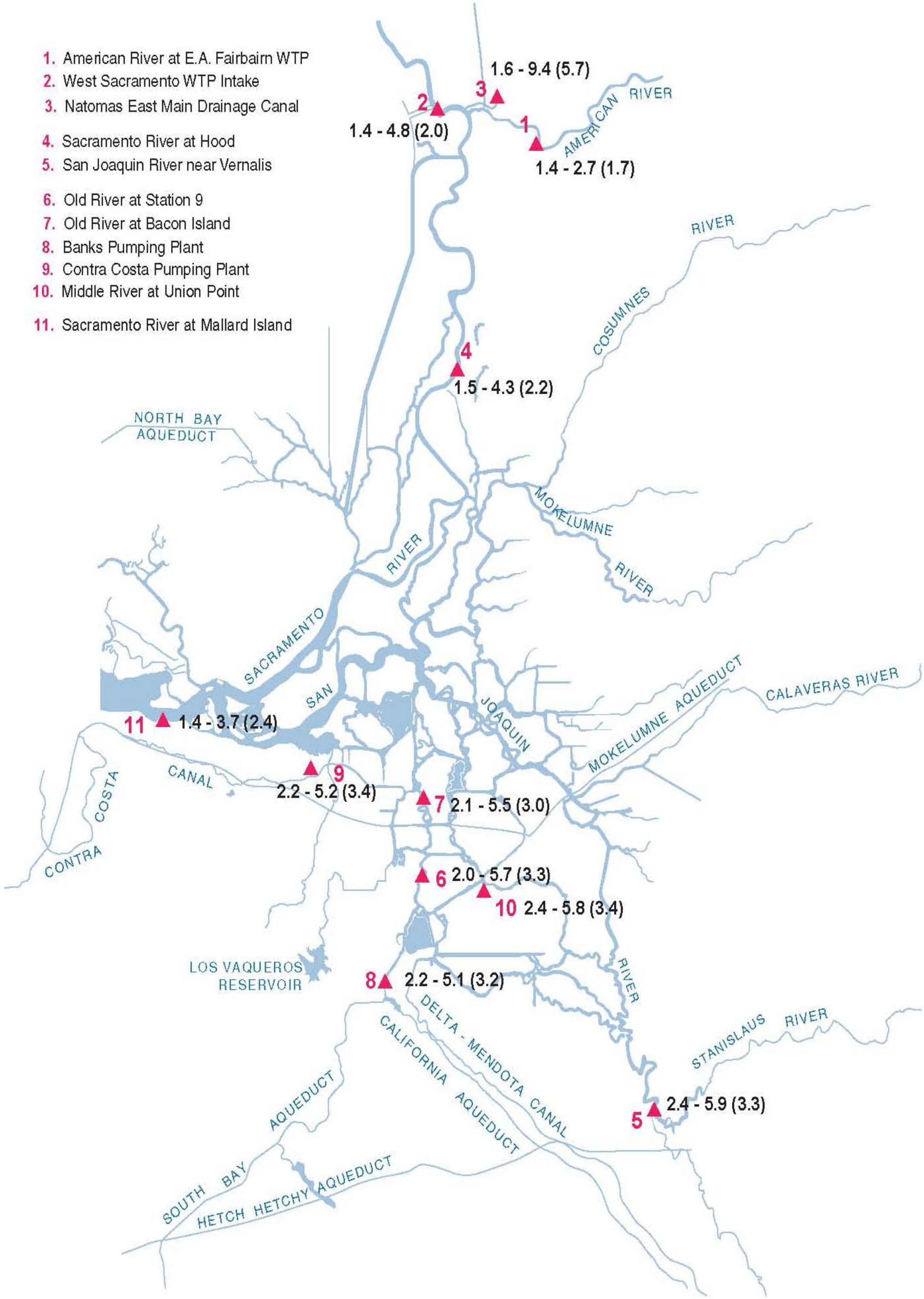


Table 3-1 Summary of organic carbon at 11 MWQI stations

		Oct 2005 – Sep 2007				Oct 2001 – Sep 2005	
Station	Constituent [a]	Sample number	Range -- mg/L ---------	Average	Median	Range --------- mg/L	Median ---------
Stations north of the Delta							
American River at E.A. Fairbairn WTP	TOC	24	1.4-2.7	1.8	1.7	1.2–2.8	1.5
	DOC	24	1.2-2.5	1.6	1.6	1.1–2.7	1.4
West Sacramento WTP Intake	TOC	24	1.4-4.8	2.2	2.0	1.2–5.4	2.0
	DOC	24	1.3-4.7	2.1	1.9	1.1–4.9	1.9
Natomas East Main Drainage Canal	TOC	31	1.6-9.4	5.9	5.7	3.0–36.6	5.9
	DOC	31	3.8-8.9	5.6	5.3	4.2–22.3	5.7
Sacramento River at Hood							
	TOC	88	1.5–4.3	2.3	2.1	1.2–5.5	1.9
	DOC	88	1.4–4.0	2	1.9	1.0–5.1	1.7
San Joaquin River near Vernalis							
	TOC	89	2.4–5.9	3.4	3.3	2.1–10.5	3.8
	DOC	89	2.1–5.9	3.0	3.0	2.0–9.2	3.0
Channel and diversion stations							
Old River at Station 9	TOC	24	2.0–5.7	3.4	3.3	1.9–8.4	3.5
	DOC	24	2.1–5.7	3.3	3.1	1.8–8.2	3.3
Old River at Bacon Island	TOC	24	2.1–5.5	3.3	3.0	1.7–7.5	3.2
	DOC	24	1.9–5.3	3.1	2.8	1.8–7.1	3.0
Banks Pumping Plant	TOC	64	2.2–5.1	3.3	3.2	1.9–8.4	3.1
	DOC	64	2.2–4.8	3.1	3.1	1.9–8.3	2.9
Contra Costa Pumping Plant	TOC	22	2.2–5.2	3.5	3.4	2.1–6.3	3.1
	DOC	22	2.1–5.2	3.2	3.0	2.2–6.5	3.1
Middle River at Union Point	TOC	15	2.4–5.8	3.5	3.4	–	–
	DOC	15	2.2–5.5	3.3	3.2	–	–
Mallard Island							
	TOC	24	1.4–3.7	2.5	2.4	1.6–5.5	2.3
	DOC	24	1.3–3.8	2.3	2.1	1.3–4.9	1.9

a. Both TOC and DOC were determined by the wet oxidation method.

Table 3-2 Summary of organic carbon during 3 consecutive sampling periods

Station	Study period	TOC (mg/L)			DOC (mg/L)		
		Range	Average	Median	Range	Average	Median
Sacramento River at Hood	2006–2007	1.5–4.3	2.4	2.2	1.4–4.0	2.1	2.0
	2004–2005	1.2–4.9	2.2	1.9	1.0–4.3	2.1	1.7
	2002–2003	1.2–5.5	2.1	1.8	1.2–5.1	1.9	1.7
	2001–2007	1.2–5.5	2.2	1.9	1.0–5.1	2.0	1.8
San Joaquin River near Vernalis	2006–2007	2.4–5.9	3.4	3.4	2.1–5.9	3.0	3.0
	2004–2005	2.2–10.5	4.1	3.8	2.1–9.2	3.6	3.2
	2002–2003	2.1–7.8	3.8	3.7	2.0–8.0	3.2	2.9
	2001–2007	2.1–10.5	3.8	3.7	2.0–9.2	3.3	3
Banks Pumping Plant	2006–2007	2.2–5.1	3.3	3.2	2.2–4.8	3.1	3.1
	2004–2005	2.2–8.4	3.5	3.1	2.2–8.2	3.3	2.9
	2002–2003	1.9–8.4	3.3	3.2	1.9–8.3	3.2	2.9
	2001–2007	1.9–8.4	3.4	3.2	1.9–8.3	3.2	2.9

Chapter 4 Bromide

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Chapter 4 Bromide

Depending on the disinfection process used, carcinogenic bromide compounds can be formed in two ways during drinking water disinfection. If chlorine is used for disinfection, the chlorination of water containing bromide and organic carbon leads to the formation of brominated trihalomethanes, which may cause liver, kidney, or central nervous system problems and may increase the risk of cancer (EPA 2008). If ozone is used, bromate is formed, which is a potential carcinogen (EPA 2008). The US Environmental Protection Agency (EPA) has not developed a maximum contaminant level (MCL) for bromide. In finished drinking water, the MCL for bromate is 0.01 and the MCL for total trihalomethanes is 0.080 (EPA 2008).

This chapter summarizes bromide data collected at 11 stations in the Delta region from October 1, 2005, to September 30, 2007. A brief discussion of seasonality and some limited spatial comparisons will be made for 6 seawater-affected stations.

Stations North of the Delta

During the reporting period, Municipal Water Quality Investigations (MWQI) staff sampled 1 station on the American River at the E.A. Fairbairn Water Treatment Plant (WTP), 1 station on the Sacramento River at the West Sacramento WTP Intake, and a station on the Natomas East Main Drainage Canal (NEMDC), which is an urban drainage canal.

Of the 22 samples collected at the American River at E.A. Fairbairn WTP, bromide was never detected (Table 4-1). At the West Sacramento WTP Intake, 50% of the samples had bromide above the method detection limit (MDL) of 0.01 mg/L. Concentrations ranged from 0.01 to 0.02 mg/L at the West Sacramento WTP, which had an average and a median of 0.01 mg/L (Table 4-1).

Table 4-1 Summary of bromide at 11 MWQI stations

Bromide concentrations at NEMDC were higher than those found at the American River station and the West Sacramento WTP Intake (Table 4-1). Bromide was reported below the MDL in only 3% of the 29 samples. For the positive samples, bromide concentrations ranged from 0.01 to 0.08 mg/L (Table 4-1). Both average and median concentrations were 0.04 mg/L. Higher bromide levels at NEMDC were mostly due to urban sources. Although bromide concentrations were higher at the NEMDC station than at the American and Sacramento river stations, water inflows to the NEMDC were relatively small compared to the combined inflows to the American and Sacramento rivers (Figure 3-2). Median flow at NEMDC (487 cfs) was less than 3% of the combined daily flows from the Sacramento and American rivers (18,232 cfs). Therefore, bromide loads from NEMDC to the Sacramento River downstream and to the Delta was small.

Sacramento River at the Hood Station

Water at the Sacramento River at Hood station is a mixture of inflows shortly after they enter the legal Delta. Most inflows come from the American and Sacramento rivers. Like the American River at the E.A. Fairbairn WTP Intake and the Sacramento River at the West Sacramento WTP Intake, bromide concentrations at the Hood station were near the MDL with bromide concentrations below the MDL in 42% of the 43 samples (Table 4-1). For samples where bromide was detectable, bromide concentrations ranged from 0.01 to 0.02 mg/L (Table 4-1). Both the average and median bromide concentrations were 0.01 mg/L (Table 4-1).

San Joaquin River Station near Vernalis

Of the 44 samples collected at the San Joaquin River (SJR) near Vernalis, bromide concentrations ranged from 0.02 to 0.35 mg/L with an average and median of 0.18 mg/L (Table 4-1).

Seasonal patterns of bromide in the SJR reflect both rainfall and agricultural practices in the watershed. The San Joaquin Valley is mostly irrigated agricultural land. Irrigation water for the area can come from east side rivers, ground water and the Delta-Mendota Canal (DMC), which diverts water from the south Delta. Water diverted from the DMC is a considerable source of bromide loads to the valley (DWR 2003, 2005, 2006). When irrigation water is applied, bromide concentrates on the soil surface through evapotranspiration. Following either irrigation or rainfall, runoff returns previously accumulated bromide from the soil surface to the SJR. In addition to irrigation water adding bromide to the system, some soils in the area developed from old marine deposits containing high levels of bromide. Bromide in these soils is washed into the river during wet months or through agricultural runoff. In some areas, shallow groundwater also carries high levels of bromide and can move into the SJR through seepage. Depending on the water year type, dilution of bromide concentrations by upstream freshwater inflows may be insignificant. During dry years, winter freshwater inflows are mostly trapped behind upstream reservoirs for flood control or storage purposes, resulting in less dilution downstream. This results in bromide concentrations in the lower part of the river remaining high during the winter months. This pattern was observed during the dry water year (WY) 2007. However, WY 2006 did not see this pattern due to high runoff in the wet season. In the wet winter of WY 2006, high levels of rainfall caused heavy releases from upstream reservoirs resulting in the downstream dilution of bromide (Figures 2-5 and 4-1).

Figure 4-1 Bromide at San Joaquin River near Vernalis

Bromide concentrations were generally higher during the start of the wet months when greater precipitation or intentional winter flooding of agricultural fields resulted in high bromide levels. This could be seen from November to December in WY 2006 and from November through March in WY 2007 (Figures 4-1). Bromide concentrations were the lowest from mid-April to mid-June of WY 2006 and mid-May to mid-June of WY 2007 (Figure 4-1), which coincided with the Vernalis Adaptive Management Plan

(VAMP) period (see Chapter 2). Bromide concentrations appeared to increase after the VAMP period from June to October in the summary period (Figure 4-1). The VAMP period also represents the growing season in the San Joaquin Valley, which is when drainage return waters make up a greater proportion of SJR flows.

Delta Channel and Diversion Stations

Channel stations

MWQI monitored bromide at 3 channel stations: Old River at Station 9, Old River at Bacon Island, and Middle River at Union Point. During the reporting period, bromide was always above the reporting limit (Table 4-1). Median concentrations of bromide were 0.12 mg/L at Station 9, 0.10 mg/L at Bacon Island, and 0.10 mg/L at Union Point (Table 4-1).

Temporal patterns were similar for all channel stations (Figure 4-2) and were similar to those of organic carbon (Figures 3-5 and 3-6). Depending on the water year for the Sacramento and San Joaquin valleys, concentrations were higher from October to January and declined over time from February to April or May (Figure 4-2). This seasonal pattern differed from that of the SJR station near Vernalis (Figure 4-1). At Vernalis, bromide was more variable and remained elevated over a longer period of time than at the channel stations. These differences may be due to the greater influence of Sacramento River water (Figure 6-9). At Bacon Island and Station 9, bromide concentrations increased from July to September or October of both water years with peak concentrations during the wet months (Figure 4-2). Dry month increases in bromide were directly related to the reduced total Delta outflows from July to November of each water year. Low total Delta outflows from July to November allowed seawater intrusions to increase bromide concentrations (Figures 2-5 and 6-9).

Figure 4-2 Bromide at Delta Channel Stations

Diversion Stations

Samples from 2 Delta diversion stations—Banks Pumping Plant and Contra Costa Pumping Plant #1—were collected during the reporting period. The median bromide concentration at Banks Pumping Plant was 0.12 mg/L and the median concentration at the Contra Costa Pumping Plant was 0.14 mg/L. The medians of both stations were comparable, though the range was wider at the Contra Costa Pumping Plant, resulting in a higher average bromide concentration at the Contra Cost Pumping Plant than at the Banks Pumping Plant (Table 4-1). Higher bromide concentrations at the Contra Costa Pumping Plant may have been due to seawater influences (Figure 4-9).

Seasonal patterns were similar between diversion stations and between channel stations (Figures 4-2 and 4-3). WY 2007 was a drier year than WY 2006 for both the Sacramento and San Joaquin valleys (Table 2-2). Due to increased river inflows from the much wetter WY 2006, bromide concentrations were high at the beginning of the wet months, but were diluted through the rest of the wet months. As a result, concentrations at

Figure 4-3 Bromide at Diversion Stations

Banks remained low and bromide concentrations at the Contra Costa Pumping Plant decreased from April to August of WY 2006 (Figures 4-3, 6-9, and 6-10). The increases in bromide concentrations from December to February of WY 2007 were due to reduced releases from upstream reservoirs and decreased tributary inflows to the Delta. In response to the reduced runoff and lower river inflows to the Delta, bromide concentrations at both diversion stations increased from April to September of WY 2007. These seasonal patterns were different from those observed at the SJR station near Vernalis (Figure 4-1), reflecting the influence of multiple sources at the diversion pumps.

Mallard Island

The Mallard Island station is more indicative of seawater influence than are the other stations. Water at this station is a mixture of water from rivers and channels in the Delta, as well as water from the Bay. A total of 23 monthly samples were collected from this station during the current summary period. Concentrations ranged from below the reporting limit to 15.3 mg/L, making it the most widely variable at all 11 stations (Table 4-1). The average and median bromide concentrations were 4.35 and 3.10 mg/L, respectively.

In both watersheds, WY 2006 had lower bromide concentrations during the wet season than WY 2007. Bromide concentrations for the dry seasons were comparable at Mallard Island. In WY 2006, bromide concentrations remained low through much of the wet season due to high total Delta outflow; the concentrations increased from July through November as total Delta outflow decreased. In WY 2007's wet season, bromide concentrations remained high, which may be related to low runoff from contributing watersheds. Bromide concentrations increased from April through September due to reduced total Delta outflow and low reservoir releases (Figures 2-3, 2-4, and 2-5). As a result, the increase in seawater inflows resulted in rising bromide concentrations in August and September. From the EC and volumetric fingerprints (Figures 6-9 and 6-10), it is evident that just a small volume of seawater (Martinez) greatly influences Mallard Island's salinity. (Martinez is the western or sea-ward boundary of the model used for the EC and volumetric fingerprints.) This increase in salinity coincides with decreased total Delta outflows (Figure 2-5) and increased bromide concentrations (Figure 4-4).

Figure 4-4 Bromide concentrations at the Mallard Island station

Relationship between Bromide and Chloride

Bromide concentrations were very low at 4 of the 11 MWQI grab sampling stations. These stations included the 3 stations north of the Delta and the station at Sacramento River at Hood in the northern Delta. Water at these stations came largely from the American and Sacramento river watersheds, which contain very low levels of bromide. Although there were wastewater discharges upstream of the Hood station, their influence on bromide concentrations was minor.

Bromide levels at the other 7 stations were much higher than those of the northern stations. The bromide in waters at these stations came either directly or indirectly from seawater. A detailed discussion on the origin of bromide and seawater influence on these 6 stations has been presented in a previous data summary report (DWR 2005). As discussed in that report, bromide and chloride are strongly correlated and the relationship mimics that found in seawater. Seawater contains approximately 65 mg/L of bromide and 19,000 mg/L of chloride. Therefore, the bromide/chloride ratio in seawater is roughly 0.0034. Like chloride, bromide is a conservative constituent and does not degrade or react with its environment. This ratio should be seen in Delta waters if seawater is their sole source of bromide and chloride.

During the current summary period, a total of 170 grab samples from 7 stations were analyzed for both bromide and chloride. A nearly perfect linear relationship was found between bromide and chloride (Figure 4-5). This linear relationship can be described by this linear regression equation:

Figure 4-5 The relationship between bromide and chloride at six stations

$$\text{Bromide} = 0.0036 * \text{Chloride} - 0.0309, [r^2 = 0.984, p<0.000]$$

In Figure 4-5, all bromide values greater than 0.70 mg/L were from the Mallard Island station, which is more influenced by seawater intrusion. Excluding data from Mallard Island, the relationship between bromide and chloride remained linear and was represented by the following equation:

$$\text{Bromide} = 0.0033 * \text{Chloride} - 0.0173, [r^2 = 0.971, p<0.000]$$

From these two equations, the bromide/chloride ratio in waters of the 7 central and western Delta stations was from 0.0033 to 0.0036, which are the same as the ratio found in seawater. Bromide to chloride ratios indicate bromide in central and western Delta waters came primarily from seawater.

Comparisons Between Current Reporting Period and Previous Periods

Stations North of the Delta

At the American River and West Sacramento Intake stations, the range and median concentrations during the current reporting period were comparable to those found during the previous 4 water years (Table 4-1). At both sites, bromide concentrations were below the MDL for the past 4 water years. At NEMDC, the median concentrations for the current period were comparable to those found during the previous 4 water years (Table 4-1).

Sacramento River at Hood

The median and range bromide concentrations for this reporting period were comparable to those found during the previous 4 water years (Tables 4-1 and 4-2). Over the last 6 water years, the median bromide concentrations showed little variability or statistical differences. The only statistical differences occurred when WY 2003, WY 2004, and WY 2006 were compared with WY 2002, which had a relatively high median bromide concentration. P-values for these comparisons with WY 2002 were 0.0011 for WY 2003, 0.0006 for WY 2004, and 0.000 for WY 2006. Figure 4-6 shows summary boxplots for all 6 water years.

Figure 4-6 Bromide concentrations at Hood: 2002 WY to 2007 WY

San Joaquin River near Vernalis Station

The bromide concentrations for this reporting period were less variable than those measured during the previous 4 water years when concentrations ranged between 0.02 and 0.62 mg/L with a median of 0.28 mg/L (Tables 4-1 and 4-2). The 2005 to 2007 reporting period had the lowest median of all 6 water years (Figure 4-7, Table 4-2). Statistically, bromide concentrations for both WYs 2005 and 2006 were different from WYs 2002, 2003, and 2004 with each comparison having a p-value of 0.000 (Dunn's Multiple Comparison test). Bromide concentrations in 2007 were statistically lower than in 2002, but statistically higher than in 2006; both comparisons had a p-value of 0.007. All other year comparisons were found to be insignificant.

Figure 4-7 Bromide concentrations in the San Joaquin River near Vernalis: 2002 WY to 2007 WY

Table 4-2 Summary of bromide during three consecutive sampling periods

Channel and Diversion Stations

The median bromide concentrations for Station 9 and for Bacon Island were approximately the same as those found during the previous 4 water years (Tables 4-1 and 4-2). Bromide was not sampled at Union Point during the previous 4 water years (Table 4-1).

At the Contra Costa Pumping Plant and Banks stations, the range and medians for the current reporting period were very similar to that of the prior 4 water years (Table 4-1). At the Banks station, median and range for the current reporting period were comparable to the medians and ranges of the prior 4 water years (Figure 4-8, Table 4-2). There were no statistical differences in bromide concentrations among all 6 water years except in WY 2006 where median bromide concentrations were statistically lower than WY 2002 (Dunn's Multiple Comparison test, p= 0.013).

Figure 4-8 Bromide Concentrations in the Sacramento River at Banks: 2002 WY to 2007 WY

Mallard Island

The median and range of bromide concentrations of the current reporting period were similar to those found during the previous 4 water years. The median concentration of this summary period was slightly higher than that of the previous 4 water years (Table 4-1).

Summary

Bromide concentrations were higher at those stations closer to seawater influence (Figure 4-9). Of the 11 stations sampled, the Mallard Island station is the closest to the Bay and had the highest median bromide concentrations (4.35 mg/L) of all stations (Figure 4-9). The SJR near Vernalis had the second highest bromide concentrations with a median of 0.18 mg/L. Elevated bromide in the SJR was attributable to agricultural drainage returns, which are indirectly influenced by seawater and the direct effects of seawater intrusion during periods of reduced Delta outflows.

Figure 4-9 Bromide: Range, median (mg/L)

Median bromide concentrations at the 2 diversion stations (Banks and Contra Costa Pumping Plant) were 0.12 and 0.22 mg/L (Figure 4-9). The stations at the north end of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below the reporting limit of 0.01 mg/L (Figure 4-9).

Compared with the previous 4 water years, overall median bromide concentrations remained unchanged at all stations except at the Vernalis station where the median was lower and at the Mallard Island station where the median bromide concentrations were slightly higher for this reporting period.

Bromide to chloride ratios indicated bromide in central and western Delta waters came primarily from seawater.

Chapter 4 Bromide

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Figure 4-1 Bromide at the San Joaquin River near Vernalis

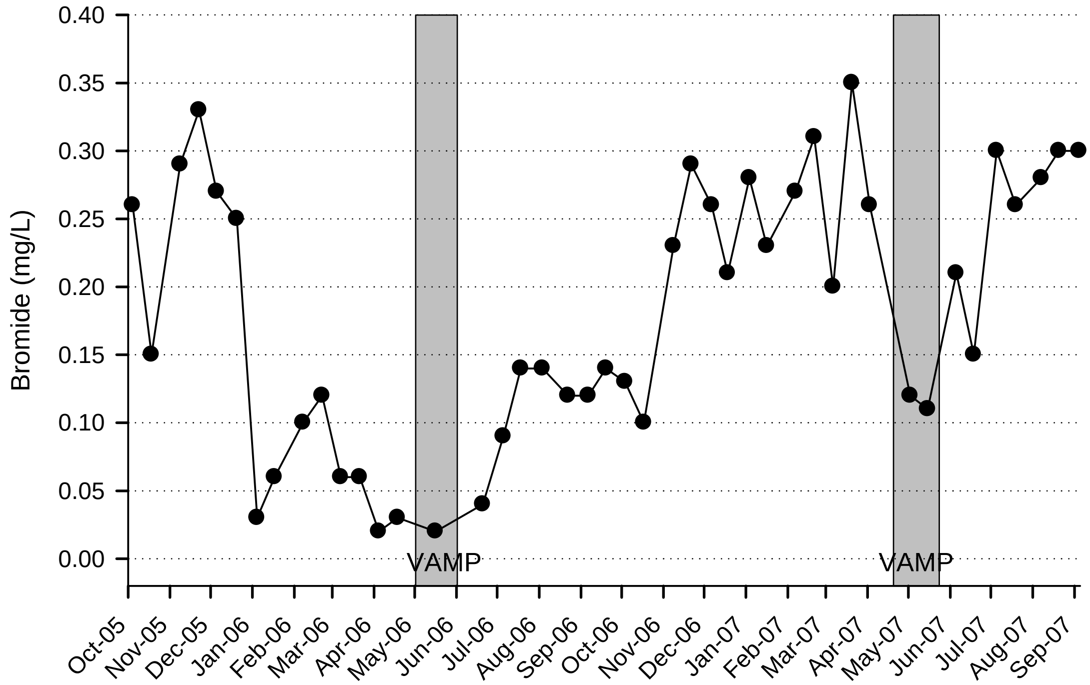

Figure 4-2 Bromide at Delta channel stations

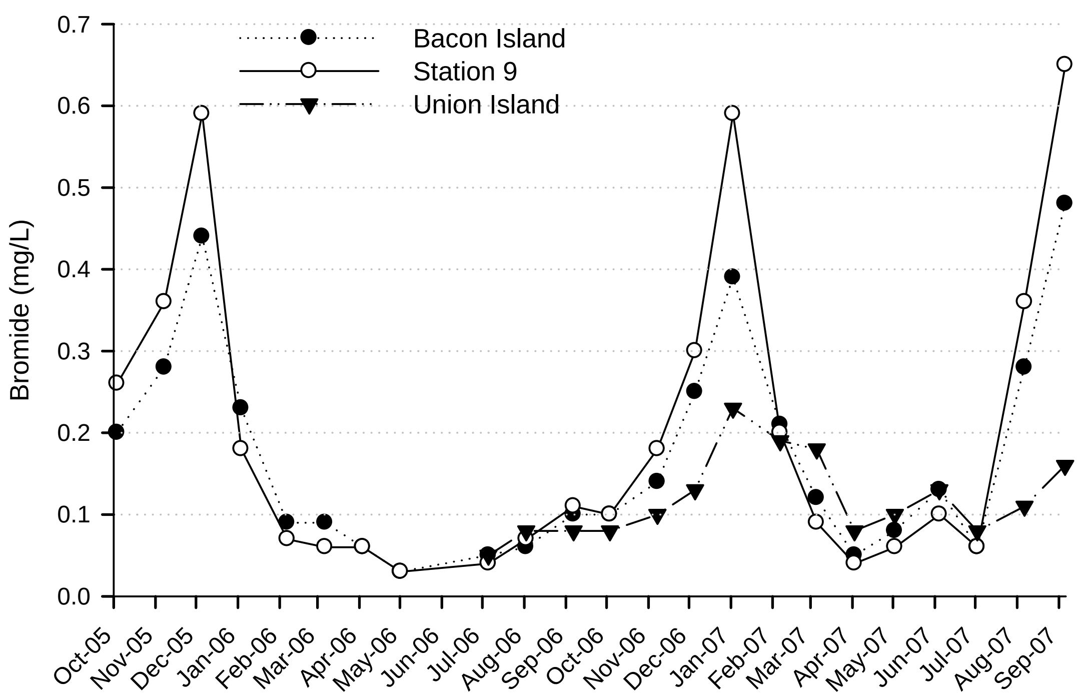

Figure 4-3 Bromide at diversion stations

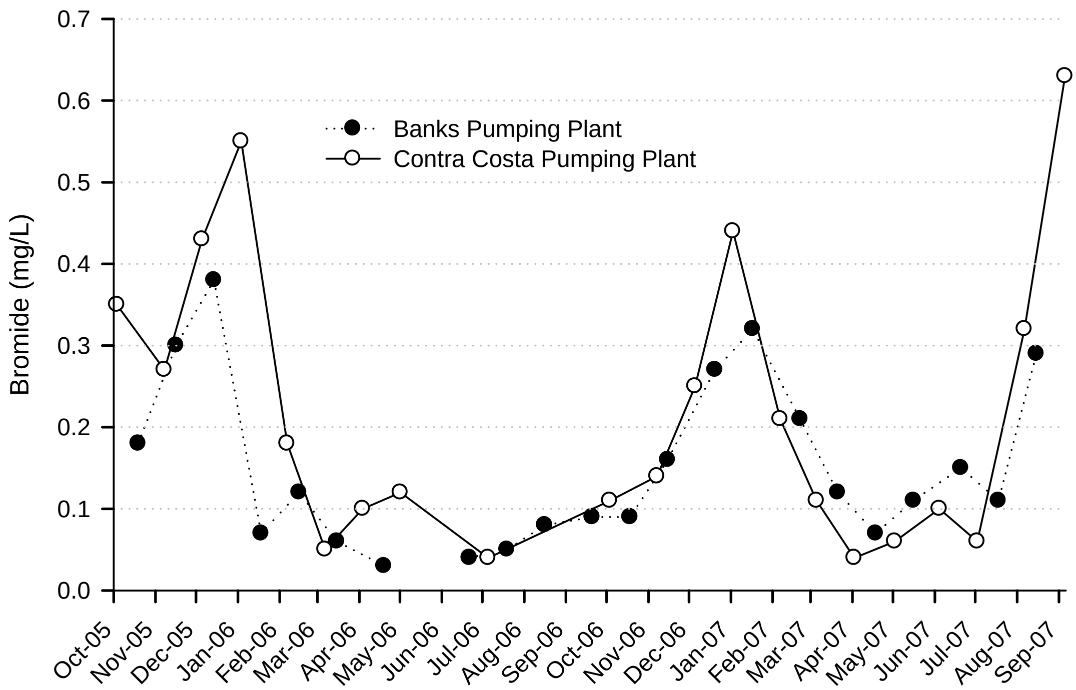

Figure 4-4 Bromide concentrations at the Mallard Island station

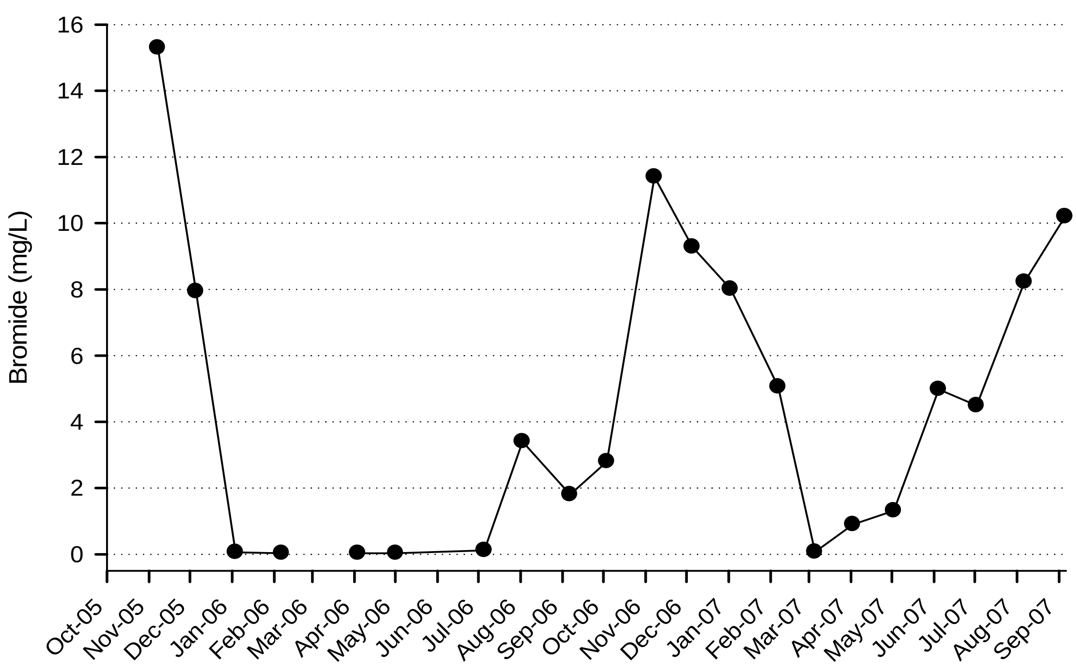

Figure 4-5 The relationship between bromide and chloride at 6 stations

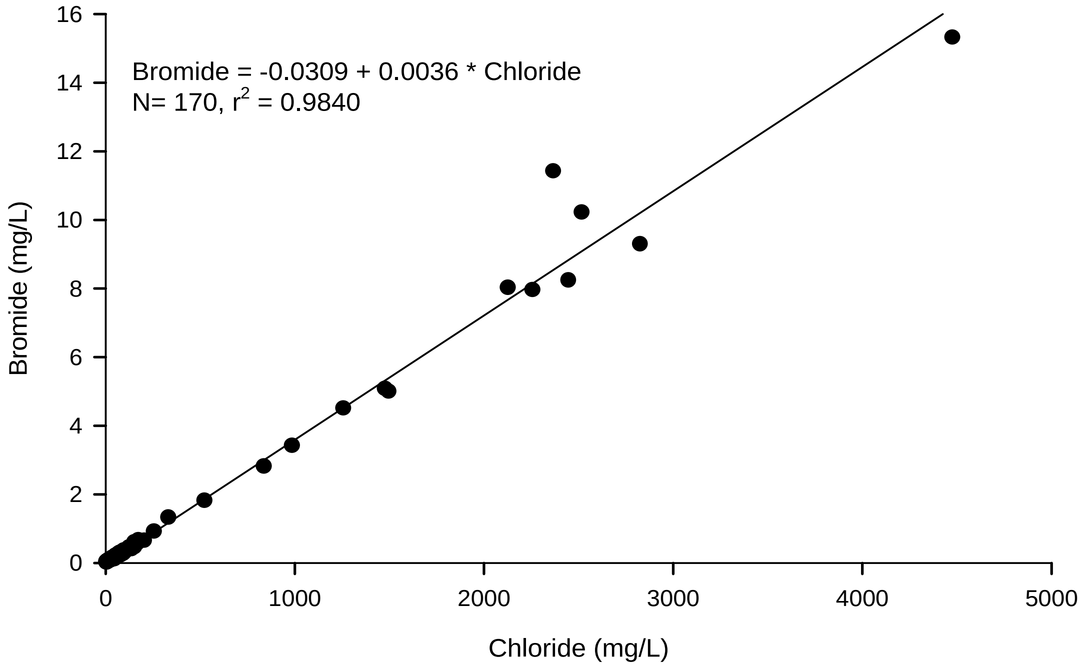

Figure 4-6 Bromide concentrations at Hood, WY 2002 to WY 2007

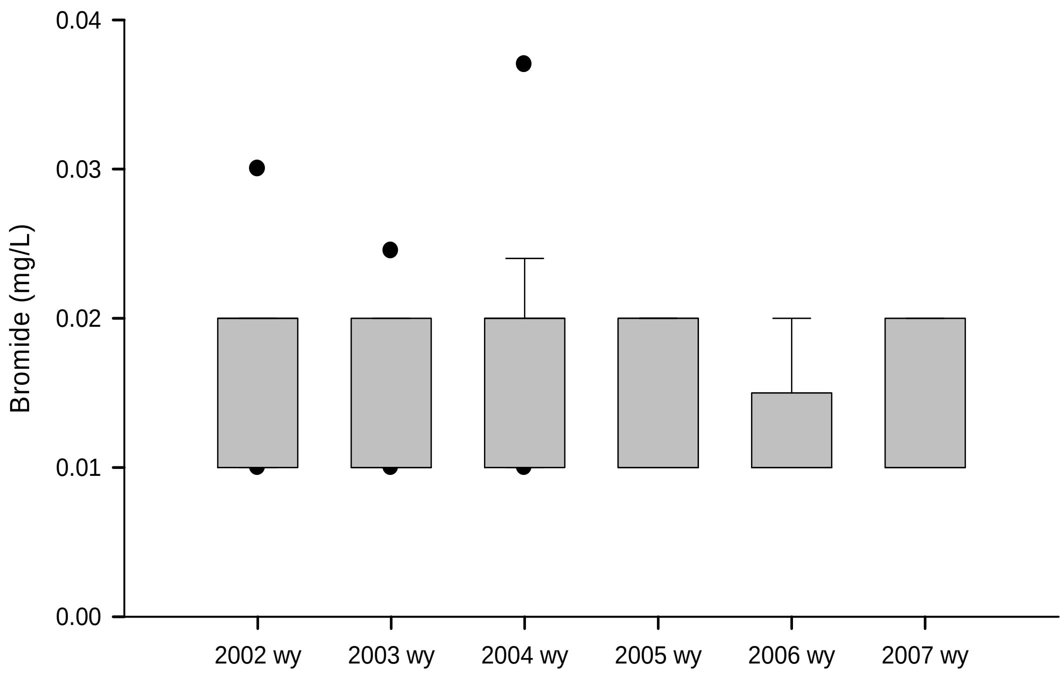

Figure 4-7 Bromide concentrations in the San Joaquin River near Vernalis, WY 2002 to WY 2007

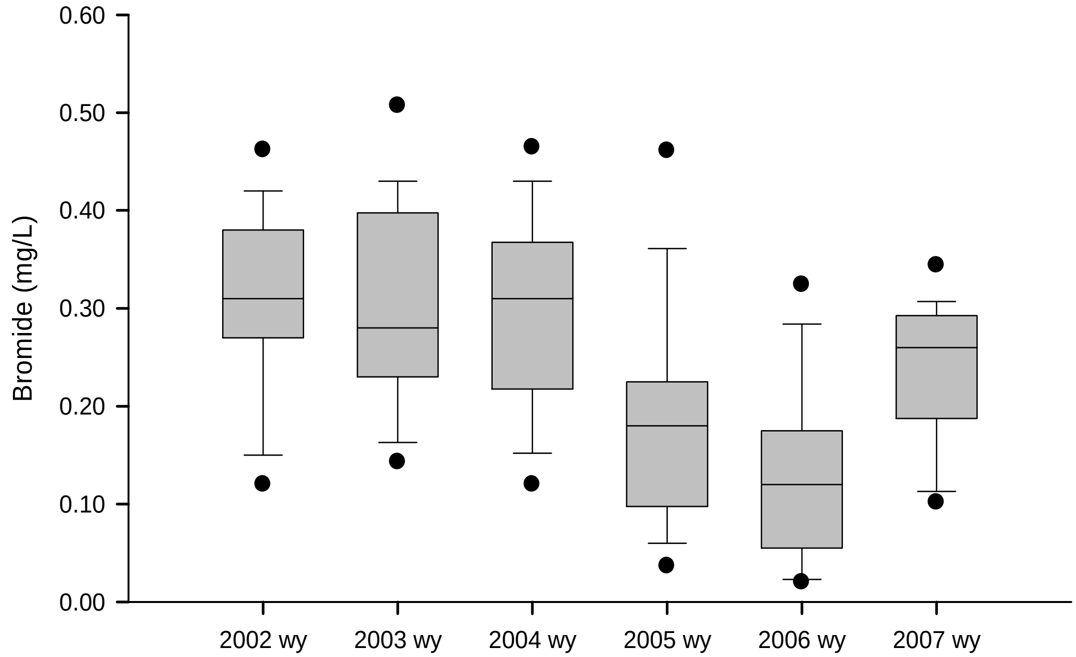

Figure 4-8 Bromide concentrations in the Sacramento River at Banks, WY 2002 to WY 2007

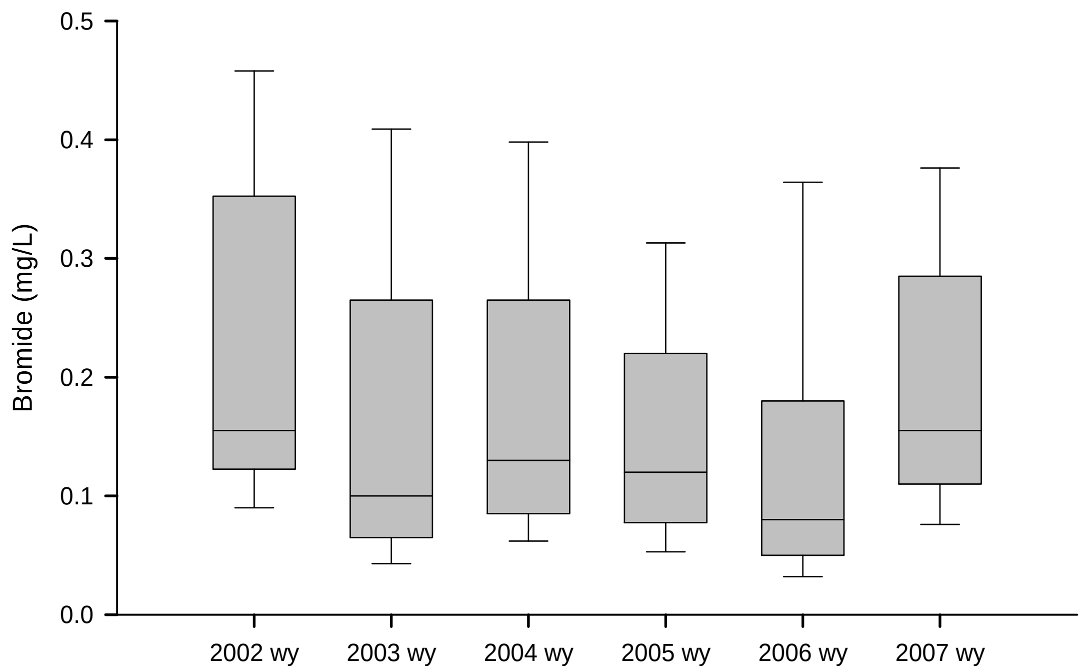

Figure 4-9 Bromide measurements: Range (median) in mg/L

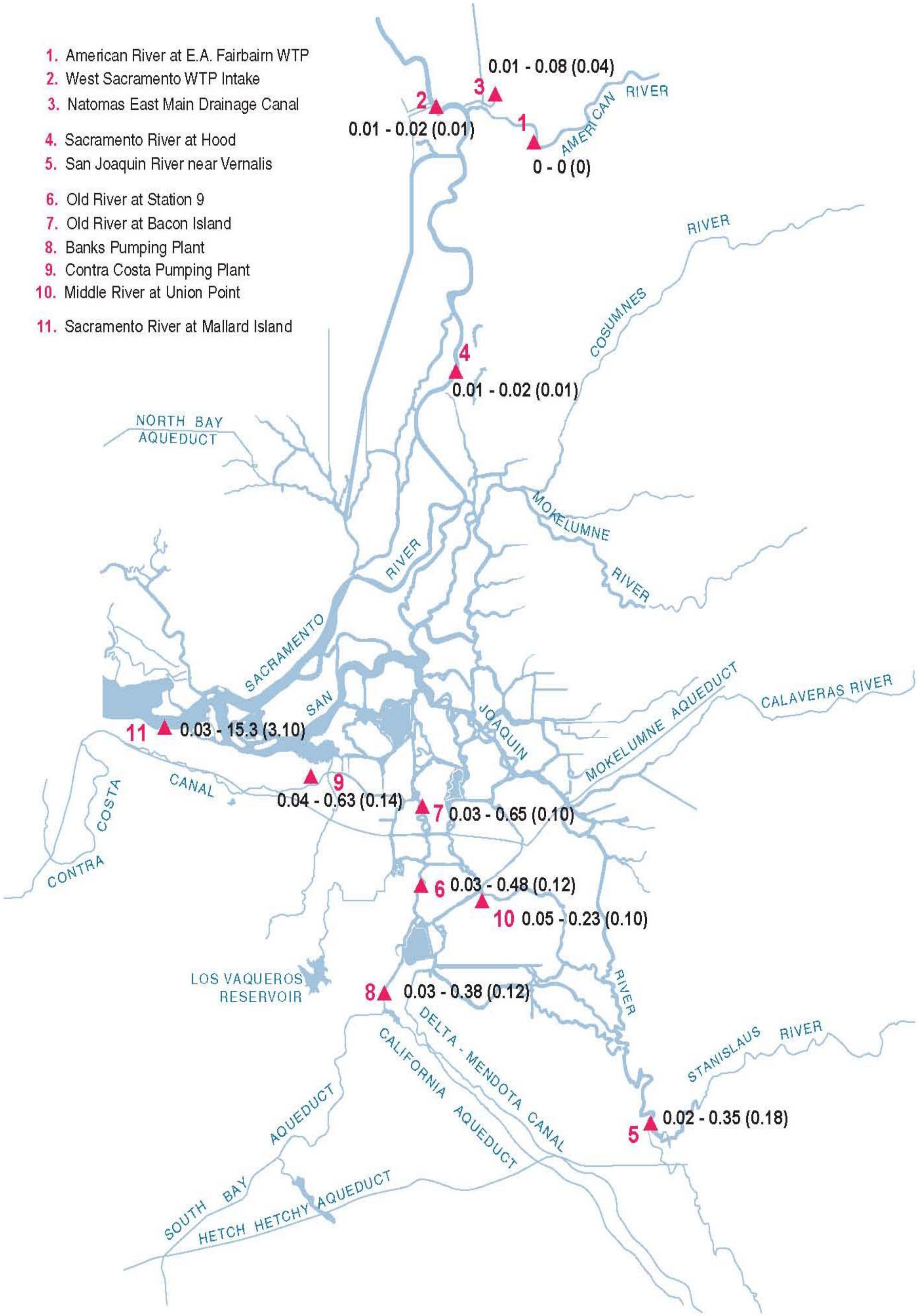

Table 4-1 Summary of bromide at 11 MWQI stations

	Oct 2005 - Sep 2007				Oct 2001 - Sep 2005	
Station	Detects/ Sample number	Range	Average	Median	Range	Median
		---------- mg/L ----------			---------- mg/L ---------	
Stations North of the Delta						
American River at E.A. Fairbairn WTP	0/22	–	–	–	–	–
West Sacramento WTP Intake	11/22	0.01-0.02	0.01	0.01	0.01–0.05	0.02
Natomas East Main Drainage Canal	27/29	0.01-0.08	0.04	0.04	0.01–0.20	0.05
Sacramento River at Hood	25/43	0.01-0.02	0.01	0.01	0.01–0.05	0.01
San Joaquin River near Vernalis	44/44	0.02-0.35	0.18	0.18	0.02–0.62	0.28
Channel and diversion stations						
Old River at Station 9	23/23	0.03-0.48	0.17	0.12	0.03–0.50	0.11
Old River at Bacon Island	23/23	0.03-0.65	0.20	0.10	0.01–0.60	0.09
Banks Pumping Plant	22/23	0.03-0.38	0.15	0.12	0.04–0.47	0.13
Contra Costa Pumping Plant	21/21	0.04-0.63	0.22	0.14	0.03–0.73	0.17
Middle River at Union Point	15/15	0.05-0.23	0.12	0.10	–	–
Mallard Island	22/23	0.03-15.3	4.35	3.10	0.01–18.10	2.17

Table 4-2 Summary of bromide during 3 consecutive sampling periods

Station	Study period	Br (mg/L) Range	Average	Median
Sacramento River at Hood	2006–2007	0.01–0.02	0.01	0.01
	2004–2005	0.01–0.04	0.02	0.02
	2002–2003	0.01–0.05	0.02	0.01
	2001–2007	0.01–0.05	0.02	0.01
San Joaquin River near Vernalis	2006–2007	0.02–0.35	0.18	0.18
	2004–2005	0.02–0.62	0.26	0.24
	2002–2003	0.12–0.60	0.31	0.30
	2001–2007	0.02–0.62	0.26	0.26
Banks Pumping Plant	2006–2007	0.03–0.38	0.15	0.12
	2004–2005	0.05–0.31	0.13	0.11
	2002–2003	0.04–0.47	0.19	0.15
	2001–2007	0.03–0.47	0.17	0.13

Chapter 5 Nutrients

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Chapter 5 Nutrients

Nutrient concentrations indicate the potential for algal and vascular plant growth throughout the Delta. Excess nutrients lead to significant water quality problems, including harmful algal blooms, hypoxia, increases in human pathogens, and deterioration in taste, odor, and other aesthetic qualities. The US Environmental Protection Agency (EPA) has established primary maximum contaminant levels (MCLs) for nitrate of 45 mg for NO_3/L and 10 mg N/L for nitrate plus nitrite. However, no federal or State drinking water standards have been developed for phosphorus. The EPA has been working on the development and adoption of national nutrient criteria for water quality standards since 2001.

Monitored nutrients include dissolved nitrate, combined nitrate and nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, and orthophosphates. In this report, total nitrogen was calculated as the sum of TKN plus nitrate plus nitrite, while inorganic nitrogen was calculated as the sum of ammonia plus nitrate plus nitrite. Both total phosphorus and orthophosphate were monitored. Orthophosphate is the only form that is generally available for algal and plant uptake, but total phosphorus is a better indicator of the productivity of a system (Archibald Consulting 2007).

Stations North of the Delta

Of the 11 stations monitored, the lowest median concentrations of nutrients were found at the American River at E.A. Fairbairn Water Treatment Plant (WTP) Intake and at the West Sacramento WTP Intake. These stations had the lowest inorganic and total nitrogen medians (Table 5-1). Nitrogen concentrations at both stations followed regular seasonal patterns of biological uptake during the spring and summer, and increased nitrogen concentrations during the fall and winter. Increases in the fall and winter occurred as nitrogen was mobilized from the soil during runoff and sediment releases from inflows and precipitation (Figure 5-1).

Table 5-1 Summary of inorganic, organic, and total nitrogen, Oct 2005 through Sep 2007

Figure 5-1 Nutrient concentrations at West Sacramento WTP Intake

At both stations, concentrations of total phosphorus and orthophosphates followed seasonal patterns similar to those for nitrogen (Figure 5-1). Phosphate concentrations were low in the summer due to biological activity. In the winter, concentrations increased due to runoff.

With the exception of the Vernalis station, the Natomas East Main Drainage Canal (NEMDC) had the highest median concentrations of nitrogen, total phosphorus, and orthophosphates. The Vernalis station had slightly higher median concentrations of inorganic and total nitrogen (Tables 5-1 and 5-2). Unlike the nearby river stations, concentrations of inorganic nitrogen at NEMDC were often higher than concentrations of TKN (Figure 5-2). Most of the total phosphorus was present as dissolved orthophosphate (Figure 5-2). This elevation in inorganic nutrients may be attributed to nitrogen and phosphorus fertilizers used in some areas of the watershed. NEMDC collects water from a variety of sources, including surface drainage from a highly

Table 5-2 Summary of total phosphorus and orthophosphates data at 11 MWQI stations

Figure 5-2 Nutrient concentrations at Natomas East Main Drainage Canal

populated watershed, small amounts of agricultural drainage, and a wastewater treatment plant. Seasonally, both nitrogen and phosphorus were diluted by the heavy rains in water year (WY) 2006. WY 2007 had relatively little rain and nitrogen concentrations remained high, while phosphate levels showed some dilution (Figures 5-1 and 5-2).

Sacramento River at Hood

A wastewater treatment plant, the Morrison Creek drainage, and an active marina discharge upstream from the Hood station and downstream from the West Sacramento WTP station. Median concentrations of inorganic nitrogen, total nitrogen, and phosphorus were higher at Hood than at upstream sites (Tables 5-1 and 5-2), such as the American River and West Sacramento WTP stations. Wastewater discharges and urban runoff were probably partially responsible for these increases (Figure 5-3). Nutrient levels tended to increase seasonally with increased runoff during the winter and fall. Nutrient levels tended to fall during the summer due to biological uptake; however, nutrients levels rose from mid May through July, which were the dry months of WY 2007 (Figure 5-3).

Figure 5-3 Nutrient concentrations at Sacramento River at Hood

San Joaquin River near Vernalis

Among all stations, the highest median inorganic and total nitrogen concentrations were found at the San Joaquin River (SJR) near Vernalis (Table 5-1). Nutrient seasonality at this station was complicated by applications of nitrogen and phosphorus fertilizers on agricultural lands along the SJR and its tributaries. During the wet months of both WYs, nutrient levels increased with precipitation; however, the WY 2006 levels were diluted by a large amount of runoff (Figure 2-5). This was not the case in WY 2007 where nutrient levels generally remained high throughout the summer and winter (Figure 5-4). When the Vernalis Adaptive Management Plan (VAMP) was in effect, nutrient levels dropped; however, nitrogen levels began to rise in June each year and reached the highest dry-month levels between July and October (Figure 5-4). These increased concentrations are possibly due to the growing season and more specifically with the agricultural drainage inflows to the river. Because a considerable portion of nitrogen is bound with organic carbon, higher organic carbon concentrations were detected at Vernalis. TKN, orthophosphates, and total phosphorus concentrations at Vernalis were lower than those found at NEMDC, but higher than the stations north of the Delta.

Figure 5-4 Nutrient concentrations at San Joaquin River near Vernalis

Channel and Diversion Stations

Water at the channel and diversion stations come from multiple sources. The ranges and medians of nutrient concentrations at the channel and diversion stations were close to those found at Hood, but less than those found at Vernalis (Tables 5-1 and 5-2). Nitrogen and phosphorus concentrations were generally higher during the wet months and lower during the dry months of each water year (Figures 5-5 and 5-6). Increased algal activities in the rivers and channels of the Delta may be the cause of lower nitrogen concentration during the dry months; however, at no time did the system appear to be nutrient limited as concentrations below the detection limits were never recorded. Higher concentrations of nutrients occurred from December to March in response to rainfall; however, as precipitation continued, the concentration of nutrients gradually decreased. Cyclical patterns of seasonal change were less obvious for both total phosphorus and orthophosphates. Concentrations at the channel stations at Middle River at Union Point and Old River at Station 9 were comparable to those at the diversion station at Banks Pumping Plant (Figure 5-5). At these 3 stations, nutrients levels generally increased or decreased based on the relative contribution of high nutrient San Joaquin River waters (Figures 2-10 and 5-5). Contra Costa Pumping Plant #1 (CCPP) is a diversion station that pumps water from Rock Slough which generally has a high percentage of Sacramento River water (Figures 2-9 and 5-6). Total nitrogen at CCPP and Old River at Bacon Island were statistically different (p=0.5413), which could be the result of some samples collected at CCPP during periods of no pumping.

Figure 5-5 Nutrient concentrations at stations near Clifton Court

Figure 5-6 Nutrient concentrations at Old River at Bacon Island and

Mallard Island

Nitrogen and phosphorus concentrations at the Mallard Island station were comparable to those at the channel and diversion stations (Tables 5-1 and 5-2). Low nutrient concentrations at Mallard Island may be attributed to several factors, including seawater influence, water diversion through pumping, and biological consumption of nutrients within the Delta. Of all the stations surveyed, Mallard Island is the most susceptible to tidal and seawater influences. Seawater with low nitrogen concentration diluted nitrogen concentrations at Mallard Island (Figure 5-7). In addition, when water passes through the biologically diverse and complex Delta, much of the nitrogen may be consumed before it reaches the Mallard Island station.

Figure 5-7 Nutrient concentrations at Mallard Island

Summary

Figures 5-8 and 5-9 show summary box plots by station for nitrogen and phosphorus. Among the 11 stations monitored for nitrogen and phosphorus, median inorganic and total nitrogen concentrations ranged from 0.04 to 1.41 mg/L and 0.14 to 1.90 mg/L, respectively. Median total phosphorus and orthophosphates ranged from 0.01 to 0.35 mg/L and 0.01 to 0.22 mg/L, respectively. The lowest nutrient concentrations were found at the American River at E.A. Fairbairn WTP, the West Sacramento WTP intake, and the Contra Costa Pumping Plant (Tables 5-1 and 5-2). The highest inorganic nitrogen and total nitrogen concentrations were found at the SJR near Vernalis and NEMDC (Figure 5-8 and Table 5-1), while the highest total phosphorus and orthophosphates concentration was found at NEMDC (Figure 5-9 and Table 5-2). Although the Hood station is near the north boundary of the Delta and receives high quality water from the American River, nutrient concentrations were much higher than at nearby stations. Elevated concentrations are possibly due to urban loads and wastewater

Figure 5-8 Nitrogen concentrations at sampling stations

Figure 5-9 Phosphorus concentrations at sampling stations

discharges upstream. Nutrient concentrations at most Delta channel and diversion stations were comparable to those at the Hood station. Due to the diluting influences of seawater, concentrations at the Mallard Island station were comparable or slightly lower that those found in the Delta channel and diversion stations.

Most stations showed the same overall seasonal patterns. Nutrient concentrations were generally higher in the winter than in the summer, but in WY 2006, which had heavy amounts of precipitation, elevated nutrient levels became diluted as the winter season progressed. In contrast, during the dry WY 2007, low levels of rainfall never diluted high nutrient concentrations. This effect was most pronounced at the Vernalis station, which already had higher nutrient concentrations during the summer due to agricultural runoff. Concentrations remained high throughout the winter and no discernable drop-off in nutrients occurred from approximately from June 2006 through September 2007.

Chapter 5 Nutrients

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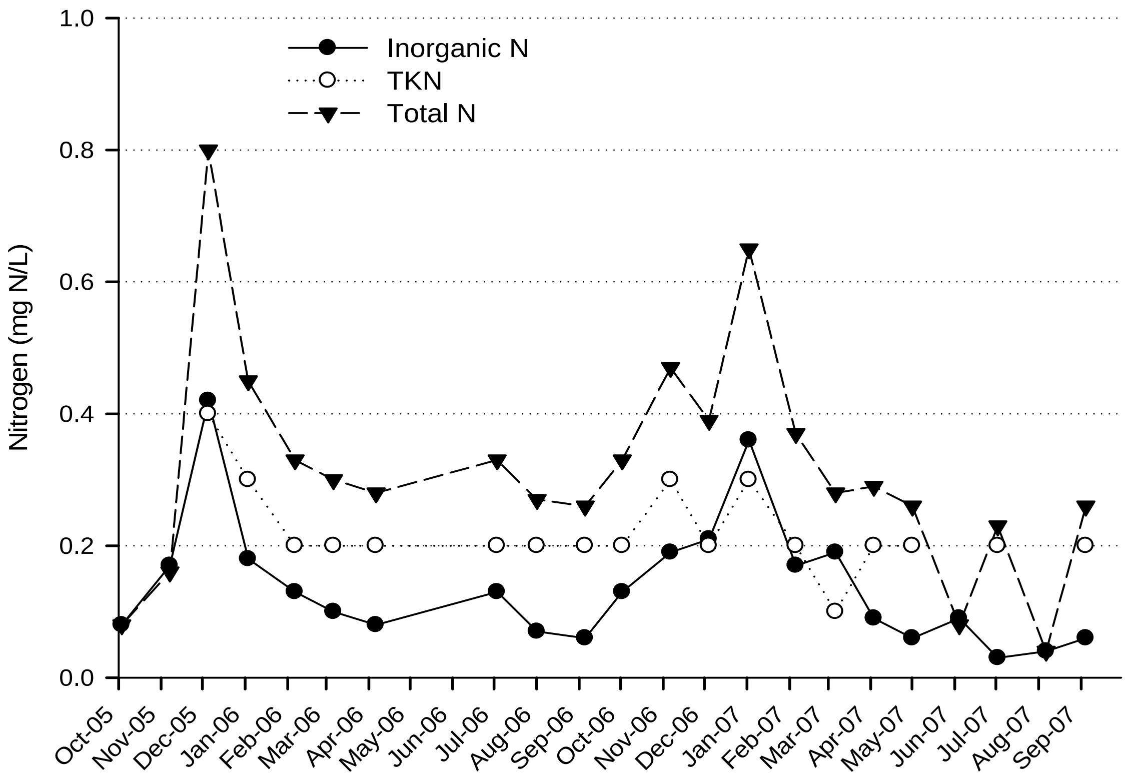


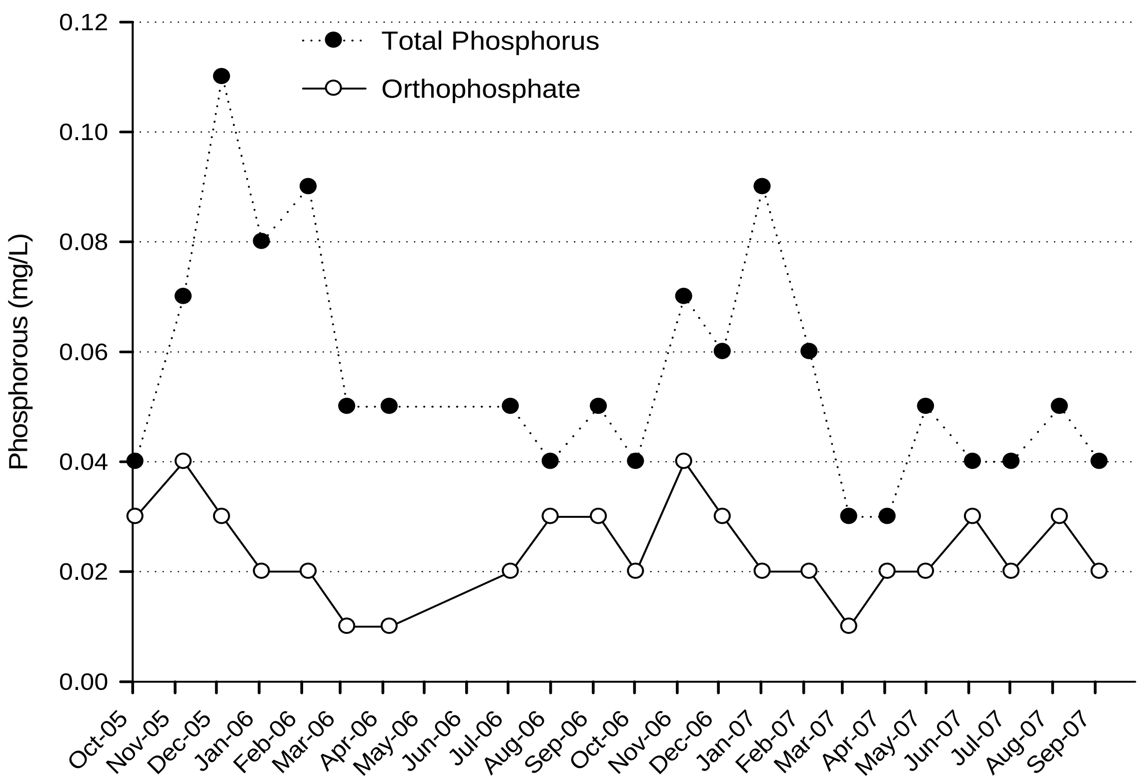
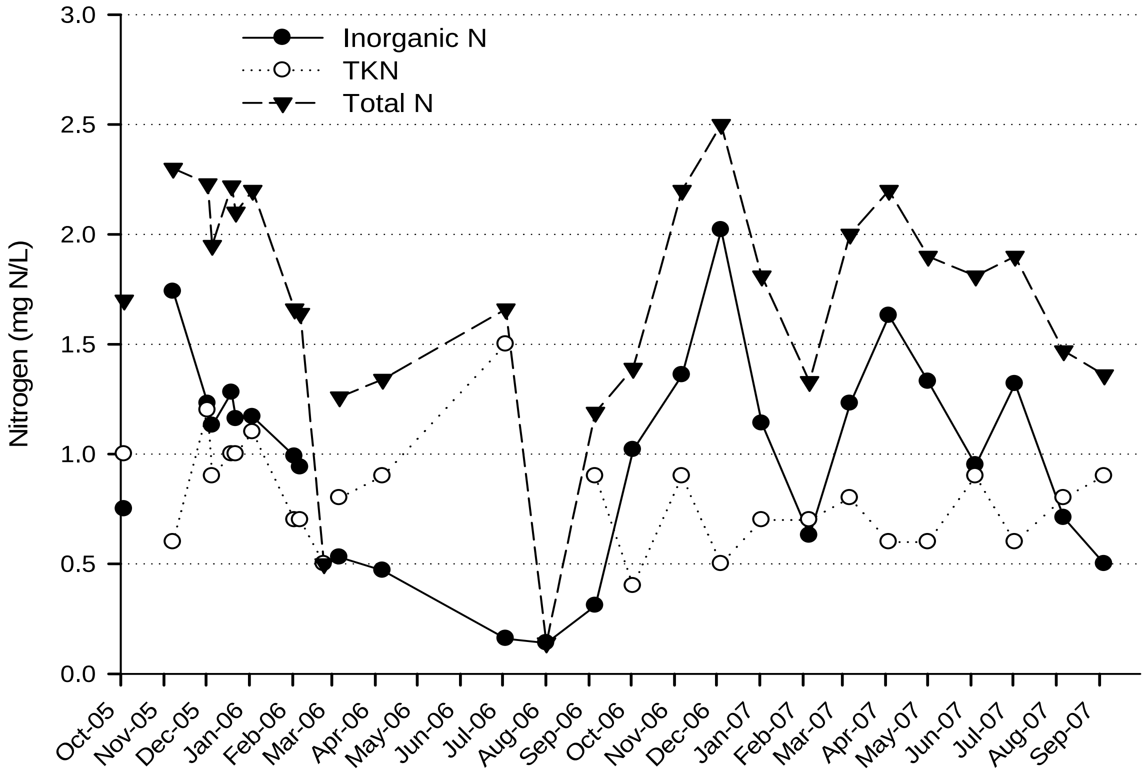


Figure 5-2 Nutrient concentrations at Natomas East Main Drainage Canal



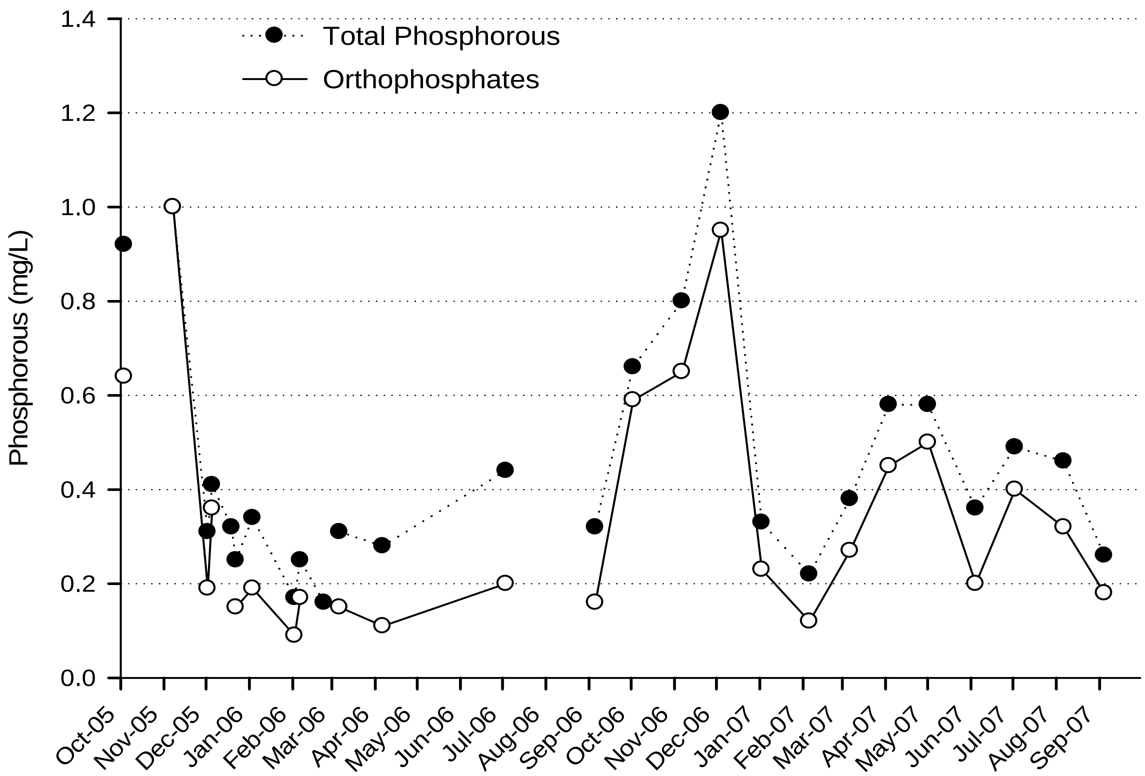


Figure 5-3 Nutrient concentrations at Sacramento River at Hood

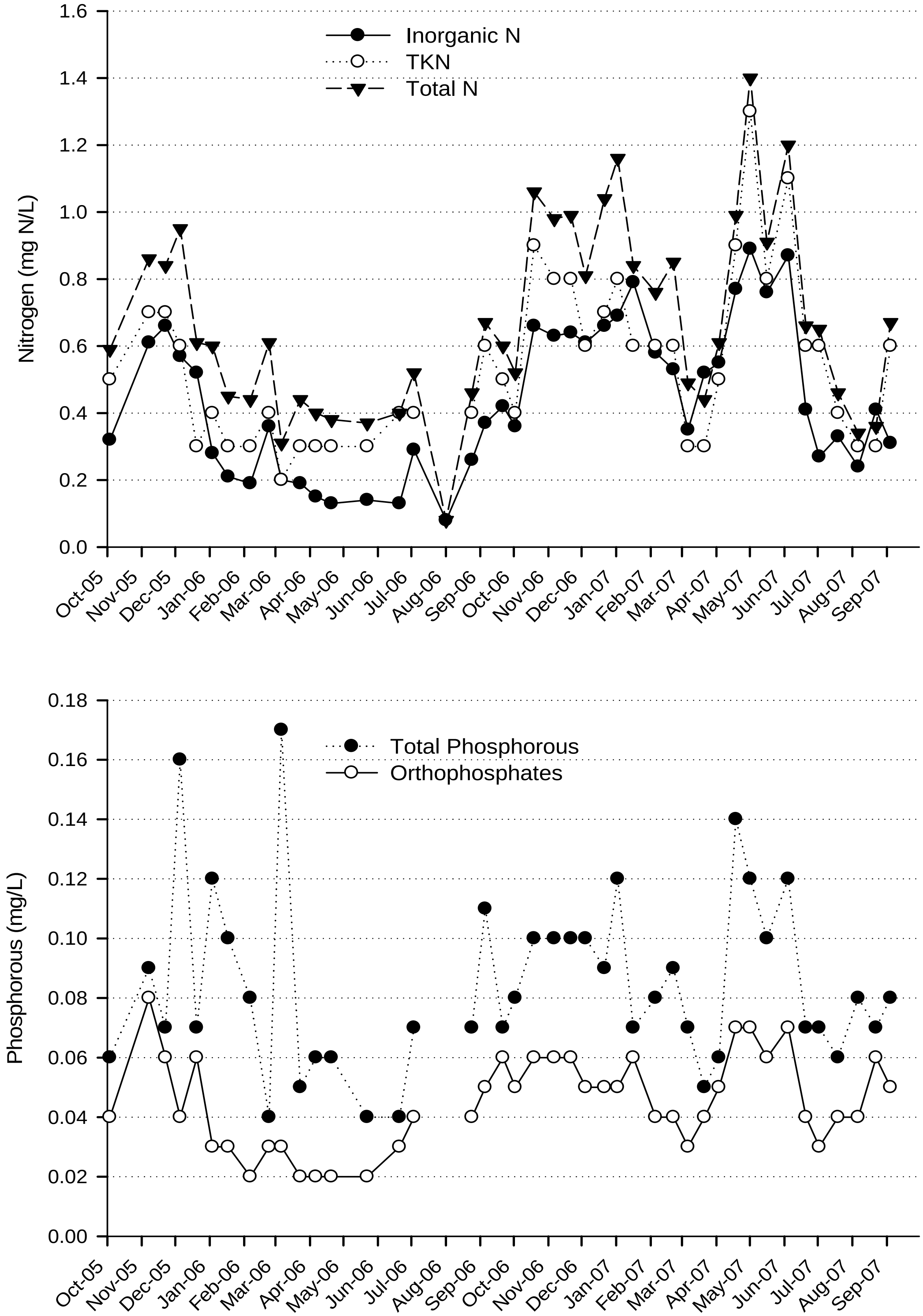


Figure 5-4 Nutrient concentrations at San Joaquin River near Vernalis

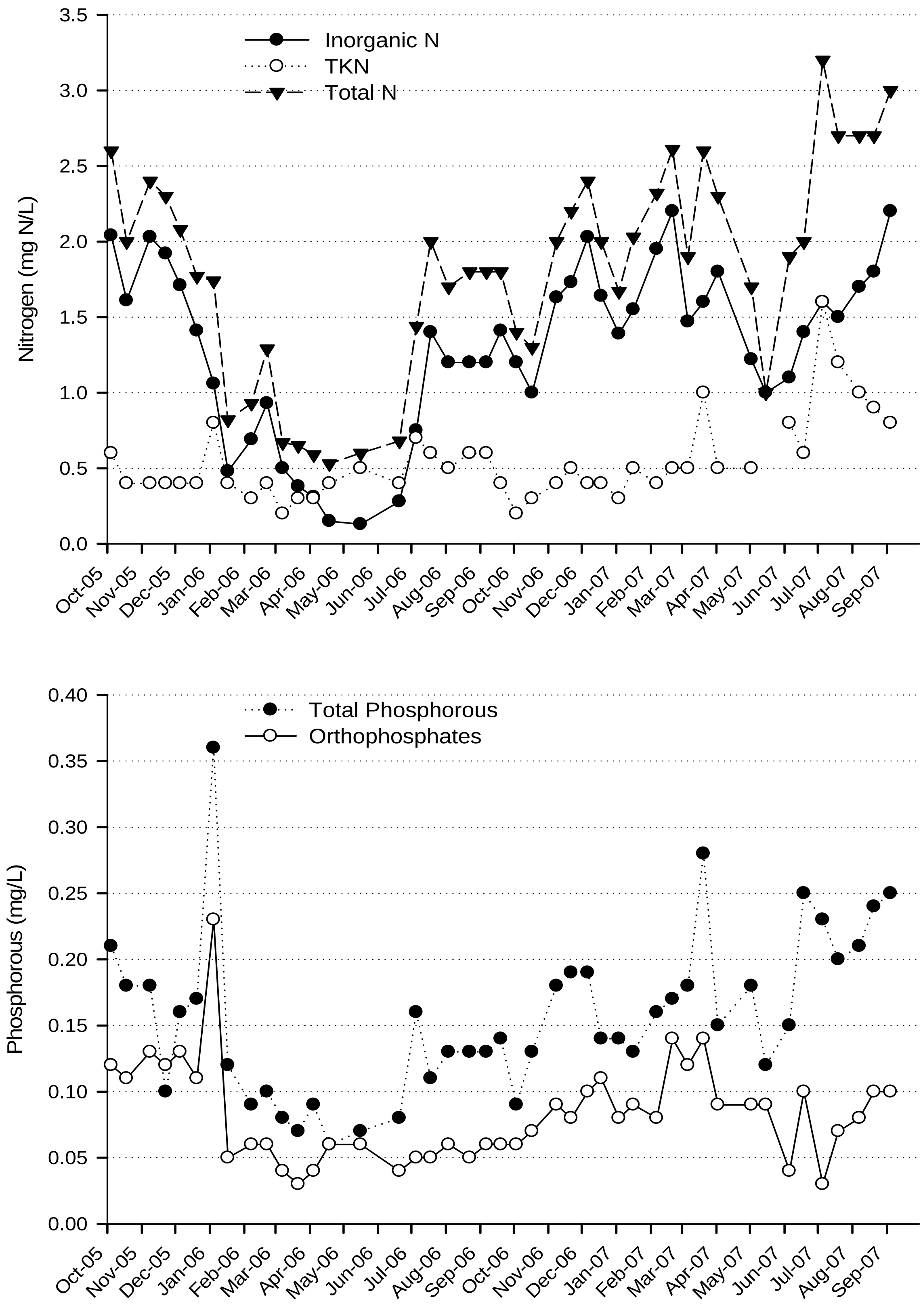
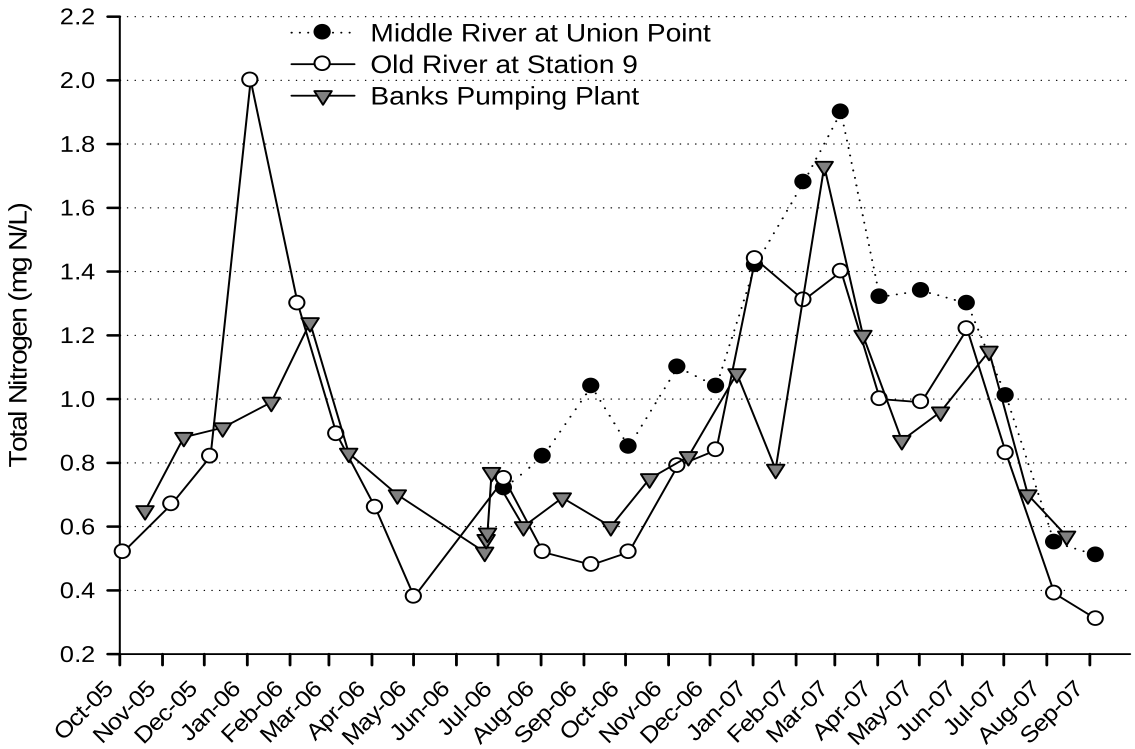


Figure 5-5 Nutrient concentrations at stations near Clifton Court Forebay

Nitrogen



Phosphorus

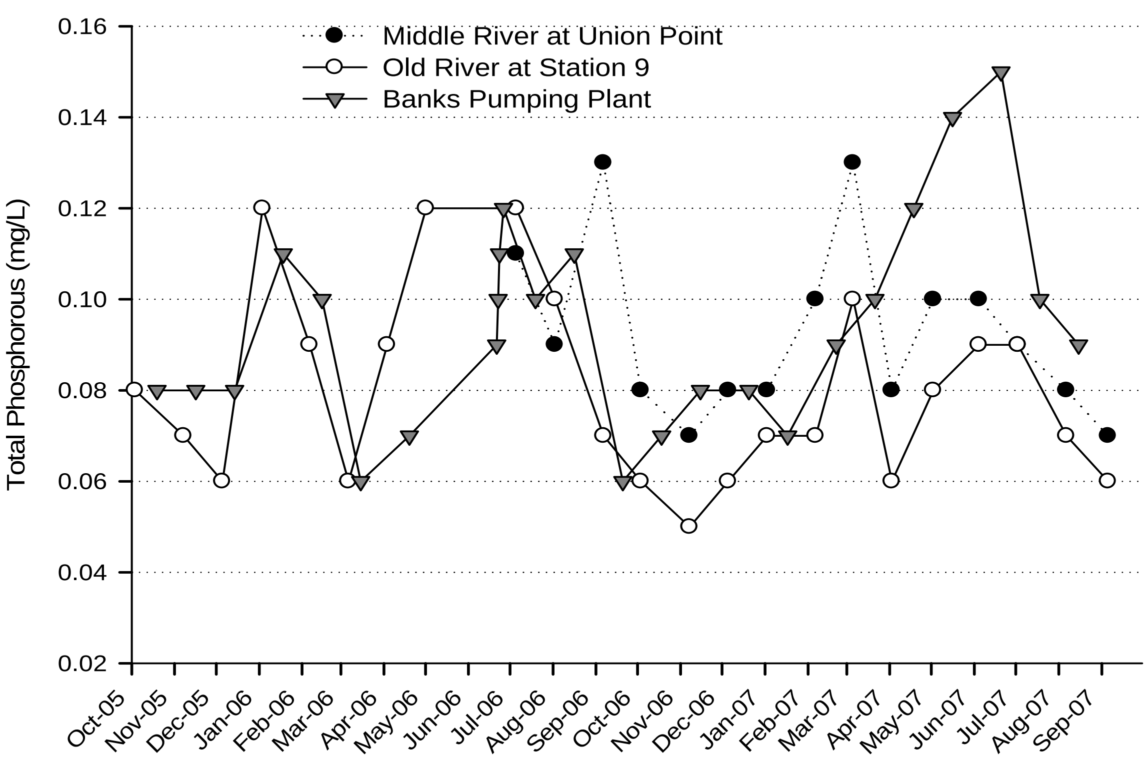
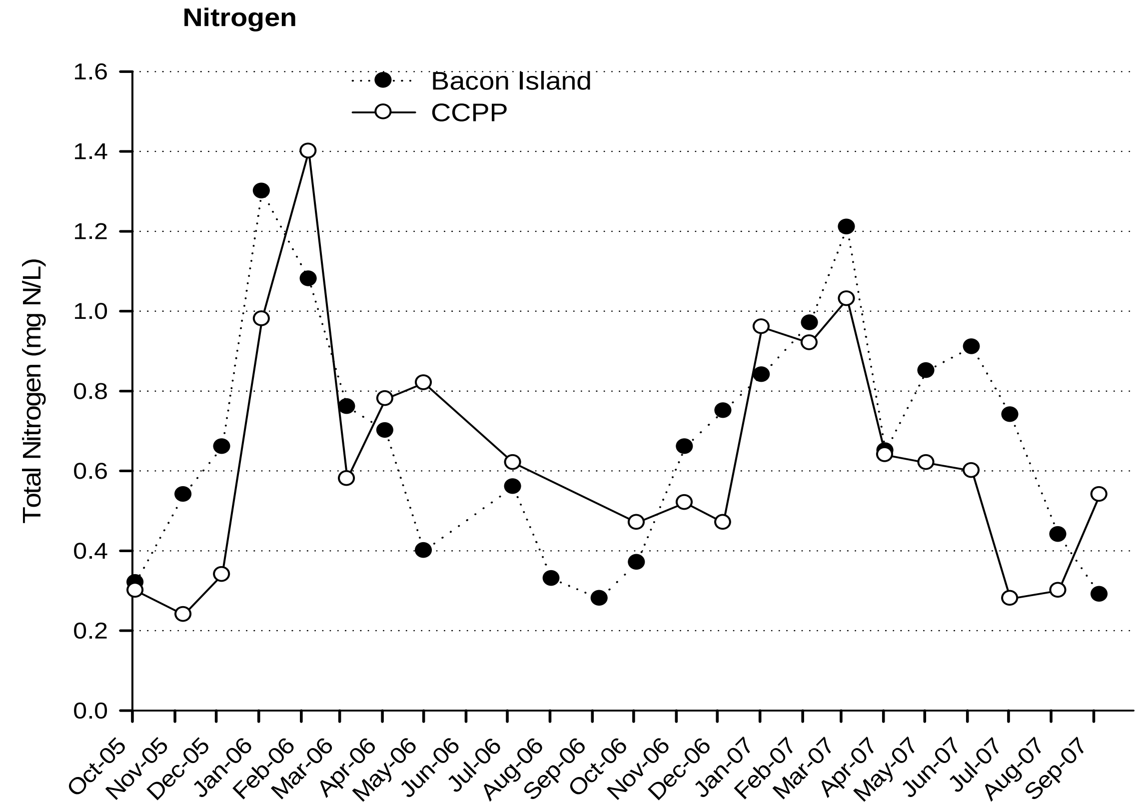


Figure 5-6 Nutrient concentrations at Old River at Bacon Island and Contra Costa Pumping Plant



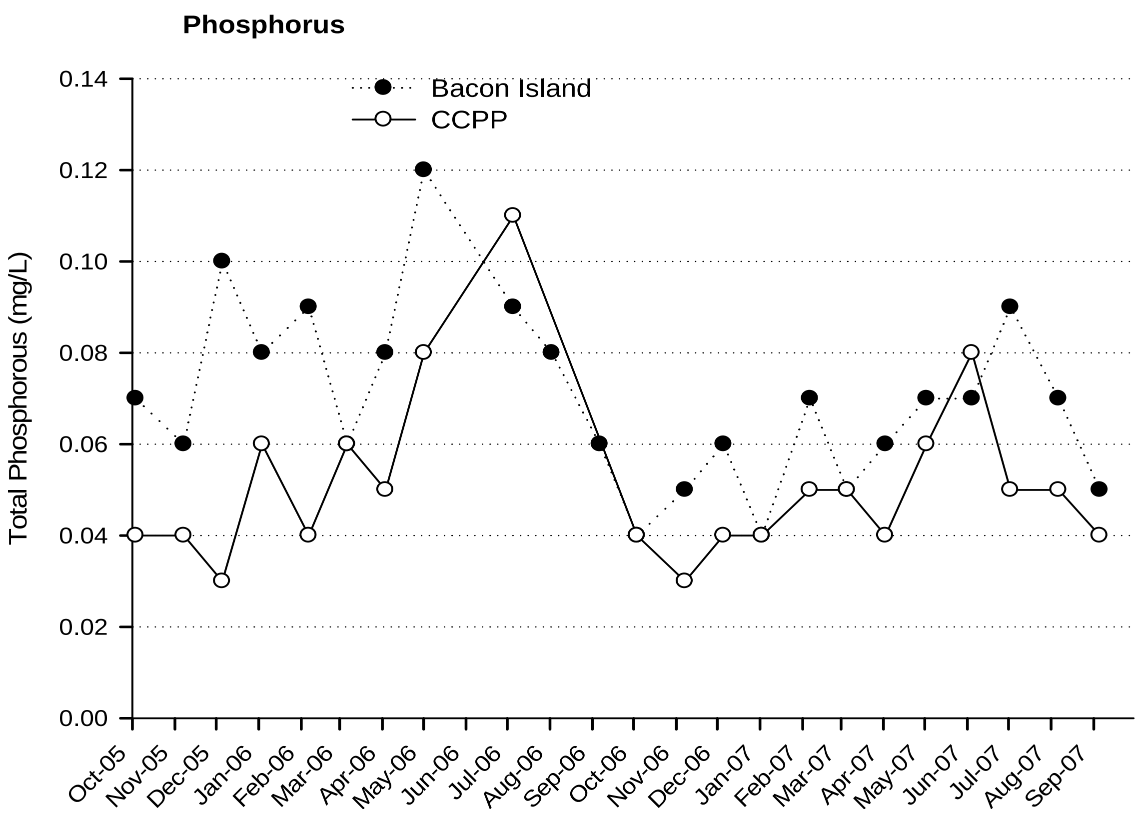


Figure 5-7 Nutrient concentrations at Mallard Island

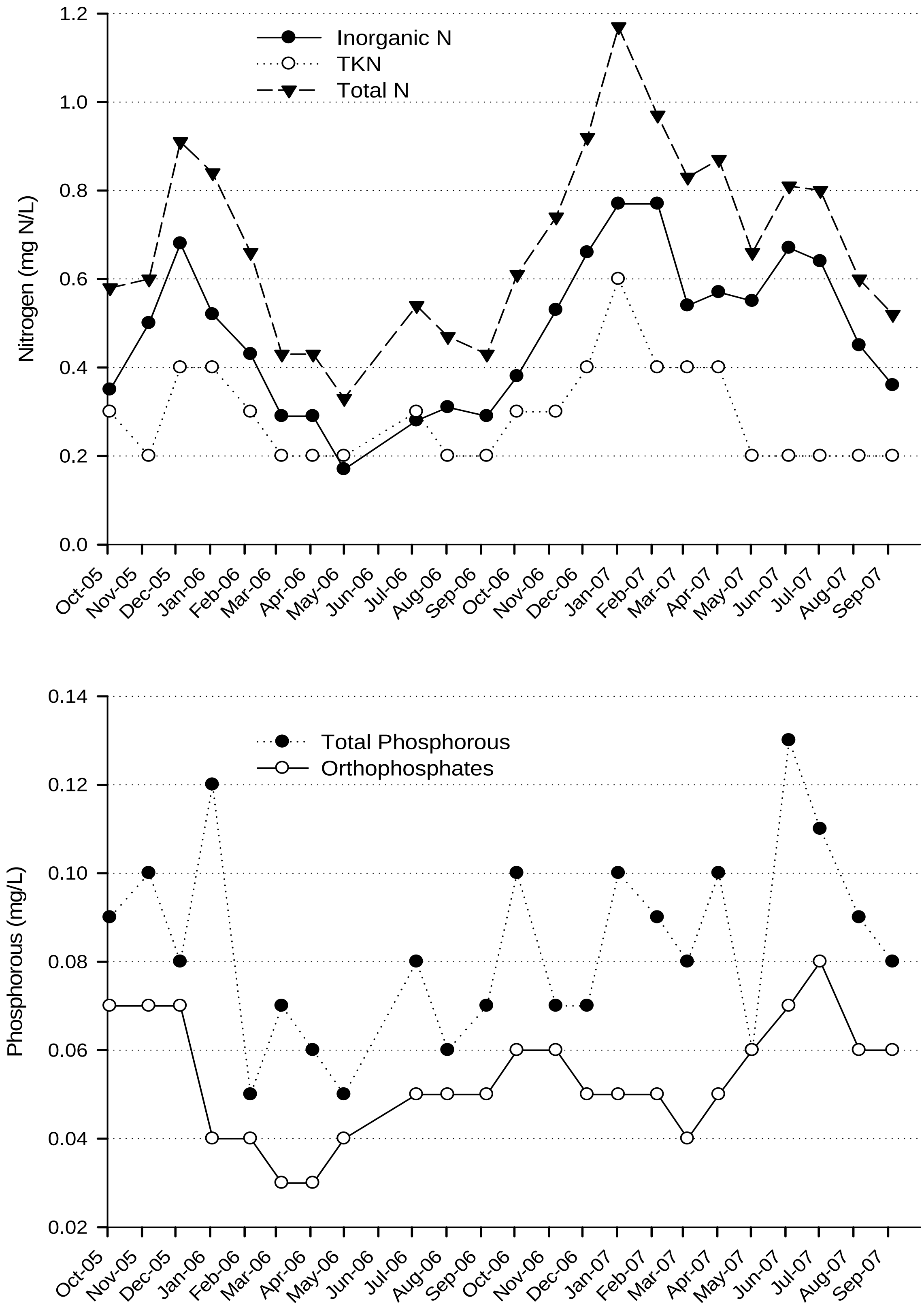


Figure 5-8 Nitrogen concentrations at sampling stations

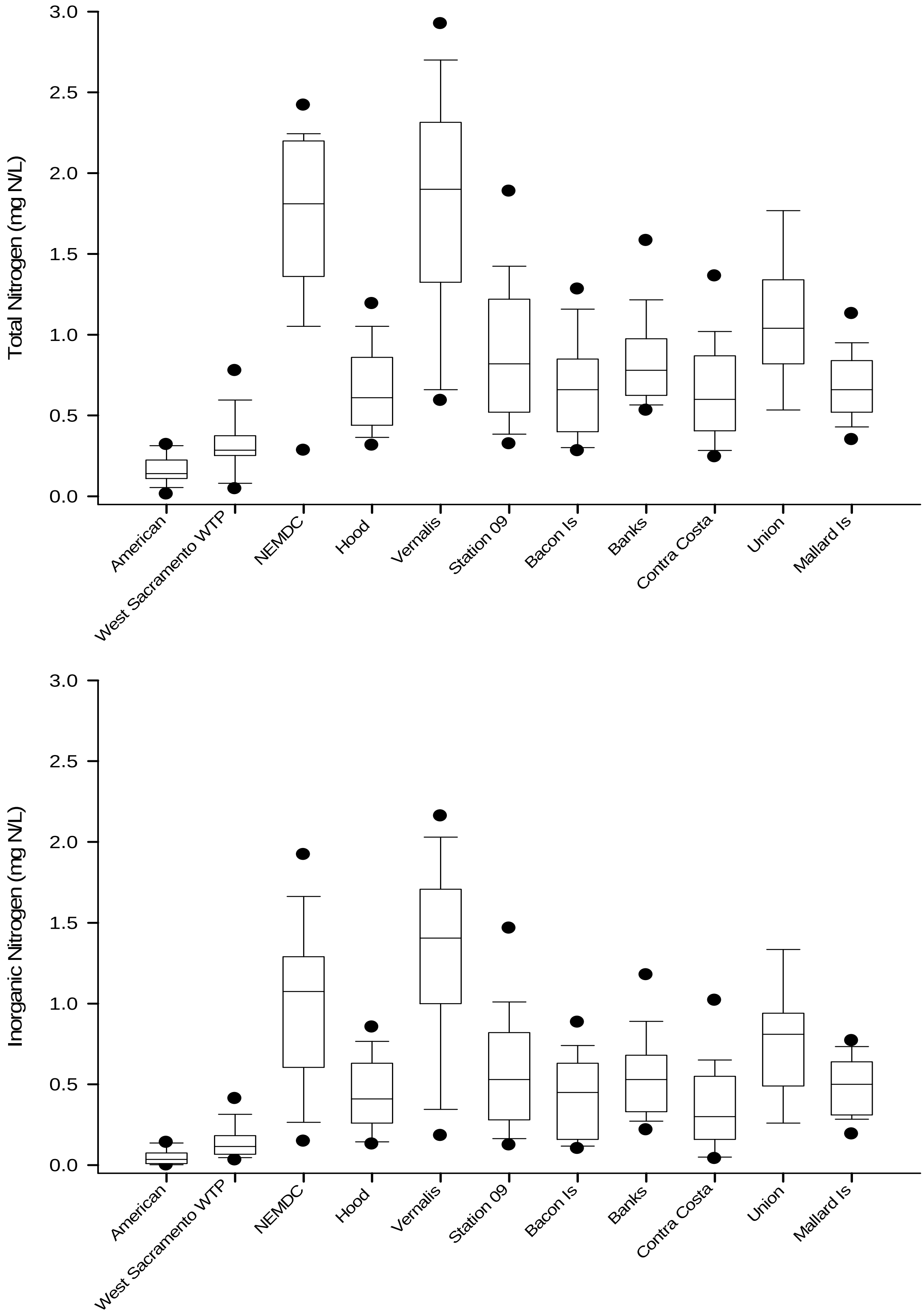


Figure 5-9 Phosphorus concentrations at sampling stations

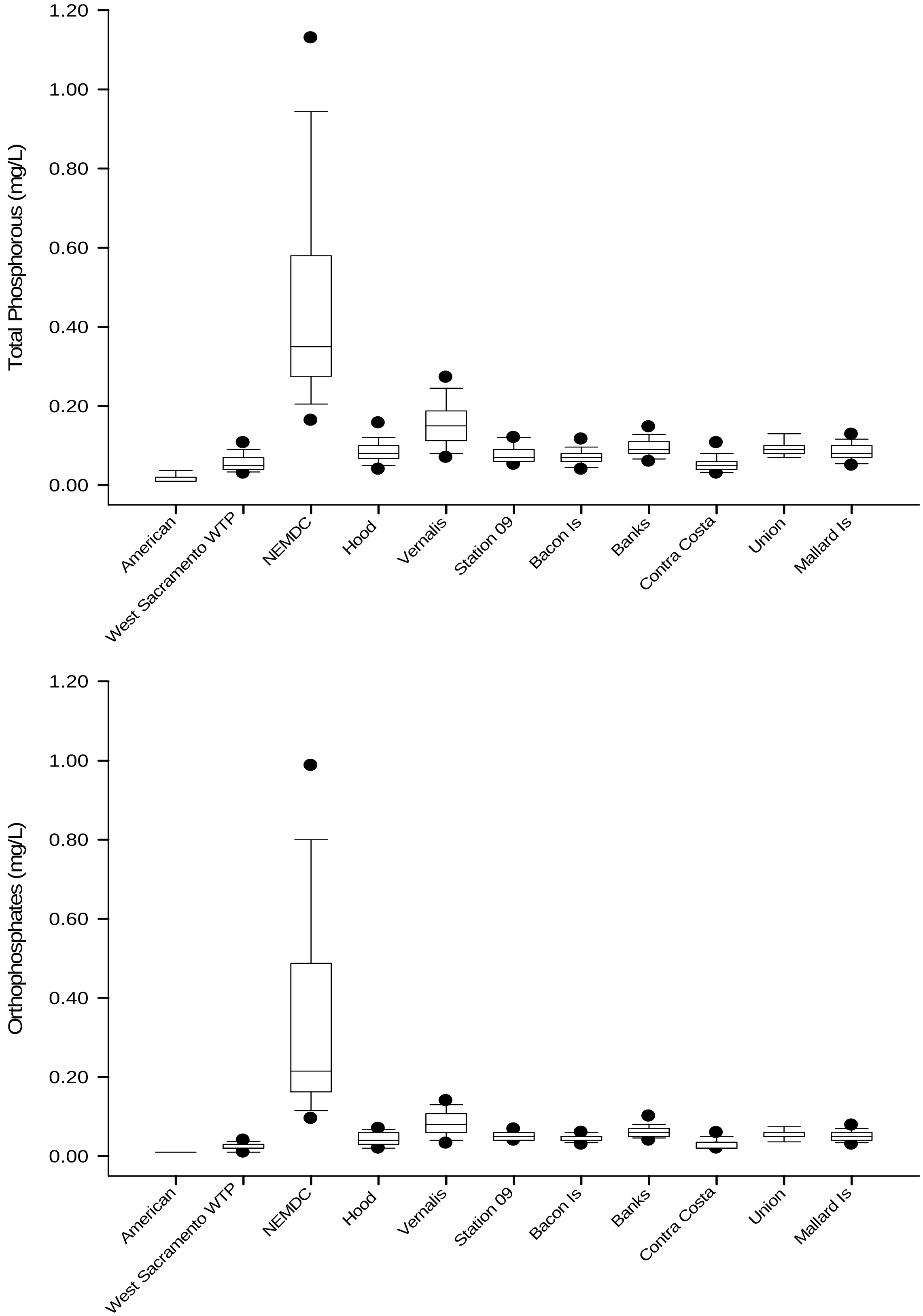


Table 5-1 Summary of inorganic, organic, and total nitrogen, Oct 2005 through Sep 2007

	Inorganic N *			Total Kjeldahl nitrogen (TKN)			Total nitrogen **		
	Range	Average	Median	Range	Average	Median	Range	Average	Median
Station		mg/L as N			mg/L as N			mg/L as N	
Stations North of the Delta									
American River at E.A. Fairbairn WTP	0.00-0.14	0.05	0.04	0.1-0.2	0.1	0.1	0.01-0.32	0.17	0.14
West Sacramento WTP Intake	0.03-0.42	0.14	0.12	0.1-0.4	0.2	0.2	0.04-0.80	0.31	0.29
Natomas East Main Drainage Canal	0.14-2.02	0.99	1.08	0.4-1.5	0.8	0.8	0.14-2.50	1.70	1.81
Sacramento River at Hood	0.08-0.89	0.44	0.41	0.2-1.3	0.5	0.5	0.08-1.40	0.67	0.61
San Joaquin River near Vernalis	0.13-2.20	1.31	1.41	0.2-1.6	0.5	0.5	0.58-3.20	1.81	1.90
Channel and diversion stations									
Old River at Station 9	0.12-1.57	0.57	0.53	0.2-0.6	0.4	0.3	0.31-2.00	0.87	0.82
Old River at Bacon Island	0.10-0.92	0.42	0.45	0.2-0.5	0.3	0.3	0.28-1.30	0.68	0.66
Banks Pumping Plant	0.20-1.30	0.55	0.53	0.2-0.5	0.3	0.3	0.52-1.73	1.85	0.78
Contra Costa Pumping Plant	0.04-1.02	0.35	0.3	0.2-0.5	0.4	0.4	0.24-1.40	0.64	0.6
Middle River at Union Point	0.23-1.46	0.76	0.81	0.2-0.6	0.4	0.4	0.51-1.90	1.11	1.04
Mallard Island	0.17-0.77	0.48	0.5	0.2-0.6	0.3	0.3	0.33-1.17	0.68	0.66

* Inorganic N includes ammonia,nitrate and nitrite.

** Total Nitrogen includes TKN and nitrate and nitrite

Table 5-2 Summary of total phosphorus and orthophosphates data at 11 MWQI stations

	Total Phosphorus				Orthophosphates			
Station	Positive detects/ sample number	Range	Average	Median	Positive detects/ sample number	Range	Average	Median
		-------- mg/L -----------				--------- mg/L ---------		
Stations North of the Delta								
American River at E.A. Fairbairn WTP	18/22	0.01-0.10	0.02	0.01	1/22	0.01-0.01	0.01	0.01
West Sacramento WTP Intake	22/22	0.03-0.11	0.06	0.05	22/22	0.01-0.04	0.02	0.02
Natomas East Main Drainage Canal	26/27	0.16-1.20	0.45	0.35	24/26	0.09-1.00	0.34	0.22
Sacramento River at Hood	42/42	0.04-0.17	0.08	0.08	42/42	0.02-0.08	0.05	0.04
San Joaquin River near Vernalis	44/44	0.06-0.36	0.16	0.15	44/44	0.03-0.23	0.08	0.08
Channel and diversion stations								
Old River at Station 9	23/23	0.05-0.12	0.08	0.07	23/23	0.04-0.07	0.05	0.05
Old River at Bacon Island	23/23	0.04-0.12	0.07	0.07	23/23	0.03-0.06	0.05	0.05
Banks Pumping Plant	25/25	0.06-0.15	0.09	0.09	25/25	0.04-0.11	0.06	0.06
Contra Costa Pumping Plant	21/21	0.03-0.11	0.05	0.05	21/21	0.02-0.06	0.03	0.02
Middle River at Union Point	15/15	0.07-0.13	0.09	0.09	15/15	0.03-0.08	0.05	0.05
Mallard Island	23/23	0.05-0.13	0.08	0.08	23/23	0.03-0.08	0.05	0.05

Chapter 6 Salinity

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Chapter 6 Salinity

Salinity is the concentration of dissolved salts in a given volume of an aqueous solution. High levels of salinity can cause an unpleasant taste, making it less suitable for drinking water purposes. It also creates scale build-up in water delivery pipes, and its usefulness for blending with other source waters diminishes as its salinity increases. The State of California established enforceable secondary maximum contaminant levels (MCLs) for salinity (Appendix A).

In an aqueous solution, dissolved salts exist as charged species and increase the electrical conductance of water. As a result, the electrical conductivity (EC) of a solution is used as an indirect measure of its salinity. A more direct measure of salinity is the weight of the total dissolved solids (TDS) present in a sample. The Department of Public Health (DPH) has set recommended MCLs for EC and TDS of 900 microSiemens per centimeter (µS/cm) and 500 mg/L, respectively.

Stations North of the Delta

American River at the E.A. Fairbairn Water Treatment Plant (WTP)

Previous reports have documented that, regardless of season, the American River station has had the least saline water of all sampled stations. The results presented during this reporting period are consistent with that pattern (Table 6-1). EC and TDS values ranged from 40 to 67 µS/cm and 28 to 45 mg/L, respectively, for the 22 samples taken during the reporting period. Median EC was 56 µS/cm and median TDS was 37 mg/L (Table 6-1). The median values for EC between the wet 2006 water year (WY) and the dry 2007 WY differed by only 9.5 µS/cm. Seasonally EC and TDS were highest in the winter and lowest in the summer (Figure 6-1).

Table 6-1 Summary of EC and TDS data, October 2005 through September 2007

Figure 6-1 EC and TDS at E.A. Fairbairn WTP Intake

Sacramento River at West Sacramento WTP Intake

The West Sacramento WTP intake is just upstream of the confluence of the Sacramento and American rivers on the Sacramento River. For the 22 samples collected, EC and TDS ranged from 76 to 198 µS/cm and 52 to 122 mg/L, respectively. Median EC for the 2-year period was 146 µS/cm and median TDS was 91 mg/L (Table 6-1). Conductivity was generally higher in the dry 2007 WY than the wet 2006 WY (Figure 6-2). It was especially low during the high runoff period from January to April 2006

Figure 6-2 EC and TDS at West Sacramento WTP Intake

Natomas East Main Drainage Canal

The Natomas East Main Drainage Canal (NEMDC) watershed collects runoff from urban mixed land use areas, as well as a wastewater treatment plant. This runoff, combined with NEMDC's small flow volumes, resulted in elevated EC and TDS values.

During the reporting period, 29 samples were collected at NEMDC. EC values ranged from 116 to 448 µS/cm and TDS ranged from 74 to 275 mg/L (Table 6-1). The lowest EC values were observed during and after storms in 2005 and 2006 (Figure 6-3). Median EC and TDS were 314 µS/cm and 193 mg/L, respectively, for the 2-year period (Table 6-1). Median EC for the dry 2007 WY was statistically higher than in the wet 2006 WY (Mann-Whitney, $p = 0.043$).

Figure 6-3 EC and TDS at the NEMDC station

Sacramento River at Hood

Salinity patterns at the Sacramento River at Hood station were similar to the salinity patterns at the Sacramento at West Sacramento WTP (Figures 6-4a and b). For the 42 samples collected, EC and TDS ranged from 73 to 189 µS/cm and 46 to 115 mg/L, respectively. EC values at the Hood site were statistically similar to those of the West Sacramento WTP Intake site (Mann-Whitney, $p = 0.854$, $p = 0.917$, 2006 and 2007 WYs, respectively). Median EC was 147 µS/cm and median TDS was 89 mg/L (Table 6-1).

Figure 6-4 EC and TDS at Sacramento River at Hood

San Joaquin River near Vernalis

The Vernalis station generally had high EC and TDS values except when there was heavy rainfall or large releases from upstream reservoirs (Figure 6-5). The high mineral content of the soils of the San Joaquin Valley, saline irrigation return water, and recirculation of salts contributed to the elevated salinity of the San Joaquin River. Between May and June 2006, Vernalis and Hood ECs were almost equal because of heavy snowmelt runoff and reservoir releases in the San Joaquin River watershed (Figure 2-4). Median EC and TDS values were higher for the Vernalis station than any other MWQI monitoring station except the Mallard Island station, which experiences seawater influences (Table 6-1). Forty-four samples were collected during the sampling period. EC values ranged from 99 to 776 µS/cm with a median of 492 µS/cm. TDS measurements ranged from 64 to 456 mg/L with a median of 285 mg/L. For the San Joaquin River, the WY 2006 was classified as wet and WY 2007 as critically dry. EC values for samples collected in WY 2007 were statistically higher than those collected in WY 2006 (Mann Whitney, $p = 0.0006$).

Figure 6-5 EC and TDS at the San Joaquin River near Vernalis

Channel and Diversion Stations

Channel Stations

MWQI has historically sampled 2 channel stations along the Old River: Station 9 and Bacon Island. Beginning in July 2006, samples were also collected from a third channel station, on the Middle River at Union Point. The 3 channel stations are relatively close to each other, and as such, EC and TDS values were similar between stations (Table 6-1, Figures 6-6 and 6-11). Median EC for the 2-year period was highest at Union Point and lowest at Bacon Island, while the range of EC values was largest at Bacon Island and smallest for Union Point. These results suggest that the influence of the San

Figure 6-6 EC and TDS at the Delta channel stations

Figure 6-11 Electrical conductivity: Range (median) µS/cm

Joaquin River and agricultural drainage contributed to a higher median salinity at Union Point, while the variation in seawater intrusion and Sacramento River flow at Bacon Island produced a wider range of observed EC.

The EC fingerprints demonstrated that the San Joaquin River had a stronger influence throughout the year at Clifton Court Forebay than it did further north along the Old River (Figures 6-9 and 6-10). However, a comparison of the volumetric fingerprints to the EC fingerprints demonstrated the large effect water from the Martinez water had on EC (Figures 6-9 and 6-10). This is further demonstrated by comparing the time-series graph of EC in the Old River at Bacon Island (Figure 6-6a) to the fingerprint graphs for Old River near Bacon Island (Figure 6-9). The highest EC values occurred when there was an increase in the percentage of Martinez water.

Diversion Stations

Samples were taken from the 2 Delta diversion stations at the Harvey O. Banks and the Contra Costa County pumping plants. For the 21 samples taken during the reporting period, EC at the Contra Costa Pumping Plant #1 (CCPP) ranged from 162 to 812 µS/cm, with a median of 428 µS/cm. TDS ranged from 96 to 452 mg/L, with a median of 247 mg/L (Table 6-1). At Banks, 22 samples were taken during the reporting period. EC ranged from 125 to 567 µS/cm with a median of 337 µS/cm. TDS concentrations at the Banks site ranged from 74 to 345 mg/L with a median of 191 mg/L.

CCPP and Banks were sometimes affected by saltwater intrusion from the west, especially in the early winter when Delta outflow was low and tides were strong (Figures 6-7 and 2-5). A comparison of Figure 6-7b to the volumetric fingerprint of Clifton Court Forebay (Figure 6-10) showed that seasonal high EC values occurred at Banks when Martinez water was likely present in Clifton Court Forebay waters. The same pattern was exhibited for the CCPP in which EC values were elevated when the percentage of Martinez water was likely highest in Old River near Bacon Island (Figure 6-7a, 6-9). In the spring and early summer months of 2006, high flows on the San Joaquin River resulted in it being the dominant water source at Clifton Court and Old River (Figures 2-5, 6-9, and 6-10). During the same period, EC at Banks and the CCPP were at their lowest values. Two anomalously high values were detected at the CCPP in April and May 2006. These values may have reflected differences between the time of sample collection and pumping times at CCPP; it may also be caused by the effects of local runoff.

Figure 6-7 EC and TDS at Delta diversion stations

Figure 6-8 EC and TDS at Mallard Island station

Figure 6-9 EC and volumetric fingerprints at Old River

Figure 6-10 EC and volumetric fingerprints at Clifton Court Forebay

In both water years, the salinity of the south Delta waters peaked in the early winter. At those times, conductivity at Banks was less than the conductivity of the San Joaquin River at Vernalis and the Old River at the channel stations. This was likely due to the movement of less saline water from the north Delta flowing upstream through the Middle River. A Mann-Whitney comparison between EC samples from Banks and those from the Middle River at Union Point found no significant difference in EC between those stations ($p = 1.000$).

Mallard Island

Mallard Island is just downstream of the confluence of the Sacramento and San Joaquin rivers. It is the station farthest west and closest to Suisun Bay and is the most heavily influenced by seawater intrusion. During the reporting period, 23 samples were collected. EC ranged from 124 to 13,240 µS/cm with a median of 3,374 µS/cm. TDS ranged from 90 to 7,850 mg/L with a median of 2,230 mg/L. Conductivity and TDS values dropped dramatically in the spring of 2006 when Delta outflows were large, but otherwise tended to be high for the majority of the 2-year period, especially during low river inflows at the end of each year (Figure 6-8). The ECs were significantly different between water years (Mann-Whitney, $p = 0.039$)

Chloride and Sulfate

Chloride and sulfate are among the salt ions that contribute to the salinity of Delta waters. Elevated concentrations of chloride and sulfate can give finished drinking waters an unpleasant taste. Municipal water suppliers report increased taste and odor complaints from customers when chloride concentrations exceed 100 mg/L. DPH has enforceable secondary MCLs for chloride and sulfate; the recommended maximum contaminant level for both constituents is 250 mg/L.

State Water Resources Control Board (SWRCB) Water Rights Decision D-1641 includes a year-round 250 mg/L chloride objective that is in effect at the Delta export locations (Contra Costa Canal Pumping Plant #1, Clifton Court Forebay, Tracy Pumping Plant, Cache Slough at the City of Vallejo intake, and Barker Slough). An additional municipal and industrial water quality objective for chloride at the Contra Costa Canal Intake near Rock Slough specifies that the chloride level must be below 150 mg/L for a given number of days during the year, depending upon the water year classification.

With the exception of Mallard Island, concentrations of chloride and sulfate for the majority of the Delta waters were relatively low and well below the MCLs. Due to seawater influence, 70% of the samples from Mallard Island had chloride concentrations greater than 250 mg/L. Salinity at Mallard varied dramatically with Delta outflow and was especially low during the heavy runoff in 2006. Median chloride concentration over the 2-year period was 989 mg/L with a range from 8 to 4,480 mg/L. Sulfate concentrations at Mallard ranged from 9 to 616 mg/L with a median of 142 mg/L. There were no exceedances of the MCLs for chloride or sulfate at any of the other 10 MWQI monitored stations (Table 6-2).

Table 6-2 Summary of chloride and sulfate data, October 2005 through September 2007

The American River at Fairbairn WTP had very low chloride and sulfate concentrations; the maximum values were 2 mg/L and 3 mg/L, respectively. Chloride and sulfate concentrations did not exceed 12 mg/L during the reporting period at the Sacramento River at West Sacramento WTP or at Hood. At the NEMDC, chloride concentrations ranged from 7 to 42 mg/L with a median of 26 mg/L, and sulfate ranged from 7 to 28 mg/L with a median of 20 mg/L.

Median values of chloride for Bacon Island, Station 9, and Union Point stations were 36, 39, and 37 mg/L, respectively. Median values for sulfate concentrations at the 3 channel stations were 21, 24, and 26 mg/L, respectively. The CCPP had some elevated levels of chloride in comparison to the channel stations, perhaps due to a greater amount of seawater intrusion and local agriculture runoff. Chloride concentrations ranged from 16 to 208 mg/L with a median of 50 mg/L. However, sulfate, often used as a marker for seawater, was very similar among the channel and diversion stations. Sulfate values at CCPP and Banks had very similar ranges, means, and medians. The San Joaquin River at Vernalis had chloride concentrations that ranged from 7 to 104 mg/L with a median of 64 mg/L. Sulfate ranged from 8 to 114 mg/L with a median value of 60 mg/L.

Salinity of Delta Waters between Current Reporting Period and Previous Reports

Sacramento River at Hood

The salinity of the Sacramento River at Hood varied between and within seasons, but in general, the median EC and median TDS concentrations were lower in years that received more than an average amount of precipitation. Between WYs 2002 and 2007, 2006 was the only wet water year. The lowest median EC was recorded during this year, which was also significantly different from all other water years (Dunn's Multiple Comparison, $p = 0.000$) (Table 6-3). TDS concentrations for the 2006 WY were also significantly different from WYs 2002 and 2005 (Dunn's Multiple Comparison, $p = 0.000$, $p = 0.005$, WYs 2002 and 2005, respectively).

Table 6-3 Summary of salinity during three consecutive sampling periods

San Joaquin River at Vernalis

Salinity of the San Joaquin River at Vernalis tends to be high, yet decreases sharply with high flows. This was most noticeable in the 2006 to 2007 reporting period, when heavy rains in WY 2006 resulted in lower median EC and TDS levels than any other recent reporting period (Table 6-3). This was also observed statistically. In WY 2006, EC was statistically different from all other water years (Dunn's Multiple comparison test, $p = 0.000$). The dry, below normal, and dry years of 2002, 2003, and 2004 were not significantly different from each other (Dunn's Multiple Comparison, $p > 0.05$). TDS in WY 2006 was not significantly different from the wet year of 2005, but was significantly different from the below normal, dry, and critical years.

Banks Station

Samples from the past 6 years did not exceed the MCLs for EC or TDS. Changes in EC values were seasonal with increases in EC during fall months, when Delta outflow was low, and decreases in EC during winter or spring months, when Delta outflow was high. Median EC (337 µS/cm) and median

TDS (191 mg/L) were lower for the current reporting period than in the previous two reporting periods (Table 6-3). Kruskal-Wallis comparisons of either EC or TDS found no statistical differences between most water years. The only exception, for both EC and TDS was between the dry WY 2002 and the wet WY 2006 ($p=0.0027$ and $p=0.0036$, EC and TDS, respectively).

Summary

Salinity throughout the Delta and its source rivers can be affected by watershed runoff, reservoir releases, urban discharges, agricultural drainage, and, at some stations, seawater intrusion. The effect of each factor on salinity varies between stations and over time.

During the reporting period (October 2005 to September 2007), 286 samples were collected from 11 stations. EC values ranged from 40 µS/cm to 13,240 µS/cm and TDS values from 28 mg/L to 7,850 mg/L. Approximately 94% of the samples had EC values of less than 900 µS/cm. All samples with EC values greater than 900 µS/cm were collected from the Mallard Island station, the station with the greatest seawater influence. Table 6-1 summarizes the range, average, and median of EC and TDS values by station.

Of the 11 MWQI sampling stations, the American River had the lowest EC values and the lowest median EC of 56 µS/cm (Table 6-1). The Sacramento River at the West Sacramento WTP upstream of the confluence of the American and Sacramento rivers had a median EC of 146 µS/cm (Table 6-1). In contrast, the NEMDC station, with an input into the Sacramento River less than 2 miles downstream of the West Sacramento station, had an elevated median EC of 314 µS/cm (Table 6-1). NEMDC flows however, were less than 3% of the combined flows of the American and Sacramento rivers for the reporting period. Median EC on the Sacramento River at Hood, more than 15 miles downstream of the West Sacramento station and the NEMDC confluence, was comparable to median EC at the West Sacramento WTP Intake (Table 6-1). Median EC at the Sacramento River at Hood during the reporting period was 147 µS/cm. Salinity of the San Joaquin River at Vernalis during the reporting period was much greater than the salinity of the Sacramento River at Hood. Median EC at Vernalis was the second highest of the 11 MWQI stations, after Mallard Island. The high salinity of the SJR is usually attributed to irrigation returns, recirculation of salts from the Delta, and the highly mineralized soils of the San Joaquin Valley.

Despite Delta island drainage, municipal discharges, and seawater intrusion, the channel and diversion stations had median EC's lower than that of the San Joaquin Vernalis station. This was most likely due to the influence of fresh water from the north Delta. EC values increased during the fall months when inflow to the Delta was low. EC values of the channel and diversion stations decreased during months with high Delta inflows and outflows, though these sometimes lagged behind the flushing effect seen at Mallard

Island. Comparisons of the volumetric and EC fingerprints showed the influence of seawater and agricultural drainage on salinity with season.

Waters at Mallard Island typically exhibit a high degree of seawater intrusion due to its proximity to Suisun Bay and the straits leading to San Francisco Bay. Sixty percent of the samples at Mallard Island over the 2-year period had EC values greater than 1,000 µS/cm. Median EC at Mallard Island during the reporting period was 3,374 µS/cm. When Delta outflows were high in spring 2006, Mallard Island EC ranges were as low as any of the other channel and diversion monitoring stations.

Chapter 6 Salinity

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Figure 6-1 EC and TDS at E.A. Fairbairn WTP Intake

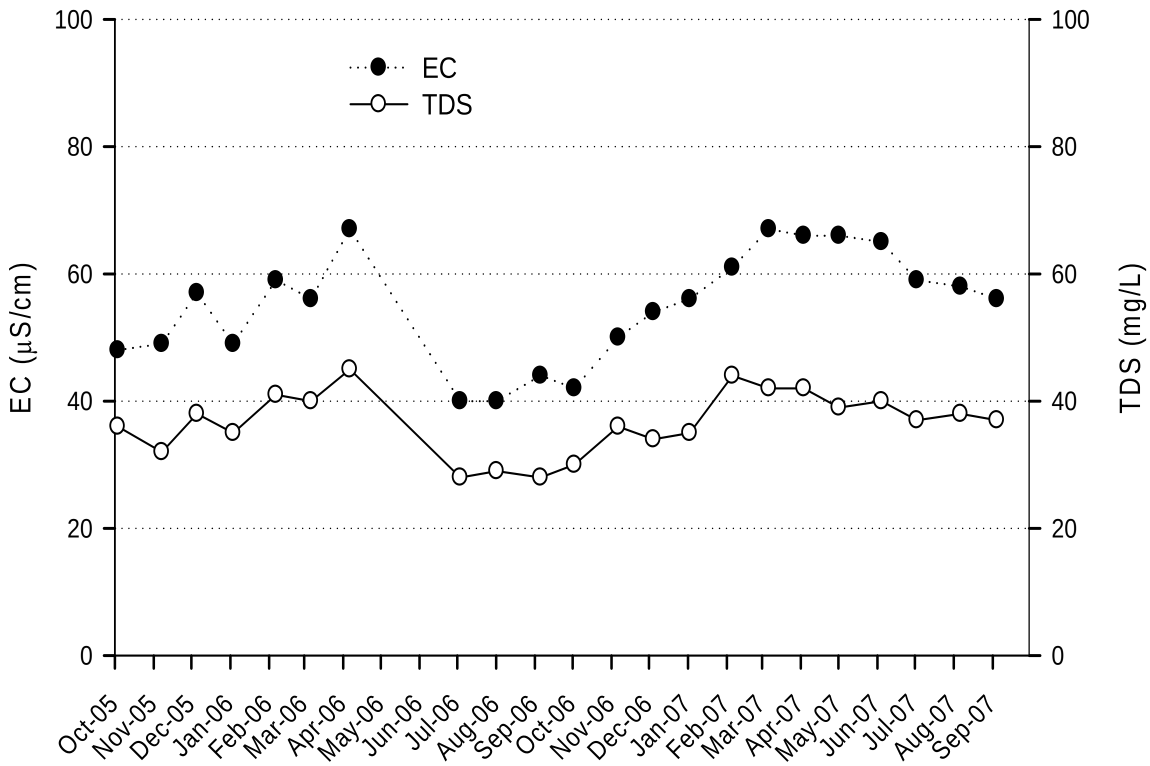


Figure 6-2 EC and TDS at West Sacramento WTP Intake

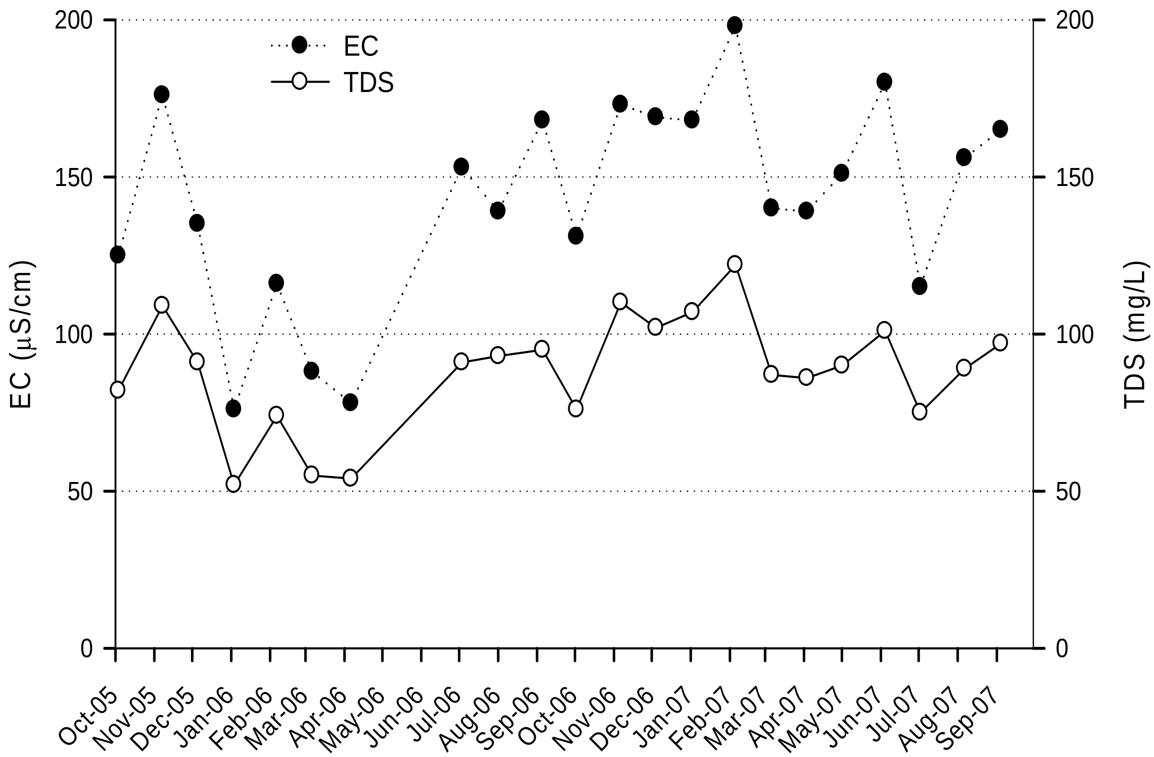


Figure 6-3 EC and TDS at the NEMDC station

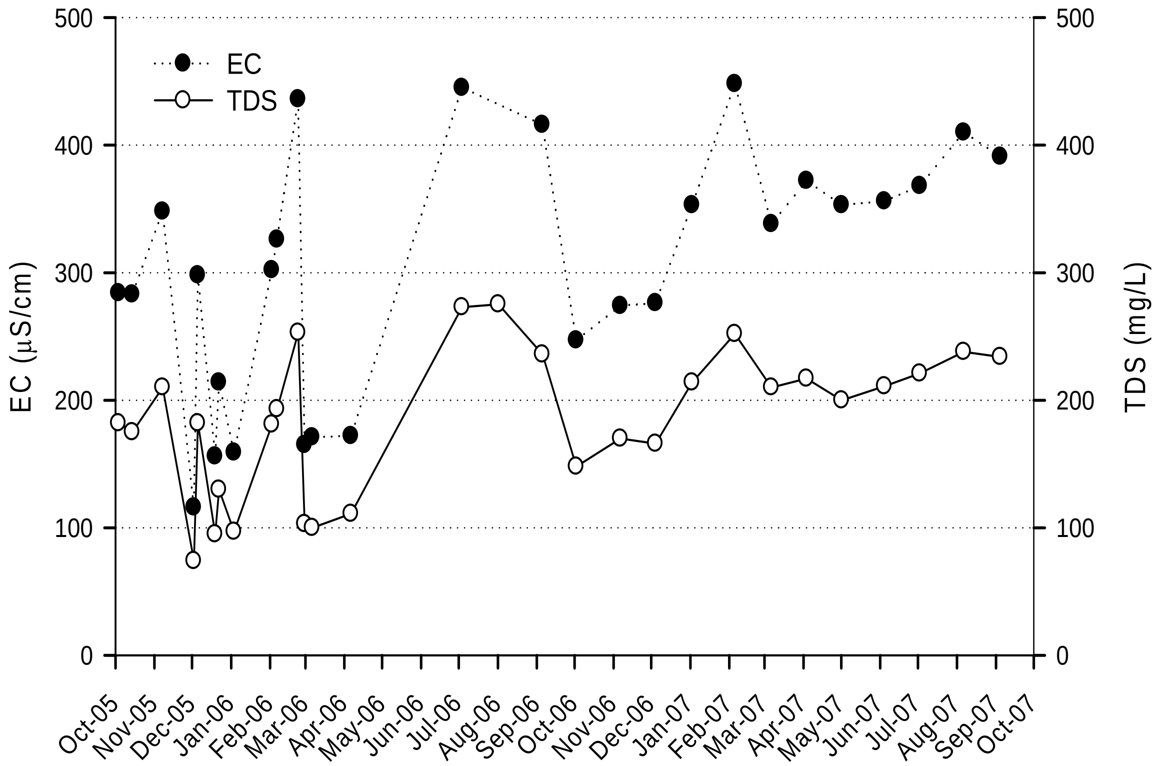
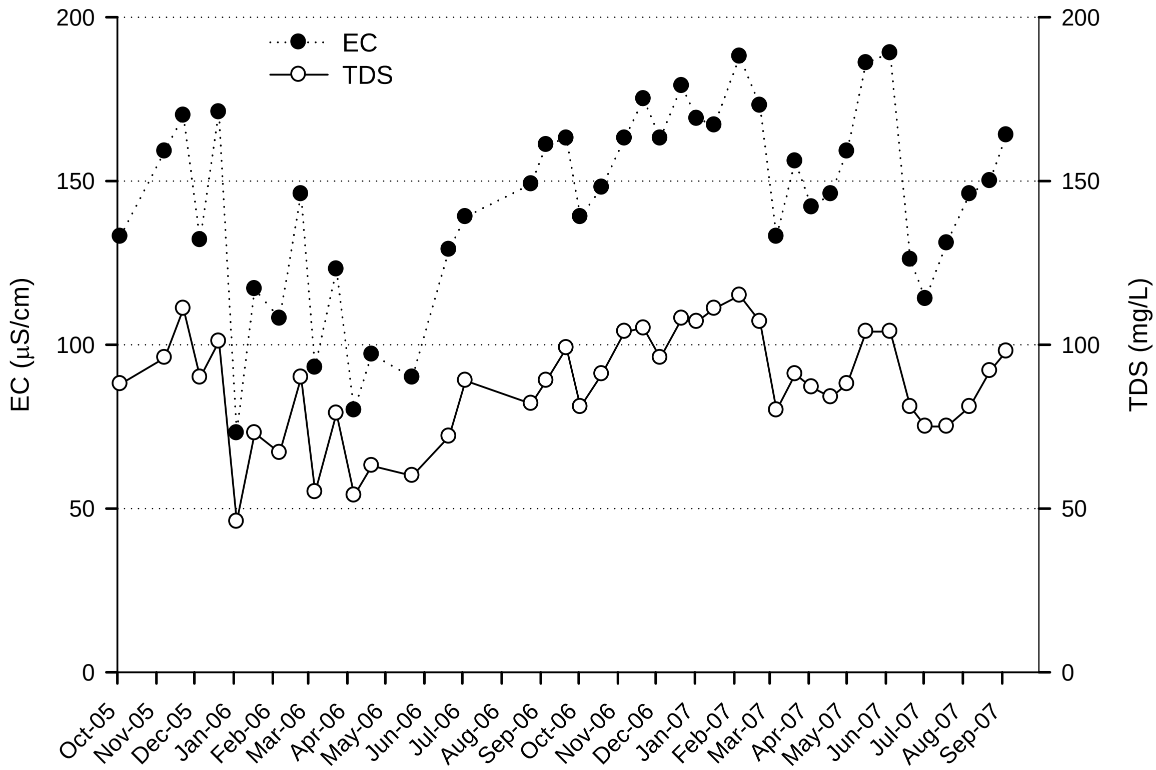


Figure 6-4 EC and TDS at Sacramento River at Hood



EC at Both Sacramento River Stations

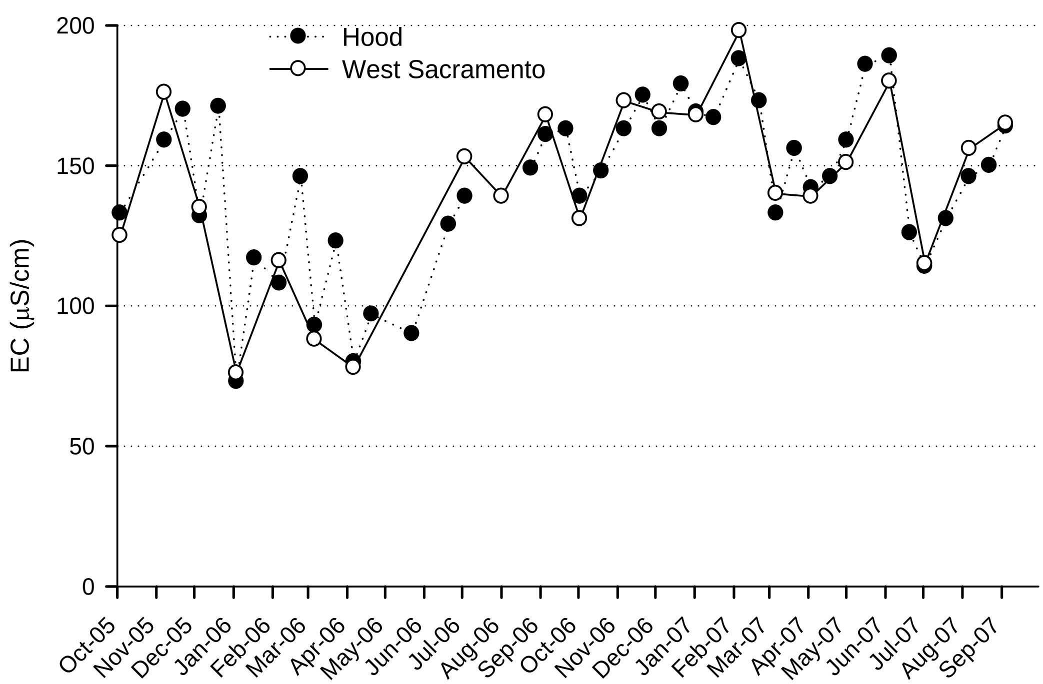


Figure 6-5 EC and TDS at the San Joaquin River near Vernalis

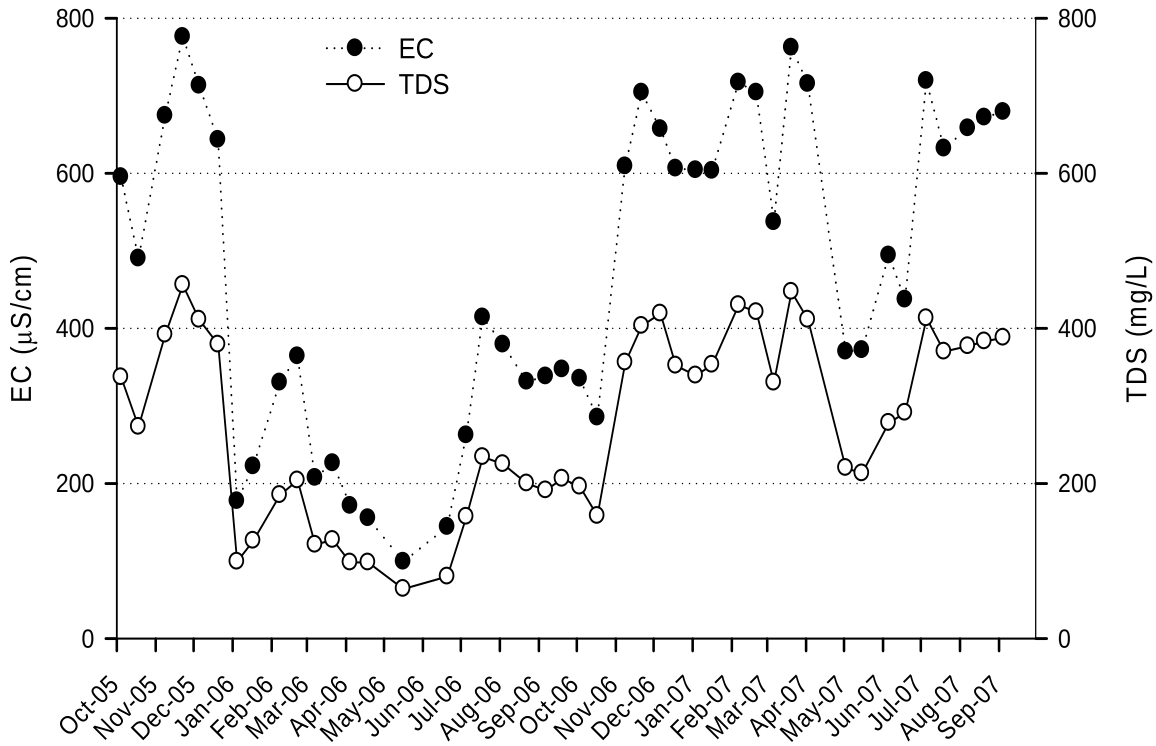
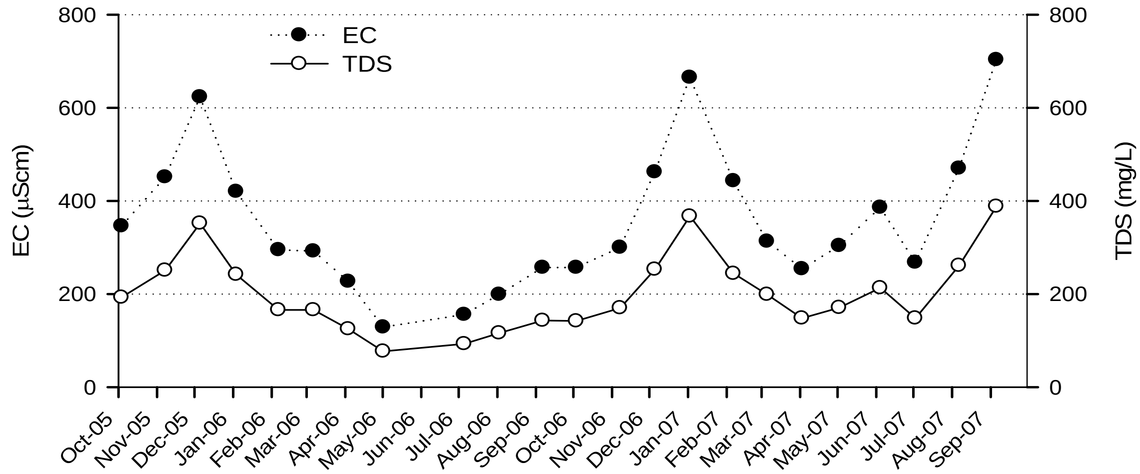
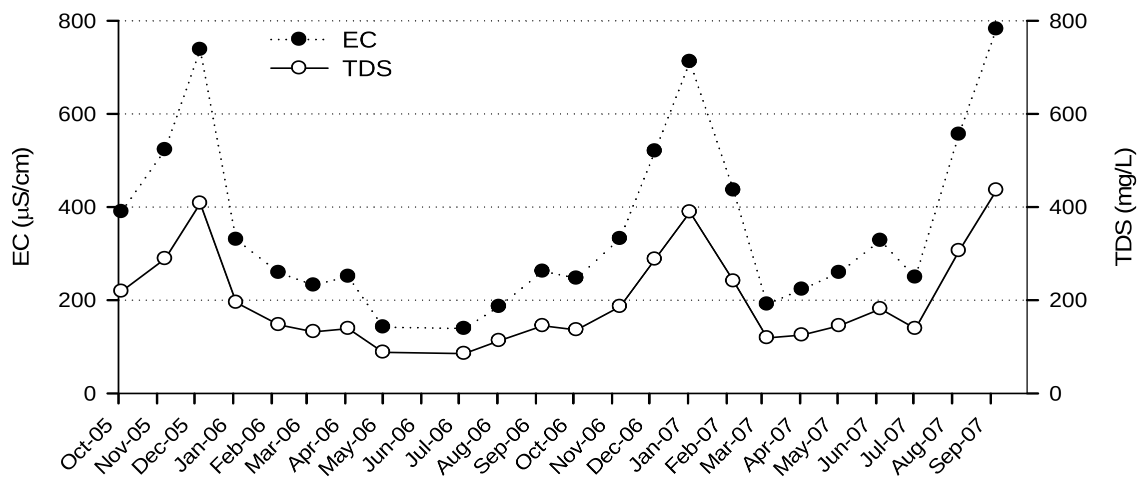


Figure 6-6 EC and TDS at the Delta channel stations

Old River at station 09



Old River at Bacon Island



Middle River at Union Point

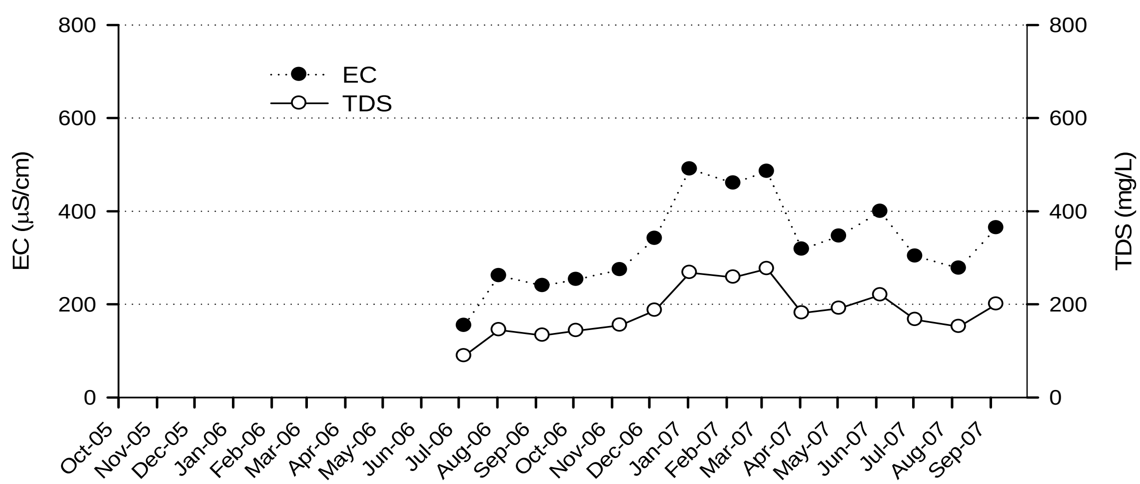
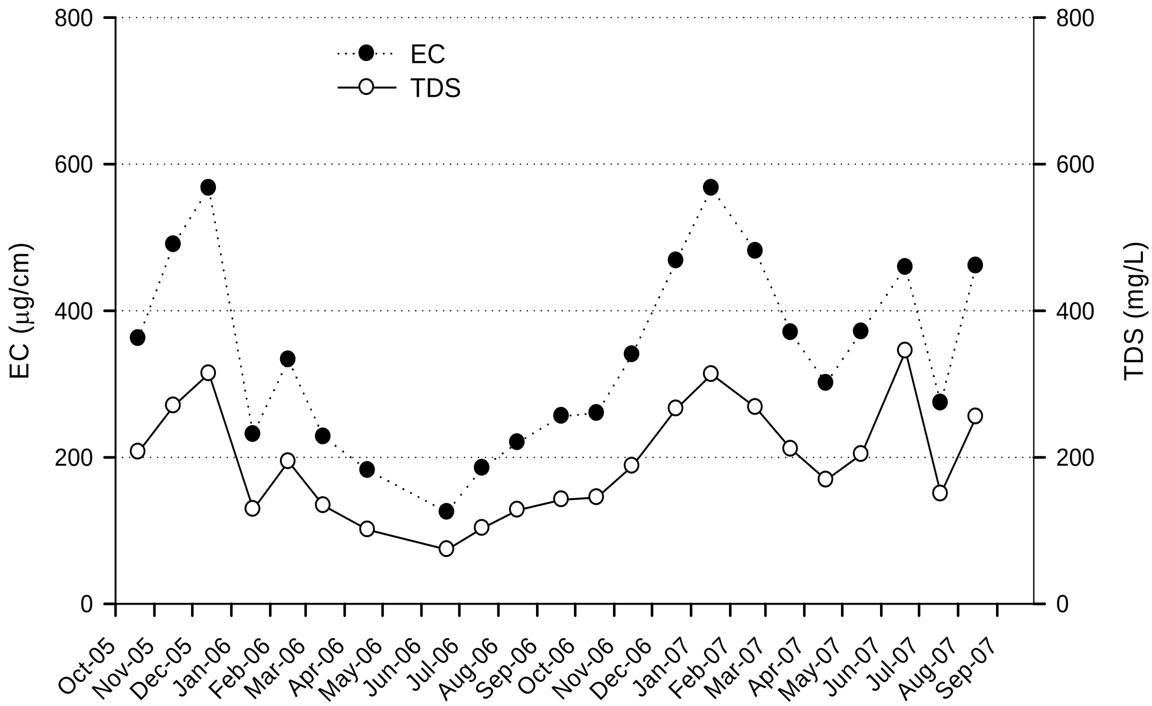


Figure 6-7 EC and TDS at Delta diversion stations

Banks Pumping Plant



Contra Costa Pumping Plant

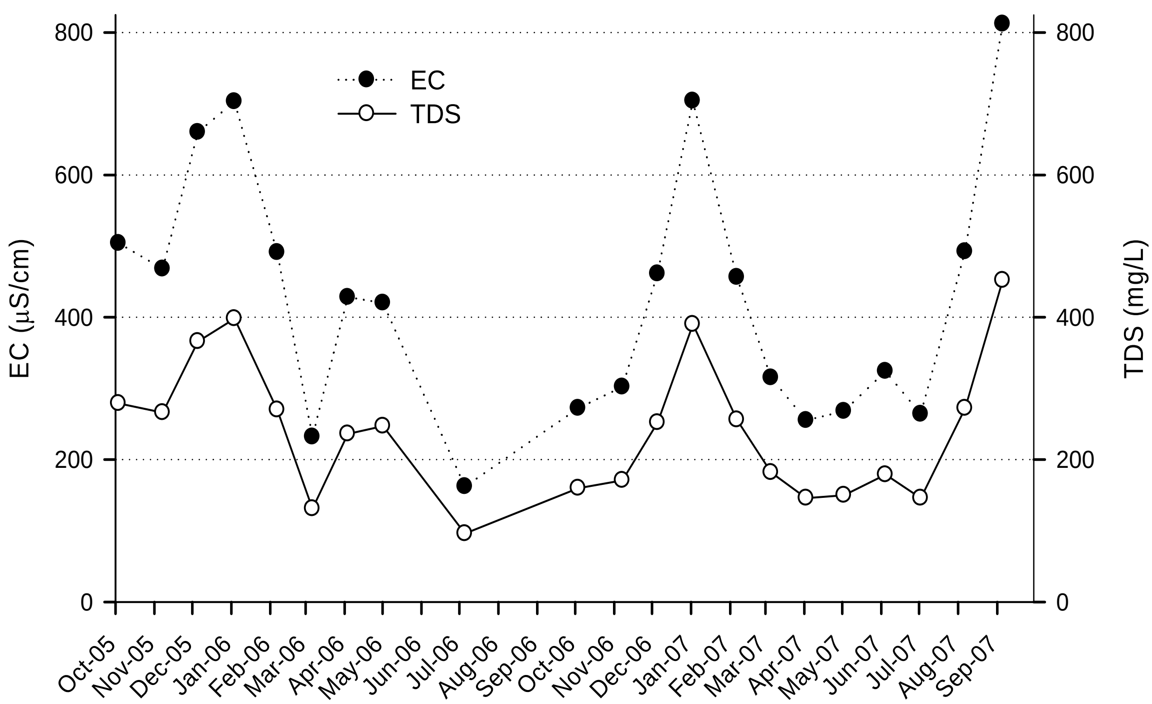


Figure 6-8 EC and TDS at Mallard Island station

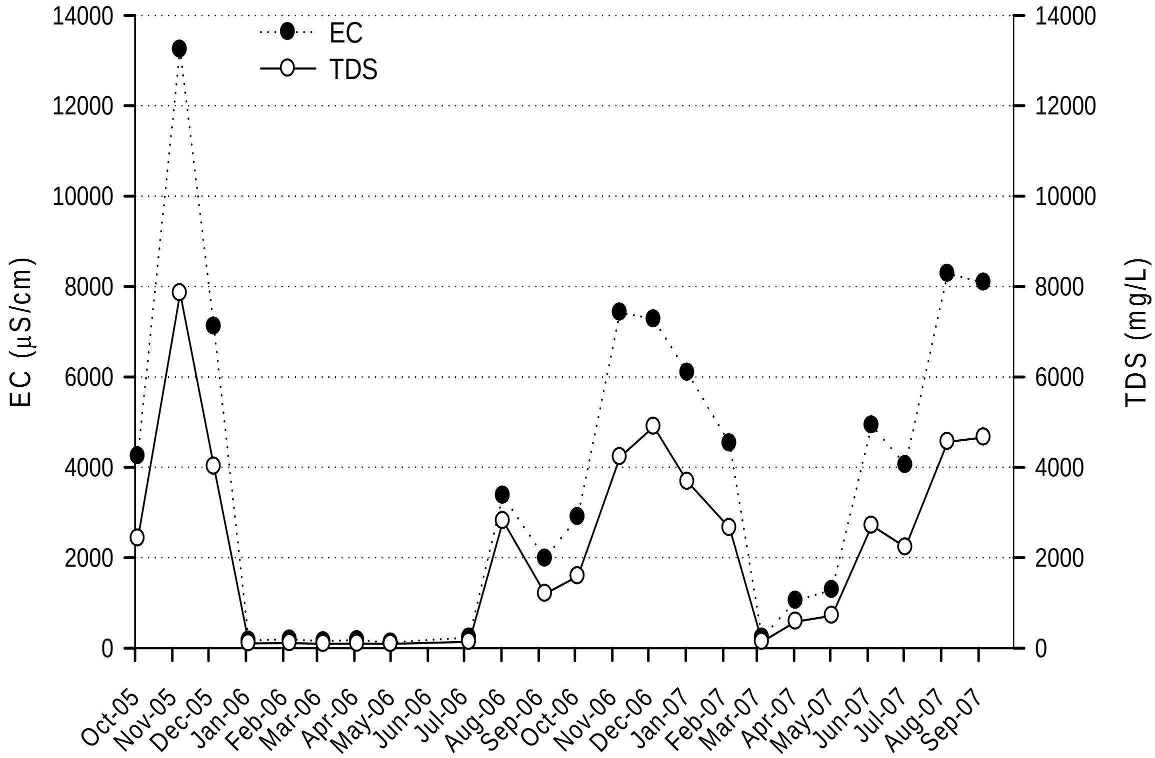
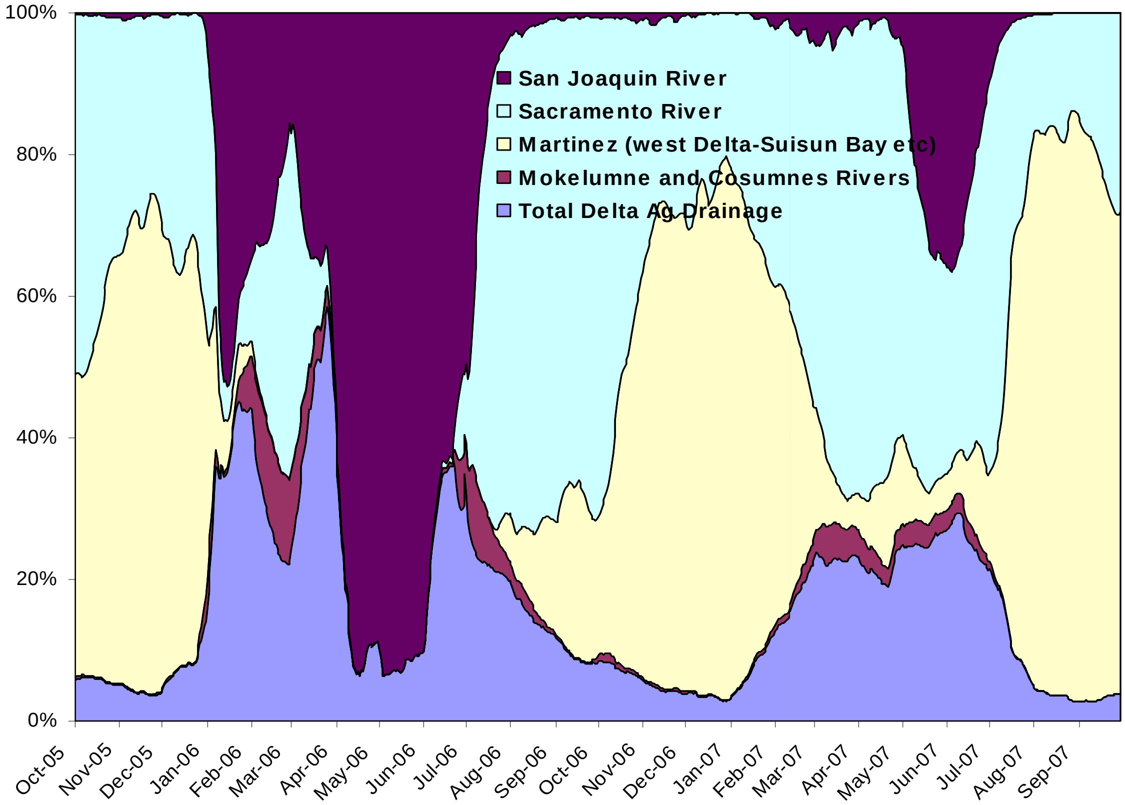


Figure 6-9 EC and volumetric fingerprints at Old River

EC fingerprint



Volumetric fingerprint

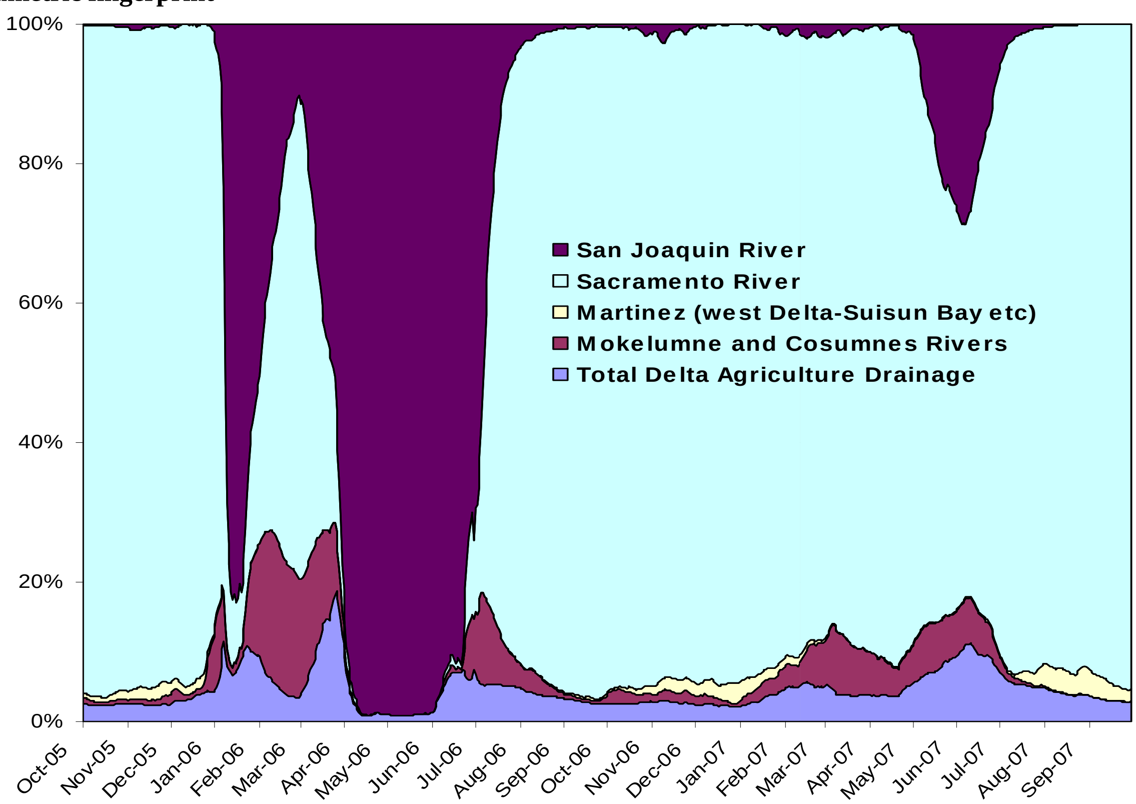
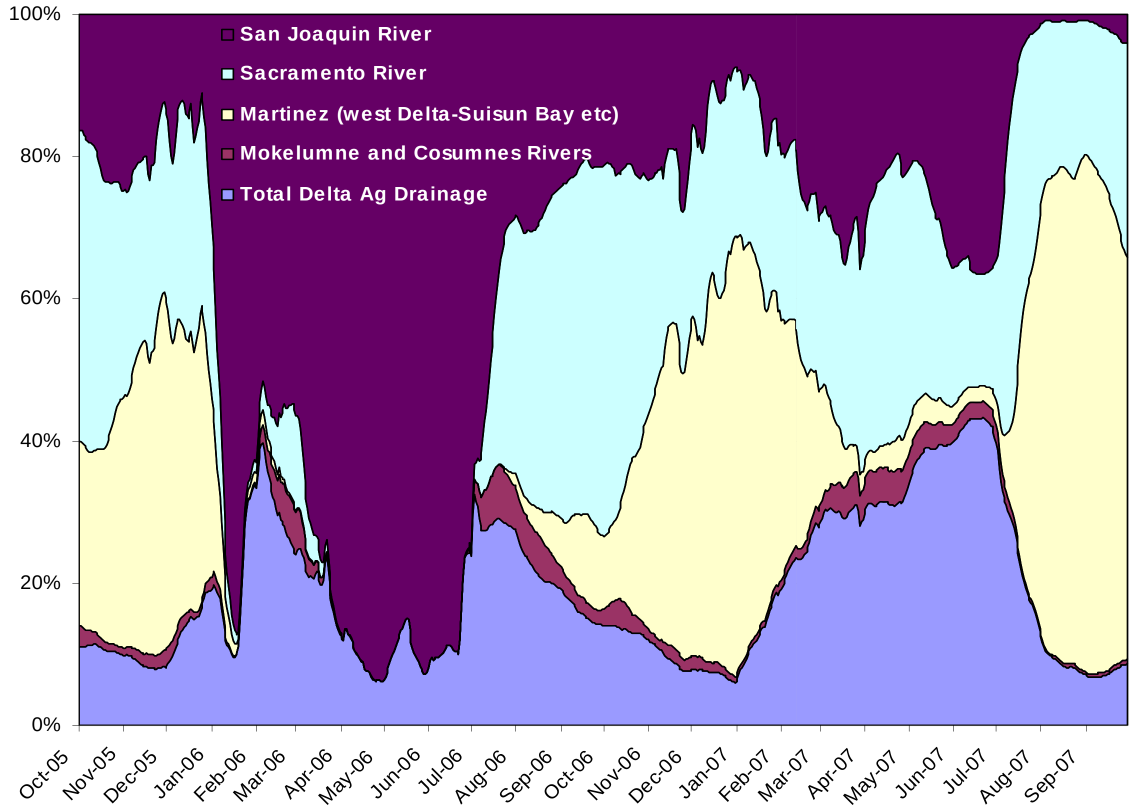


Figure 6-10 EC and volumetric fingerprints at Clifton Court Forebay

EC fingerprint



Volumetric fingerprint

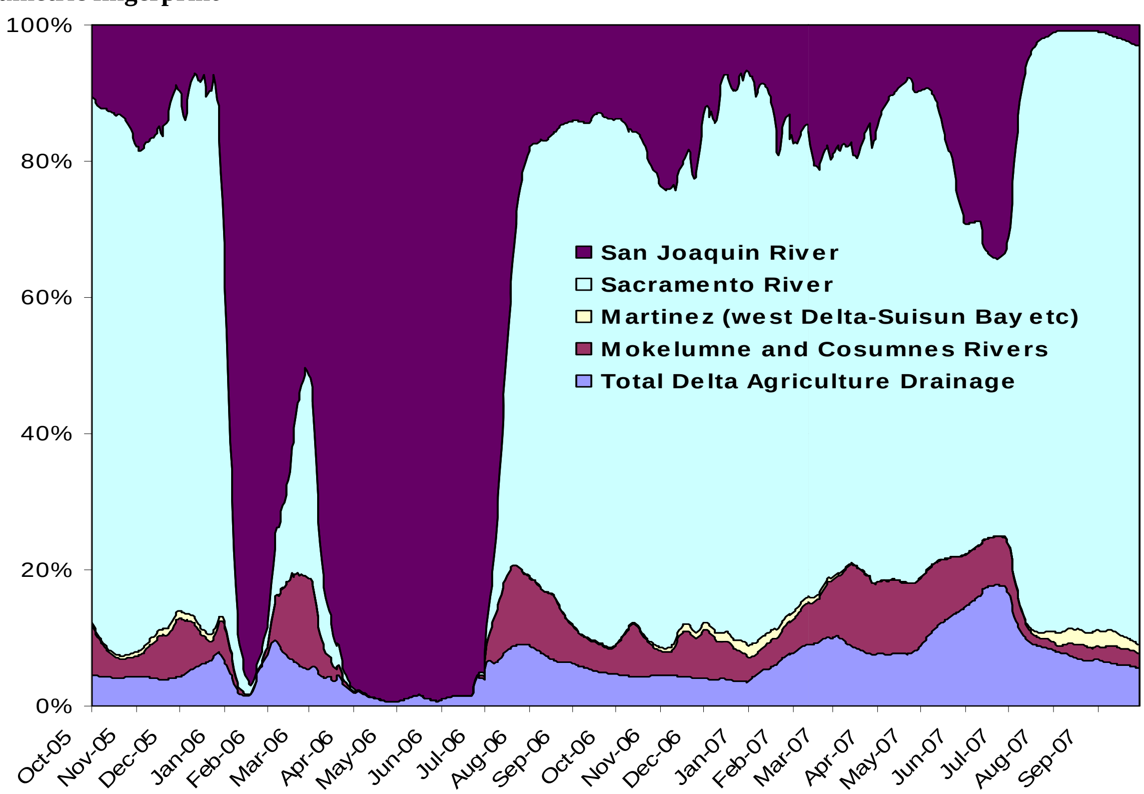


Figure 6-11 Electrical conductivity: Range (median) µS/cm

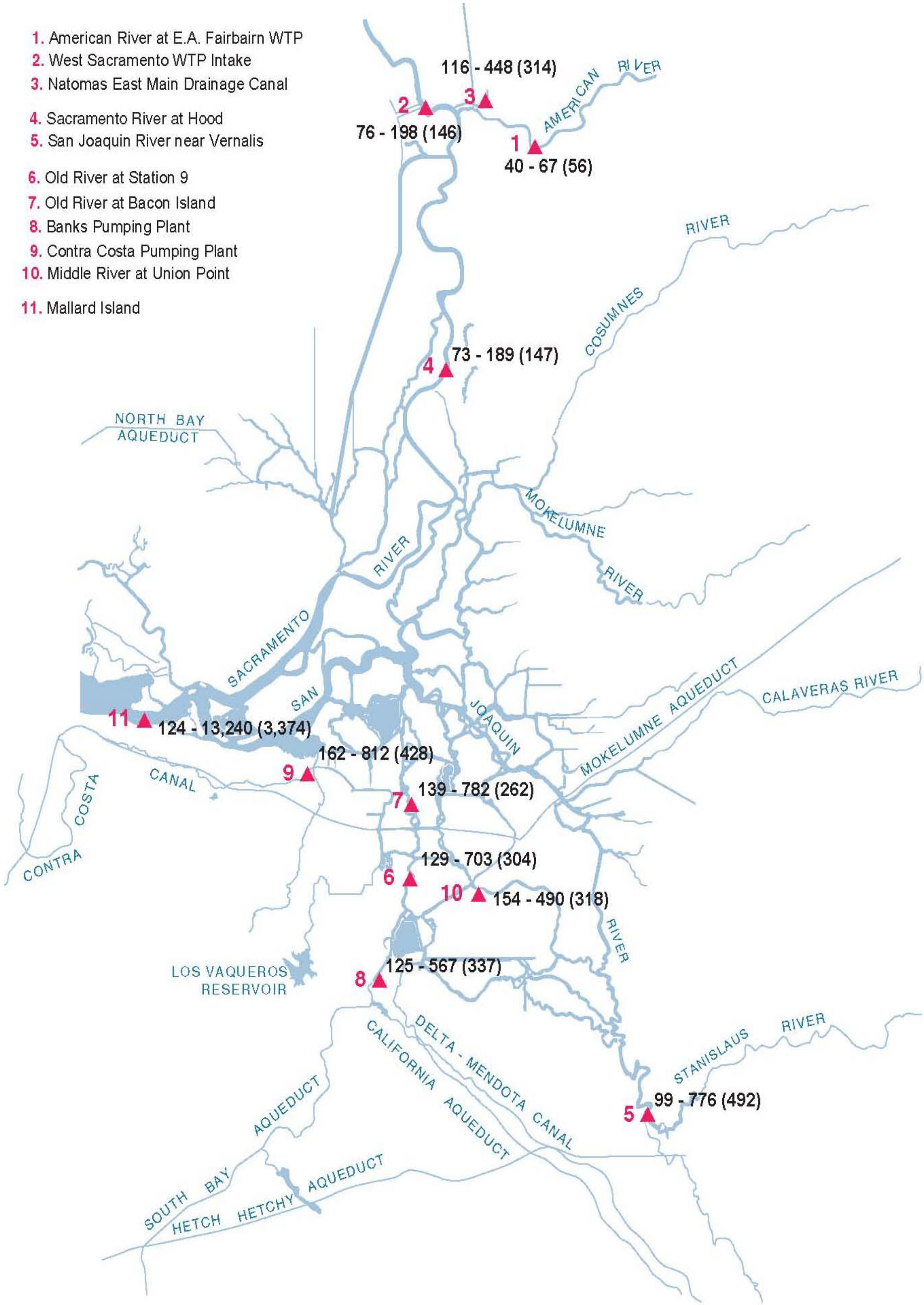


Table 6-1 Summary of EC and TDS data, October 2005 through September 2007

	EC (µS/cm)				TDS (mg/L)			
Station	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
Stations north of the Delta								
American River at E.A. Fairbairn WTP	22	40–67	55	56	22	28–45	37	37
West Sacramento WTP Intake	22	76–198	143	146	22	52–122	88	91
Natomas East Main Drainage Canal	28	116–448	303	314	29	74–275	185	193
Sacramento River at Hood	42	73–189	144	147	42	46–115	87	89
San Joaquin River near Vernalis	44	99–776	476	492	44	64–456	278	285
Channel and diversion stations								
Old River at Station 9	23	129–703	357	304	23	77–388	201	171
Old River at Bacon Island	23	139–782	360	262	23	85–436	202	147
Middle River at Union Point	15	154–490	331	318	15	89–276	184	181
Contra Costa Pumping Plant	21	162–812	428	428	21	96–452	240	247
Banks Pumping Plant	22	125–567	342	337	22	74-345	196	191
Mallard Island	23	124–13,240	3,787	3,374	23	90–7,850	2,243	2,230

Table 6-2 Summary of chloride and sulfate data, October 2005 through September 2007

Station	Chloride (mg/L)				Sulfate (mg/L)			
	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
Stations north of the Delta								
American River at E.A. Fairbairn WTP	22	1–2	2	2	22	1–3	2	2
West Sacramento WTP Intake	22	2–7	4	4	22	2–9	6	6
Natomas East Main Drainage Canal	29	7–42	25	26	29	7–28	19	20
Sacramento River at Hood	43	2–10	6	6	43	3–12	7	6
San Joaquin River near Vernalis	44	7–104	61	64	44	8–114	60	60
Channel and diversion stations								
Old River at Station 9	23	10–154	56	39	23	12–40	24	24
Old River at Bacon Island	23	12–177	61	36	23	10–33	21	21
Middle River at Union Point	15	16–86	43	37	15	12–51	27	26
Banks Pumping Plant	22	12–120	50	43	22	14-50	27	26
Contra Costa Pumping Plant	21	16–208	74	50	21	15–54	29	25
Mallard Island	23	8–4,480	1,201	989	23	9–616	173	142

Table 6-3 Summary of salinity during three consecutive sampling periods

Station	Study period	EC (µS/cm)			TDS (mg/L)		
		Range	Average	Median	Range	Average	Median
Sacramento River at Hood	2006–2007	73–189	144	147	46–115	87	89
	2004–2005	111–240	161	154	69–140	97	93
	2002–2003	114–239	163	160	72–138	100	102
	2001–2007	73–240	159	156	46–140	94	93
San Joaquin River near Vernalis	2006–2007	99–776	476	492	64–456	278	285
	2004–2005	120–1,170	679	710	75–635	330	347
	2002–2003	352–1,180	748	715	208–654	445	414
	2001–2007	99–1180	671	677	64–654	338	355
Banks Pumping Plant	2006–2007	125–567	342	337	74–345	196	191
	2004–2005	196–671	377	350	108–378	218	204
	2002–2003	173–666	407	387	104–409	239	212
	2001–2007	125–671	380	356	74–409	220	203

Chapter 7 Other Water Quality Constituents

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Chapter 7 Other Water Quality Constituents

This chapter summarizes the data for monitored parameters and constituents with primary and secondary drinking water standards that were not discussed in the previous chapters. These constituents can either have health impacts or affect the taste, odor, and appearance of drinking water.

Constituents with Primary Standards

Nine inorganic metals with primary standards—arsenic, beryllium, barium, cadmium, chromium, lead, mercury, nickel, and selenium—were monitored by O&M's Water Quality Section at the H.O. Banks Pumping Plant. These constituents are known to have detrimental impacts to human health at levels above their maximum contaminant level (MCLs). Beryllium, barium, cadmium, lead, and mercury were not detected in any of the 22 samples over the 2-year period. Chromium, nickel and selenium were detected in some samples, but at levels below their respective MCLs (Table 7-1). Arsenic was the only constituent to be monitored at both the Banks station and at the Natomas East Main Drainage Canal (NEMDC) station and it was detected in all samples for both stations. Arsenic concentrations in all samples were below the MCL. Median concentration of arsenic at Banks and NEMDC were 0.002 mg/L and 0.003 mg/L, respectively.

Table 7-1 Summary of regulated primary constituents

Ammonia, Nitrate, and Combined Nitrate and Nitrite

There are federal and State enforceable standards for nitrate, nitrite, and combined nitrate-nitrite concentrations in drinking water. Nitrate is converted into nitrite in the human body. Elevated levels of nitrite have the potential to cause adverse health effects. Furthermore, nitrite can react with other substances and form nitrosamines, which have been demonstrated to be carcinogenic. The California Department of Public Health (DPH) has set a MCL of 45 mg/L for nitrate as (NO3). The US Environmental Protection Agency (EPA) and DPH have a MCL of 10 mg/L as (N) for combined nitrate-nitrite.

MWQI monitored for nitrate as (NO3) and combined nitrate-nitrite as (N) at all 11 sampling stations. Nitrate and nitrite was detected at all stations below their respective MCLs (Table 7-2). The highest concentrations were at the Vernalis and NEMDC stations.

Table 7-2 Summary of ammonia, nitrate and nitrate + nitrite from October 2005 through September 2007

Ammonia as a drinking water constituent is not regulated by primary or secondary standards. The EPA recommends, however, that ammonia be considered as a potential source of nitrates in drinking water (EPA 2006b). Primary sources of ammonia in surface waters are fertilizers, sewage, and livestock manure (EPA 2006b). Of the 11 sampling stations, the Sacramento River at Hood had the highest concentrations of ammonia (Table 7-2). The relatively elevated ammonia concentrations at Hood may be due to the upstream proximity of the Sacramento Regional Wastewater Treatment Plant.

Constituents with Secondary Standards

Municipal drinking water that is aesthetically displeasing or odious might cause a consumer to resort to an unhealthy source of water. As such, the State of California has enforceable secondary standards for constituents that can affect the taste, odor, and appearance of finished drinking water.

Of the metallic constituents with secondary MCLs, aluminum, copper, iron and manganese were monitored at the Banks and NEMDC stations. Additionally, silver and zinc were monitored at Banks, but neither constituent was detected in any of the 22 samples. Copper, iron, and manganese concentrations at Banks were low and below their respective MCLs in samples where they were detected (Table 7-3). Aluminum was only detected once at Banks and at a concentration of approximately 5% of its MCL. Concentrations of aluminum, iron, and manganese were elevated at NEMDC in comparison with Banks. Manganese concentrations exceeded the MCL of 0.05 mg/L at NEMDC in 5 samples. Aluminum and iron concentrations exceeded their respective MCLs in 1 sample during the reporting period. Copper concentrations at NEMDC were low throughout the reporting period. The relatively elevated concentrations of metals at NEMDC are not a concern for water exports due to the NEMDC's relatively low flows.

Table 7-3 Summary of secondary constituents

Boron

Boron is an unregulated constituent; however, DPH requires it to be monitored in drinking water . Exposure to high levels of boron has been linked to reproductive and developmental harm in mice (EPA 2006a) same comments as footnotes on previous page). Compounds that contain boron occur naturally and have been found in Sacramento aquifer groundwater (EPA 2006a). Industrial products such as insecticides and textiles also contain boron. DPH has set an Action Level (AL) of 1 mg/L for dissolved boron in drinking water.

During water years (WYs) 2006 and 2007, MWQI monitored boron at all 11 stations (Table 7-4). Boron was not detected in the American River or in the Sacramento River at West Sacramento Water Treatment Plant (WTP) during the reporting period. The NEMDC station had low concentrations (median 0.1 mg/L) for the reporting period except for 1 sample in March 2006, which had a dissolved boron concentration of 9 mg/L. Samples from Hood had no detectable amounts of boron. Thirty-eight of the 44 samples from the San Joaquin River at Vernalis had boron concentrations ranging from 0.1 to 0.5 mg/L. Among the channel and diversion stations, Banks had the most detects. Concentrations of boron at the channel and diversion stations, including Banks, were below 0.4 mg/L for all samples. Mallard Island had

Table 7-4 Summary of boron data at MWQI stations

the highest concentrations of boron due to seawater influence. Seawater typically has a boron concentration of 5 mg/L. Concentrations at Mallard ranged from 0.1 to 1.1 mg/L for the 15 samples where boron was detected.

pH

Precipitation and dissolution of carbonates in an aqueous solution is influenced by pH. There are no enforceable regulations for pH in finished drinking water. The pH for all stations ranged from 6.1 to 9.0 (Table 7-5). The majority of samples tended to be slightly alkaline, and the median pH at 11 stations ranged between 7.7 and 8.0. The American River at E.A. Fairbairn WTP had the lowest median pH of 7.4.

Table 7-5 Summary of pH and alkalinity, October 2005 through September 2007

Alkalinity

Alkalinity is the concentration $CaCO_3$ mg/L derived from a measure of the sum of all titratable bases (Clesceri and others 1998). Alkalinity is unregulated in drinking water. However, requirements for removal of organic carbon from source waters for drinking purposes are based on organic carbon concentrations and alkalinity (EPA 1998b).

Total alkalinity as mg/L of $CaCO_3$ ranged from 16 to 158 mg/L (Table 7-5). The American River had the lowest median alkalinity (23 mg/L as $CaCO_3$) and the smallest range (16 to 27 mg/L as $CaCO_3$) (Figure 7-1). The NEMDC station had the greatest median alkalinity (81 mg/L as $CaCO_3$) and the largest range (33 to 158 mg/L as $CaCO_3$) (Figure 7-1). The Sacramento River near Hood had a median alkalinity of 59 mg/L as $CaCO_3$ (Figure 7-1). Median alkalinity at the San Joaquin River (SJR) near Vernalis (81 mg/L as $CaCO_3$) was comparable to NEMDC's median alkalinity (Figures 7-1 and 7-2). The channel and diversion stations had median values of alkalinity from 61 to 67 mg/L as $CaCO_3$ (Figure 7-2). Mallard Island had a median alkalinity value of 66 mg/L as $CaCO_3$ (Figure 7-2).

Figure 7-1 Alkalinity north of the Delta

Figure 7-2 Alkalinity of the San Joaquin River at the Vernalis, Mallard Island channel and diversion stations

Hardness

Hardness in this report is calculated and defined as the sum of the calcium and magnesium concentrations expressed as calcium carbonate ($CaCO_3$) in mg/L (Clesceri and others 1998). Hard water reduces the solubility of soaps and detergents and contributes to scaling in boilers and industrial equipment. General guidelines for classification of waters are: 0 to 60 mg/L as $CaCO_3$, soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/l, hard; and more than 180 mg/l, very hard.

Table 7-6 Summary of hardness and turbidity data, October 2005 through September 2007

The lowest hardness of the 11 monitored stations was in samples from the American River at E.A. Fairbairn WTP (Table 7-6). The median hardness of the samples from the American River was 21 mg/L as $CaCO_3$ (Figure 7-3). Waters with the greatest hardness were from the Mallard Island station, which is heavily influenced by seawater intrusion (Figure 7-4). For the 2-year period, median hardness as $CaCO_3$ at Mallard Island was 356 mg/L. The

Figure 7-3 Hardness in rivers north of the Delta

Figure 7-4 Hardness of the San Joaquin River at Vernalis, Mallard Island, channel, and diversion stations

Sacramento River at West Sacramento WTP and near Hood had similar ranges and median values of hardness (Figure 7-3); the range of hardness values as $CaCO_3$ for both stations was 30 to 77 mg/L. Median values were 56 and 55 mg/L as $CaCO_3$ for West Sacramento and Hood, respectively. NEMDC had a median hardness of 92 mg/L as $CaCO_3$ (Figure 7-3). Waters of the San Joaquin River near Vernalis were relatively hard, with a median hardness of 117 mg/L as $CaCO_3$ (Figure 7-4). Channel stations had median hardness values greater than the Sacramento River and less than the San Joaquin River (Figure 7-4). The median hardness values for the 3 channel stations ranged from 74 to 77 mg/L as $CaCO_3$. Both diversion stations' medians were elevated in comparison to the channel stations (Figure 7-4). Median hardness at the Contra Costa Pumping Plant #1 (CCPP) and at Banks was 90 and 80 mg/L as $CaCO_3$, respectively.

Turbidity

Turbidity is an optical measurement of the opacity of water. Suspended particulate matter in a body of water impairs the transmission of light through the water. As such, turbidity is a general indirect measurement of the concentration of particulate matter suspended in the water column. High values of turbidity in riverine systems are usually seen following storm events, which increase the sediment loads.

Table 7-7 Summary of inorganic and miscellaneous constituents

Over the 2-year reporting period, turbidity ranged between 1 and 108 NTU (Nephelometric Turbidity Unit) (Table 7-6). The lowest median turbidity value of 2 NTU was from the American River at the E.A. Fairbairn WTP (Figure 7-5). Stations along the Sacramento and San Joaquin rivers—West Sacramento, Hood, Vernalis, Mallard Island—had larger medians for turbidity (12 to 20 NTU), perhaps due to high water velocities following storm events (Figures 7-5 and 7-6). NEMDC had a median turbidity of 17 NTU (Figure 7-5). Channel and diversion stations had median turbidities between 6 and 9 NTU (Figure 7-6).

Figure 7-5 Turbidity north of the Delta

Figure 7-6 Turbidity of the San Joaquin River at Vernalis, Mallard Island, channel, and diversion stations

Summary

Constituents with primary standards are known to have health risks associated with them when they are present in drinking water at concentrations greater than their MCL. Of the monitored constituents with primary standards, beryllium, barium, cadmium, lead, and nickel were never detected. The remaining constituents with primary standards (arsenic, chromium, nickel, selenium, nitrate, nitrate-nitrite) never exceeded their respective MCLs during the sampling period (Tables 7-1 and 7-2).

Secondary MCLs exist for constituents that can affect the taste, odor, or appearance of finished drinking water (Table 7-3). Of the metallic constituents, silver and zinc were not detected. Aluminum, copper, iron, and manganese were detected below their respective MCLs at Banks. Copper was detected at NEMDC, but concentrations never exceeded 0.004 mg/L (the MCL for copper is 1.0 mg/L). Aluminum and iron concentrations exceeded

MCLs in 1 sample from NEMDC. Manganese was found in concentrations above its MCL in 5 of the 28 samples (~18%) from NEMDC.

Boron concentration exceeded the DPH unregulated action level of 1 mg/L in 1 sample from NEMDC. Concentrations of boron in all other samples were either low or not detected.

Chapter 7 Other Water Quality Constituents

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Figure 7-1 Alkalinity north of the Delta

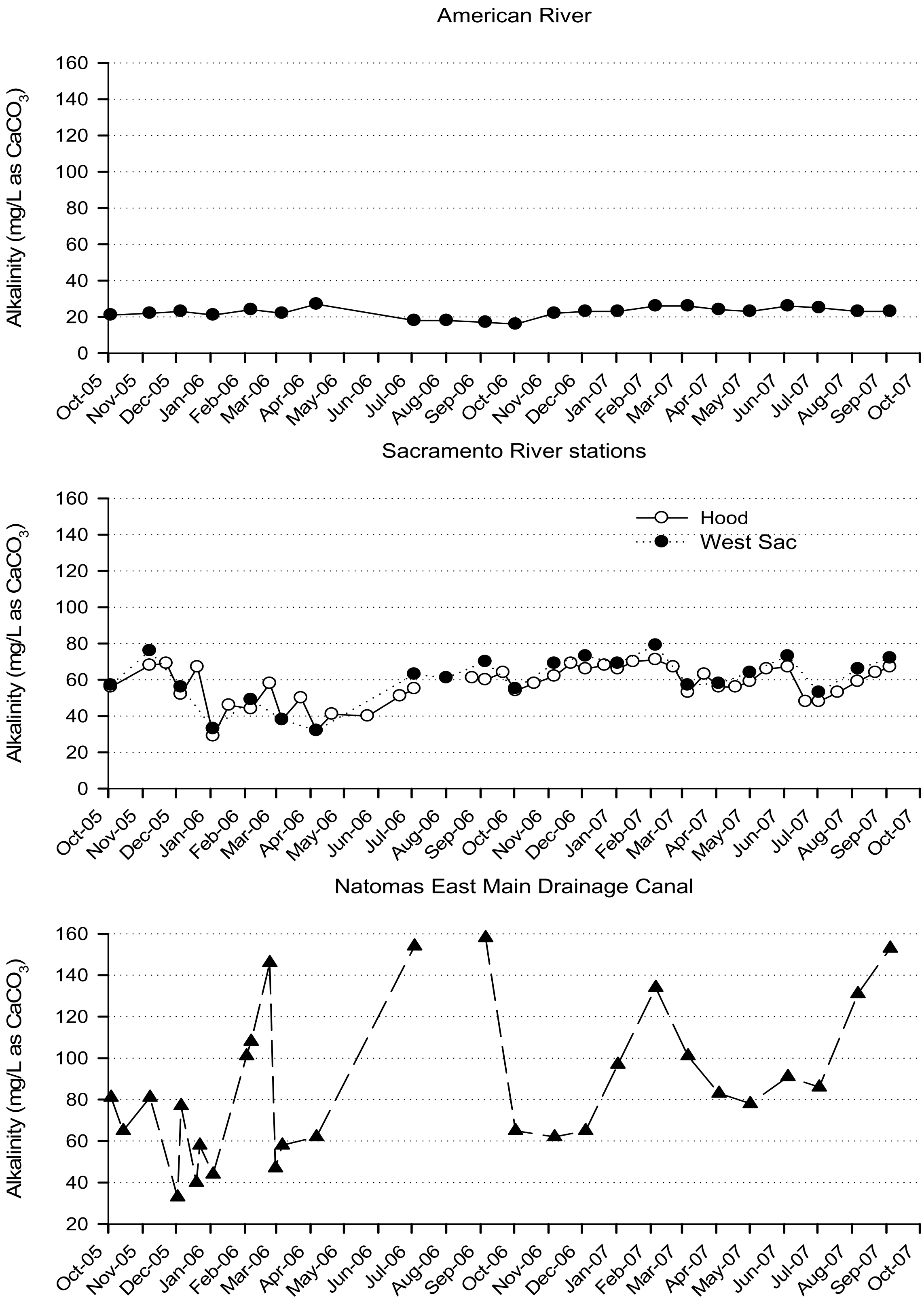


Figure 7-2 Alkalinity of the San Joaquin River near Vernalis, Mallard Island, channel, and diversion stations

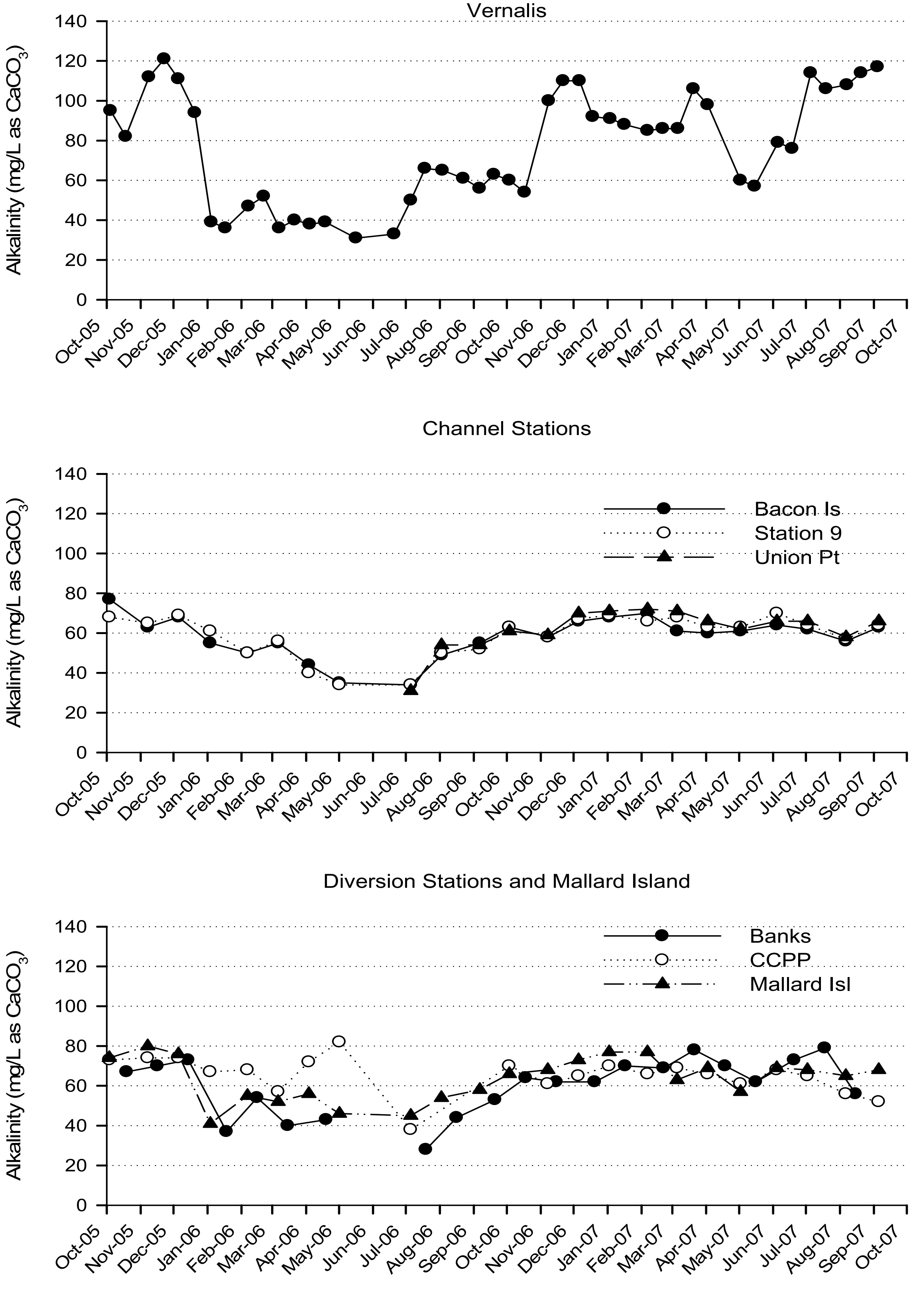


Figure 7-3 Hardness north of the Delta

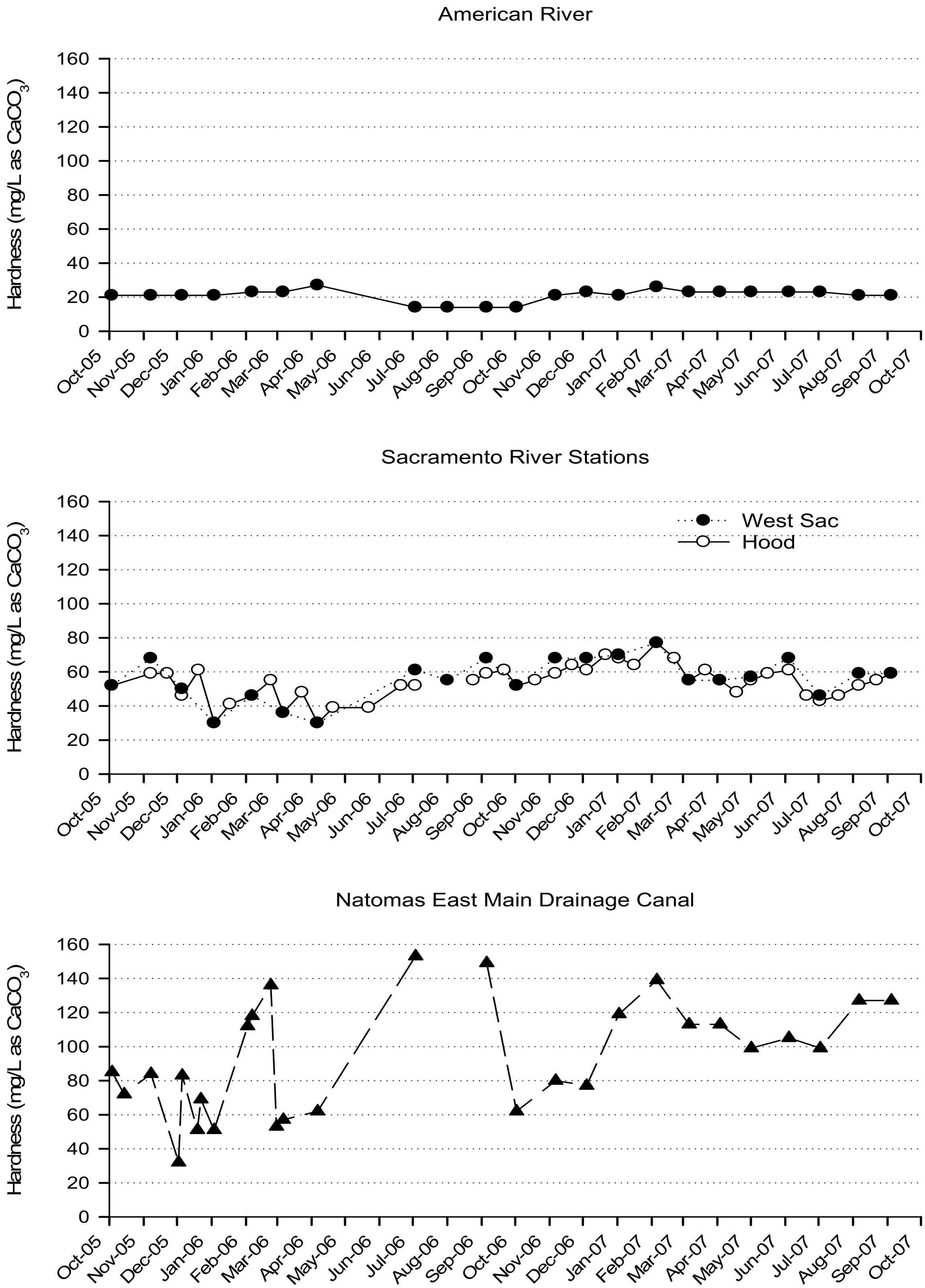


Figure 7-4 Hardness of the San Joaquin River near Vernalis, Mallard Island, channel, and diversion stations

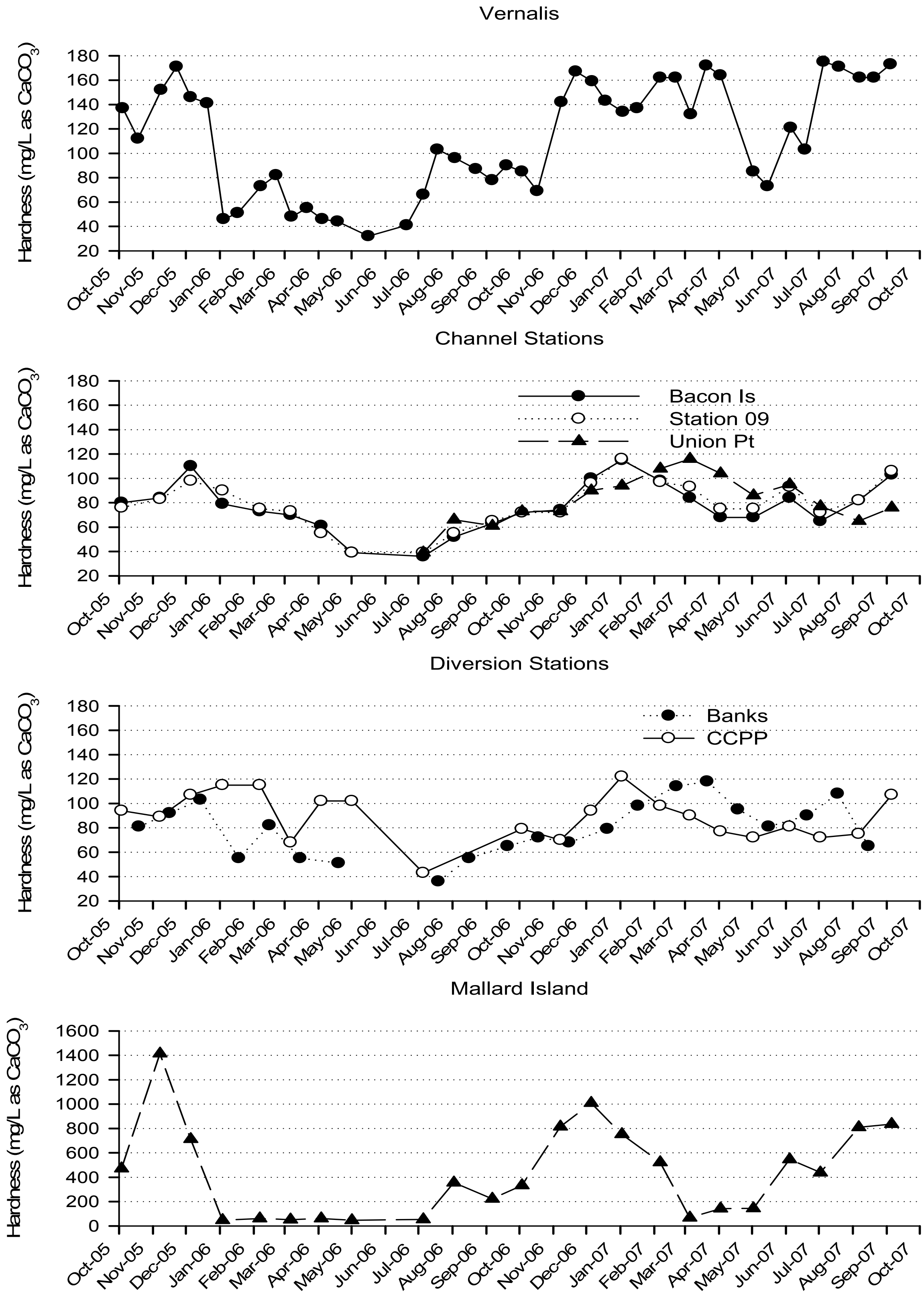
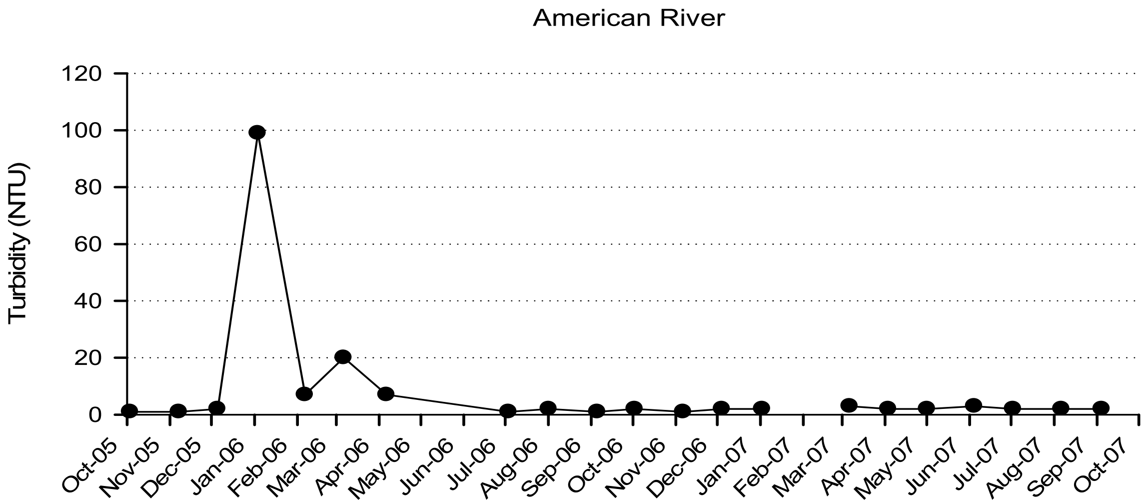
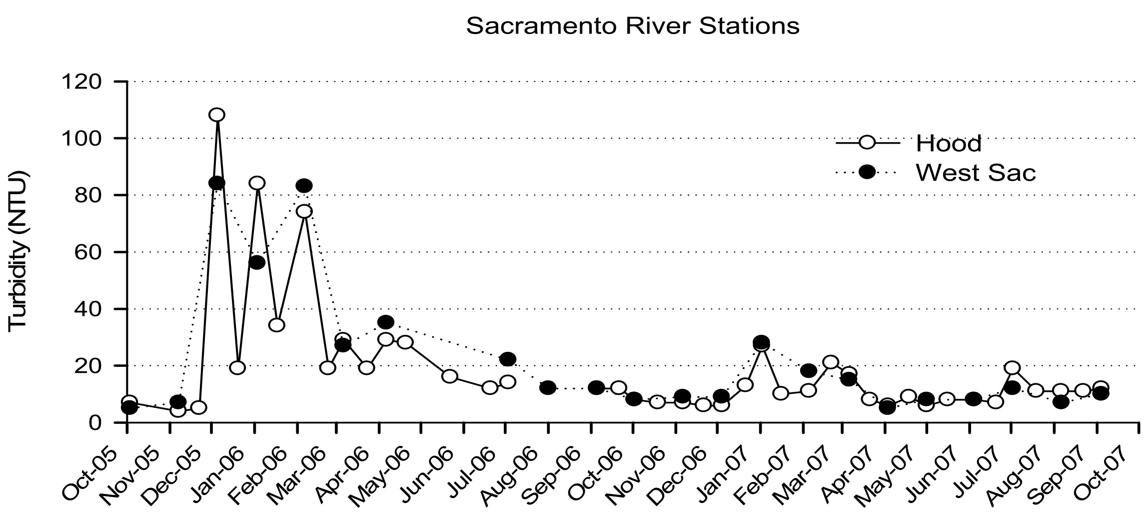


Figure 7-5 Turbidity north of the Delta





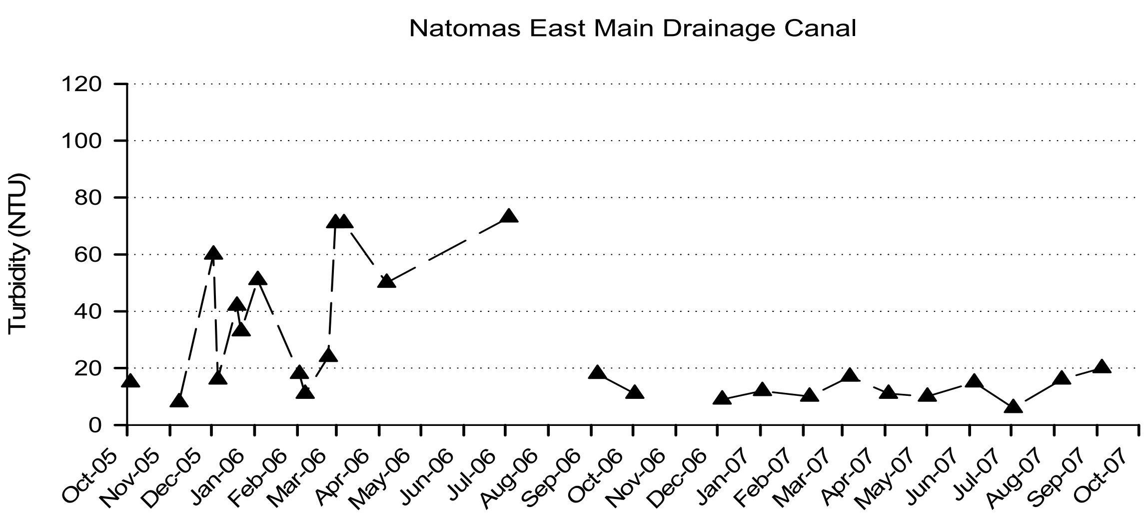


Figure 7-6 Turbidity of the San Joaquin River near Vernalis, Mallard Island, channel, and diversion stations

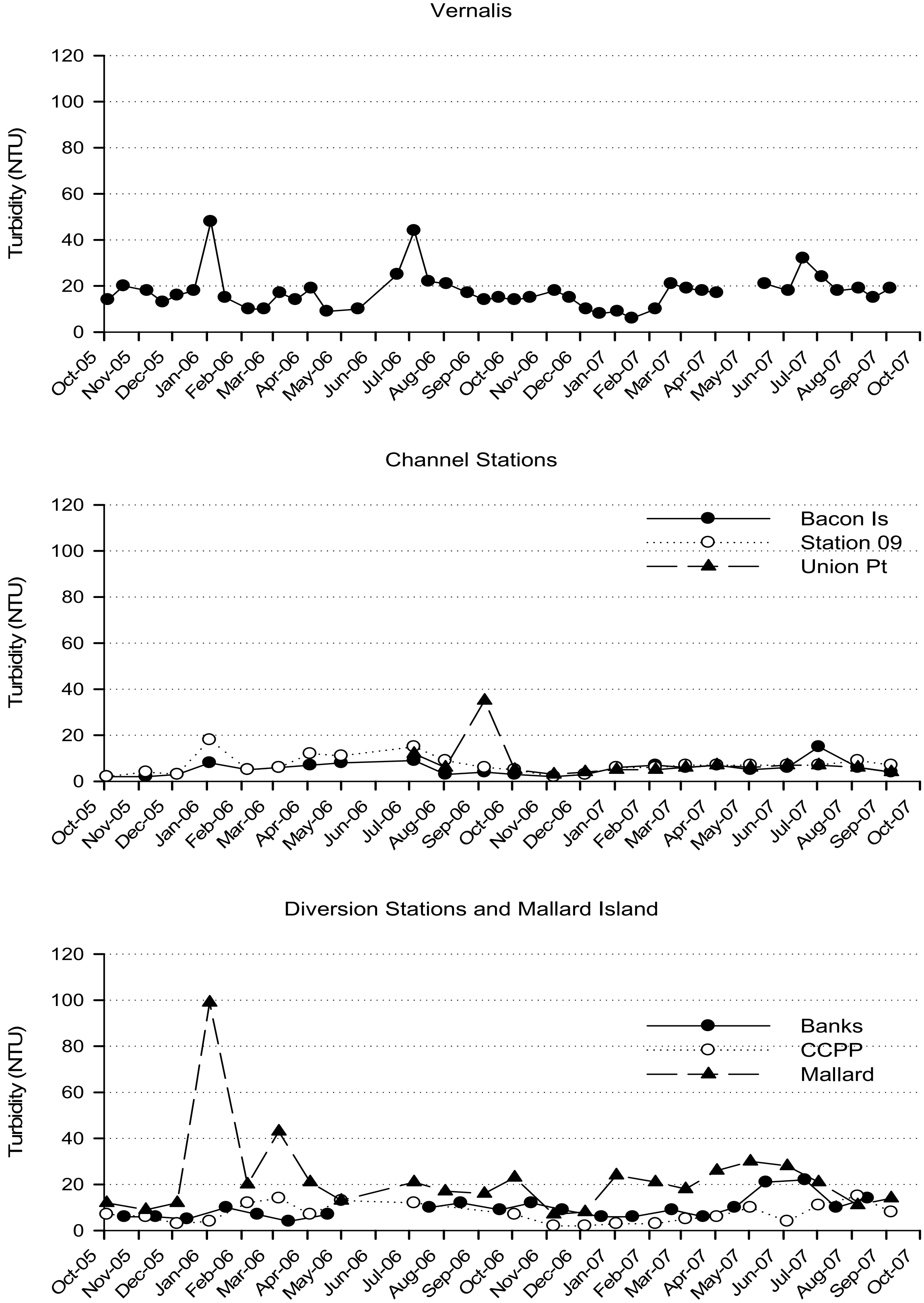


Table 7-1 Summary of regulated primary constituents

Constituents	MCL (mg/L)	Detects/ Sample Number	Range	Median
		Banks		
Arsenic	0.01	22/22	0.001–0.002	0.002
Beryllium	0.004	0/22	–	–
Barium	1	0/22	–	–
Cadmium	0.005	0/22	–	–
Chromium	0.05	18/22	0.001–0.003	0.002
Lead	0.015	0/22	–	–
Mercury	0.002	0/22	–	–
Nickel	0.1	22/22	0.001-0.002	0.001
Nitrate	45	22/25	0.8–5.1	2.3
Nitrate + Nitrite	10	25/25	0.17–1.23	0.48
Selenium	0.05	10/22	0.001-0.002	0.001
		NEMDC		
Arsenic	0.01	28/28	0.002–0.008	0.003

Table 7-2 Summary of ammonia, nitrate and nitrate + nitrite from October 2005 through September 2007

Station	Ammonia (mg N/L)			Nitrate (mg NO3/L)			Nitrate + Nitrite (mg N/L)		
	Detects/ Number	Range	Median	Detects/ Number	Range	Median	Detects/ Number	Range	Median
Stations North of the Delta									
American River at E.A. Fairbairn WTP	4/22	0.01–0.03	0.02	14/22	0.1–0.7	0.2	20/22	0.01–0.13	0.04
West Sacramento WTP Intake	8/22	0.01–0.03	0.02	21/22	0.2–1.6	0.6	22/22	0.03–0.40	0.12
Natomas East Main Drainage Canal	22/29	0.02–0.20	0.04	29/29	0.8–10.7	4.3	26/29	0.14–2.00	1.01
Sacramento River at Hood	42/43	0.05–0.79	0.28	43/43	0.2–1.4	0.5	42/43	0.04–0.36	0.12
San Joaquin River near Vernalis	27/44	0.01–0.12	0.03	44/44	0.5–9.5	5.9	44/44	0.10–2.20	1.40
Channel and diversion stations									
Old River at Station 9	22/23	0.02–0.17	0.04	23/23	0.4–6.4	2.1	23/23	0.08–1.40	0.49
Old River at Bacon Island	23/23	0.01–0.12	0.03	23/23	0.3–3.5	1.7	23/23	0.08–0.80	0.40
Banks Pumping Plant	24/25	0.03–0.08	0.05	22/25	0.8–5.1	2.3	25/25	0.17–1.23	0.48
Contra Costa Pumping Plant	16/21	0.01–0.07	0.02	19/21	0.2–5.3	1.3	19/21	0.04–1.00	0.28
Middle River at Union Point	15/15	0.01–0.14	0.04	15/15	0.8–5.9	3.1	15/15	0.21–1.40	0.74
Mallard Island	23/23	0.04–0.20	0.07	23/23	0.5–6.7	1.7	23/23	0.13–0.61	0.4

Table 7-3 Summary of secondary constituents

	Banks (mg/L)				NEMDC (mg/L)			
Constituents	**MCL**	**Detects/Sample Number**	**Range**	**Median**	**MCL**	**Detects/Sample Number**	**Range**	**Median**
Aluminum	0.2	1/22	0.011	0.011	0.2	26/28	0.011–0.419	0.032
Copper	1.0	22/22	0.001–0.003	0.002	1.0	28/28	0.002–0.004	0.002
Iron	0.3	21/22	0.005-0.065	0.015	0.3	28/28	0.012–0.323	0.081
Manganese	0.05	17/22	0.007–0.018	0.013	0.05	28/28	0.010–0.084	0.035
Silver	0.1	0/22	–	–	0.1			
Zinc	5.0	0/22	–	–	5.0			

Table 7-4 Summary of boron data at MWQI stations [a]

Station	Detects/ Sample Number	Range	Average	Median
		---------------------mg/L---------------		
Stations North of the Delta				
American River at E.A. Fairbairn WTP	0/22	–	–	–
West Sacramento WTP Intake	0/22	–	–	–
Natomas East Main Drainage Canal	15/29	0.1–9.0	0.7	0.1
Sacramento River at Hood	0/43	–	–	–
San Joaquin River near Vernalis	38/44	0.1–0.5	0.3	0.2
Channel and diversion stations				
Old River at Station 9	9/23	0.1–0.2	0.1	0.1
Old River at Bacon Island	2/23	0.1–0.2	0.2	0.2
Banks Pumping Plant	15/23	0.1–0.2	0.1	0.1
Contra Costa Pumping Plant	9/21	0.1–0.3	0.2	0.1
Middle River at Union Point	5/15	0.1–0.2	0.1	0.1
Mallard Island	15/23	0.1–1.1	0.5	0.4

a. Boron is currently an unregulated constituent that requires monitoring.

Table 7-5 Summary of pH and alkalinity, October 2005 through September 2007

Station	pH			Alkalinity (mg/L as CaCO3)			
	Number of Samples	Range	Median	Number of Samples	Range	Average	Median
Stations North of the Delta							
American River at E.A. Fairbairn WTP	22	6.1–7.8	7.4	22	16–27	22	23
West Sacramento WTP Intake	22	6.4–8.2	7.9	22	32–79	60	62
Natomas East Main Drainage Canal	28	6.4–8.4	7.9	28	33–158	88	81
Sacramento River at Hood	42	6.4–8.2	7.7	42	29–71	57	59
San Joaquin River near Vernalis	44	6.6–9.0	7.9	44	31–121	76	81
Channel and diversion stations							
Old River at Station 9	23	6.5–8.2	7.8	23	34–70	59	63
Old River at Bacon Island	23	7.3–8.7	7.9	23	34–77	58	61
Banks Pumping Plant	22	6.3–8.2	7.8	22	28–79	60	62
Contra Costa Pumping Plant	21	6.6–8.8	8.0	21	38–82	65	67
Middle River at Union Point	15	7.3–8.0	7.8	15	31–72	62	66
Mallard Island	23	6.6–8.2	7.8	23	41–80	63	66

Table 7-6 Summary of hardness and turbidity data, October 2005 through September 2007

Station	Hardness (mg/L as $CaCO_3$)				Turbidity (NTU)			
	Number of Samples	Range	Average	Median	Number of Samples	Range	Average	Median
Stations North of the Delta								
American River at E.A. Fairbairn WTP	22	14–27	21	21	21	1–99	8	2
West Sacramento WTP Intake	22	30–77	56	56	22	5–84	22	12
Natomas East Main Drainage Canal	28	32–153	94	92	26	6–73	27	17
Sacramento River at Hood	42	30–77	54	55	41	4–108	19	12
San Joaquin River near Vernalis	44	32–175	113	117	43	6–48	18	17
Channel and diversion stations								
Old River at Station 9	23	39–116	78	75	23	2–18	7	7
Old River at Bacon Island	23	36–115	77	74	23	2–15	6	6
Middle River at Union Point	15	39–116	82	77	15	3–35	8	6
Banks Pumping Plant	22	36–118	79	80	22	4–22	10	9
Contra Costa Pumping Plant	21	43–122	89	90	21	2–15	7	7
Mallard Island	23	46–1,414	431	356	23	7–99	22	20

Table 7-7 Summary of inorganic and miscellaneous constituents

Constituents	Findings	Regulation compliance
Constituents with adverse effects on human health		-
Aluminum	Detected in 1 out of 22 samples Value: 0.011	Never exceeded State or federal MCL of 0.2 mg/L
Arsenic	Detected in all 22 samples; range: 0.001–0.002 mg/L; median: 0.002 mg/L	Never exceeded federal MCL of 0.01 mg/L
Barium, beryllium, cadmium, lead and mercury	Never detected	Never exceeded federal primary MCL
Chromium (total)	Detected in 18 out of 22 samples; range: 0.001–0.003 mg/L; median: 0.002 mg/L	Never exceeded federal MCL of 0.1 mg/L or State MCL of 0.05 mg/L
Copper	Detected in all 22 samples; range: 0.001–0.003 mg/L; median: 0.002 mg/L	Never exceeded State or federal MCL of 1.0 mg/L
Nickel	Detected in all 22 samples; range: 0.001–0.002 mg/L; median: 0.001 mg/L	Never exceeded State MCL of 0.1 mg/L
Nitrate	Detected in 22 out of 25 samples; range: 0.8–5.1 mg/L; median: 2.3 mg/L	Never exceeded State MCL of 45 mg/L
Nitrate+Nitrite (as N)	Detected in all 25 samples; range: 0.17–1.23 mg/L; median: 0.48 mg/L	Never exceeded State MCL of 10 mg/L
Selenium	Detected in 10 of 22 samples; range: 0.001–0.002 mg/L; median: 0.001mg/L	Never exceeded federal MCL of 0.05 mg/L
Constituents with adverse effects on taste, odor, or appearance		
Iron	Detected in 21 of 22 samples; range: 0.005–0.065 mg/L; median: 0.015 mg/L	Never exceeded federal MCL of 0.3 mg/L
Manganese	Detected in 17 of 22 samples; range: 0.007–0.018 mg/L; median: 0.013 mg/L	Never exceeded federal MCL of 0.05 mg/L
Silver and zinc	Never detected	Never exceeded federal secondary MCL

MCL = maximum contaminant level

Chapter 8 Data Quality Control

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Chapter 8 Data Quality Control

Overview

This data quality review covers the reporting period from October 1, 2005, through September 30, 2007. Data from 11 stations were collected through the Municipal Water Quality Investigations (MWQI) Program during this reporting period.

The data review was performed using the available quality control (QC) data stored in the Department of Water Resources' (DWR) Field and Laboratory Information Management System (FLIMS) database. This database was used to retrieve the data and flag the analyses that were outside established control limits.

The data quality review indicated that the 2005–2007 MWQI project data were of acceptable quality overall. A few analyses were outside the control limits, but they were not considered to have a significant impact on the overall data quality for the project. The results of the review are presented below.

Field Procedures Quality Control

Field Duplicates

Field duplicates are replicate samples taken at a randomly selected station during each field run to evaluate the precision of field and laboratory procedures. The results of field duplicate analyses are evaluated by calculating relative percent differences (RPDs) and comparing the RPDs with established control limits. The equation for expressing precision is:

$$RPD = (D1-D2)/[(D1+D2)/2] \times 100,$$

where D1 is the first sample value and D2 is the second sample value. During the study period, 1,027 field duplicate analyses were performed and 48 (4.6%) of the RPDs exceeded the acceptable control limits (Table 8-1). These duplicate results indicate that field and laboratory procedures were of acceptable precision for the project.

Table 8-1 Field duplicates

Field Blanks

Field blanks monitor contamination originating from the collection, transport, and storage of environmental samples. Filtered blanks help check for contamination from field sample processing procedures. Unfiltered blanks check for contamination from containers and preservatives. In the study period, 965 field blank analyses were performed, and 26 (2.7%) field blanks exceeded the control limit (Table 8-2).

Table 8-2 Field blanks

Internal Quality Controls

Internal QCs are performed by the laboratory to control the accuracy and precision of the measurement process and determine whether the lab operations are within acceptable QC limits. Environmental samples are grouped in "batches," with approximately 20 samples per batch. Generally, one of each type of QC measure, such as method blank, matrix spike, etc., is performed with each batch to confirm that the analytical method is in control. In some cases, the laboratory performs more than one of each of the QC measures to ensure the quality of the batch. The total number of internal QC analyses performed per analyte is shown in Table 8-3. The following is a review of the internal QC for the project.

Table 8-3 Total internal quality control batches grouped by analyte

Sample Holding Times

Holding time is the period that a sample can be stored after collection and preservation without significantly affecting the accuracy of its analysis. If any analytes exceed holding time limits, the results of the specific analyses should be interpreted with caution. During the 2005-2007 study period, no analytes exceeded the holding time limit.

Method Blanks

Method blanks are analyzed with every sample set and are used to determine the level of contamination that exists in the analytical procedure. A total of 2,794 method blanks were performed from October 2005 through September 2007, and 7 (0.25%) exceeded the control limits.

The analytes with method blank contamination are shown in Table 8-4. Elimination of blank contamination is more difficult for some analytical methods; therefore, each method has its own specific level of acceptance. Table 8-5 shows the frequency of method blank contamination for these analytes, but the frequency of method blank contamination was low for all the analytes in question.

Table 8-4 Method blank exceedances

Table 8-5 Number of batches with method blank exceedances

Laboratory Control Samples and Duplicates

Laboratory control sample (LCS) recoveries are analyzed to verify that the analytical method does not exceed the control limits. The LCS is a standard made from a different source than the calibration standard and is spiked into blank water. The LCS is then analyzed, and the results are compared to the laboratory's control limits. During the period of October 2005 through September 2007, 4,907 LCS analyses were performed, and 11 LCSs exceeded the control limits (Table 8-6). The frequency with which the LCS was outside the control limits was very low (Table 8-7), but whenever the results fall outside the control limits, sample results are deemed unacceptable. Once it is corrected and the LCS is within limits, the samples are reanalyzed. There were 2,422 LCS duplicates performed during the study period (Table 8-8) and 6 duplicates exceeded the control limits. The analytes that exceeded the limits were for Kjeldahl nitrogen and phosphorus.

Table 8-6 LCS recovery exceedances

Table 8-7 Frequency of QC batches with LCS recovery exceedances

Table 8-8 LCS duplicate recovery exceedances

Table 8-9 Number of LCS duplicate recovery exceedances

Matrix Spike Recovery

Matrix spike recoveries are used to describe the precision and accuracy of an analytical measurement. The results of matrix spike recoveries indicate the accuracy of analysis given the interference peculiar to a given matrix. Matrix spikes are prepared by adding a known concentration of analyte to an environmental sample with a known background concentration. The percent recovery must fall within acceptable limits. During the study period, 8,477 matrix spike recoveries were performed, and 80 (0.94%) exceeded the control limits. The batches with matrix spike recoveries outside the control limits are shown in Table 8-10. The analytes that had matrix spike exceedances were bromide, calcium, Kjeldahl nitrogen, magnesium, phosphorus, and sodium. The analytes with the highest frequency of exceedance were Kjeldahl nitrogen (17.5%) and sodium (6.5%) (Table 8-11). Some of the recoveries were high, but the RPDs and LCSs for those batches were within limits; therefore, the batch is considered in control. Recoveries that were lower than the control limits can be attributed to matrix interference, but the LCS for each of those batches was in control.

Table 8-10 Matrix spike recovery exceedances

Table 8-11 Frequency of QC batches with matrix spike recovery exceedances

Matrix Spike Duplicates

Matrix spike duplicate results indicate the precision of the analytical method in a given matrix. The difference between the duplicate samples is reported as an RPD. This difference is compared against the laboratory's control limits as a conservative approach to determining precision. During the study period, 3,620 matrix spike duplicates were performed. Only 15 matrix spike duplicate batches exceeded the control limits (0.41%) (Table 8-12). The analytes were Kjeldahl nitrogen, calcium, phosphorus, and sodium; the frequency of exceedance is shown in Table 8-13. These analytes were out of recovery limits for the matrix spikes and the spike duplicates, which suggests matrix interference. The LCS recoveries are within limits for these analytes; therefore, the batch is considered in control.

Table 8-12 Matrix spike duplicate recovery exceedances

Table 8-13 Number of matrix spike duplicate recovery exceedances

Chapter 8 Data Quality Control

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Table 8-1 Field duplicates

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	Units	RPD	RPD Limit
Dissolved Ammonia	10/3/2006	CA1006B1245	CA1006B1248	0.02	0.03	mg/L as N	40.00%	20%
Dissolved Ammonia	2/6/2007	CB0207B0011	CB0207B0013	0.01	0.02	mg/L as N	66.67%	20%
Dissolved Ammonia	7/2/2007	CC0707B0595	CC0707B0599	0.02	0.01	mg/L as N	66.67%	20%
Dissolved Ammonia	9/5/2007	CC0907B0800	CC0907B0802	0.02	0.01	mg/L as N	66.67%	20%
Dissolved Ammonia	3/6/2006	CA0306B0201	CA0306B0205	0.01	0	mg/L as N	200.00%	20%
Dissolved Boron	11/7/2005	CA1105B1532	CA1105B1534	0	0.1	mg/L	200.00%	20%
Dissolved Bromide	1/4/2006	CB0106B0011	CB0106B0016	0.04	0.03	mg/L	28.57%	20%
Dissolved Bromide	11/7/2005	CA1105B1522	CA1105B1526	0.02	0.01	mg/L	66.67%	20%
Dissolved Bromide	8/1/2006	CA0806B0891	CA0806B0895	0.01	0	mg/L	200.00%	20%
Dissolved Bromide	8/6/2007	CC0807B0679	CC0807B0680	0	0.01	mg/L	200.00%	20%
Dissolved Nitrate	11/7/2005	CA1105B1522	CA1105B1526	0.8	1	mg/L	22.22%	20%
Dissolved Nitrite + Nitrate	1/3/2006	CB0106B0001	CB0106B0002	0.15	0.2	mg/L as N	28.57%	20%
Dissolved Nitrite + Nitrate	8/1/2006	CA0806B0891	CA0806B0895	0.09	0.07	mg/L as N	25.00%	20%
Dissolved Nitrite + Nitrate	12/4/2006	CB1206B0287	CB1206B0290	0.04	0.03	mg/L as N	28.57%	20%
Dissolved Ortho-phosphate	3/6/2007	CA0307B0289	CA0307B0290	0.02	0.03	mg/L as P	40.00%	20%
Dissolved Sodium	4/6/2006	CA0406B0366	CA0406B0367	3	4	mg/L	28.57%	20%
Dissolved Sodium	2/5/2007	CB0207B0001	CB0207B0004	2	3	mg/L	40.00%	20%
Total Kjeldahl Nitrogen	12/5/2005	CA1205B1687	CA1205B1691	0.4	0.3	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	1/2/2007	CA0107B0011	CA0107B0015	0.3	0.4	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	2/6/2007	CB0207B0011	CB0207B0013	0.4	0.3	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	4/2/2007	CB0407B0197	CB0407B0201	0.3	0.5	mg/L as N	50.00%	25%
Total Kjeldahl Nitrogen	5/2/2007	CB0507B0366	CB0507B0370	0.3	0.5	mg/L as N	50.00%	25%
Total Kjeldahl Nitrogen	6/4/2007	CC0607B0451	CC0607B0455	0.6	0.4	mg/L as N	40.00%	25%
Total Kjeldahl Nitrogen	7/2/2007	CC0707B0595	CC0707B0599	0.3	0.4	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	1/3/2006	CB0106B0001	CB0106B0002	0.3	0.4	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	10/2/2006	CA1006B1235	CA1006B1236	0.3	0.4	mg/L as N	28.57%	25%

Table 8-1 continues on next page

Table 8-1 continued

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	Units	RPD	RPD Limit
Total Kjeldahl Nitrogen	3/6/2007	CA0307B0289	CA0307B0290	0.4	0.3	mg/L as N	28.57%	25%
Total Kjeldahl Nitrogen	4/3/2007	CB0407B0230	CB0407B0234	0	0.2	mg/L as N	200.00%	25%
Total Kjeldahl Nitrogen	6/4/2007	CC0607B0441	CC0607B0445	0.2	0	mg/L as N	200.00%	25%
Total Kjeldahl Nitrogen	7/2/2007	CC0707B0585	CC0707B0586	0.4	0.6	mg/L as N	40.00%	25%
Total Organic Carbon	5/2/2007	CB0507B0366	CB0507B0370	0	3.4	mg/L as C	200.00%	30%
Total Organic Carbon	1/3/2006	CB0106B0001	CB0106B0002	4.6	6.4	mg/L as C	32.73%	30%
Total Phosphorus	11/7/2005	CA1105B1532	CA1105B1534	0.03	0.04	mg/L	28.57%	25%
Total Phosphorus	2/6/2006	CA0206B0057	CA0206B0060	0.06	0.09	mg/L	40.00%	25%
Total Phosphorus	5/1/2006	CA0506B0524	CA0506B0528	0.08	0.12	mg/L	40.00%	25%
Total Phosphorus	11/7/2006	CB1106B0163	CB1106B0165	0.04	0.03	mg/L	28.57%	25%
Total Phosphorus	8/6/2007	CC0807B0689	CC0807B0691	0.08	0.05	mg/L	46.15%	25%
Total Phosphorus	12/4/2006	CB1206B0287	CB1206B0290	0	0.01	mg/L	200.00%	25%
Total Phosphorus	2/5/2007	CB0207B0001	CB0207B0004	0	0.01	mg/L	200.00%	25%
Turbidity	10/3/2005	CA1005B1317	CA1005B1321	3	2	N.T.U.	40.00%	15%
Turbidity	8/2/2006	CA0806B0913	CA0806B0917	11	9	N.T.U.	20.00%	15%
Turbidity	11/7/2006	CB1106B0163	CB1106B0165	0	2	N.T.U.	200.00%	15%
Turbidity	2/6/2007	CB0207B0011	CB0207B0013	4	3	N.T.U.	28.57%	15%
Turbidity	3/5/2007	CA0307B0261	CA0307B0265	7	6	N.T.U.	15.38%	15%
Turbidity	4/3/2007	CB0407B0230	CB0407B0234	6	5	N.T.U.	18.18%	15%
Turbidity	9/4/2007	CC0907B0783	CC0907B0784	10	12	N.T.U.	18.18%	15%
UV Absorbance @254nm	11/7/2006	CB1106B0163	CB1106B0165	0.07	0.058	absorbance/cm	18.75%	10%
UV Absorbance @254nm	4/3/2007	CB0407B0230	CB0407B0234	0.034	0.03	absorbance/cm	12.50%	10%

Table 8-2 Field blanks

Analyte	Collection date	Sample number	Result	Reporting limit	Units
Dissolved Ammonia	1/3/2006	CB0106B0010	0.02	0.01	mg/L as N
Dissolved Ammonia	1/3/2006	CB0106B0019	0.01	0.01	mg/L as N
Dissolved Iron	2/15/2006	DA0206B0026	0.006	0.005	mg/L
Dissolved Nitrite + Nitrate	9/4/2007	CC0907B0792	0.01	0.01	mg/L as N
Dissolved Organic Carbon	12/19/2005	CZ1205B20398	8	0.5	mg/L as C
Dissolved Organic Carbon	6/18/2007	CC0607B0543	0.6	0.5	mg/L as C
Dissolved Organic Carbon	6/20/2007	CC0607B0540	0.5	0.5	mg/L as C
Dissolved Ortho-phosphate	5/15/2007	CB0507B0493	0.09	0.01	mg/L as P
Total Copper	6/21/2006	DA0606B0257	0.001	0.001	mg/L
Total Kjeldahl Nitrogen	3/21/2006	CA0306B0298	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	3/23/2006	CA0306B0313	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	4/6/2006	CA0406B0375	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	4/20/2006	CA0406B0479	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	5/16/2006	CA0506B0588	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	6/20/2006	CA0606B0746	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	7/5/2006	CA0706B0801	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	5/15/2007	CB0507B0493	0.5	0.1	mg/L as N
Total Kjeldahl Nitrogen	9/20/2007	CC0907B0849	0.1	0.1	mg/L as N
Total Phosphorus	10/3/2005	CA1005B1325	0.01	0.01	mg/L
Total Phosphorus	9/5/2006	CA0906B1080	0.01	0.01	mg/L
Total Phosphorus	9/19/2006	CA0906B1215	0.02	0.01	mg/L
Total Phosphorus	2/6/2007	CB0207B0020	0.01	0.01	mg/L
Total Phosphorus	5/1/2007	CB0507B0360	0.01	0.01	mg/L
Total Phosphorus	5/15/2007	CB0507B0493	0.18	0.01	mg/L
Total Phosphorus	8/20/2007	CC0807B0728	0.01	0.01	mg/L
Total Phosphorus	8/22/2007	CC0807B0745	0.01	0.01	mg/L

Table 8-3 Total internal quality control batches grouped by analyte

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank
Minor Elements						
Alkalinity	Std Method 2320 B	168	84	236	115	84
Aluminum	EPA 200.8	88	44	164	45	44
Antimony	EPA 200.8	78	39	114	35	39
Arsenic	EPA 200.8	88	44	194	46	44
Barium	EPA 200.8	82	41	119	22	41
Boron	EPA 200.7	171	82	334	160	112
Berryllium	EPA 200.8	78	39	114	35	39
Cadmium	EPA 200.8	78	39	117	33	39
Chromium	EPA 200.8	78	39	146	37	39
Copper	EPA 200.8	88	44	192	49	44
Iron	EPA 200.8	88	44	192	49	44
Lead	EPA 200.8	78	39	143	37	39
Manganese	EPA 200.8	88	44	181	48	44
Mercury	EPA 200.8	44	22	95	27	22
Nickel	EPA 200.8	78	39	114	35	39
pH	pH - Std Method 2320 B					84
Selenium	EPA 200.8	88	44	196	39	44
Silver	EPA 200.8	78	39	117	33	39
Turbidity	EPA 180.1	166	82			146
Zinc	EPA 200.8	78	39	143	37	39
Calcium	EPA 200.7	171	82	342	164	112
Magnesium	EPA 200.7	171	82	342	164	112
Potassium	EPA 200.7	167	80	302	145	110
Sodium	EPA 200.7	171	82	338	163	112
Bromide						
Bromide	EPA 300.0 28d Hold	235	115	578	285	70
Organic Carbon and UVA						
Dissolved Organic Carbon (DOC)	EPA 415.1 (D) Ox	162	81			80
Total Organic Carbon (TOC)	EPA 415.1 (T) Ox	164	82			84
Total Organic Carbon (TOC)	EPA 415_1 (T) Cmbst	122	60			61
Organic Carbon (Dissolved) by Combustion	EPA 415.1 (D) Cmbst	102	51			51
UV Absorbance @254nm	Std Method 5910B	102	49			95

Table 8-3 continued on next page

Table 8-3 continued

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank
Salinity						
Conductance (EC)	Std Method 2510-B					86
Chloride	EPA 300.0 28d Hold	235	115	910	452	70
Sulfate	EPA 300.0 28d Hold	235	115	858	423	70
Total Dissolved Solids (TDS)	Std Method 2540-C					97
Total Suspended Solids	EPA 160.2					23
Hardness	Std Method 2340 B					
Nutrients						
Nitrate	EPA 300.0 28d Hold	235	115	742	365	70
Nitrate	EPA 300.0 48 hr (N03, OP)	2	1			1
Nitrite+Nitrate	Std Method 4500-NO3-F Modified	174	87	268	134	87
Ammonia	EPA 350.1	172	86	276	138	86
Kjeldahl Nitrogen	EPA 351.2	164	82	160	80	83
Ortho-phosphate	EPA 365.1 (DWR Modified)	174	87	276	138	86
Ortho-phosphate	Std Method 4500-P, F					
Phosphorus	EPA 365.4	166	83	174	87	83
Totals		3350	1651	4813	1803	1952

Table 8-4 Method blank exceedances

Analyte	Method	Batch number	Result	Reporting limit	Units
Kjeldahl Nitrogen	EPA 351.2	BL05B20570	0.2	0.1	mg/L as N
Kjeldahl Nitrogen	EPA 351.2	BL05B20847	0.2	0.1	mg/L as N
pH	Std Method 2320 B	BL06B22652	6.4	0.1	pH Units
pH	Std Method 2320 B	BL07B24296	6.5	0.1	pH Units
pH	Std Method 2320 B	BL07B24337	5.6	0.1	pH Units
Phosphorus	EPA 365.4	BL07B24263	0.1	0.01	mg/L
Phosphorus	EPA 365.4	BL07B25321	0.02	0.01	mg/L

Table 8-5 Number of batches with method blank exceedances

Analyte	Method	Total batches	Batches with method blanks out of limits	Frequency of samples out of limits (%)
Kjeldahl Nitrogen	EPA 351.2	83	2	2.4
pH	Std Method 2320 B	84	3	3.5
Phosphorus	EPA 365.4	83	2	2.4

Table 8-6 LCS recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Kjeldahl Nitrogen	EPA 351.2	BL05B20608	125.40	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B21175	122.50	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B22412	123.00	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B22446	126.90	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B22833	130.80	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B22833	124.00	80-120
Kjeldahl Nitrogen	EPA 351.2	BL06B22928	130.00	80-120
Kjeldahl Nitrogen	EPA 351.2	BL07B23996	71.20	80-120
Kjeldahl Nitrogen	EPA 351.2	BL07B25079	120.50	80-120
Phosphorus	EPA 365.4	BL06B22929	124.78	80-120
Phosphorus	EPA 365.4	BL06B23338	73.96	80-120

Table 8-7 Frequency of QC batches with LCS recovery exceedances

Analyte	Total laboratory control samples	LCS recoveries out of limits	Frequency of samples out of limits (%)
Kjeldahl Nitrogen	164	9	5.5
Phosphorus	166	2	1.2

Table 8-8 LCS duplicate recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Kjeldahl Nitrogen	EPA 351.2	BL06B21585	22.31	0-20
Kjeldahl Nitrogen	EPA 351.2	BL06B21798	25.22	0-20
Kjeldahl Nitrogen	EPA 351.2	BL06B23321	24.1	0-20
Kjeldahl Nitrogen	EPA 351.2	BL07B23996	28.95	0-20
Phosphorus (Total)	EPA 365.4	BL06B21647	19.18	0-15
Phosphorus (Total)	EPA 365.4	BL06B23338	22.77	0-15

Table 8-9 Number of LCS duplicate recovery exceedances

Analyte	Total LCS duplicates	LCS duplicate recoveries out of limits	Frequency of samples out of limits (%)
Kjeldahl nitrogen	82	4	4.8
Phosphorus	83	2	2.4

Table 8-10 Matrix spike recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Bromide	EPA 300.0 28d Hold	BL06B22889	55.6	80-120
Bromide	EPA 300.0 28d Hold	BL06B22889	54.68	80-120
Calcium	EPA 200.7 (D)	BL05B20632	-91.60	80-120
Calcium	EPA 200.7 (D)	BL05B20632	-71.60	80-120
Calcium	EPA 200.7 (D)	BL05B20836	140.60	80-120
Calcium	EPA 200.7 (D)	BL05B20836	134.60	80-120
Calcium	EPA 200.7 (D)	BL05B20937	134.60	80-120
Calcium	EPA 200.7 (D)	BL05B20937	139.60	80-120
Calcium	EPA 200.7 (D)	BL05B20937	143.50	80-120
Calcium	EPA 200.7 (D)	BL05B20937	138.50	80-120
Calcium	EPA 200.7 (D)	BL05B21031	37.40	80-120
Calcium	EPA 200.7 (D)	BL05B21031	67.40	80-120
Calcium	EPA 200.7 (D)	BL06B22121	61.30	80-120
Calcium	EPA 200.7 (D)	BL06B22121	41.30	80-120
Calcium	EPA 200.7 (D)	BL06B22121	123.60	80-120
Calcium	EPA 200.7 (D)	BL06B22121	143.60	80-120
Calcium	EPA 200.7 (D)	BL06B22121	123.60	80-120
Calcium	EPA 200.7 (D)	BL06B22121	143.60	80-120
Calcium	EPA 200.7 (D)	BL07B24015	122.20	80-120
Calcium	EPA 200.7 (D)	BL07B24015	130.20	80-120
Kjeldahl Nitrogen	EPA 351.2	BL05B20570	137.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL05B20608	131.00	70-130
Kjeldahl Nitrogen	EPA 351.2	BL05B20872	148.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL05B20872	144.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21175	139.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21646	53.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21646	55.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21701	64.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21701	66.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21731	63.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21731	64.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21798	65.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B21798	68.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22099	55.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22099	49.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22341	66.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22375	136.00	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22416	154.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22416	152.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22565	135.00	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22565	160.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22677	153.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22883	18.00	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22883	415.25	70-130
Kjeldahl Nitrogen	EPA 351.2	BL06B22971	57.50	70-130
Kjeldahl Nitrogen	EPA 351.2	BL07B24806	17.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL07B25318	147.75	70-130
Kjeldahl Nitrogen	EPA 351.2	BL07B25318	45.00	70-130

Table 8-10 continued on next page

Table 8-10 continued

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Magnesium	EPA 200.7 (D)	BL06B22121	73.40	80-120
Phosphorus	EPA 365.4	BL06B21413	72.00	80.7-120.7
Phosphorus	EPA 365.4	BL06B21609	74.00	80.7-120.7
Phosphorus	EPA 365.4	BL06B21854	123.00	80.7-120.7
Phosphorus	EPA 365.4	BL06B21854	134.00	80.7-120.7
Phosphorus	EPA 365.4	BL06B22140	70.00	80.7-120.7
Phosphorus	EPA 365.4	BL06B22975	75.00	80.7-120.7
Phosphorus	EPA 365.4	BL07B23784	135.00	80.7-120.7
Phosphorus	EPA 365.4	BL07B24808	47.00	80.7-120.7
Sodium	EPA 200.7 (D)	BL05B20632	-41.50	80-120
Sodium	EPA 200.7 (D)	BL05B20632	18.50	80-120
Sodium	EPA 200.7 (D)	BL05B20836	254.00	80-120
Sodium	EPA 200.7 (D)	BL05B20836	234.00	80-120
Sodium	EPA 200.7 (D)	BL05B20937	324.00	80-120
Sodium	EPA 200.7 (D)	BL05B20937	344.00	80-120
Sodium	EPA 200.7 (D)	BL05B20937	282.00	80-120
Sodium	EPA 200.7 (D)	BL05B20937	272.00	80-120
Sodium	EPA 200.7 (D)	BL05B21018	75.60	80-120
Sodium	EPA 200.7 (D)	BL05B21018	69.60	80-120
Sodium	EPA 200.7 (D)	BL05B21031	64.50	80-120
Sodium	EPA 200.7 (D)	BL05B21031	74.50	80-120
Sodium	EPA 200.7 (D)	BL06B21707	59.70	80-120
Sodium	EPA 200.7 (D)	BL06B21707	149.70	80-120
Sodium	EPA 200.7 (D)	BL06B22089	149.90	80-120
Sodium	EPA 200.7 (D)	BL06B22089	155.90	80-120
Sodium	EPA 200.7 (D)	BL06B22089	147.00	80-120
Sodium	EPA 200.7 (D)	BL06B22089	146.00	80-120
Sodium	EPA 200.7 (D)	BL06B22121	42.50	80-120
Sodium	EPA 200.7 (D)	BL06B22121	42.50	80-120
Sodium	EPA 200.7 (D)	BL06B23390	75.00	80-120
Sodium	EPA 200.7 (D)	BL06B23390	75.50	80-120

Table 8-11 Frequency of QC batches with matrix spike recovery exceedances

Analyte	Total matrix spikes	Matrix spike recoveries out of limits	Frequency of samples out of limits (%)
Bromide	578	2	0.34
Calcium	342	18	5.3
Kjeldahl Nitrogen	160	28	17.5
Magnesium	342	2	0.58
Phosphorus	174	8	4.6
Sodium	338	22	6.5

Table 8-12 Matrix spike duplicate recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Calcium	EPA 200.7	BL05B20632	24.51	0-20
Calcium	EPA 200.7	BL05B21031	57.25	0-20
Calcium	EPA 200.7	BL06B22121	38.99	0-20
Kjeldahl Nitrogen	EPA 351.2	BL05B20847	35.16	0-30
Kjeldahl Nitrogen	EPA 351.2	BL06B22677	44.38	0-30
Kjeldahl Nitrogen	EPA 351.2	BL06B22883	183.4	0-30
Kjeldahl Nitrogen	EPA 351.2	BL06B22971	41.92	0-30
Kjeldahl Nitrogen	EPA 351.2	BL07B24806	129	0-30
Kjeldahl Nitrogen	EPA 351.2	BL07B25318	106.6	0-30
Phosphorus (Total)	EPA 365.4	BL06B22975	38.71	0-25
Phosphorus (Total)	EPA 365.4	BL07B24808	70.34	0-25
Sodium	EPA 200.7	BL05B20632	521.7	0-20
Sodium	EPA 200.7	BL06B21707	85.96	0-20
Sodium	EPA 200.7	BL06B22121	90.32	0-20
Sodium	EPA 200.7	BL06B22822	30.18	0-20

Table 8-13 Number of matrix spike duplicate recovery exceedances

Analyte	Total matrix spike duplicates	Matrix spike duplicate recoveries out of limits	Frequency of samples out of limits (%)
Kjeldahl nitrogen	80	6	7.5
Calcium	164	3	1.8
Phosphorus	87	2	2.3
Sodium	163	4	2.4

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Appendix A
Current State and Federal Drinking Water Standards

Available online at

http://www.wq.water.ca.gov/owq_content/regulations.cfm

or on CD inserted in report

Appendix B
Data Files

Available online at
http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm

or on CD inserted in report