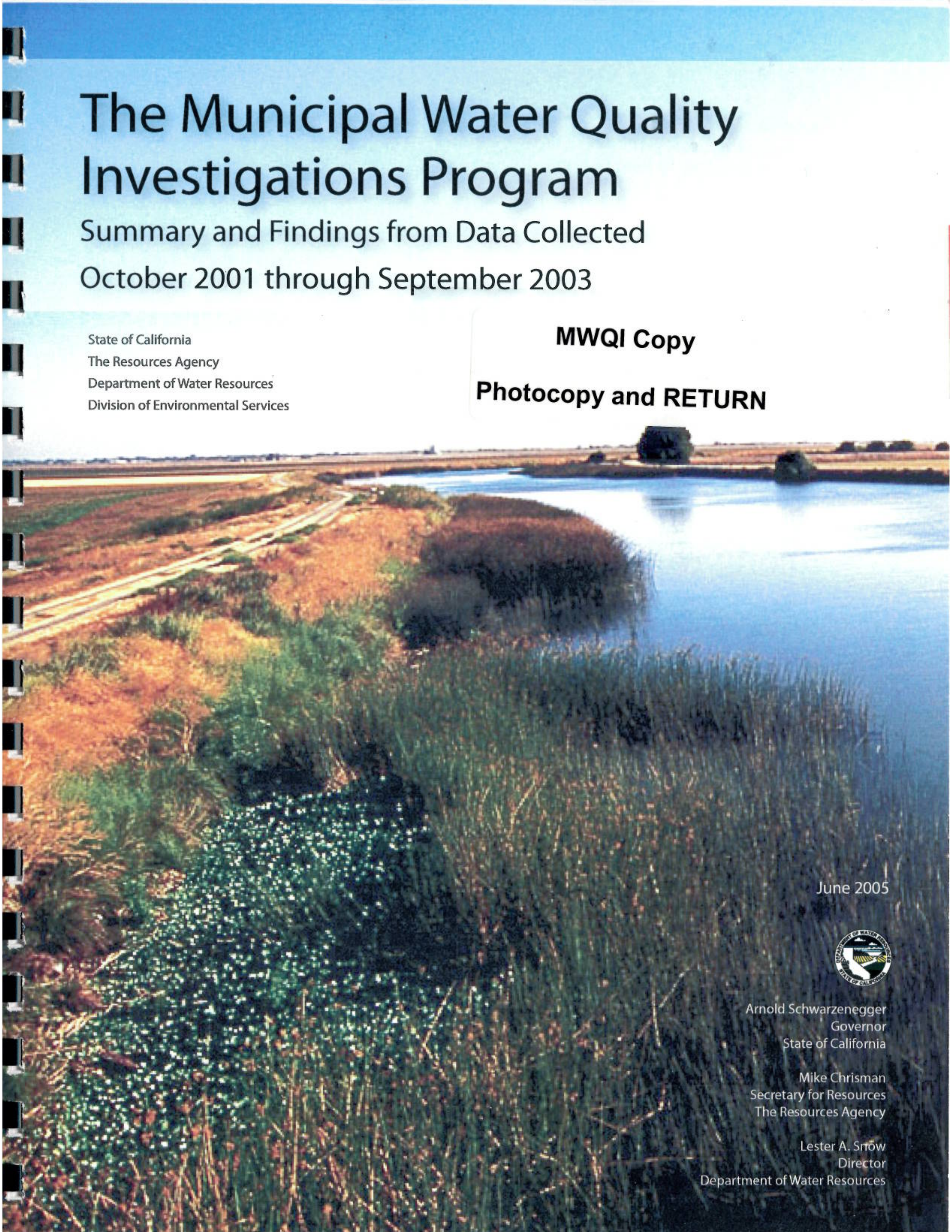
The Municipal Water Quality Investigations Program

Summary and Findings from Data Collected

October 2001 through September 2003

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



June 2005

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Foreword

The Sacramento-San Joaquin Delta (the 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 affected by a variety of degrading factors. Close monitoring of Delta waters is necessary to ensure delivery of high quality source waters to urban water 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 that are 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 annual or multi-year data summary reports. The previous three-year report (July 2003) summarized data collected through September 2001. The current report summarizes and interprets monitoring data collected from October 1, 2001, to September 30, 2003, 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 web site: http://www.wq.water.ca.gov/mwq/index.htm. For further information about the MWQI Program, please visit its Web site or contact Dan Otis, Chief of the Municipal Water Quality Program Branch, (916) 651-9683, or send your request to: MWQI Program, P.O. Box 942836, Sacramento, CA 94236-0001.

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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
Casitas Municipal Water District
Castaic Lake Water Agency
Central Coast Water Authority
Coachella Valley Water District
County of Kings
Crestline-Lake Arrowhead Water Agency
Desert Water Agency
Dudley Ridge Water District
Empire-West Side Irrigation District
Kern County Water Agency
Littlerock Creek Irrigation District
Metropolitan Water District of Southern California
Mojave Water Agency
Napa County Flood Control and Water Conservation District
Oak Flat Water 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
Tulare Lake Basin Water Storage District

MWQI Participant:

Contra Costa Water District

Metric Conversion Factors

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)

Acronyms and Abbreviations

af	acre-foot/acre-feet
AL(s)	action level(s)
APHA	American Public Health Association
AWWA	American Water Works Association
BLM	US Bureau of Land Management
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
CVRWQCB	Central Valley Regional Water Quality Control Board
D/DBP(s)	disinfectant/disinfection byproduct(s)
DES	Division of Environmental Services of DWR
DHS	California Department of Health Services
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DWR	California Department of Water Resources
EC	electrical conductivity
EPA	US Environmental Protection Agency
ESWTR	Enhanced Surface Water Treatment Rule
FLIMS	Field and Laboratory Information Management System
HAAs	Haloacetic acids
IC	Ion Chromatography
ICP	Inductively Coupled Plasma Optical Emission Spectroscopy
IEP	Interagency Ecological Program
IQR	interquartile range
L	Liters
LCS	laboratory control sample
maf	million acre-feet
MCL	maximum contaminant level
MDL	method detection limit
mg/L	milligrams per liter
MTBE	methyl tertiary-butyl ether
MWDSC	Metropolitan Water District of Southern California
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
OWQ	Office of Water Quality

pH	negative log of the hydrogen ion activity
POC	particulate organic carbon
QA/QC	quality assurance/quality control
RPD(s)	relative percent difference(s)
SJR	San Joaquin River
SRWTP	Sacramento Regional Wastewater Treatment Plant
$SUVA_{254}$	specific UVA_{254}
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TCAA	trichloroacetic acid
TDS	total dissolved solids
THM	trihalomethane
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSS	total suspended solids
TTHMFP	total trihalomethane formation potential
USBR	US Bureau of Reclamation
US EPA	see EPA
UVA_{254}	ultraviolet absorbance measured at a wavelength of 254 nanometers
VAMP	Vernalis Adaptive Management Plan
WDL	Water Data Library
WTP	water treatment plant
WWTP	wastewater treatment plant
WY	water year
µg/L	micrograms per liter
µm	micrometers
µS/cm	microsiemens per centimeter

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Executive Summary

Purpose

The purpose of this report is to summarize water quality data collected in the Sacramento-San Joaquin Delta (the Delta) region from October 2001 through September 2003. The Municipal Water Quality Investigations Program (MWQI) of the California Department of Water Resources (DWR) regularly reports findings to the State Water Contractors and the public by preparing annual or multiyear reports summarizing water quality data collected from various sites in or near the Delta. The previous report presented data collected over 3 years through September 2001.

Background

In the State of California, two-thirds of the water consumption occurs south of Sacramento, but two-thirds of the precipitation occurs north of Sacramento mostly as snow and rainfall in the Sierra Nevada and the Sacramento Valley. Precipitation is unevenly distributed throughout the year with most of the annual precipitation occurring from November through April (wet months). Water from the wet months must be stored outside the Delta and transported through the Delta before it is exported or diverted. Water quality deteriorates as the water traverses the complex Delta tributaries and channels, especially during dry and critical water years when annual precipitation is low.

When water reaches the Delta, many factors degrade water quality. These include intrusion of seawater with high salinity and bromide, releases of organic carbon from the vast area of carbon-rich peat soils, growth and decay of phytoplankton in Delta waterways, returns of Delta island drainage, urban runoff and discharges, and recirculation of irrigation waters through the San Joaquin Valley.

The Delta water system is highly complex, and water operations in the Delta are constrained by competing interests. Accordingly, it will not be feasible to solve all water quality problems affecting the Delta in the near term. Frequent monitoring is necessary to identify water quality changes and spatial and seasonal patterns to assist Delta water users to treat and manage their source waters. Computer models are currently being developed or refined to enable water quality forecasts to be made. Long-term monitoring data are essential to the development, calibration, and validation of these computer models, such as the DSM2 model developed by DWR modelers. These models may subsequently be used for long-term resource and facilities planning and project operations.

Scope of Report

Presented are data from 11 MWQI stations (Figure A). Four of the stations monitor water quality from the San Joaquin River (SJR), the Sacramento River, and the American River as they flow into 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 represents SJR water quality as it enters the Delta.


Figure A Location of MWQI monitoring stations, 2001–2003

Six of the 11 stations are within the Delta or at diversion points in the Delta. Two of the stations—Old River at Station 9 and Old River at Bacon Island—are Delta channel stations representing quality of mixed waters primarily from the SJR and Sacramento River. Water is being diverted near the Old River at Station 9 at a pumping station of the Contra Costa Water District (CCWD). Three of the 6 stations—Banks Pumping Plant, Delta-Mendota Canal (DMC) at McCabe Road, and Contra Costa Pumping Plant No. 1—are diversion points that reflect the quality of waters being diverted from the Delta at these points. The Sacramento River at Mallard Island is a station at the western end of the Delta, which is most susceptible to seawater influence due to its proximity to the San Francisco and Suisun bays. CCWD has an intake at Rock Slough, which is near Mallard Island. CCWD only operates this intake during high Delta outflow conditions when chloride concentrations are acceptable. In addition, MWQI also monitored an urban drainage site—Natomas East Main Drainage Canal.

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.

Summary of Findings

The constituents of most concern for Delta source waters include organic carbon, bromide, and salinity. Organic carbon and bromide concentrations were found to be elevated in Delta source waters. Salinity may be elevated during dry runoff years. None of the other constituents was found at concentrations above the State or federal maximum contaminant levels (MCLs) for finished drinking water.

Organic Carbon

Organic carbon in the Delta and its tributaries differed both seasonally and spatially (Figure B). Median total organic carbon (TOC) for the American and Sacramento River stations north of the Delta was 2 mg/L or less, whereas median TOC for the SJR near Vernalis was 3.7 mg/L. The median TOC at Mallard Island was 2.4 mg/L, which was different from concentrations from either the Sacramento River or SJR stations, reflected the multiple sources of water at this station. The 2 Delta channel stations—Old River at Station 9 and Old River at Bacon Island—and the 3 diversion stations—Banks Pumping Plant, DMC, and Contra Costa Pumping Plant #1—receive water from both the SJR and the Sacramento River. Despite dilutional effects of water from the Sacramento River, median TOC concentrations for these stations ranged from 3.2 to 3.5 mg/L, which were close to that of the SJR near Vernalis station, suggesting that additional sources of organic carbon exist. Agricultural drainage and in-channel production are probable sources of organic carbon.

Figure B Total organic carbon: range (median), unit (mg/L)

Compared with the previous summary period (1998–2001), median TOC concentrations of most stations did not change significantly except for the SJR near Vernalis station, where median TOC concentration increased about 19%.

Seasonal patterns of organic carbon concentrations differed between tributary and channel stations. At each tributary station, organic carbon was generally significantly higher during the wet months than during the dry months. Seasonal patterns at the 2 Delta channel stations and at the 3 diversion stations differed from those at SJR and the Sacramento River stations, further indicating additional organic carbon sources.

Bromide

The data confirmed findings from MWQI's previous summary report that bromide in Delta waters came primarily from seawater. Bromide concentrations were higher at those stations closer to seawater influence than away from seawater influence (Figure C). Of the 11 stations, the Mallard Island station is the closest to the bay and had the highest median bromide (2.00 mg/L) of all stations (Figure C). The SJR near Vernalis had the second highest bromide concentrations with a median of 0.3 mg/L. Elevated bromide in the SJR was 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 DMC, which contains considerable bromide (Figure C). Bromide and other salts in irrigation waters are concentrated and discharged to the SJR where they re-enter the Delta and mix with waters being diverted into the DMC. 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.

Figure C Bromide: range (median), unit (mg/L)

Median bromide concentrations at the diversion stations ranged from 0.15 to 0.22 mg/L (Figure C). The stations at the north end of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below its reporting limit of 0.01 mg/L (Figure C). Urban discharges and runoff from the watersheds in the Sacramento Valley were not significant sources of bromide in Delta waters because bromide concentrations were low in waters of the American and Sacramento rivers and the Natomas East Main Drainage Canal.

Compared with the previous summary period, median bromide concentrations remained unchanged except at the Contra Costa Pumping Plant #1 and the SJR near Vernalis station, where median bromide concentrations were significantly higher. The lower bromide levels at Contra Costa Pumping Plant #1 and the SJR near Vernalis were due to the greater runoff amounts in the watersheds during the previous summary period.

Seasonal patterns of bromide differed from those of organic carbon. Unlike organic carbon, bromide loads do not increase with high precipitation from the Sacramento Valley; precipitation dilutes bromide concentrations. However, precipitation in the San Joaquin Valley may increase loads because rain flushes salts from the soils into the SJR.

High Delta outflows lower bromide levels at seawater-affected stations such as Mallard Island and nearby stations. During the reporting period, Delta outflows in 2003 water year were higher than in 2002 WY, and bromide concentrations at Mallard were kept low from January to August 2003. Freshwater outflow not only keeps seawater from entering the Delta, it also dilutes bromide already present in the waters. Therefore, bromide levels were lower during wet years when outflows were greater and significantly higher during dry or critical water years when Delta outflows were less.

Salinity

Seawater influence was the primary source of salinity throughout the western Delta as indicated by the high median electrical conductivity (EC) and the wide EC range at Mallard Island (Figure D). Among the river stations, EC of SJR water was significantly higher than in waters from the American and Sacramento rivers. This was apparently due to the high level of salts in the irrigation returns from the San Joaquin Valley and recirculation of salts from the Delta, into the San Joaquin Valley through the DMC, then back to the Delta through the SJR.

Figure D Electrical conductivity: range (median), unit: (µS/cm)

EC was significantly lower at Delta channel and diversion stations than at the SJR due to the dilutional effects of water from the Sacramento River. Median EC at the Delta channel stations ranged from 285 to 324 µS/cm (Figure D). EC became higher at the diversion stations, especially at the DMC (Figure D).

In addition to seawater intrusion, EC in Delta waters is also affected by sources that include watershed runoff, urban discharges, and agricultural drainage. Salinity loads from the watersheds were significant during the wet months, especially after each of the first few major rain events.

Other Constituents

During the 2-year reporting period, MWQI monitored constituents known either to have adverse human health effects or to affect taste, odor, or appearance of finished drinking water. Monitoring was at the diversion stations. Of all the constituents monitored, none was found at concentrations above the State or federal MCLs (Table A). The highest concentrations of lead, selenium, chromium, arsenic, iron, manganese, copper, and zinc never exceeded the objectives specified in "Article 19 Water Quality" of the Standard Provisions for Water Supply Contract.

Table A Inorganic and miscellaneous constituents

Figure A Location of MWQI monitoring stations, 2001–2003

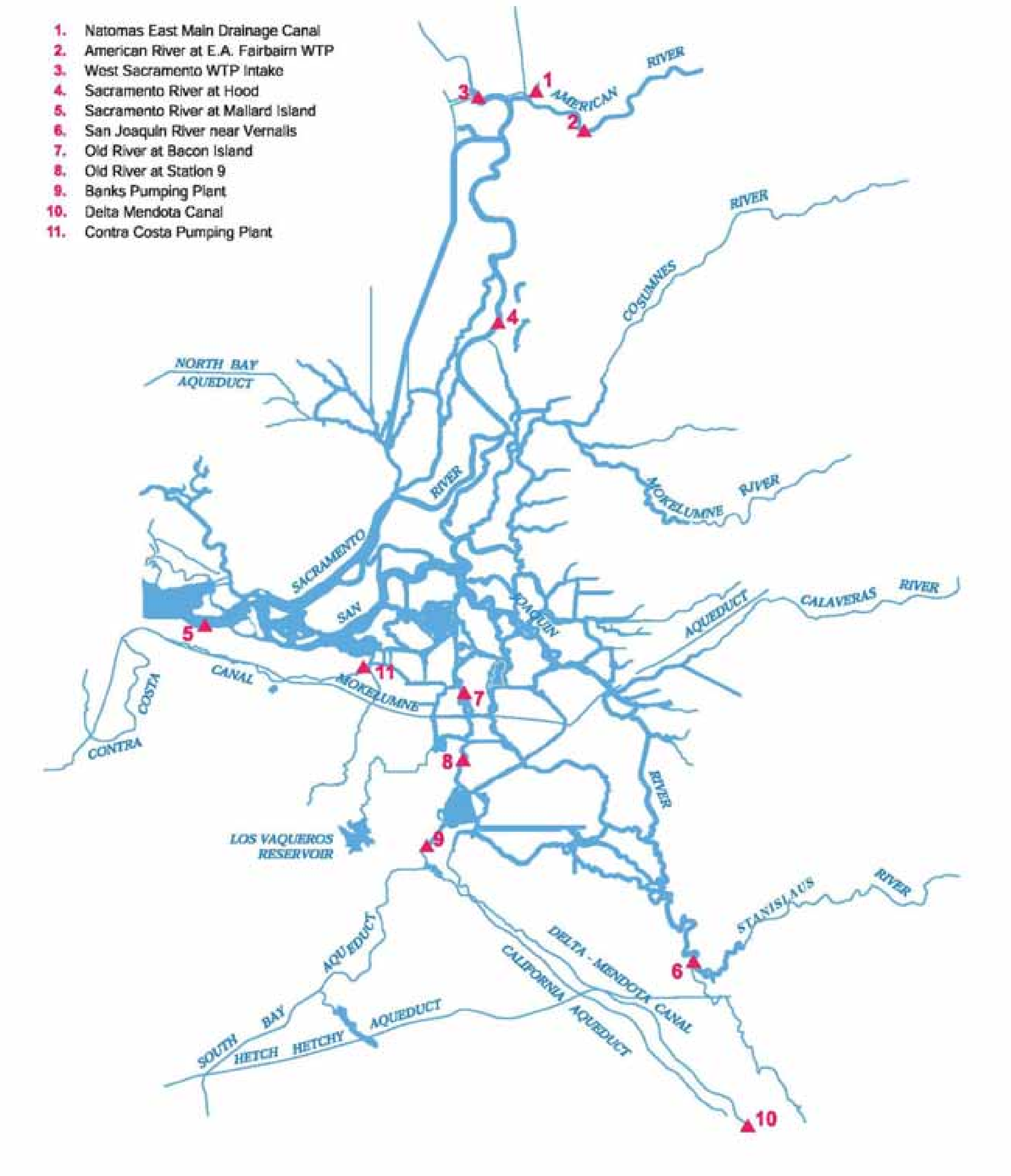

Figure B Total organic carbon: range (median), unit (mg/L)

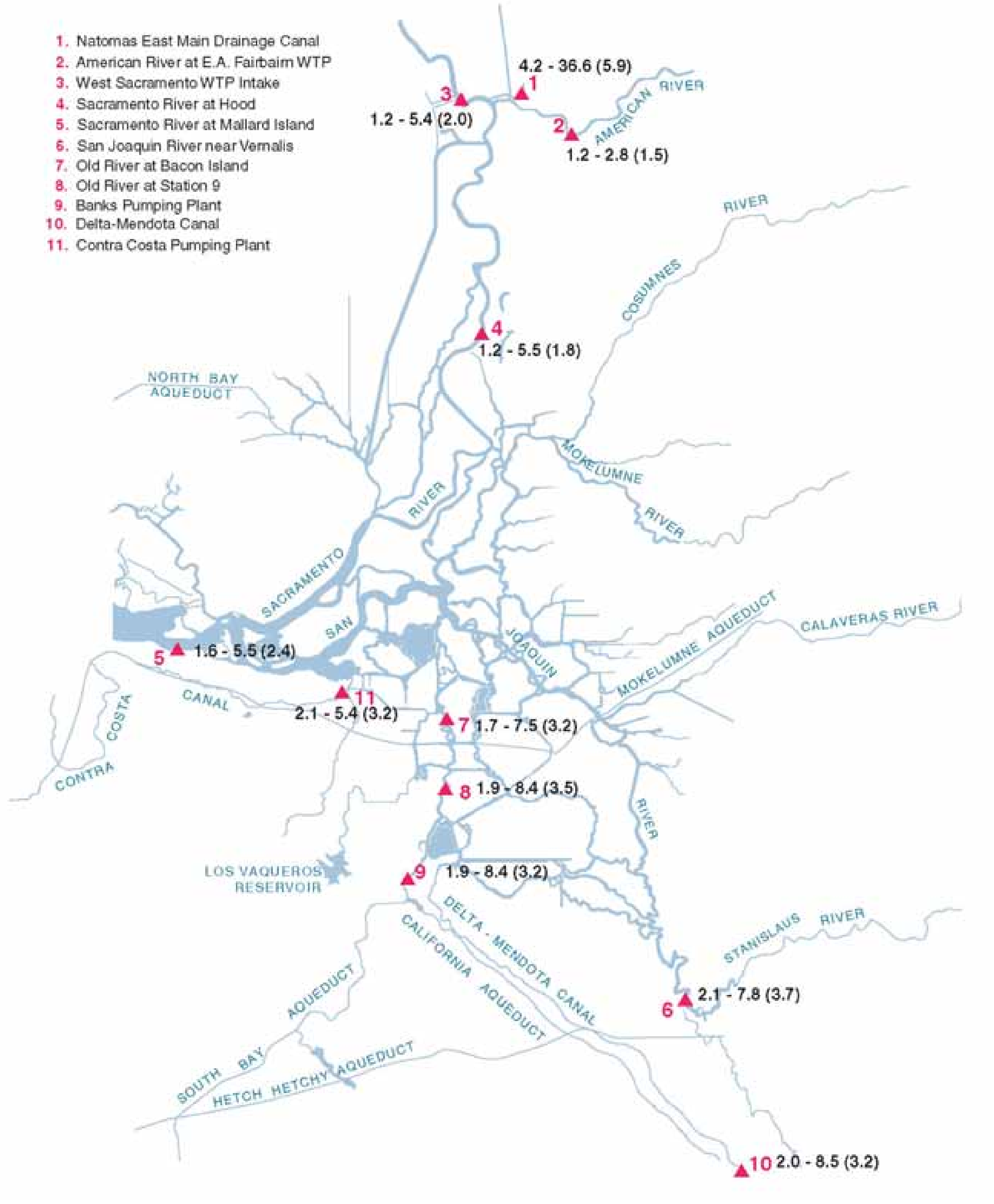

Figure C Bromide: range (median), unit (mg/L)

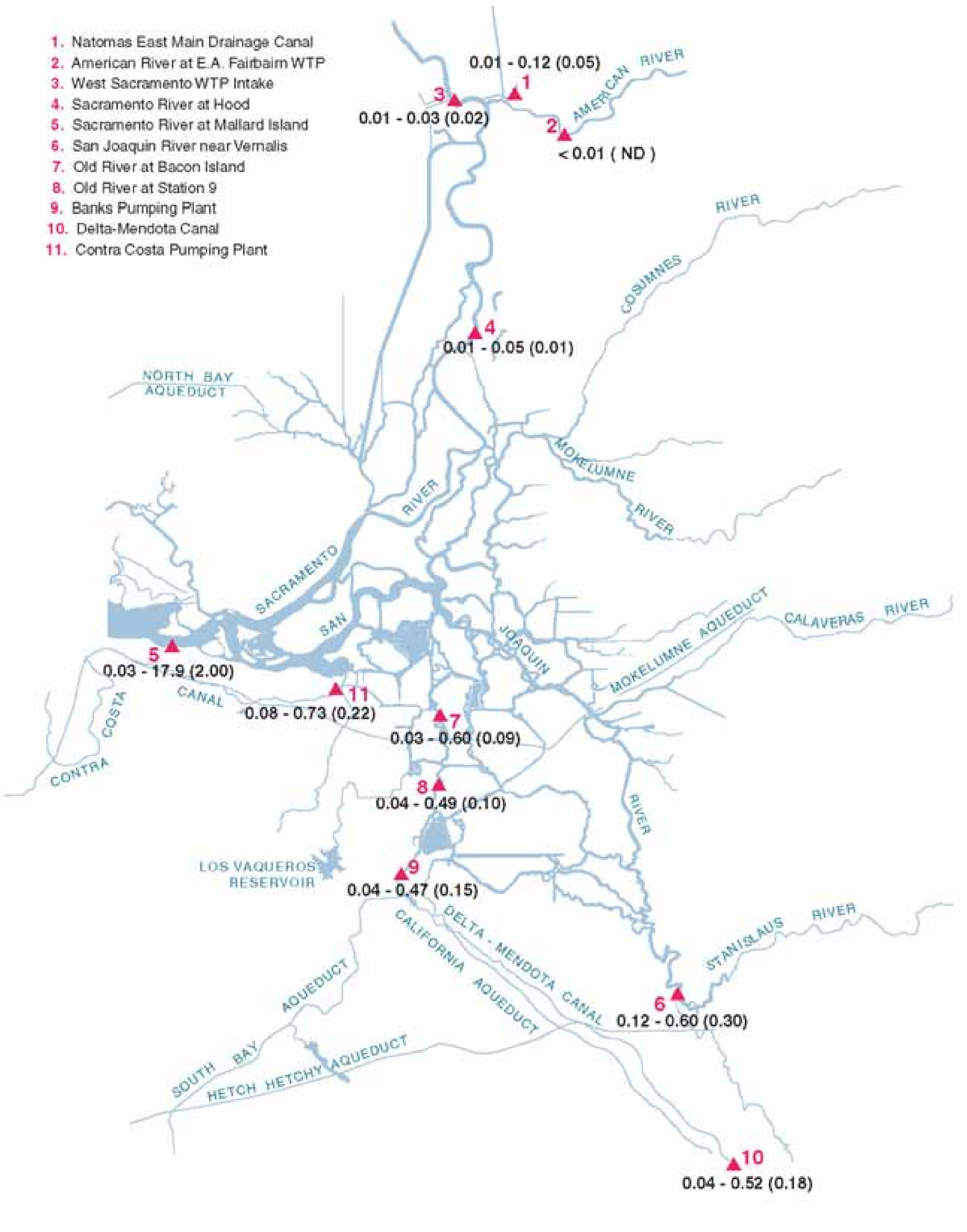

Figure D Electrical conductivity: range (median), unit: (µS/cm)

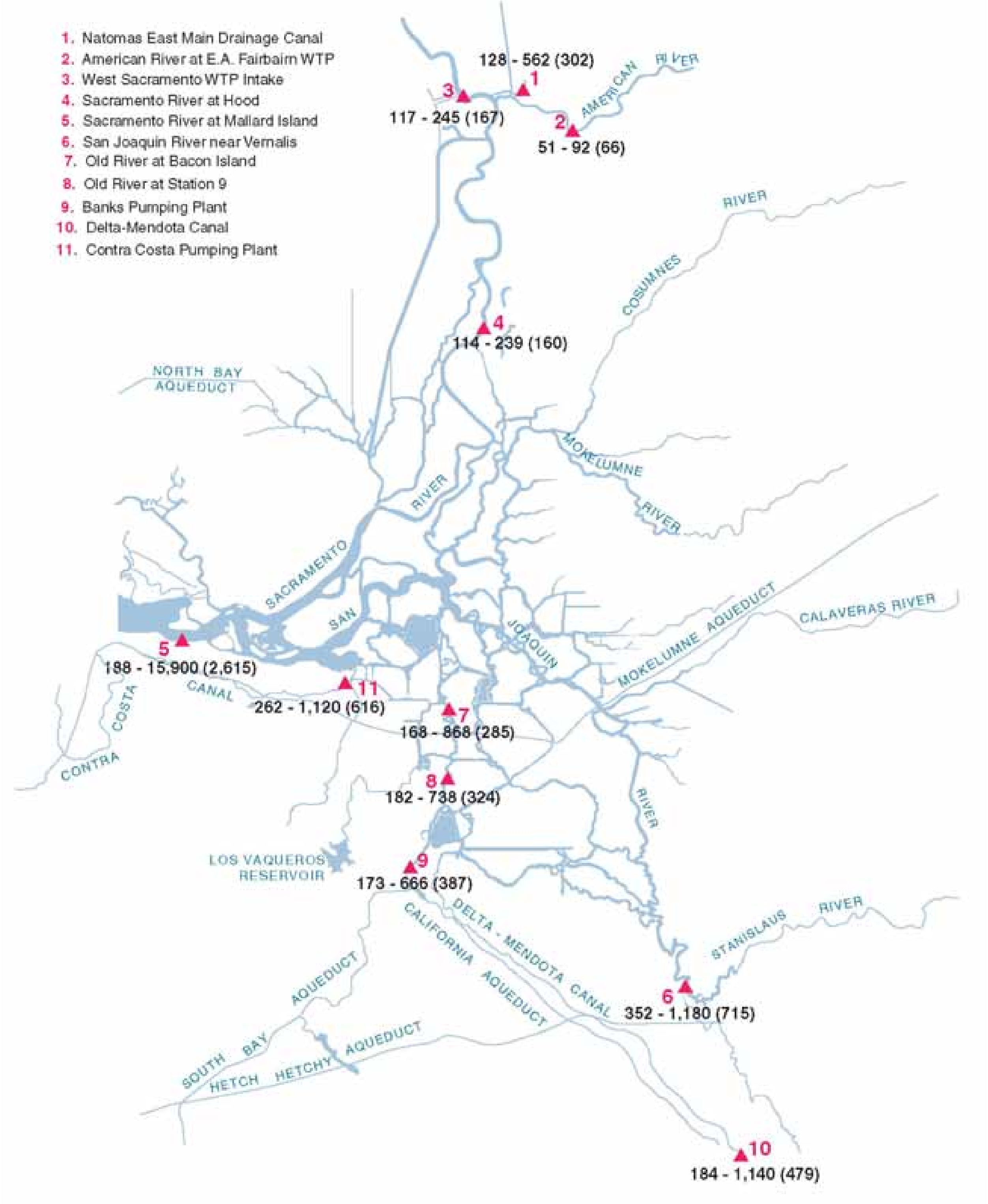

Table A Inorganic and miscellaneous constituents

Constituents	Findings	Regulation compliance
Constituents with adverse effects on human health		
Aluminum	Never detected at or above reporting limits	Never exceeded State or federal MCL of 0.2 mg/L
Antimony, cadmium, and lead	Never detected at or above reporting limits	Never exceeded federal primary MCL
Arsenic	Detected at or above reporting limit in all 48 samples; range: 0.001–to 0.003 mg/L; median: 0.002 mg/L	Never exceeded federal MCL of 0.01 mg/L
Barium	Of 40 samples collected at diversion stations, 15 samples were found at the reporting limit at or above 0.05 mg/L (38%) range:0.05-0.06; median:0.06	Never exceeded federal MCL of 2 mg/L or DHS MCL of 1 mg/L
Chromium (total)	Detected at or above reporting limit in 44 out of 48 samples (92%); range: 0.001–0.009 mg/L; median: 0.003 mg/L	Never exceeded federal MCL of 0.1 mg/L or DHS MCL of 0.05 mg/L
Copper	Detected at or above reporting limit in all 48 samples collected at 2 diversion stations; range: 0.001–0.009 mg/L; median: 0.002 mg/L	Never exceeded State or federal MCL of 1.0 mg/L
Mercury	Of 41 samples, none was found at or above reporting limit of 0.0002 mg/L	Never exceeded federal MCL of 0.002 mg/L
Nickel	Detected at or above reporting limit in 44 of 46 samples (96%); range: 0.001–0.003; median: 0.001 mg/L	Never exceeded DHS MCL of 0.1 mg/L
Nitrate+Nitrite (as N)	Detected in all 24 samples at Banks; range: 0.13–1.7 mg/L, median: 0.53 mg/L	Never exceeded DHS MCL of 10 mg/L
Selenium	Detected at or above reporting limit in 9 of 24 samples (38%); range: 0.001–0.002 mg/L; median: 0.001	Never exceeded federal MCL of 0.05 mg/L
Constituents with adverse effects on taste, odor, or appearance		
Iron	Detected at or above reporting limit in 24 of 48 samples collected at 2 diversion stations (50%); range: 0.005–0.085 mg/L; median: 0.02 mg/L	Never exceeded federal MCL of 0.3 mg/L
Manganese	Detected at or above reporting limit in 22 of 48 samples collected at 2 diversion stations (46%); range: 0.006–0.028 mg/L, median: 0.01 mg/L	Never exceeded federal MCL of 0.05 mg/L
Silver	Never detected at or above reporting limit in any of the 40 samples collected at 2 diversion stations	Never exceeded federal MCL of 0.1 mg/L
Zinc	Detected at or above reporting limit in 2 out of 48 samples collected at 2 diversion stations (4%) Range:0.005 -0.015	Never exceeded federal MCL of 5 mg/L

Chapter 1 Introduction

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Chapter 1 Introduction

Overview

This report summarizes and interprets monitoring data collected by the Municipal Water Quality Investigations Program of the Department of Water Resources (DWR) from October 1, 2001, to September 30, 2003. The previous MWQI report was completed in July 2003 and summarized data collected from August 1998 through September 2001 (DWR 2003).

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

Major water quality constituents examined in this report include organic carbon, bromide, salinity, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of current interest. MWQI resumed nutrient monitoring at most stations beginning November 2002. Nutrient data collected during this reporting period are presented in a separate chapter.

Statistical analyses in this report are not as extensive as they were in the previous summary report, but some basic statistics, seasonal patterns, and brief discussions on sources of some constituents are presented. The raw data for all examined constituents are available both online and on a CD-ROM (see Appendix A).

Appendix A

Neither this nor the previous report discusses water quality in the context of drinking water standards because source waters are not regulated to meet standards for finished drinking water. However, at some Delta diversion stations, certain constituents are discussed in the context of existing State and federal drinking water regulations and water quality objectives specified in the long-term water supply contracts between DWR and each SWC. This report does not present the details of the regulations, standards, or provisions; the regulations and standards may be found in Chapter 2 of *Sanitary Survey Update Report 2001* (DWR 2001). The Standard Provisions for Water Supply Contract between DWR and the SWCs is available from the Project Water Contracts Unit, State Water Project Analysis Office of DWR.

Interpretations in this report are based on either monthly or weekly grab sampling data. Results and interpretations from grab sampling data, especially monthly data, have limitations in explaining spatial and seasonal patterns in the Delta, given its complex hydrology. Therefore, MWQI collaborated with DWR's Modeling Section to develop computer models using grab sampling data and hydrologic information, particularly at tidally influenced locations. Progress made by DWR modelers may be found at: http://modeling.water.ca.gov/branch/reports.html. MWQI is committed to the use of modeling tools to provide more extensive interpretations of its monitoring data and to enable water quality forecast to be made.

Monitoring Stations

Figure 1-1 Location of MWQI monitoring stations, 2001–2003

Geographic locations of the 11 monitoring stations are presented in Figure 1-1. During the reporting period, MWQI collected samples at 9 stations; the Division of Operations and Maintenance (O&M) of DWR collected samples for MWQI at the Banks and Delta-Mendota Canal (DMC) stations.

Samples were generally taken monthly; but samples were collected weekly at the Hood station on the Sacramento River and the San Joaquin River (SJR) near Vernalis station (Table 1-1). Starting November 2001, weekly sampling was increased to 6 stations during wet months, which were sampled for turbidity, electrical conductivity, alkalinity, total organic carbon (TOC), dissolved organic carbon (DOC), and bromide (Table 1-1). With approval of the MWQI committee, MWQI discontinued monitoring Delta drainage stations during this reporting period. MWQI has collected extensive historical grab sampling data from drainage sites throughout the Delta. However, accurate estimates of salt and organic carbon loads have proven to be difficult, and the value of continuing to take grab samples from drainage sites is questionable. However, MWQI will consider conducting special studies on drainage sites in the future.

Table 1-1 MWQI monitoring stations, 2001–2003

For this report, the 11 sampling stations were divided into 5 functional groups for discussion purposes (Table 1-1). Stations within each group are either geographically or hydrologically related except for the Natomas East Main Drainage Canal station, which is an urban drainage tributary to the Sacramento River (Table 1-1). MWQI is now conducting a special study on NEMDC. Therefore, data from NEMDC will be briefly discussed and presented separately from most other stations. Although the Old River at Station 9 is treated as a channel station in this report, Contra Costa Water District (CCWD) has an intake very close to this station. The Mallard Island station is traditionally considered a station on the Sacramento River. However, it receives water from both the SJR and the Sacramento River, and it is affected by waters from the San Francisco and Suisun bays.

CCWD has an intake at Mallard Slough, which is close to MWQI's Mallard Island monitoring station. CCWD operates this intake only when Delta outflows are high and chloride concentrations are below regulatory limits. The Mallard Island station shows the most seawater influence of all the Delta stations. When Delta outflows are low during dry runoff years or during dry months of each year, water quality (electrical conductivity and bromide in particular) at this station reflects a mixture of fresh and marine waters and, thus, is an indicator of water quality that may be affecting Delta diversion stations. Therefore, water quality at this station is also discussed separately throughout this report.

Program Changes

During the reporting period, MWQI made some changes to increase monitoring frequency and improve data quality and site access.

Monitoring frequency at 6 stations was increased from monthly to weekly from November 1 to April 30 of each year. The increased monitoring served as a temporary alternative to real-time carbon and anion data while awaiting construction and installation of planned real-time monitoring facilities at key stations. When the real-time stations and analyzers are in service, the need for increased grab sampling will be re-evaluated.

For the weekly samples, turbidity, electric conductivity, alkalinity, TOC, DOC, and bromide were analyzed. The standard minerals were not included in the weekly samples because historical data have shown these parameters are of less concern in Delta source waters and monthly sampling data are sufficient.

Following a recommendation in the previous data report (DWR 2003a), MWQI resumed nutrient monitoring in November 2002. Initial monitoring has been monthly, but may be expanded in both frequency and locations, depending on the data collected during this period. The objective of this phase of sampling is to collect nutrient data at key stations for examination of seasonal and spatial trends. More extensive sampling may be conducted to study the effects of nutrients on in-channel production of organic carbon and the interrelationships between nutrient fluxes and organic carbon levels, especially during the summer months.

MWQI relocated the station in Old River at Bacon Island to improve quality of data collected there. Prior to January 2002, samples were taken behind an agricultural processing plant. The sampling point was approximately 20 feet from the river bank within riparian plants that prevented free waterflow. In addition, boating activities in Old River stirred up river sediments, causing the water to become cloudy and potentially nonrepresentative of that site. In order to take a more representative sample, MWQI moved the station approximately 300 feet downstream to a mail boat dock, which extends about 25 feet into Old River. The new sampling site is free of riparian vegetation and less susceptible to disturbances from passing boats. Thus, a more representative sample can be taken.

Frequently Used Terms

This report uses certain abbreviations, acronyms, and terminology. A list of acronyms and abbreviations 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, 2002 WY runs from October 1, 2001, to September 30, 2002.

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

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

Dry Year, Below Normal Year, and Above Normal Year: Runoff year types indicating low, moderately high, and high total unimpaired runoff in a watershed, respectively, as defined in http://cdec.water.ca.gov/cgi-progs/iodir/wsihist.

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

DMC at McCabe Road: A sampling site along the Delta-Mendota Canal at mile 67.2 about 0.87 miles upstream of McCabe Road. Mile 0.00 of the DMC is at the diversion point from the Old River.

Reporting period: The period from October 1, 2001, to September 30, 2003, which includes 2 water years. Thus, “the reporting period” may also be referred to as “the 2 water years” throughout the report.

VAMP: 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 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 excludes the inorganic nitrogen species such as ammonia, nitrate, and nitrite.

Figure 1-1 Location of MWQI monitoring stations, 2001–2003

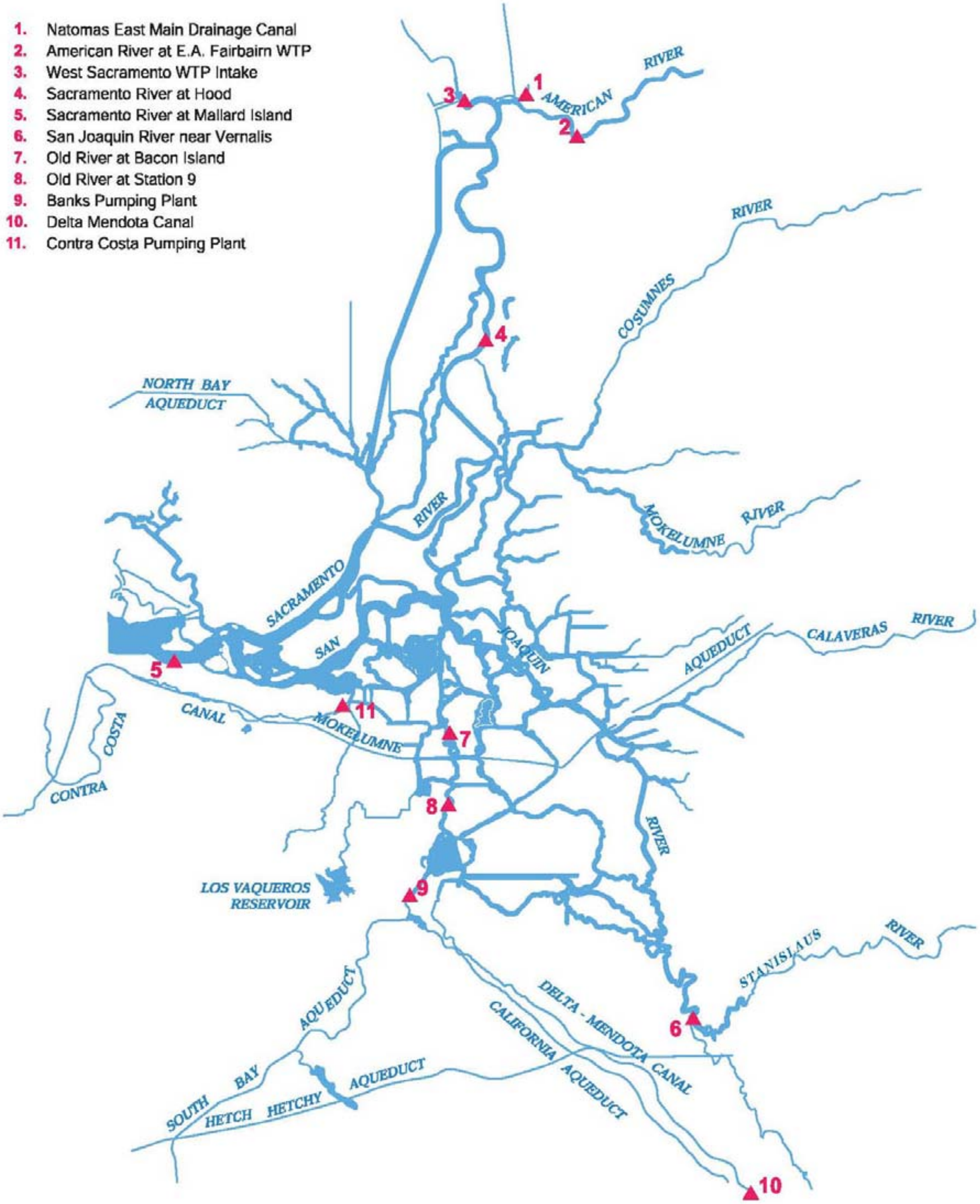

Table 1-1 MWQI monitoring stations, 2001–2003

Station	DWR station number	Monitoring frequency
American and Sacramento River stations		
American River at E.A. Fairbairn WTP[a]	A0714010	Monthly / weekly (Nov-April) [b]
Sacramento River at West Sacramento WTP Intake	A0210451	Monthly / weekly (Nov-April)
Sacramento River at Hood	B9D82211312	Weekly
San Joaquin River stations		
San Joaquin River near Vernalis	B0702000	Weekly
Delta channel stations		
Old River at Station 9	B9D75351342	Monthly / weekly (Nov-April)
Old River at Bacon Island	B9D75811344	Monthly / weekly (Nov-April)
Delta diversion stations		
Banks Pumping Plant	KA000331	Monthly
Delta-Mendota Canal at McCabe Road	DMC06716	Monthly
Contra Costa Pumping Plant	B9591000	Monthly
Other stations		
Mallard Island	E0B80261551	Monthly
Natomas East Main Drainage Canal	A0V83671280	Monthly / event-based [c] (Nov-April)

a. WTP = water treatment plant.

b. Weekly sampling from November through April for turbidity, electrical conductivity, alkalinity, TOC, DOC, and bromide.

c. Monitoring approximately weekly depending on storm events.

Chapter 2 Data Collection and Analysis

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Chapter 2 Data Collection and Analysis

Sample Collection

The Municipal Water Quality Investigations (MWQI) Field Support Group collected samples at 9 of the 11 stations. The Division of Operations and Maintenance of the Department of Water Resources (DWR) collected samples at the Banks and Delta-Mendota Canal stations. Because samples from all stations cannot be collected within one day due to distances between stations and differences in sampling frequencies, samples at the sites were collected on 2 to 3 different one-day sampling runs within one week's period, with each sampling day covering a group of geographically close stations or stations with the same sampling frequency.

A set of sample documentation forms was generated for each site before each sample run. These forms included a Sample Submission Form and a Test Request Form, which contained site information, sample description, an automatically assigned sample number, and the requested laboratory and field tests. The forms were generated from a Field and Laboratory Information Management System (FLIMS), an automatic laboratory information, data tracking, and management system. MWQI field staff also use FLIMS to prepare sample containers and preservation methods. DWR's Bryte Chemical Laboratory supplied all necessary sampling materials to MWQI Field Support Group and performed all laboratory analyses. Bryte Laboratory's requirements for sample containers, preservation techniques, and sample holding times for the included constituents are summarized in Table 2-1.

Table 2-1 MWQI water sample collection and preservation

Samples were collected from each site approximately 3 feet below the surface. At stations with a sample collection platform, a stainless steel bucket was used to collect the sample. At stations without a platform, a round, 2-liter, stainless steel container attached to the end of a 15-foot extension pole was used to collect the sample; in this case, 4 or 5 subsamples were combined to make a composite sample.

All samples were prepared and filtered, when necessary, onsite in a specially equipped mobile laboratory van. Samples were preserved according to techniques listed in Table 2-1 and stored on ice inside an ice chest for transportation to Bryte Laboratory. Certain field measurements were also taken onsite, but these measurements are generally not included in this report. However, certain onsite measurements were useful during internal data audits when laboratory data for the same measurements seemed questionable. Large discrepancies between field and laboratory values occasionally triggered corrective action in the laboratory. Chapter 10 has discussion and details about corrective actions made on data in this report.

For quality control purposes, the MWQI Field Support Unit regularly collects quality assurance/quality control samples according to QA/QC requirements established within DWR. These samples included equipment blanks, field blanks, and duplicate site samples. QA/QC samples were processed in the same manner as regular grab samples.

Laboratory Analysis

Bryte Chemical Laboratory, a fully certified environmental laboratory in West Sacramento, analyzed all samples for the constituents in this report. The methods and reporting limits for the included constituents are summarized in Table 2-2.

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

Samples were submitted to the laboratory on the same day of collection. The sample container was labeled with FLIMS-generated sample labels indicating the sample identification number and other required information. After the samples and necessary forms were cross-checked and verified, the receiving clerk at Bryte signed and dated the Test Request Forms with a copy to the sampler. All samples received by the laboratory were placed in appropriate storage cabinets or refrigerators for various sample types (that is, metals, standard minerals, etc.) or sent directly to the test area.

All pertinent field information—including date, time, location, sampling personnel, field measurements, requested laboratory tests, and additional information—was logged into and tracked by FLIMS after sample collection. Following data login, FLIMS notified laboratory personnel of the samples to be analyzed. The samples were then processed within an allowed holding time (Table 2-1). Analytical results were entered into FLIMS, which is connected to the DWR Water Data Library (WDL), the destination database for all MWQI monitoring data.

Data Quality

Once analyses were completed, the remaining sample was kept for 30 to 60 days in storage before being discarded. Sample retention is necessary for evaluating and ensuring acceptable results. Bryte Laboratory follows a set of internal QA/QC audit procedures, which include evaluation of data for blanks (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 2002). The QA/QC Unit of the Office of Water Quality performs data quality checks routinely on data in WDL. Results of data quality evaluations for constituents included in this report are presented in Chapter 10.

In this report, constituents at concentrations below their reporting limits are treated as "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 one method are shown in Table 2-2. To minimize discrepancy of data resulting from method changes, this report included data from a single method for each constituent.

Statistical Analysis

Unlike the previous summary report (DWR 2003a), this report's statistical analyses are less extensive, typically including summary statistics and some nonparametric comparisons. Most data are presented in descriptive graphics. Summary statistics were computed using Microsoft Excel. Nonparametric statistical comparisons were made using Minitab, Release 13.

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

- Data range: data between the minimum and the maximum.
- 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.
- Median: more resistant measure for water quality data, thus a generally preferred measure over the mean.

Descriptive Plots

Descriptive plots are mostly in the form of temporal graphs. Monthly or weekly data are plotted with time to demonstrate general behavior of the data during the reporting period.

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

Nonparametric Statistical Methods

The majority of monitoring data for the included constituents was not normally distributed, thus parametric statistical methods may not be robust. When necessary, a nonparametric test—the Mann-Whitney test (also called the Wilcoxon Rank-sum test)—was used for comparisons of medians among stations. These distribution-free tests are as powerful as their parametric equivalents for most water quality data, but do not require normal data distribution or data transformation.

Table 2-1 MWQI water sample collection and preservation

Constituent	Container	Sample preparation	Sample size (mL)	Preservative	Holding time
Alkalinity	Polyethylene	Filtered	500	4 ^oC	14 days
Electrical conductivity (EC)	Polyethylene	Filtered	500	4 ^oC	28 days
Hardness by calculation	Polyethylene	Filtered	250	HNO_3, pH<2	6 months
Hardness, total by calculation	Polyethylene	Unfiltered	250	HNO_3, pH<2	6 months
ICP cations, dissolved - Na,Ca,Mg, K, B, Si	Polyethylene, acid washed	Filtered	250	HNO_3, pH<2	6 months
ICP cations, total - Na,Ca,Mg, K, B, Si	Polyethylene, acid washed	Unfiltered	250	HNO_3, pH<2	6 months
ICP/MS trace metals, dissolved	Polyethylene, acid washed	Filtered	500	HNO_3, pH<2	6 Months
ICP/MS trace metals, total	Polyethylene, acid washed	Unfiltered	500	HNO_3, pH<2	6 Months
IC anions - Cl, SO_4, Br, F	Polyethylene	Filtered	500	4 ^oC	28 days
Mercury by cold vapor	Polyethylene, acid washed	Unfiltered	500	4 ^oC, HNO_3, pH<2	28 days
Mercury by ICP/MS	Polyethylene, acid washed	Filtered	500	4 ^oC, HNO_3, pH<2	28 days
Nitrate, nitrite (nutrient)	Polyethylene	Filtered	250	-20 ^oC, dark	48 hours
Nitrate, nitrite (nutrient DWR Modified)	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
Nitrate, nitrite (Std Mineral-IC Anions)	Polyethylene	Filtered	500	4 ^oC	48 hours
Nitrate, nitrite (Std Mineral DWR Modified)	Polyethylene	Filtered	500	4 ^oC	28 days
Nitrogen, ammonia	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
Nitrogen Kjeldahl, total (TKN)	Polyethylene	Unfiltered	250	-20 ^oC, dark	28 days
Organic carbon, dissolved (DOC)	Glass, clear VOA	Filtered	40	4 ^oC, HNO_3, pH<2	28 days
Organic carbon, total (TOC)	Glass, clear VOA	Unfiltered	40	4 ^oC, HNO_3, pH<2	28 days
Orthophosphate	Polyethylene	Filtered	250	4 ^oC	48 hours
Orthophosphate DWR modified	Polyethylene	Filtered	250	-20 ^oC, dark	28 days
pH	Polyethylene	Unfiltered	250	4 ^oC	ASAP

Table continued on next page

Table 2-1 continued

Constituent	Container	Sample preparation	Sample size (mL)	Preservative	Holding time
Phosphorous, total	Polyethylene	Unfiltered	250	-20 ^oC, dark	28 days
Solids, total dissolved (TDS)	Polyethylene	Filtered	500	4 ^oC	7 days
Turbidity	Polyethylene	Unfiltered	500	4 ^oC	48 hours
UVA	Polyethylene	Filtered	250	4 ^oC	14 days
Volatile organic analysis (MTBE, etc.)	Glass, amber VOA	Unfiltered	40, X 2, Teflon, no air	4 ^oC, HCl, pH<2	14 days

Note: Condensed from Appendix A, *Bryte Chemical Laboratory Quality Assurance Manual* (Fong 2002).
ext = extraction

Table 2-2 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	0.1
	EPA	415.1 Wet oxidation, IR, automated	0.1
Dissolved organic carbon (DOC)	EPA	415.1 Wet oxidation, IR, automated	0.1
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
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
Sodium		273.1 AA Flame	1
		200.7 ICP	1
pH	Std Methods	4500-H^+ 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	
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 2002).

[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

[b] Unit is mg/L unless otherwise indicated.

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Table 2-2 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 hybride	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 2002).

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[b] Unit is mg/L unless otherwise indicated.

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Table 2-2 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 2002).

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

b. Unit is mg/L unless otherwise indicated.

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Table 2-2 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 2002).

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

b. Unit is mg/L unless otherwise indicated.

Chapter 3 Delta Hydrology

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Chapter 3 Delta Hydrology

By **Sarojini Balachandra** and **William J. McCune**

This chapter discusses hydrologic conditions affecting water quality in rivers and channels of the Sacramento-San Joaquin Delta (the Delta). Presented are precipitation in the contributing watersheds, flow data at 2 Delta locations, calculated total Delta outflow, and hydrologic classification indices for both Sacramento and San Joaquin Valleys. A brief discussion is also presented on hydrologic influences of reservoir releases to the Sacramento and San Joaquin rivers, Delta Cross Channel operations, and South Delta Improvements. Water quality at various stations is discussed in the context of Delta hydrologic conditions for the constituents included in the following chapters.

Sacramento River Basin

Sacramento River is California's longest river, stretching 384 miles from near Mount Shasta to its mouth in the Delta. As the river runs south, several major rivers drain into the Sacramento River. These tributaries include Pit, McCloud, Feather, Yuba, and American rivers. Part of the Trinity River flow is also diverted to the Sacramento River, which carries about 31% of the State's total runoff water.

The Sacramento River Basin consists of 6 physiographic provinces, namely the Sacramento Valley, the Coast Ranges, Klamath Mountains, Cascade Range, Sierra Nevada, and the Modoc Plateau. Of these, Sacramento Valley has the largest population and greatest demands for water for both domestic and agricultural uses. Precipitation in this region is unevenly distributed within each water year with most occurring during the wet winter months and little during the dry summer months. The eastern mountain ranges and high plateau regions of the Sacramento River Basin receive large amounts of winter snow. The snowmelt is collected in reservoirs near the head waters of the Sacramento River and all the major rivers that drain into it. These reservoirs provide waterflow during the dry summer months and flood control for the Sacramento Valley during the heavy rainfall period.

Sacramento Valley has 2.1-million acres of irrigated farmlands. Forests and mines in the mountainous regions and the urban and agricultural areas in the Sacramento River Basin affect water quality of the river and the Delta.

San Joaquin River Basin

The San Joaquin River is the second largest river in the State of California. It originates from Ansel Adams Wilderness in the Sierra Nevada and flows into the Central Valley. As the river flows north in the valley, it is joined by Merced River, Tuolumne River, Stanislaus River, Mokelumne River, and Consumnes River, which all originate from the Sierra Nevada. All these rivers and the San Joaquin River (SJR) have reservoirs above the valley to collect rain and snowmelt. These reservoirs provide water to the San Joaquin Valley during the summer months. The SJR finally flows into the Delta and then into Suisun Bay.

Precipitation in the Sacramento and San Joaquin Valleys

Six weather stations were selected to represent general precipitation patterns in the Delta and the watersheds tributary to the Delta. Figure 3-1 shows their locations relative to the Delta and the Sacramento River and SJR watersheds. The 3 northern stations—Redding Fire Station, Durham, and Sacramento Executive Airport are within the Sacramento Valley; the other 3 stations— Brentwood, Stockton Fire Station, and Madera—are in the San Joaquin Valley. Data for Redding Fire Station, Stockton Fire Station, and Sacramento Executive Airport were obtained from the Western Regional Climate Center in Reno, Nevada. Data for the remainder of the stations were from the California Irrigation Management Information System (CIMIS) of the California Department of Water Resources (DWR).

The 3 stations within the Sacramento Valley (the northern stations) generally recorded more intense rain with a mean daily precipitation of 0.3 inches or more (Table 3-1), while the 3 stations in the San Joaquin Valley (the southern stations) experienced less rain with a mean daily precipitation of 0.24 inches or less (Table 3-1). During the 2-year reporting period, there were 161 rainy days at the Redding Fire Station and the highest daily precipitation was 3.07 inches; whereas there were 100 rainy days at Stockton Fire Station, and the highest daily rainfall was 1.50 inches. The southern stations recorded only a few days with more than one inch of rain; whereas northern stations recorded more days with rainfall above an inch (Table 3-1).

Numbers of rainy months were similar in both Sacramento and San Joaquin Valley (Table 3-2). However, the monthly average and median precipitation was greater in the Sacramento Valley than in the San Joaquin Valley (Table 3-2).

Cumulated precipitation in the 2002 Water Year was less than that of 2003 WY at Redding Fire Station, Durham, Stockton Fire Station, and Brentwood (Table 3-2). However, Sacramento Executive Airport in the Sacramento Valley and Madera in the San Joaquin Valley received more cumulated precipitation in 2002 than in 2003 (Table 3-2).

Most rainfall occurred from November through May at all stations (Figure 3-2). Rainfall during the months of June, July, August, and September were negligible at all stations (Figure 3-2).

Runoff Index

To classify the water years, the State Water Resources Control Board developed a hydrologic index based on the amount of unimpaired watershed runoff. The definition and method of calculating the index can be found in Water Right Decision 1641, revised March 15, 2000 (SWRCB 2000).

Unimpaired runoff represents the natural water production of a river basin unaltered by upstream exports, storage, or diversion to or import of water from other basins. For the Sacramento River system, the index uses the total runoff (in millions of acre-feet) of Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and American River

Figure 3-1 Location of selected weather stations

Table 3-1 Summary of daily precipitation (in inches) at six weather stations

Table 3-2 Summary of monthly precipitation (in inches) at six weather stations

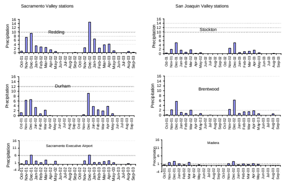


Figure 3-2 Cumulated monthly precipitation (in inches) at six weather stations

inflow to Folsom Lake. The runoff for the San Joaquin River system is the total of Stanislaus River inflow to New Melones Reservoir, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake (SWRCB 2000).

According to the runoff index system, 2002 WY was a dry year for both valleys, indicating that runoff was lower than normal (Table 3-3). The 2003 WY was above normal for the Sacramento Valley and below normal for the San Joaquin Valley (Table 3-3).

Table 3-3 Hydrologic index classification based on measured unimpaired runoff at selected rivers

The effect of precipitation and runoff on water quality at various stations is discussed in later chapters.

Reservoir Releases

Runoff from the watersheds of the Sacramento River and SJR is a primary source of domestic water for many Californians, and it provides irrigation water for about 4-million acres of cropland. The domestic water is used year round, and the irrigation water is mostly used in the dry summer months. Because the majority of the precipitation in the watersheds occurs during winter months, precipitation during the wet months must be stored in reservoirs along the major rivers and streams in the watersheds.

Monthly releases from major reservoirs on or tributary to the Sacramento River are in Figure 3-3. Water imported from the Trinity River is included with the Shasta Reservoir data. Releases from Oroville and New Bullards Bar Reservoirs are included in the Feather and Yuba rivers data. Total releases from these major reservoirs, including imports from the Trinity River, were approximately 9.439 million acre-feet in 2002 WY and 12.493 million acre-feet in the 2003 WY. Releases for 2003 WY were about 132% of those for 2002 WY.

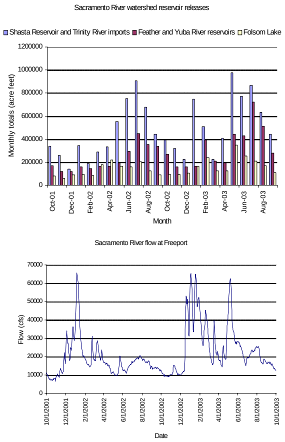


Figure 3-3 Sacramento River watershed reservoir releases and Sacramento River flow at Freeport

Releases from reservoirs in the SJR watershed are in Figure 3-4. The reservoirs included in the charts are New Melones Lake, New Hogan Reservoir, Camanche Reservoir, Millerton Lake, Lake McClure, and New Don Pedro Reservoir (Figure 3-4). Because precipitation is much higher in the Sacramento River watershed than in the SJR watershed, total releases from Sacramento reservoirs are much greater (Figures 3-3 and 3-4).

In both 2002 WY and 2003 WY, the San Joaquin total reservoir releases during the months of April through September were more than 4 times greater than releases during October through March (Figure 3-4). The releases from Sacramento reservoirs also tended to be greater during the summer than the winter, but the pattern was not nearly as clear (Figure 3-3). Total releases from these San Joaquin Valley reservoirs were approximately 4.046 million acre-feet in 2002 WY and 4.081 million acre-feet in 2003 WY, indicating little year-to-year difference.

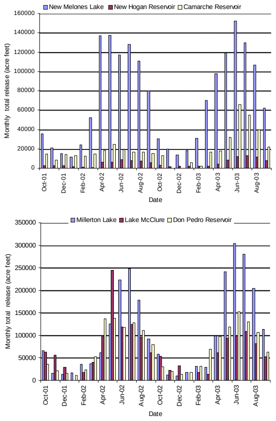


Figure 3-4 San Joaquin River watershed reservoir releases

Delta Outflows

Fresh water to the Delta primarily comes from inflows from the SJR and Sacramento River. Water inflows to the rivers come from their major tributaries, reservoirs, and drainage canals within their watersheds. A portion of the water within the Delta is diverted by the State Water Project (SWP), the Central Valley Project (CVP), and Contra Costa Water District. The remaining water is allowed to continue as Delta outflow into the Suisun and San Francisco bays in the western Delta. The diversion of fresh water from the Delta for urban and agricultural uses has the potential of creating problems within the estuary, mainly with declining fish populations.

The outflows help to control seawater influence in the western Delta by holding back the daily tides. In general, when tidal levels change from low to high, a flooding current moves the seawater inland into the bay and the Delta. When tidal levels change from high to low, ebbing current moves water from the Delta through the bay to the sea. Delta outflow needs to be maintained against the high tide to prevent salt water from entering the Delta through Suisun Bay and lowering water quality. Therefore, a steady Delta outflow is necessary to preserve the quality of source waters in the Delta.

The Interagency Ecological Program of DWR routinely calculates the daily outflows at Chipps Island at the western end of the Delta. Figure 3-5 presents the calculated Delta outflow and flows from SJR and Sacramento River in 2002 WY and 2003 WY. Total outflows in 2002 WY were less than in 2003 WY (Figure 3-5). The reduced Delta outflows during the 2002 WY adversely affected water quality at various stations, particularly those in the western and central Delta. Water quality at these stations with respect to changes in Delta outflow is discussed in later chapters.

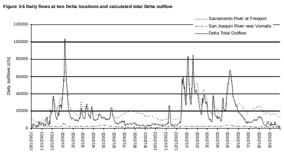


Figure 3-5 Daily flows at two Delta locations and calculated total Delta outflow

Delta Cross Channel Operations

The Delta Cross Channel is a US Bureau of Reclamation (USBR) channel that connects the Sacramento River to Snodgrass Slough. The channel diverts water from the Sacramento River to Snodgrass Slough, which opens into the Mokelumne River flowing into the central Delta. Fresh water from the Sacramento River comes through the Delta Cross Channel and improves local water quality in the Delta. The water flows from the Delta Cross Channel through about 50 miles of narrow Delta channels to the vicinity of Clifton Court Forebay and the Tracy Pumping Plant. The Delta Cross Channel diversion helps to provide adequate water supply to the diversion pumps of various agencies in the Delta, while helping to maintain adequate water quality and levels in Delta channels. Delta Cross Channel is useful for improving the quality of water in the Delta.

During the winter, the Delta Cross Channel is closed during high flows to prevent flooding in the Delta near the SJR. It is assumed that an open Delta Cross Channel would confuse the migrating fish in the Sacramento River; therefore, during fish migration, Delta Cross Channel gates are closed. Delta Cross Channel gates are operated in accordance with State Water Resources Control Board Decision 1641 (SWRCB 2000).

The schedule for opening and closing the Delta Cross Channel has been determined by the sometimes conflicting interests of maintaining good quantity and quality of water in the Delta and protecting migrating fish. The changes in the river stages and fish migration alter the schedule every year (Table 3-4), but the changes adhere to the operating procedures of Decision 1641.

Table 3-4 Delta Cross Channel operations

When the Delta Cross Channel is closed continuously during the dry period, the amount of Sacramento River water entering the eastern part of the central Delta is reduced. The electrical conductivity at Delta pumping plants rises at this time. If the pumping plants were to be operated at full capacity during this time, seawater would enter the Delta. It was observed that opening the Delta Cross Channel during the flood tide improved water quality as much as when the gates were opened all the time. It is not clear how the fish life cycles would be affected by closure of the Delta Cross Channel gates for a few hours each day. In October 2001 and May to June 2002, the Delta Cross Channel was closed for a few hours a day for several days to study the impact on fish (Table 3-4). These results may give a better understanding of fish migration and may be useful in altering Delta Cross Channel operations.

Vernalis Adaptive Management Plan

The Vernalis Adaptive Management Plan (VAMP) is designed to increase the survival of juvenile Chinook salmon smolts on their downstream migration from the SJR and its tributaries to the Delta and the ocean. This plan is implemented by increasing the flow rate at the SJR near Vernalis station for 31 days from April 15 to May 15 of each year. The flow rate increase is achieved by increasing the reservoir releases in the Merced, Stanislaus, and Tuolumne rivers and reducing the combined Banks and Tracy Pumping Plant exports to 1,500 cubic feet per second (cfs).

The Head of Old River Barrier is a temporary barrier that is erected annually during the VAMP period downstream of the Vernalis station. It prevents the flow of SJR water down Old River so that juvenile Chinook salmon will follow the SJR to the bays and ocean and avoid being drawn in the direction of the major diversion pumps.

All these measures increased the amount of water at the Vernalis station and improved water quality during the VAMP period as shown in the following chapters.

In 2002 WY during the VAMP period, average Vernalis flow was 3,300 cfs. This was a 20% increase in flow at Vernalis due to VAMP measures. The combined SWP and CVP export rate averaged 1,430 cfs (SJR Group Authority 2003) during this period.

In the 2003 WY, average Vernalis flow was 3,235 cfs. This was a 41% increase in the flow rate at Vernalis due to VAMP measures (SJR Group Authority 2004). The average combined exports in the SWP and CVP during the same time was 1,446 cfs (SJR Group Authority 2004).

South Delta Temporary Barriers

The South Delta Improvements Program is implemented by the USBR and DWR to ensure long-term capability of State and federal water projects. This program is designed to protect local agricultural diversions and SJR salmon populations. To accomplish these goals, 4 temporary rock barriers are placed each year across south Delta channels.

Three barriers are constructed to increase water levels, circulation patterns, and water quality in the south Delta for local agricultural diversions (Figure 3-6). They are constructed at Old River near Tracy, Middle River, and Grant Line Canal. These barriers were installed in 2002 and 2003 in the month of April and removed in the month of November (Table 3-5).

The fourth temporary barrier acts as a fish barrier and was constructed at the Head of Old River. It was installed in the month of April and removed in the month of May in both 2002 and 2003. This barrier was constructed again in September and removed in November in both years (Table 3-5).

It was observed that when temporary barriers were installed and the Delta Cross Channel gates were opened, daily variations and maximum electrical conductivity were lower at Tracy Fish Collection Facility near Tracy than when the SJR was allowed to flow uncontrolled to this area.

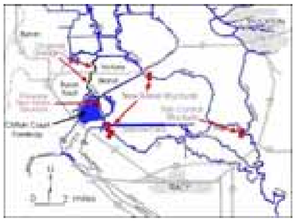


Figure 3-6 South Delta temporary barriers

Table 3-5 Temporary barriers operating schedule

Chapter 3 Delta Hydrology

Figures

Tables

Figure 3-1 Location of selected weather stations

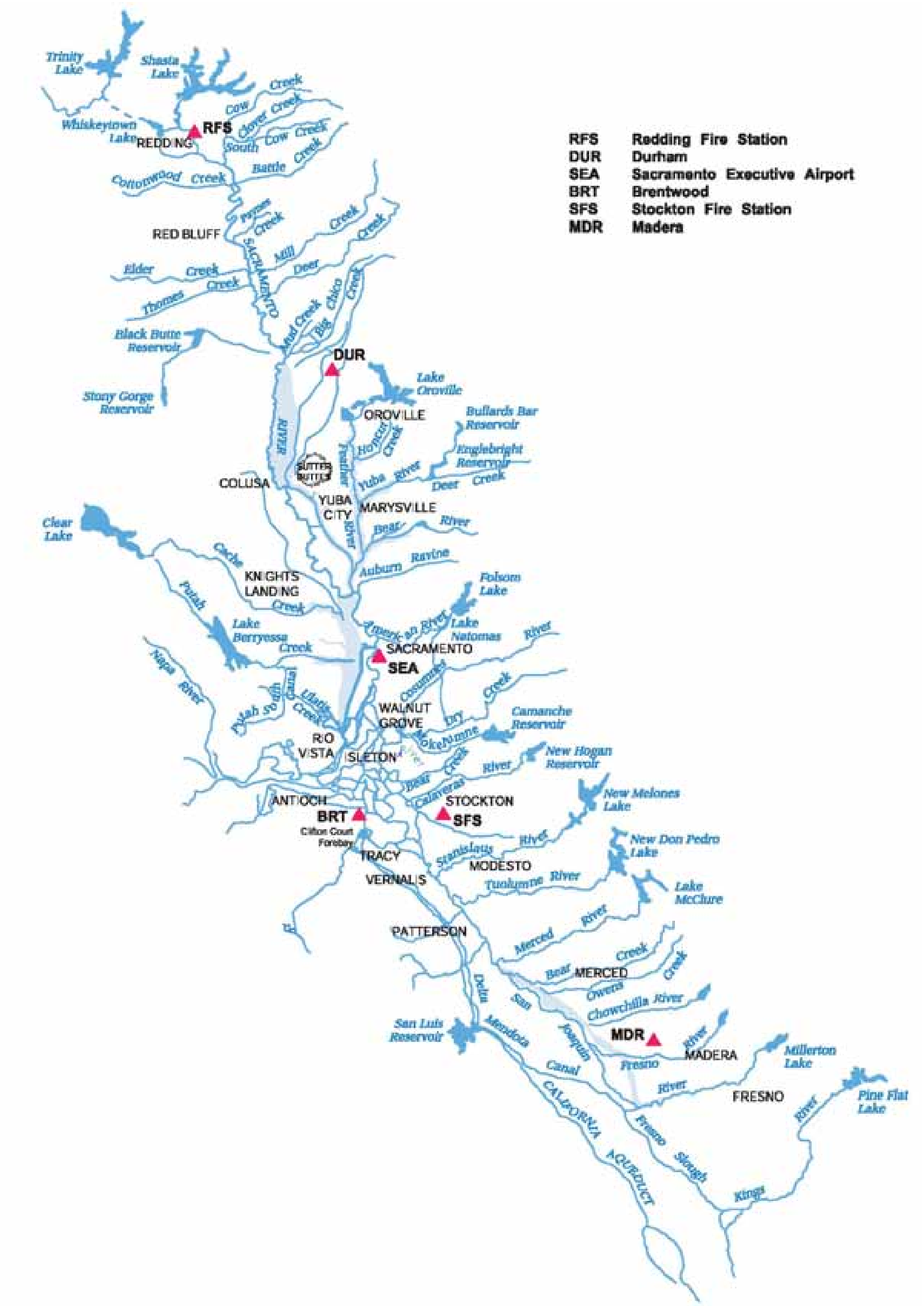


Figure 3-2 Cumulated monthly precipitation (in inches) at six weather stations

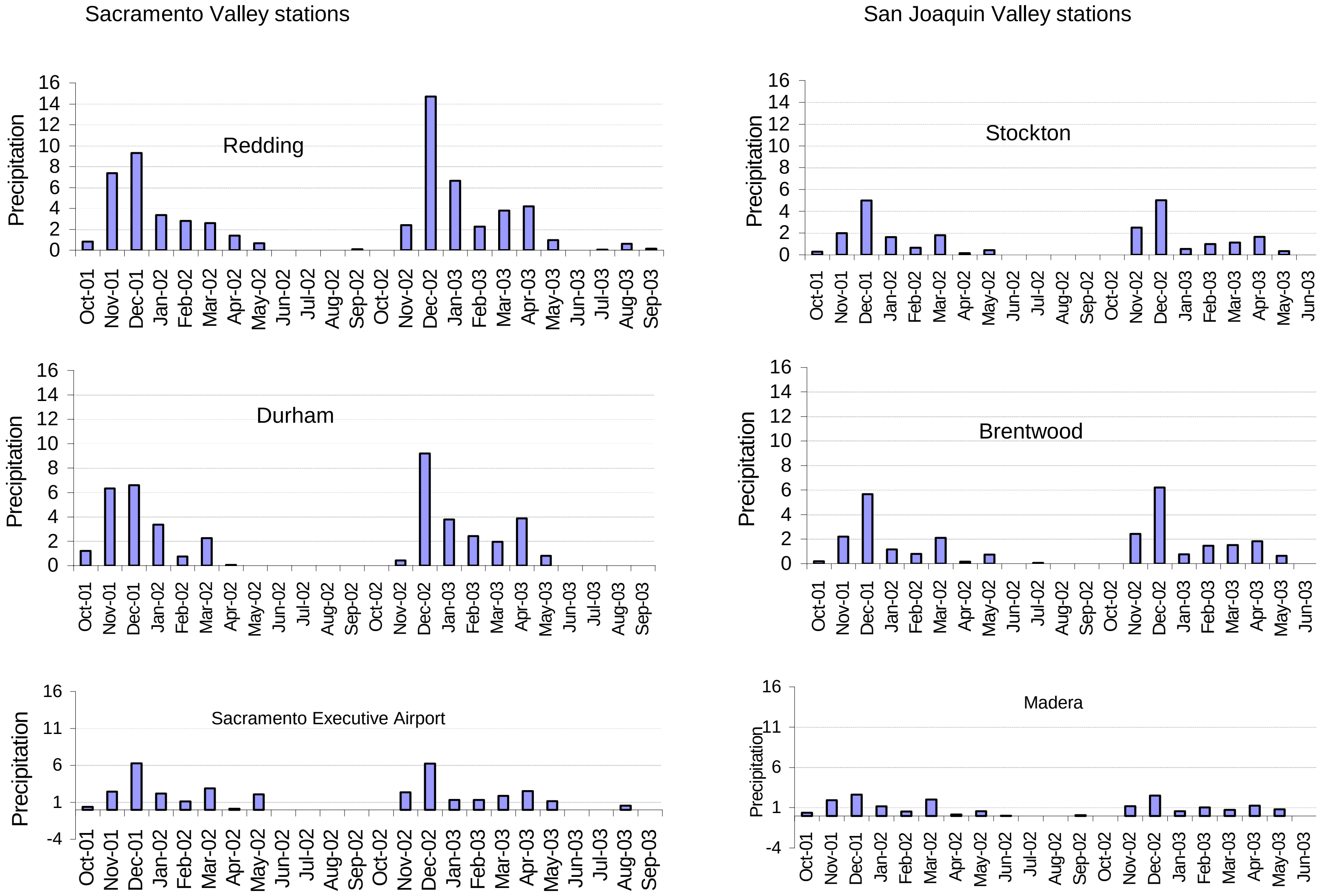
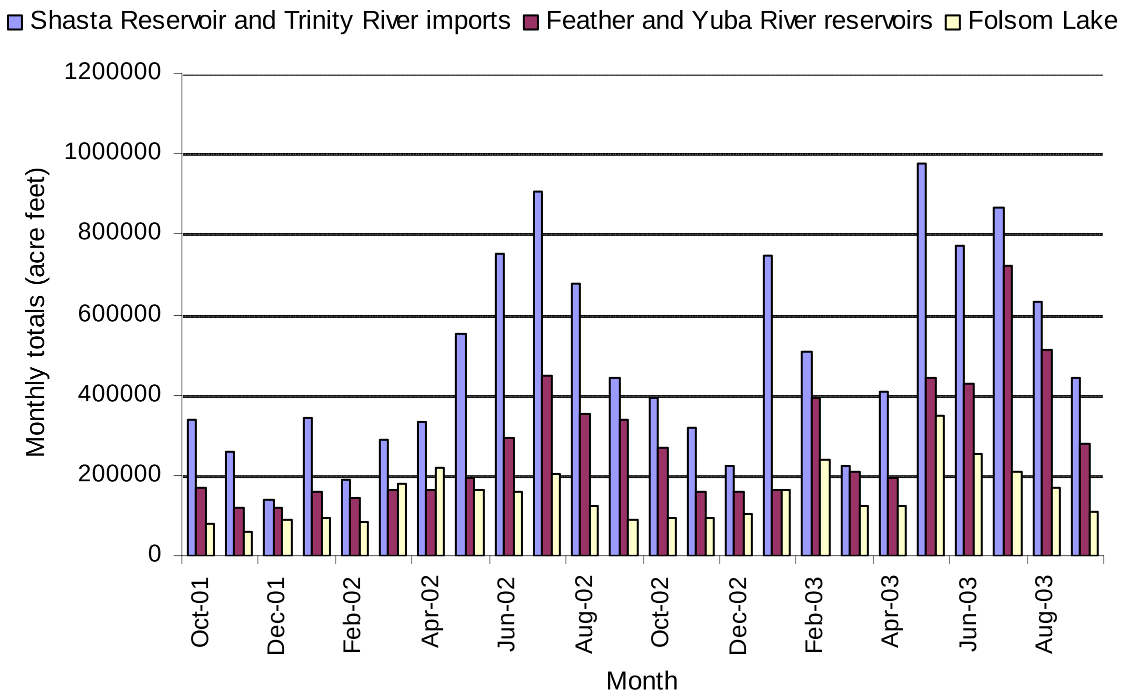
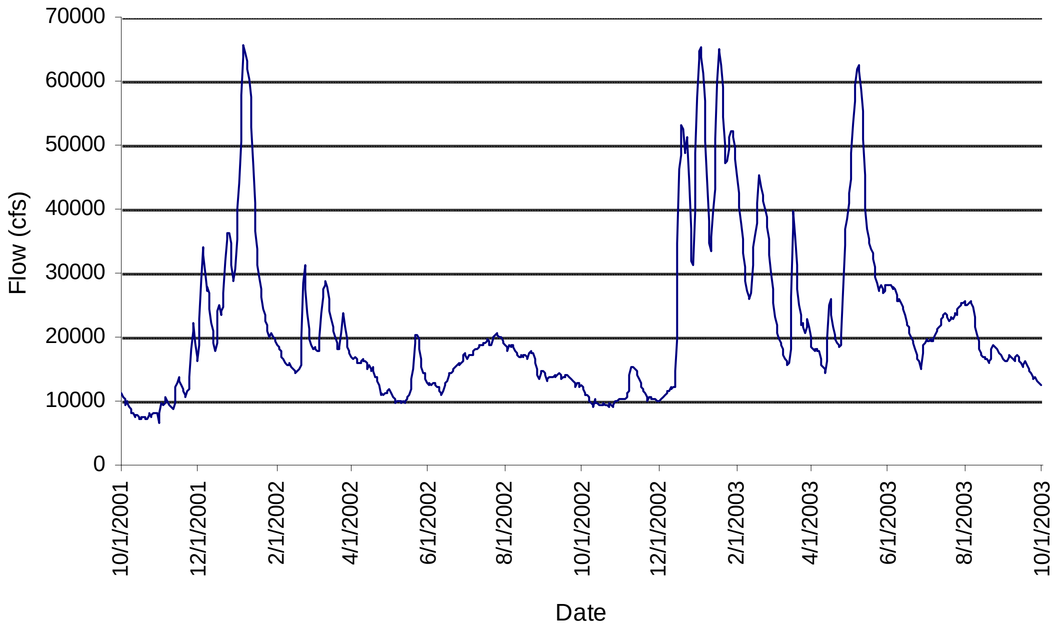


Figure 3-3 Sacramento River watershed reservoir releases[a] and Sacramento River flow at Freeport[b]

Sacramento River watershed reservoir releases



Sacramento River flow at Freeport

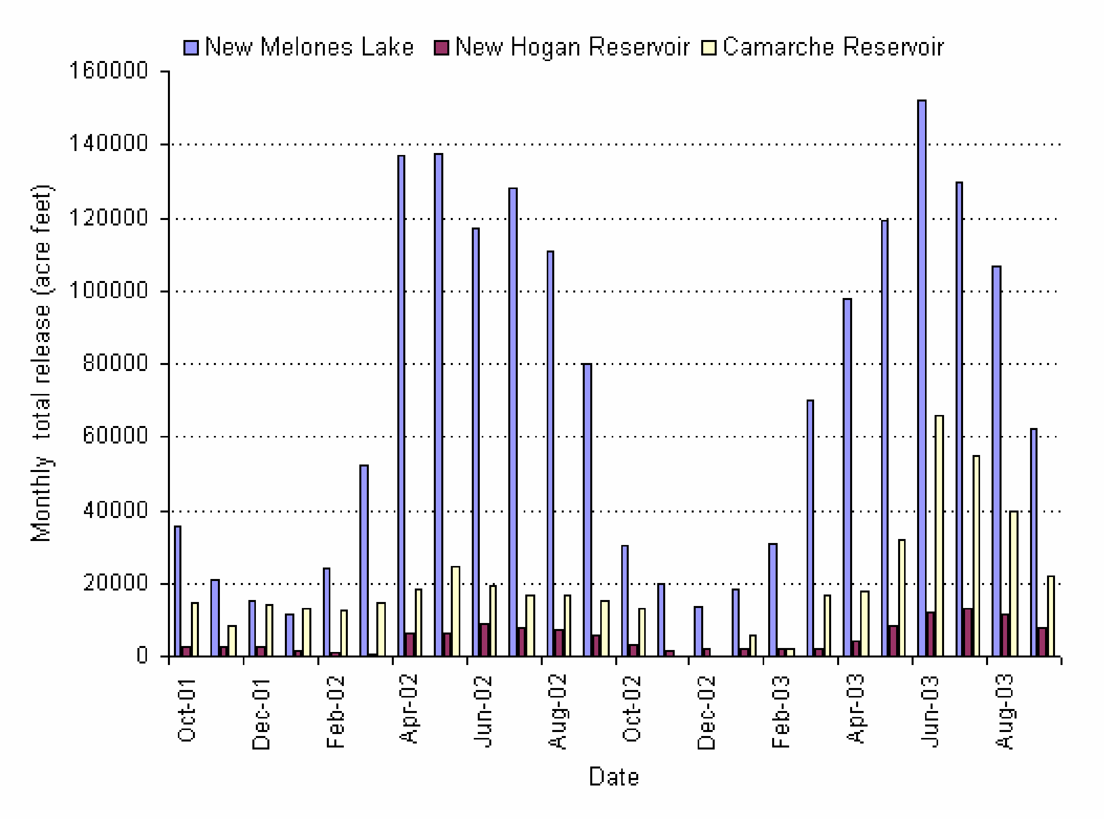


Source: DWR http://cdec.water.ca.gov/

a. Releases were calculated from CDEC data

b. Daily average flow from CDEC

Figure 3-4 San Joaquin River watershed reservoir releases



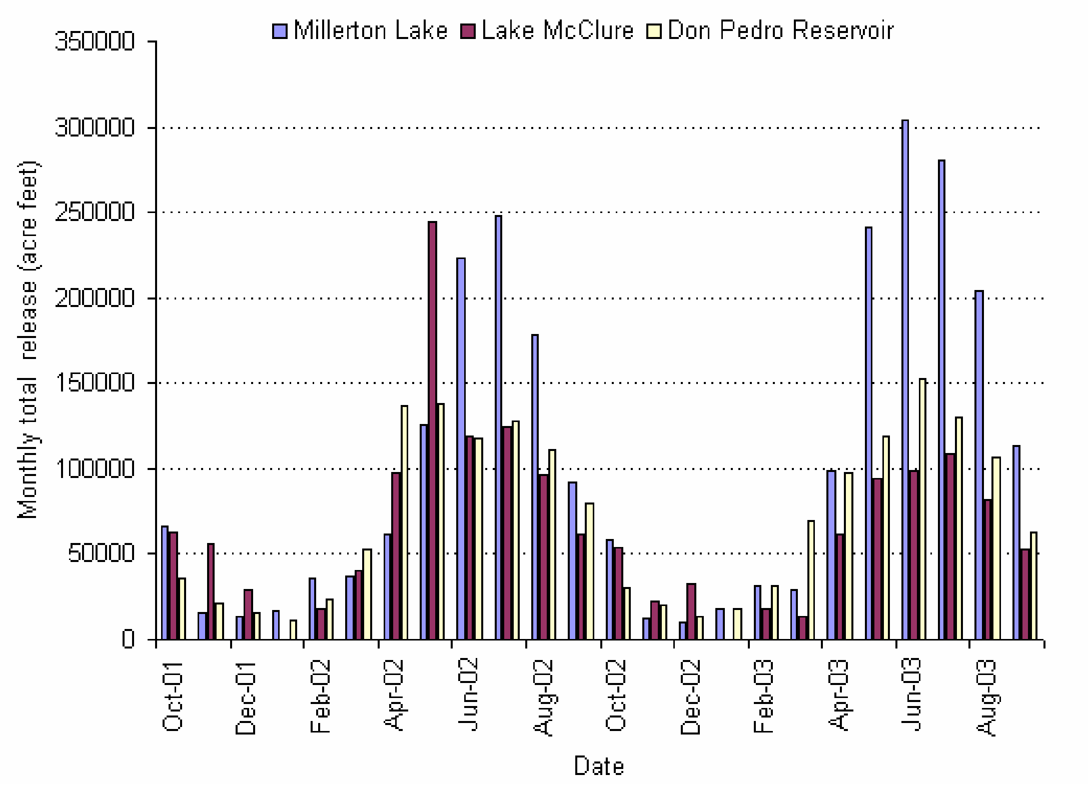
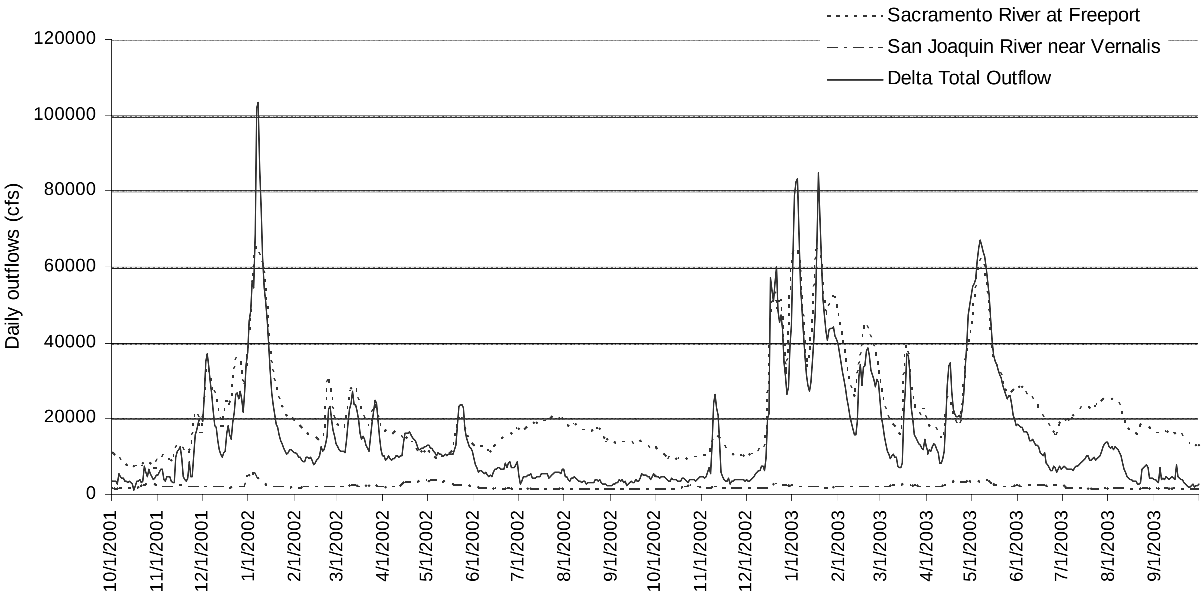
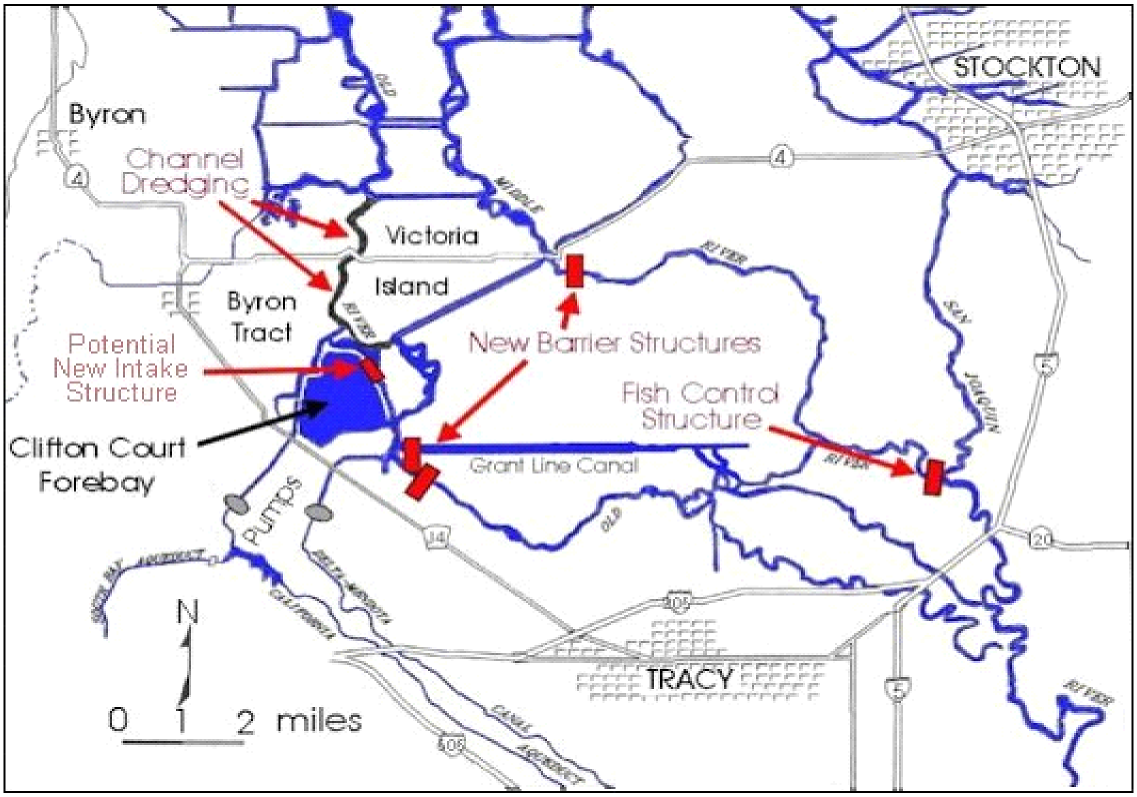


Figure 3-5 Daily flows at two Delta locations and calculated total Delta outflow



Source: California Department of Water Resources, http://cdec.water.ca.gov/, Accessed July 26, 2004

Figure 3-6 South Delta temporary barriers



Source: DWR, Division of Engineering, http://wwwdoe.water.ca.gov/projects/southdelta/

Table 3-1 Summary of daily precipitation (in inches) at six weather stations

Station	Reporting days	Days rained	Range[a]	Mean[a]	Median[a]	Days of varying intensity >= 0.1	>= 0.5	>= 1	>= 2
Sacramento Valley									
Redding Fire Station	730	161	0.01–3.07	0.4	0.22	109	43	19	2
Durham	730	117	0.01–2.05	0.37	0.19	77	33	9	1
Sacramento Executive Airport	730	116	0.01–1.67	0.3	0.19	74	24	5	0
San Joaquin Valley									
Stockton Fire Station	730	100	0.01–1.50	0.24	0.13	53	15	4	0
Brentwood	730	137	0.01–1.90	0.21	0.08	65	17	5	0
Madera	730	112	0.01–1.06	0.15	0.06	46	9	1	0

a. Calculated with data from wet days.

Table 3-2 Summary of monthly precipitation (in inches) at six weather stations

Station	Reporting months	Months rained	Monthly precipitation Range[b]	Mean[b]	Median[b]	Cumulated precipitation in water year[a] 2002	2003
Sacramento Valley							
Redding Fire Station	24	19	0.05–14.72	3.39	2.41	28.5	35.9
Durham	24	14	0.06–9.18	3.08	2.34	20.6	22.48
Sacramento Executive Airport	24	16	0.12–6.27	2.17	1.97	17.44	17.32
San Joaquin Valley							
Stockton Fire Station	24	16	0.06–5.0	1.5	1.06	11.86	12.17
Brentwood	24	20	0.01–6.19	1.42	0.78	13.03	15.42
Madera	24	19	0.01–2.62	0.92	0.73	9.36	8.1

a. Water year runs from Oct 1 to Sep 30; for example, the 2002 water year runs from 1 Oct 2001 to 30 Sep 2002.
b. Calculated with data from wet months.

Table 3-3 Hydrologic index classification based on measured unimpaired runoff at selected rivers

Water year	Sacramento Valley	San Joaquin Valley
Previous summary period		
1999	Wet	Above normal
2000	Above normal	Above normal
2001	Dry	Dry
Current summary period		
2002	Dry	Dry
2003	Above normal	Below normal

Table 3-4 Delta Cross Channel operations

Water quality concerns	Winter closure	Fish concerns	Fish study		
			Experimental period	Number of study days	Closed hours/day
Open	Closed	Closed			
8/27/01 to 10/8/01					
			10/8-/01 to 10/27/01	18	5 to 6
10/27/01 to11/21/01					
		11/21/01 to 11/29/01			
11/29/01 to 12/4/01					
	12/4/01 to 5/24/02				
5/24/02 to 5/28/02					
	5/28/02 to 5/31/02				
			5/31/02 to 6/14/02	9	8 to 9
6/14/02 to 10/16/02					
			10/16/02 to 10/19/02	3	24
10/19/02 to 12/3/02					
		12/3/02 to 12/10/02			
12/10/02 to 12/16/02					
	12/16/02 to 5/30/03				
5/30/03 to 6/2/03					
	6/2/03 to 6/6/03				
6/6/03 to 6/9/03					
	6/9/03 to 6/12/03				
6/12/03 to 12/1/03					

Note: Calculated with the data from US Bureau of Reclamation, Delta Cross Channel Operations. Maintenance schedule is not included

Table 3-5 Temporary barriers operating schedule

					Head of Old River	
Year	Work	Old River at Tracy	Middle River	Grant Line Canal	Spring	Fall
2001	Installation					
	Started	April 23	April 20	May 2	April 17	September24
	Completed	April 26	April 23	May 6	April 26	October 6
2001	Removal					
	Started	November 13	November 12	November 11	May 23	November 22
	Breached	November 14	November 18	November 12		November 22
	Completed	November 26		November 18	May 30	December 2
2002	Installation					
	Started	April 1	April 10	April 1	April 2	September 24
	Completed	April 18	April 15	April 12	April 18	October 4
2002	Removal					
	Started	November 16	November 20	November 14	May 22	November 11
	Breached	November 16	November 20	November 16	May 24	November 12
	Completed	November 29	November 23	November 25	June 7	November 21
2003	Installation					
	Started	April 1	April 12	April 1	April 1	September 2
	Closed	April 14	April 15	June 11	April 15	September 15
	Completed	April 22	April 23	June 17	April 21	September 18
2003	Removal					
	Started	November 13	November 7	November 10	May 16	November 3
	Breached	November 15	November 8	November 13	May 18	November 4
	Completed	November 25	November 10	November 25	June 3	November 13

Note: Data from California Department of Water Resources, Bay-Delta Office

Chapter 4 Organic Carbon

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Chapter 4 Organic Carbon

This chapter summarizes organic carbon data collected from 11 monitoring stations in the Sacramento-San Joaquin Delta (the Delta) region from October 1, 2001, to September 30, 2003. The Municipal Water Quality Investigations Program (MWQI) monitors both total organic carbon and dissolved organic carbon. Although some TOC and DOC were analyzed by a combustion method in addition to a chemical oxidation method (wet oxidation), data of TOC and DOC by wet oxidation will be discussed for ranges and seasonality at individual stations. A brief discussion on UVA_{254} and the relationships between TOC and DOC by the 2 different methods are also presented.

Ranges and Seasonality of Organic Carbon

American River and Sacramento River Stations

MWQI sampled 3 river stations and an urban drainage station near the northern boundary of the Delta (Figure 4-1). Water quality at these stations represents water from the American and Sacramento rivers before and right after water enters the Delta, as well as drainage from a heavily populated urban watershed.

Figure 4-1 Location of monitoring stations near the City of Sacramento

American River

Monthly and weekly (November through April) grab samples were collected from the American River at the E.A. Fairbairn Water Treatment Plant (WTP) (Figure 4-1). With a few exceptions, organic carbon at this station was generally lower than 2 mg/L (Figure 4-2). The difference between TOC and DOC was consistently small regardless of season, indicating most organic carbon was present in dissolved form (Figure 4-2). The ranges, median, and means for both TOC and DOC at this station were similar (Table 4-1), again suggesting that organic carbon was mostly in dissolved form. American River water is low in turbidity (see Chapter 8 pH, Alkalinity, Hardness, and Turbidity), thus the differences between TOC and DOC were small.

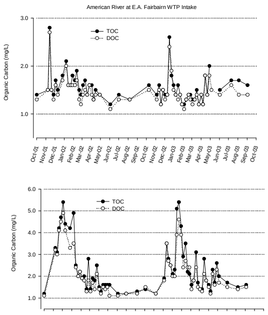

Figure 4-2 Organic carbon at American River and West Sacramento WTP Intake

American River water is generally of high quality, which does not appear to change significantly with season. Organic carbon was elevated in November 2001 and December 2002 in response to early rainfall events in the watershed, but elevated organic carbon levels did not persist. Apparent seasonality within each water year was not observed with either TOC or DOC (Figure 4-2). Median TOC and DOC between the 2 water years did not differ statistically according to the Mann-Whitney test (p was 0.1172 and 0.1959 for TOC and DOC, respectively) despite 2002 WY being a dry runoff year and 2003 WY being an above normal year (see Table 3-3).

Table 4-1 Summary of organic carbon at 11 MWQI stations

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 4-1). The median levels of TOC and DOC for the reporting period were 2.0 and 1.8 mg/L, respectively (Table 4-1), which were not statistically different according to the Mann-Whitney test (p= 0.2005). These median concentrations were higher than those of the previous 3 water years

(DWR 2003a) due to 2 successive dry runoff years in the watersheds (see Table 3-3). Organic carbon concentrations were mostly less than 3 mg/L, but early rainfall events (see Figure 3-2) in the watersheds increased organic carbon concentrations above 4 and 5 mg/L (Figure 4-2).

Unlike the American River, episodic spikes and clear seasonality of organic carbon were observed (Figure 4-2). TOC and DOC were higher during the wet months than during the dry months. Both TOC and DOC had little fluctuation during the dry months of the 2 water years (Figure 4-2). The slight increase in organic carbon in September 2002 may have been attributable to rice drainage to the Sacramento River (DWR 2003a). Although 2003 WY was a wetter year than 2002 WY in the watershed, median TOC and DOC were not significantly different according to the Mann-Whiney test (*p* was 0.3789 and 0.5069 for TOC and DOC, respectively).

Sacramento River at the Hood Station

The Hood station is on the Sacramento River shortly after the river enters the legal Delta (Figure 4-1); therefore, it is one of the 2 key MWQI monitoring stations where water quality is monitored weekly throughout each water year. Organic carbon concentrations at Hood were generally less than 3 mg/L, but were heavily influenced by rainfall events during the wet months in the Sacramento Valley (Figure 4-3). Median concentrations of TOC and DOC were 1.8 and 1.7 mg/L, respectively (Table 4-1), which were statistically different according to the Mann-Whitney test (*p*=0.0290). These median TOC and DOC concentrations were nearly the same as those found during the 1998-2001 summary period (DWR 2003a). TOC was considerably higher than DOC during the wet months (Figure 4-3), suggesting that considerable particulate organic carbon was present during rainfall periods.

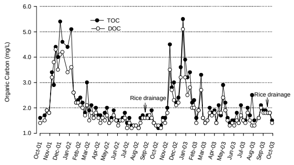

Figure 4-3 Organic carbon at Sacramento River at Hood

TOC was significantly higher during the wet months than during the dry months for each of the 2 water years with Mann-Whitney *p* values of <0.00001 and 0.0165 for WY 2002 and WY 2003, respectively (Figure 4-3). The same was true for DOC with Mann-Whitney *p* values of <0.00001 and 0.0028 for WY 2002 and WY 2003, respectively.

Compared with monthly sampling at nearby stations (Figure 4-2), weekly sampling revealed more detailed changes in organic carbon. For example, after a heavy rainfall event in early November 2002, there was no rain during the rest of November (see Appendix A for raw data) in the Sacramento Valley, and organic carbon levels returned to low levels (Figure 4-3). The rapid fall of elevated organic carbon levels is the result of both settling of particulate organic carbon in the water and dilution of organic carbon concentrations by water with relatively low organic carbon levels following initial flushing.

Appendix A

As at the West Sacramento WTP Intake station, organic carbon at Hood increased each year around September (Figure 4-3). These increases were probably due to rice drainage into the upper Sacramento River.

Despite a difference in runoff volume from the watersheds between the 2 water years, neither TOC nor DOC was significantly different (*p* was

0.5955 and 0.6368 for TOC and DOC, respectively). Median TOC and DOC were not statistically different from each other for the wet months of the 2 water years (*p* was 0.4436 and 0.5232 for TOC and DOC, respectively). DOC during the dry months was not statistically different between the 2 water years, either (*p*=0.0936). However, median TOC during the dry months of 2003 WY was significantly higher than that of the dry months of 2002 WY (*p*=0.0210), probably due to TOC increases during June, July, and August 2003 (Figure 4-3). These TOC increases were not found to be correlated with the relative percentages of inflows from the American River (data not shown).

In addition to urban discharges, TOC increases may have been affected by irrigation discharges from rice fields and row crops. Approximately half a million acres of rice is grown in the Sacramento Valley. Herbicides are usually applied in April and May. A one-month impoundment of water in the rice fields is required to ensure a good kill of weeds following herbicide application to the rice field. At the end of the impoundment period, irrigation water is discharged to the Sacramento River in June and July (Rich Breuer 2002 pers comm), thus increasing organic carbon levels.

San Joaquin River near Vernalis

The San Joaquin River near Vernalis station represents the point where the SJR enters the Delta. As at the Hood station on the Sacramento River, water quality near Vernalis was monitored weekly. Organic carbon concentrations generally varied between 2 and 5 mg/L, but were as high as 8 mg/L once during January 2002 (Figure 4-4). The median concentrations of TOC and DOC were 3.7 and 2.9 mg/L, respectively (Table 4-1), which were significantly different (*p*<0.00001), indicating significant association of organic carbon with particulate matter. These median concentrations were higher than those found during the 1998–2001 summary period (DWR 2003a). During 2002 WY and 2003 WY, river flows at the Vernalis station were substantially lower than during the 1998-2001 summary period (data not shown); organic carbon concentrations were higher during this reporting period than during the 1998–2001 summary period.

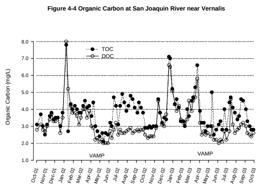

Figure 4-4 Organic carbon at San Joaquin River near Vernalis

Organic carbon concentrations during the wet months of each water year depend on rainfall events in the San Joaquin Valley. Heavy rainfall events during 2002 WY were mostly in December and January (see Figure 3-2); therefore, organic carbon spikes occurred only in January (Figure 4-4). In contrast, 2003 WY was a wetter runoff year (see Table 3-3) with more heavy rainfall events spanning from November to April (see Figure 3-2) and more organic carbon spikes observed (Figure 4-4).

Median organic carbon concentrations for the 2 water years were not significantly different (*p* was 0.9921 and 0.6874 for TOC and DOC, respectively) despite the difference in runoff year type (see Table 3-3).

For 2002 WY, except for a spike caused by early flushing of the watershed after the first heavy rainfall and some small fluctuations (Figure 4-4), TOC during the dry months was as high as during the wet months. A Mann-Whitney analysis showed that median TOC between the dry months and wet months (*p*=0.4027) were not significantly different. However, median DOC during the wet months was significantly higher than that during the dry months (*p*<0.00001). TOC during the dry months was consistently higher than DOC (Figure 4-4), and the difference in median TOC and DOC was statistically significant (*p*<0.00001), suggesting that much particulate organic carbon was present during the dry months.

The 2003 WY was a wetter runoff year compared with the 2002 WY, and more TOC fluctuations occurred during the wet months (Figure 4-4). Similar to 2002 WY, median TOC between the wet months and dry months were not statistically different (*p*=0.2322). However, as in 2002 WY, median DOC during the wet months was also significantly higher than that during the dry months (*p*=0.0004).

The higher organic carbon concentrations during the dry months were attributable to agricultural drainage returns to the SJR. Agricultural drainage enters the SJR from May to October of each year and increases organic carbon concentrations (Figure 4-4). During the dry months the lowest organic carbon level was observed in May and October. The low organic carbon levels in SJR from April to May were attributable to increased reservoir releases during the Vernalis Adaptive Management Plan period from April 15 to May 15 (see Chapter 3). Low organic carbon levels in October were probably due to less agricultural drainage at the end of the growing season.

For both water years, median TOC was not significantly different between wet and dry months (*p* was 0.4027 and 0.2322 for 2002 WY and 2003 WY, respectively). However, median DOC during the wet months was significantly higher than during the dry months for both water years (*p* was <0.00001 and 0.0004 for 2002 WY and 2003 WY, respectively).

Delta Channel Stations

Old River at Station 9

TOC and DOC differed only slightly (Figure 4-5) with similar ranges and medians (Table 4-1), suggesting that most organic carbon was in dissolved form. Organic carbon concentrations during this reporting period were similar to those found during the previous summary period (DWR 2003a).

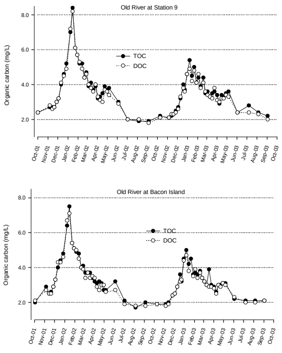

Figure 4-5 Organic carbon at two Old River stations

TOC at Station 9 comes from multiple sources, including waters from the SJR, the Sacramento River, and Delta island drainage. Seasonality patterns of organic carbon at this station differed from those at the river stations. 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 the wet months (Figure 4-5). At the Vernalis station, median organic carbon concentrations were as high during the dry months as during the wet months for both water years (Figure 4-4).

The seasonality patterns of TOC and DOC at Station 9 are probably related to elevated organic carbon in inflows from the 2 major river systems and Delta island drainage. Organic carbon concentrations in waters of both SJR and Sacramento River were elevated during the wet months (Figures 4-3 and

4-4). When inflows of high organic carbon from both river systems passed the Delta channels, organic carbon concentrations would be elevated. In addition, Delta island drainage pump-outs were higher during the wet months than during the rest of each water year. Organic carbon levels in drainage waters were also higher during the wet months. Therefore, organic carbon at Station 9 was higher during the wet months than during the dry months (Figure 4-5).

Seasonality of organic carbon was also related to the amount of runoff from the contributing watersheds. The 2003 WY was a wetter runoff year than 2002 WY; consequently, organic carbon levels were lower in 2003 WY than in 2002 WY (Figure 4-5).

Old River at Bacon Island

The ranges and seasonality of organic carbon at the Bacon Island station were similar to those at Station 9 (Figure 4-5), and TOC and DOC at both stations did not differ statistically (*p* was 0.1169 and 0.0879 for TOC and DOC, respectively). The median concentrations of TOC and DOC were 3.2 and 3.0 mg/L, respectively, which were similar to those found during the previous summary period (DWR 2003a). As discussed under Station 9 above, seasonality patterns of TOC and DOC at channel stations are probably related to elevated organic carbon in inflows from the 2 major river systems and Delta island drainage. Year-to-year variations of organic carbon concentrations were related to the amount of runoff from the contributing watersheds. The 2003 WY was a wetter runoff year than 2002 WY, thus organic carbon levels were lower in 2003 WY than 2002 WY (Figure 4-5).

Diversion Stations

Banks Pumping Plant

Samples for TOC and DOC were collected monthly at Banks Pumping Plant during the 2 water years. Similar to those at the Old River stations (Figure 4-5), median TOC and DOC concentrations did not differ significantly (*p*=0.3771) even during the wet months (Figure 4-6), indicating low particulate organic carbon in water at the Banks Pumping Plant.

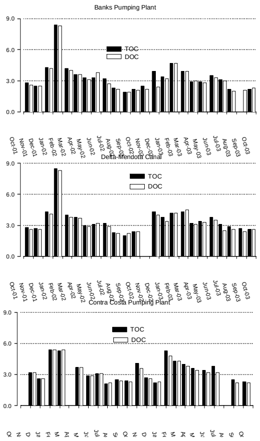

Figure 4-6 Organic carbon at three Delta diversion stations

Although TOC and DOC both had a wide range (Table 4-1), high concentrations were found mostly during the wet months of 2002 WY (Figure 4-6), which was a dry runoff year in both the Sacramento and San Joaquin watersheds. Most TOC and DOC levels varied around 3 mg/L; median TOC and DOC levels were 3.2 and 2.9 mg/L, respectively (Table 4-1), which were similar to organic carbon concentrations found during the 1998–2001 summary period (DWR 2003a). TOC and DOC concentrations did not appear to vary with the runoff year type (Figure 4-6); however, the increase in organic carbon during the wet months of 2002 WY did not occur during the wet months of 2003 WY, which was a wetter runoff year.

Organic carbon was higher during the wet months than during the dry months of each water year (Figure 4-6). The increase in organic carbon during the wet months was attributable to increased loads from contributing watersheds. Organic carbon in inflow waters to the Banks station increased during the wet months, but freshwater flow did not dilute organic carbon in the water because the dams and reservoirs released less water during the winter.

Delta-Mendota Canal at McCabe Road

Both the ranges and seasonality of TOC and DOC at the Delta-Mendota Canal (DMC) at McCabe Road resembled those found at the Banks station (Table 4-1 and Figure 4-6). TOC and DOC levels were not significantly different (p=0.3329) during the 2-year period (Figure 4-6), suggesting that organic carbon was primarily in dissolved form.

The median concentrations of TOC and DOC were 3.2 and 3.0 mg/L, respectively (Table 4-1), which were similar to organic concentrations found during the 1998–2001 summary period (DWR 2003a). As at the Banks station, organic carbon increases were observed during January of 2002 WY, but not in the wet months of the wetter 2003 WY (Figure 4-6). A Mann-Whitney analysis suggested that there was no significant difference between median TOC concentrations at Banks and the DMC stations (p=0.5753).

Contra Costa Pumping Plant #1

Samples were collected monthly at the pumping outlet of the Contra Costa Pumping Plant. A sample was collected only if the pump was operating on the day when the sampling run was scheduled. As at the Banks and DMC stations, TOC and DOC concentrations were not significantly different (p=0.6873), suggesting low particulate organic carbon in the water.

The ranges for both TOC and DOC were similar. Median TOC and DOC was the same (Table 4-1). Concentrations were similar to those found during the 1998–2001 summary period (DWR 2003a). Seasonality patterns at the Contra Costa Pumping Plant were similar to those at the other diversion stations (Figure 4-6) and those at the Old River stations (Bacon Island and Station 9). The seasonality patterns appear to have been less dependent than the Vernalis station on runoff patterns in the contributing watersheds.

Other Stations

Mallard Island Station

Water at the Mallard Island station is a mixture from several sources including the SJR and the Sacramento River, the San Francisco Bay, and drainage from in-Delta islands. Median TOC and DOC concentrations were 2.4 and 1.9 mg/L, respectively (Table 4-1), which were similar to organic concentrations found during the previous summary period (DWR 2003a). Unlike at the Sacramento River and channel stations, considerable quantities of particulate organic carbon were present in the water at the Mallard Island station; median TOC was about 26% higher than median DOC (Table 4-1).

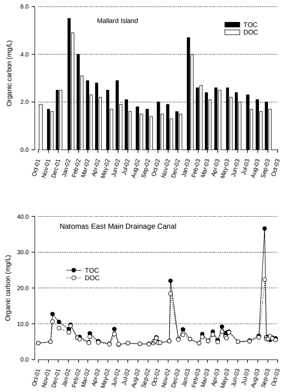

Figure 4-7 Organic carbon at Mallard Island and Natomas East Main Drainage Canal

Because water at this station comes from multiple sources, organic carbon seasonality differed from that at channel stations, the Sacramento River, and SJR (Figure 4-7). For example, an obvious spike of organic carbon during January of 2003 WY was not observed at the diversion stations (Figure 4-6), but was seen at this station (Figure 4-7).

Natomas East Main Drainage Canal

The 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. The NEMDC relative to both the American and Sacramento rivers is shown in Figure 4-1.

Organic carbon at this station was consistently high and varied around 5 mg/L during most months. Carbon concentrations were generally higher during the wet months than during the dry months (Figure 4-7). Organic carbon could spike as high as nearly 40 mg/L after initial heavy rainfall events in the watershed (Figure 4-7). The high organic carbon concentrations in November 2002 and August 2003 both followed the first significant rainfall events after long dry periods, and the runoff was the first flush of the watershed (see Figure 3-2).

Median concentrations of TOC and DOC were 5.9 and 5.7 mg/L, respectively (Table 4-1), which were considerably higher than those reported during the previous summary period (DWR 2003a). It is not yet known whether the increased concentrations were the result of trends in the watershed or due to increased sampling frequency in this reporting period. A Mann-Whitney analysis indicated that there was no significant difference between median TOC and DOC at this site (p=0.4272), suggesting that organic carbon was primarily in the dissolved form. Although organic carbon concentrations at NEMDC were much higher than those in the water of the nearby Sacramento River, the discharge was small relative to inflows from both the American and Sacramento rivers. Organic carbon loading at this site is under investigation by MWQI.

Ultraviolet Absorbance at 254 nm

This section discusses relationships between ultraviolet absorbance (UVA) and organic carbon in Delta source waters. Historically, UVA is measured at a wavelength of 254 nm, and thus is commonly referred to as UVA_{254}. UVA_{254} has been used as a surrogate measure of organic carbon for monitoring wastewater effluents and for evaluating organic matter removal by coagulation in WTPs (Eaton and others 1995). More recently, aromatic compounds have been implicated as disinfection byproduct precursors. UVA_{254} was used as an indicator of aromaticity of organic carbon and, subsequently, for predicting the abundances of precursors of various DBPs.

Ranges of UVA_{254} in Delta Waters

During the 2-year reporting period, 560 samples were collected throughout the Delta and measured for both UVA_{254} and organic carbon. A summary of sample distribution among stations and statistics is presented in Table 4-2. Based on the UVA data in Table 4-2, the 11 stations may be divided into 3 groups: rivers, channel/diversions, and urban drainage.

Table 4-2 Summary of UVA_{254} at 11 MWQI stations

The first group is the river stations, which include the American River, Sacramento River, SJR, and the Mallard Island stations. The water from these stations had the lowest UVA_{254} with medians ranging from 0.036 cm-1 to 0.084 cm-1 (Table 4-2). Among the river stations, the SJR near Vernalis had the highest median UVA_{254}, followed by the Mallard station. The American River and upper Sacramento River stations had the lowest median UVA_{254}. These spatial patterns are consistent with the spatial pattern for organic carbon (Table 4-1).

The second group—channel/diversions—includes the 2 channel stations on Old River and the diversion stations Banks Pumping Plant, DMC, and Contra Costa Pumping Plant (Table 4-2). UVA_{254} at these stations were higher than at the river stations with UVA_{254} ranging from 0.087 to 0.119 cm^{-1} (Table 4-2). The urban drainage station had the highest median organic carbon among all stations (Table 4-1) and, consequently, the highest median UVA_{254}, which was 0.164 (Table 4-2).

Specific UVA_{254} and DOC

UVA_{254} normalized on a carbon basis (that is, the ratio of UVA_{254} over DOC) is defined as specific UVA_{254} ($SUVA_{254}$). $SUVA_{254}$ has been used to compare organic carbon aromaticity and DBP formation potentials among different sites. Table 4-3 summarizes the SUVA data from 558 samples, which were measured with both UVA_{254} and DOC by oxidation.

Table 4-3 Summary of $SUVA_{254}$ at 11 MWQI stations

Based on the SUVA data, the 11 stations may be divided into 2 distinct groups. The first group includes the American River, Sacramento River, SJR, and NEMDC, which are stations either outside the Delta or near the edge of the Delta. Median $SUVA_{254}$ for these stations narrowly ranged from 0.025 cm-1 to 0.030 cm-1(Table 4-3). The other group includes the 2 channel stations, the diversion stations, and the Mallard Island station, which are in central or southern Delta. Median $SUVA_{254}$ was in the narrow range from 0.034 to 0.037 (Table 4-2).

Relationships between UVA_{254} and Organic Carbon in Delta Waters

A linear relationship exists between UVA_{254} and organic carbon (Figure 4-8). The linear relation was less variable between UVA_{254} and DOC than that between UVA_{254} and TOC (Figure 4-8). Between the 2 methods used for determining TOC and DOC, the linear relationships between TOC and DOC by oxidation and UVA_{254} had less unexplained variability than those between UVA_{254} and TOC and DOC by combustion (Figure 4-8).

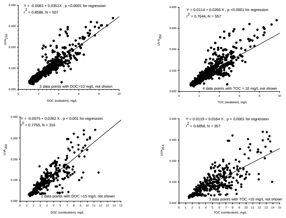

Figure 4-8 Relationships between UVA_{254} and organic carbon concentrations measured by two different methods

Despite an apparent linear relationship, considerable scattering occurred. As discussed in the previous summary report (DWR 2003a), use of a single linear relationship to describe data collected from different sites may not be appropriate. UVA_{254} varies both by site and by season. At a specific site, DOC is generally higher during the wet months than during the dry months. UVA_{254} and DOC relationships for samples collected during the dry months differed from those relationships in samples collected during the wet months, even when the samples were from the same station (DWR 2003a).

Relationships between Organic Carbon Concentrations Measured by Two Different Methods

Although TOC and DOC data summarized in previous sections were analyzed by oxidation, some TOC and DOC were determined by both combustion and oxidation. This section briefly describes some of the differences between methods. A more detailed analysis on this subject may be found in an upcoming MWQI report summarizing a multiyear method comparison study.

In general, relatively small differences were observed in DOC determined by both methods, but considerable differences were found between TOC by the 2 methods. The relationship between DOC by oxidation and combustion may be described by this linear equation:

DOC by combustion = 1.067 * DOC by oxidation + 0.767 (Figure 4-9a).

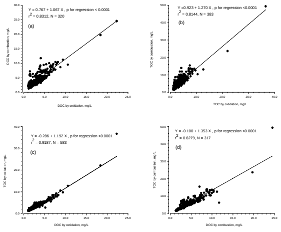

Figure 4-9(a-d) Organic carbon determined by two different methods

The slope for the above equation was 1.067, suggesting that the difference between DOC by both methods was small. In contrast, the slope for the linear equation for TOC was 1.27 (Figure 4-9b), suggesting that TOC by combustion was about 27% higher than TOC by oxidation.

There was a linear relationship between TOC and DOC by either method (Figure 4-9c and 4-9d), but the relationship between TOC and DOC by oxidation had much less unexplained variability than that between TOC and DOC by combustion. For this reason, MWQI is currently using the oxidation methods for both TOC and DOC. When using the oxidation method, TOC is approximately 20% higher than DOC; whereas TOC was 35% more than DOC using the combustion method (Figure 4-9c and 4-9d).

Chapter 4 Organic Carbon

Figures

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Figure 4-1 Location of monitoring stations (▲) near the City of Sacramento

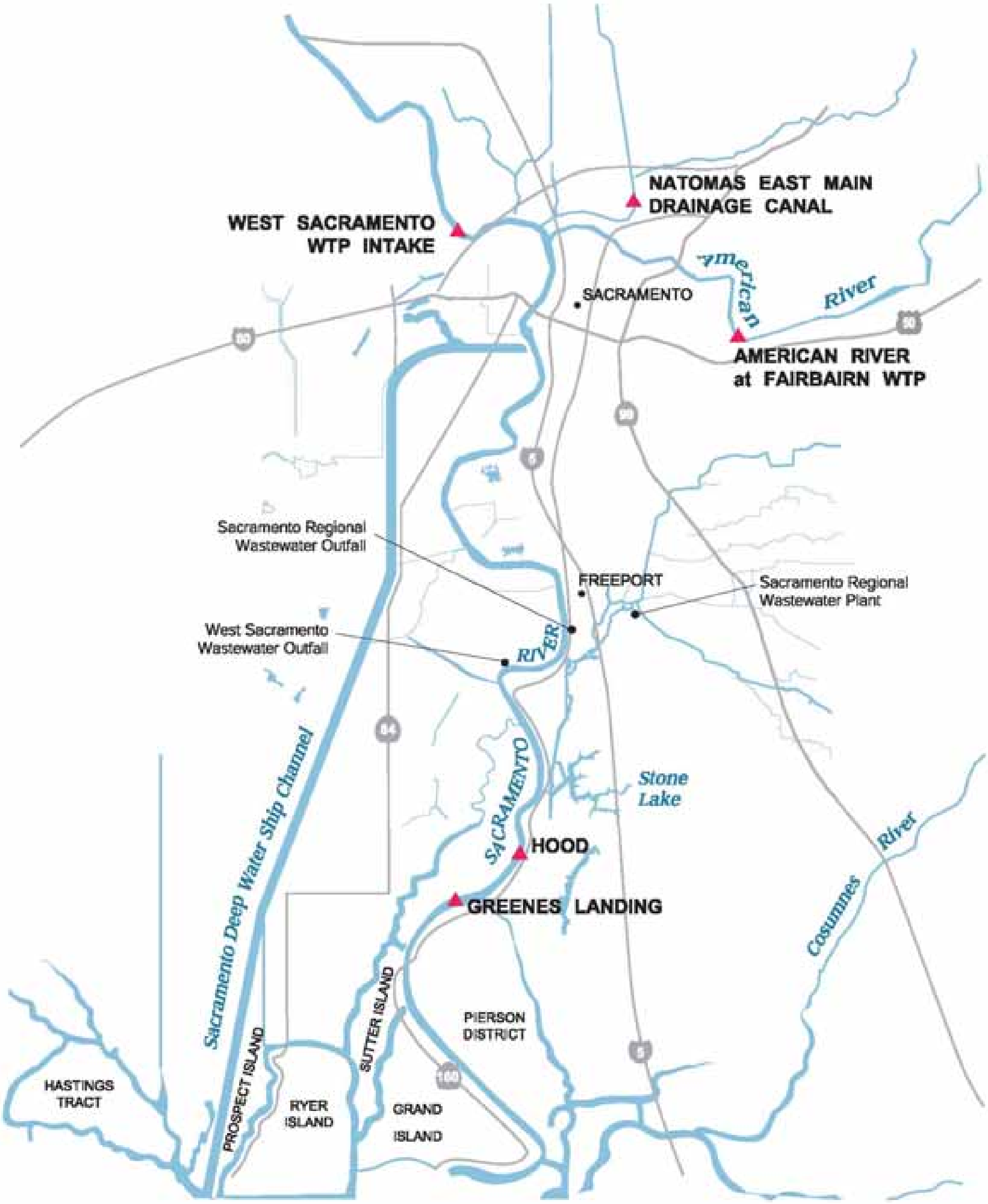
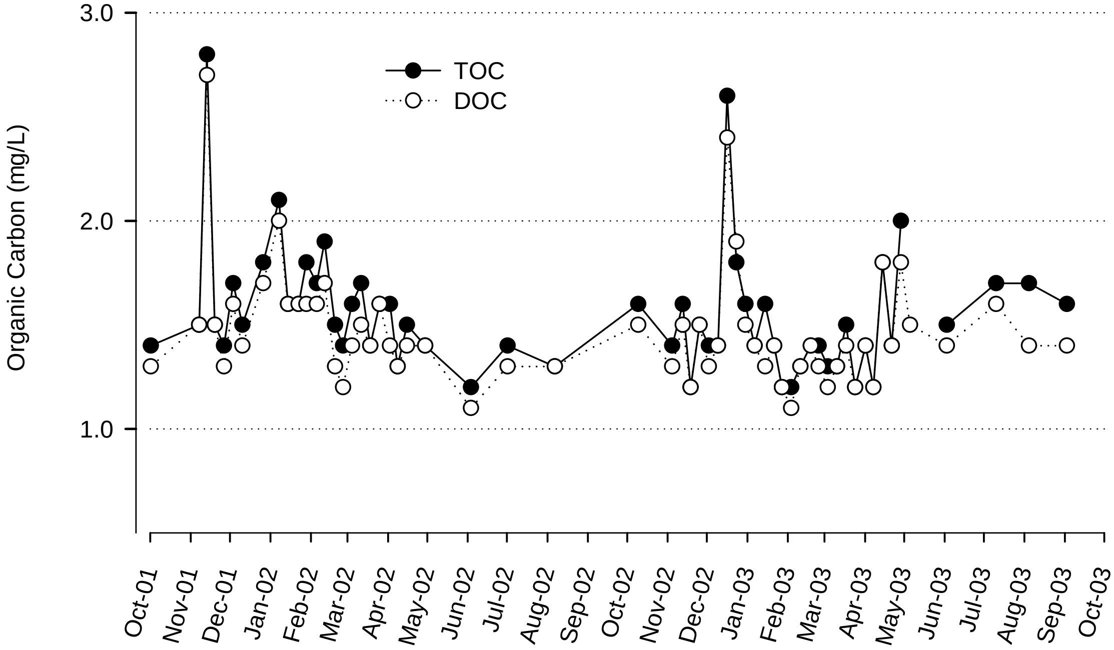


Figure 4-2 Organic carbon at the American River and West Sacramento WTP Intake

American River at E.A. Fairbairn WTP Intake



West Sacramento Water Treatment Plant Intake

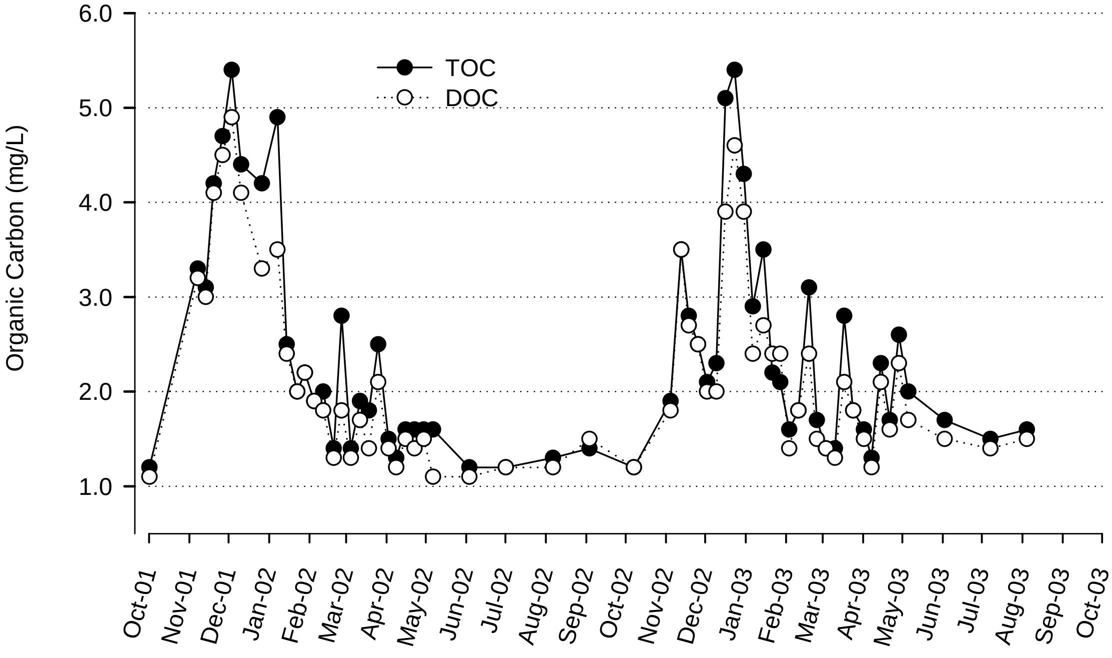


Figure 4-3 Organic carbon at Sacramento River at Hood

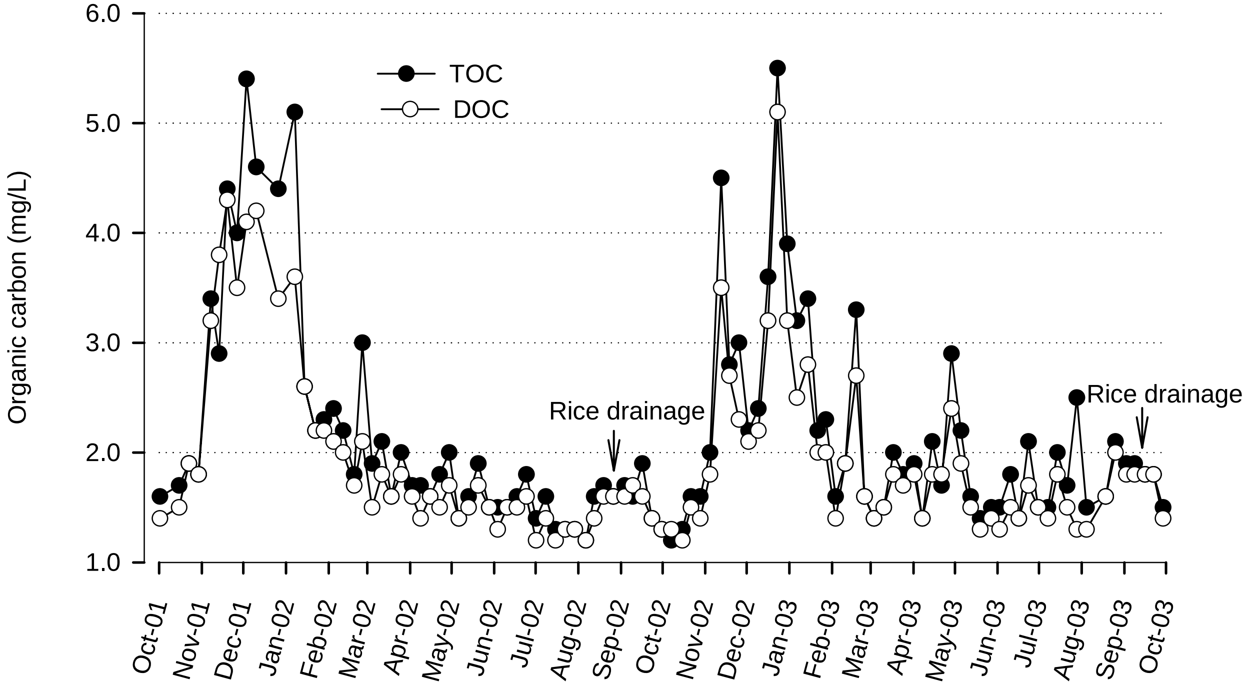


Figure 4-4 Organic carbon at San Joaquin River near Vernalis

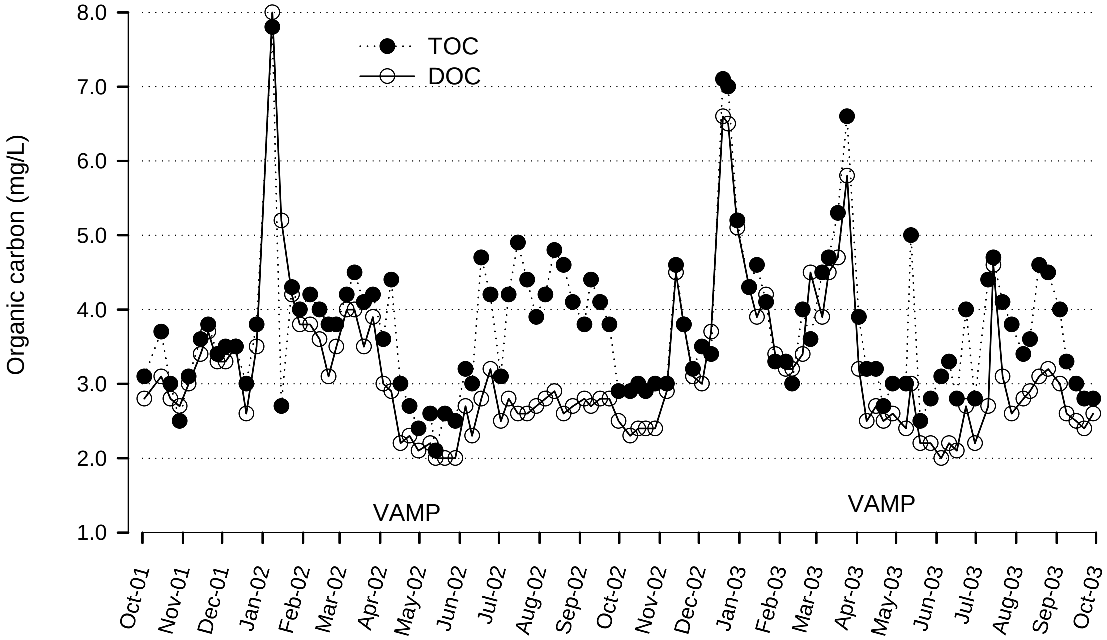
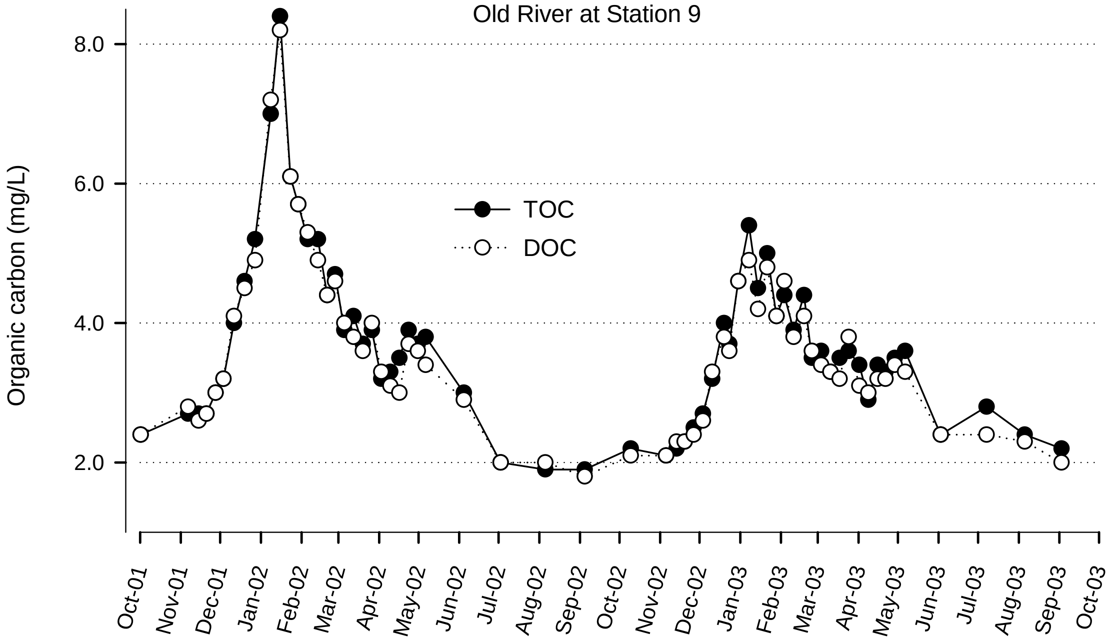


Figure 4-5 Organic carbon at two Old River stations



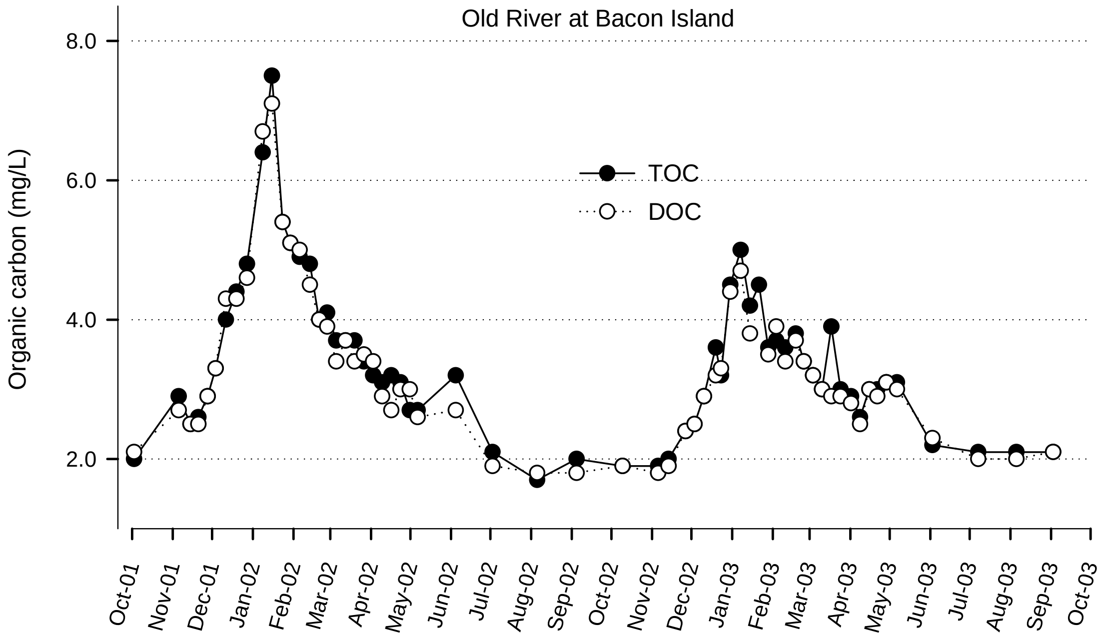
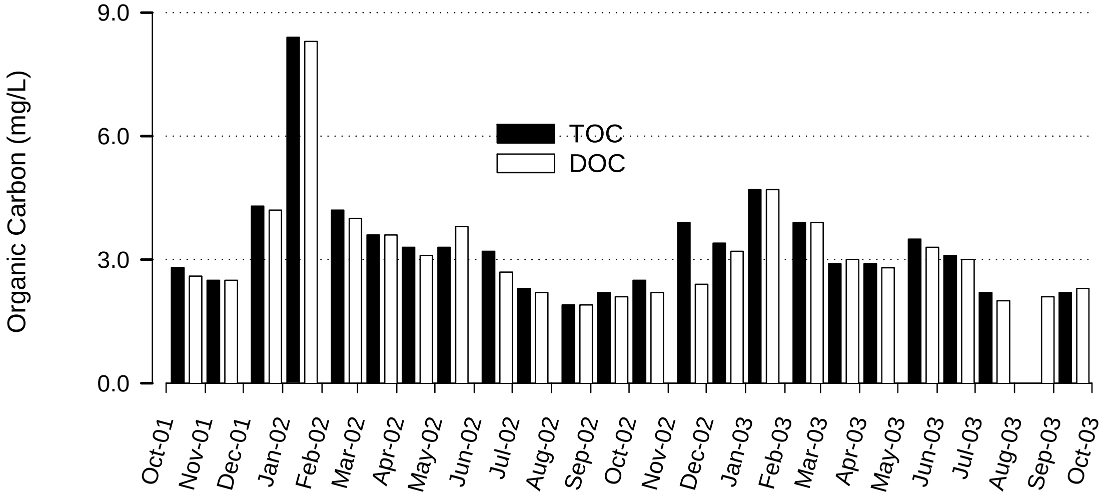
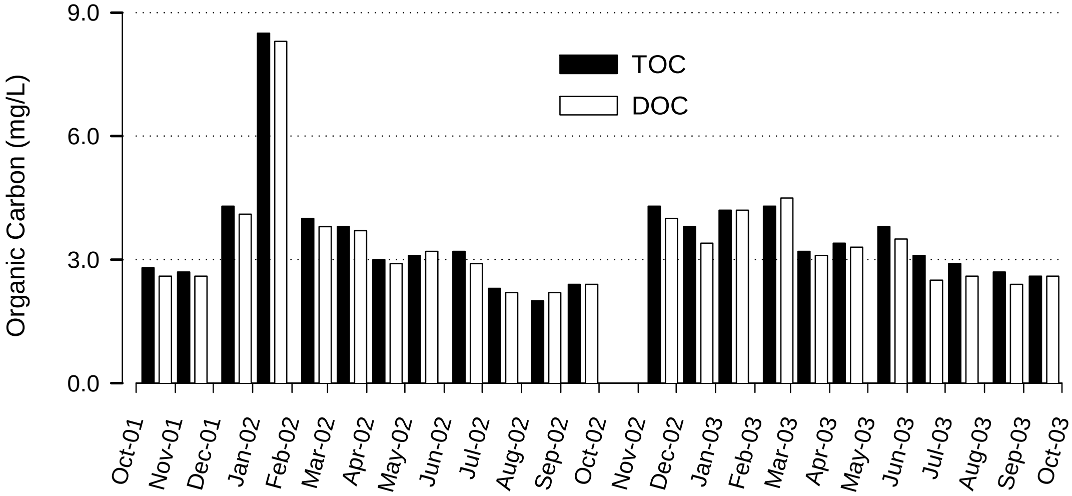


Figure 4-6 Organic carbon at three Delta diversion stations

Banks Pumping Plant



Delta-Mendota Canal



Contra Costa Pumping Plant

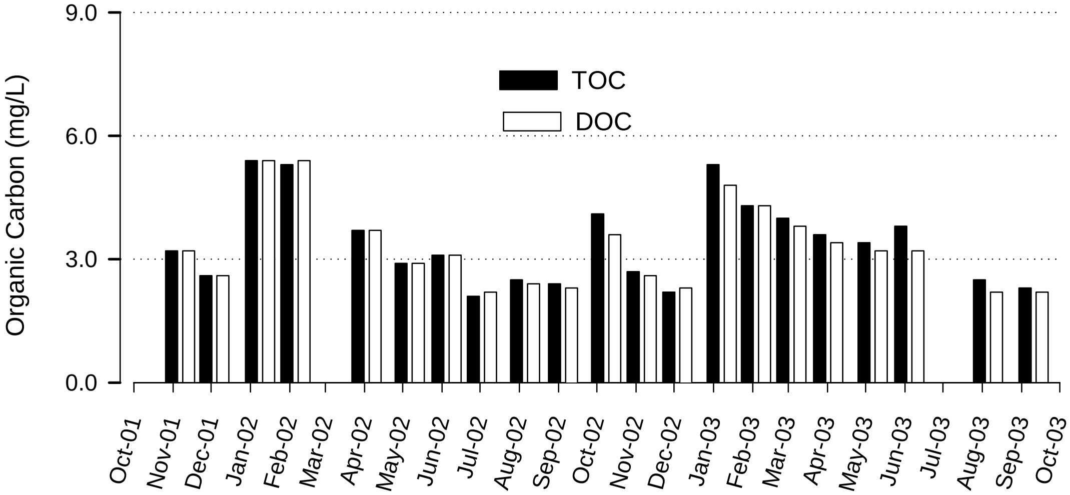
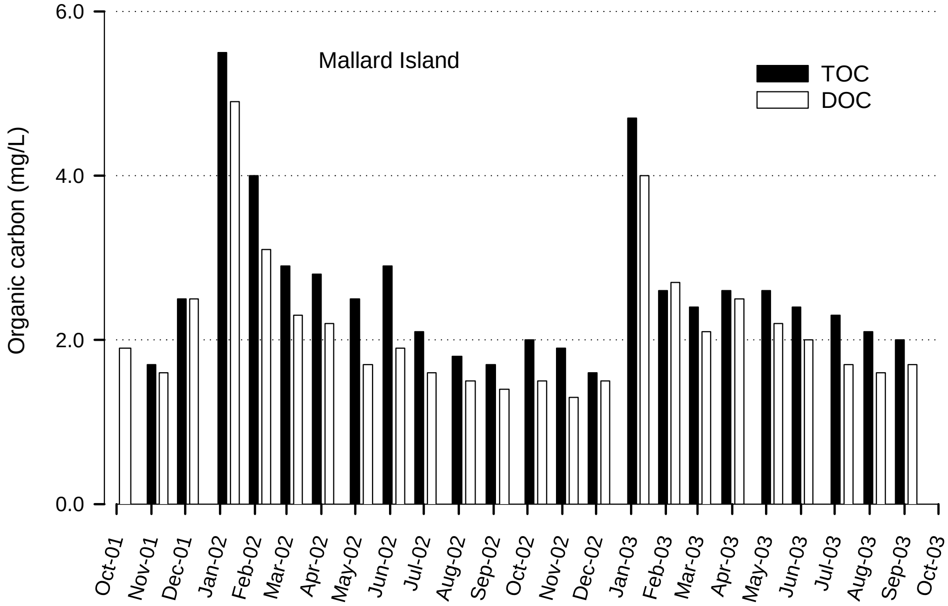


Figure 4-7 Organic carbon at Mallard Island and Natomas East Main Drainage Canal



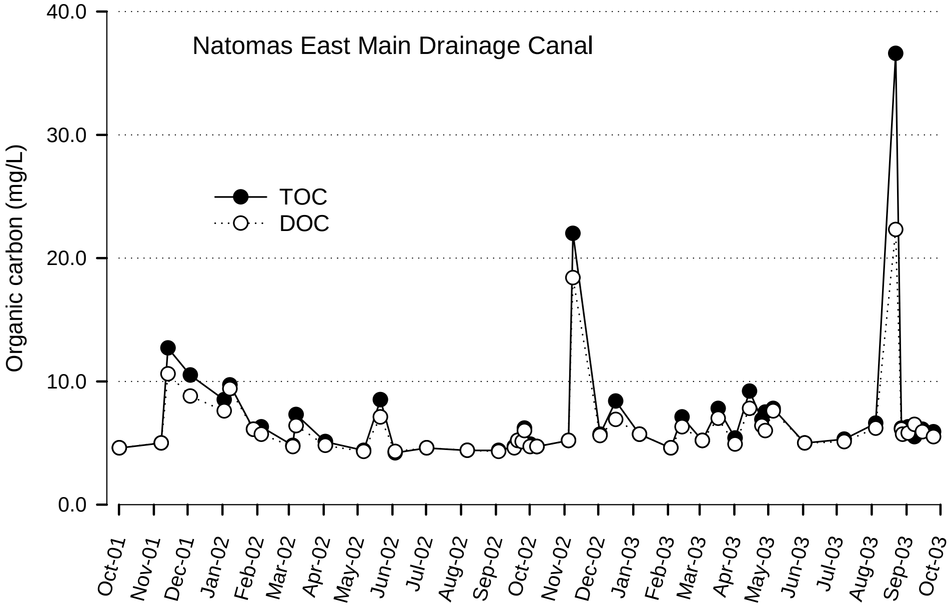


Figure 4-8 Relationships between UVA_{254} and organic carbon concentrations measured by two different methods

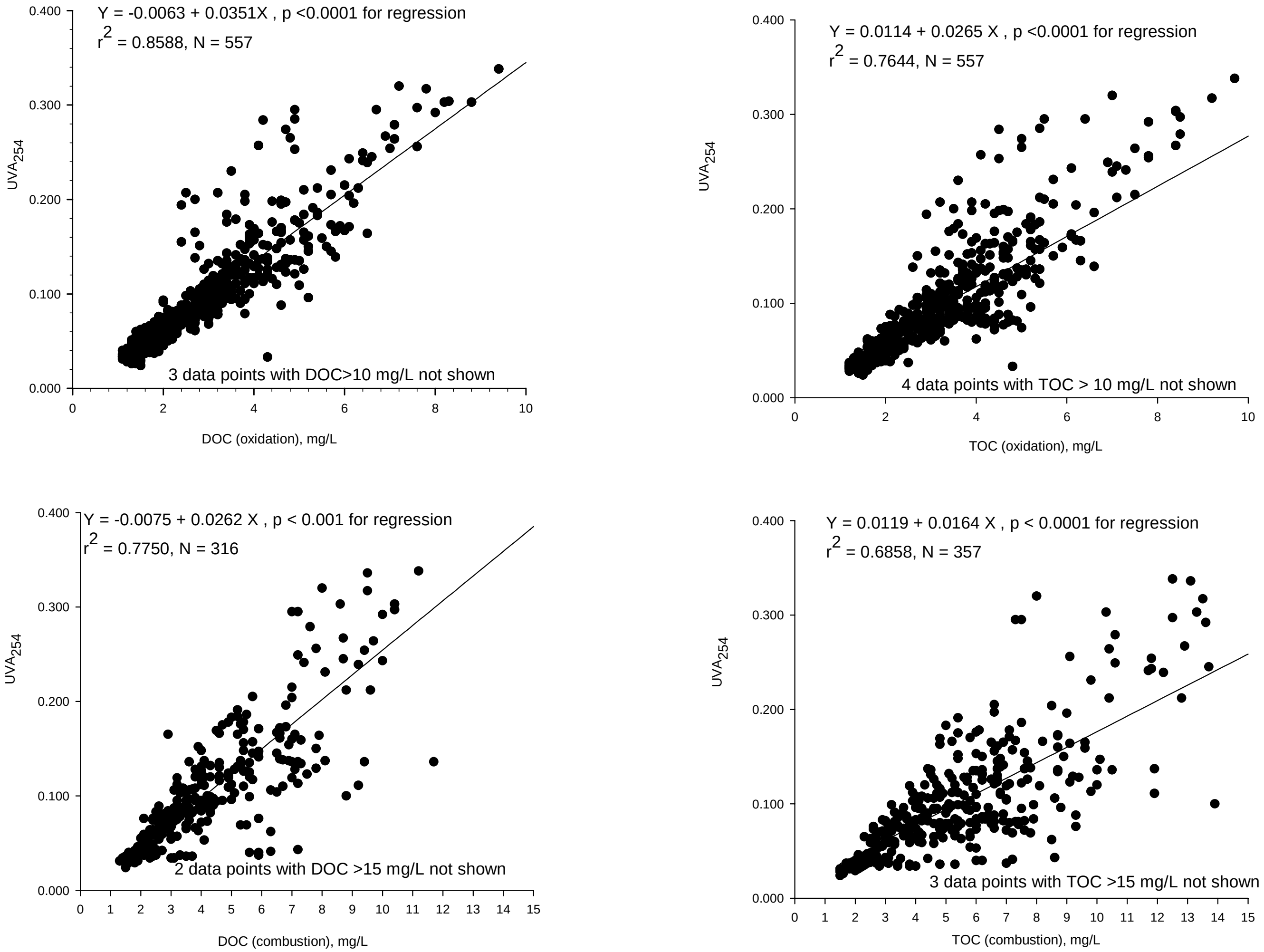


Figure 4-9 Organic carbon determined by two different methods

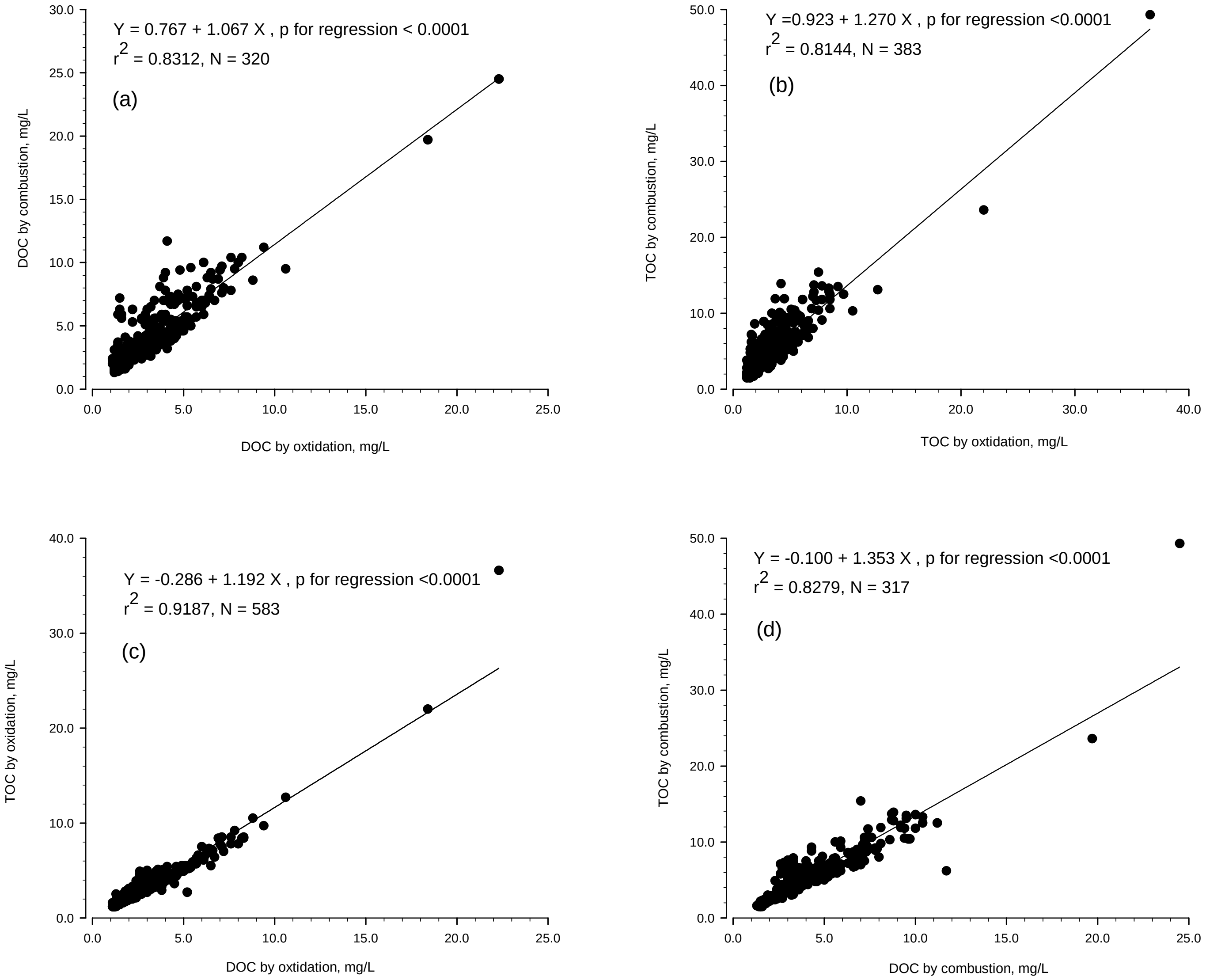


Table 4-1 Summary of organic carbon at 11 MWQI stations

Station	River mileage[a]	Constituent[b]	Sample number	------------------(units in cm-1)------------------ Range	Average	Median
American and Sacramento River						
American River at E.A. Fairbairn WTP		TOC	58	1.2–2.8	1.5	1.5
		DOC	59	1.1–2.7	1.5	1.4
West Sacramento WTP Intake	63.2	TOC	61	1.2–5.4	2.4	2.0
		DOC	61	1.1–4.9	2.2	1.8
Sacramento River at Hood	38.6	TOC	100	1.2–5.5	2.1	1.8
		DOC	100	1.2–5.1	1.9	1.7
San Joaquin River stations						
San Joaquin River near Vernalis		TOC	103	2.1–7.8	3.8	3.7
		DOC	103	2.0–8.0	3.2	2.9
Delta channel stations						
Old River at Station 9		TOC	63	1.9–8.4	3.7	3.5
		DOC	63	1.8–8.2	3.6	3.4
Old River at Bacon Island		TOC	62	1.7–7.5	3.4	3.2
		DOC	61	1.8–7.1	3.3	3.0
Diversion stations						
Banks Pumping Plant		TOC	24	1.9–8.4	3.3	3.2
		DOC	24	1.9–8.3	3.2	2.9
Delta-Mendota Canal		TOC	23	2.0–8.5	3.5	3.2
		DOC	24	2.1–8.3	3.3	3.0
Contra Costa Pumping Plant		TOC	21	2.1–5.4	3.4	3.2
		DOC	21	2.2–5.4	3.3	3.2
Other stations						
Sacramento River at Mallard Island	-4.1	TOC	24	1.6–5.5	2.6	2.4
		DOC	24	1.3–4.9	2.1	1.9
Natomas East Main Drainage Canal (NEMDC)		TOC	47	4.2–36.6	7.2	5.9
		DOC	47	4.3–22.3	6.5	5.7

a. River miles from Collinsville at the junction of the Sacramento and San Joaquin rivers.
b. Both TOC and DOC were determined by the wet oxidation method.

Table 4-2 Summary of UVA$_{254}$ at 11 MWQI stations

Station	Sample number	Range	Average	Median
		(units in cm-1)		
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	59	0.024–0.078	0.037	0.036
West Sacramento WTP Intake	61	0.031–0.200	0.072	0.057
Sacramento River at Hood	101	0.031–0.210	0.059	0.045
San Joaquin River stations				
San Joaquin River near Vernalis	102	0.058–0.292	0.095	0.084
Delta channel stations				
Old River at Station 9	62	0.063–0.320	0.137	0.119
Old River at Bacon Island	61	0.055–0.295	0.127	0.110
Diversion stations				
Banks Pumping Plant	22	0.067–0.304	0.107	0.087
Contra Costa Pumping Plant	21	0.067–0.186	0.108	0.100
Other stations				
Sacramento River at Mallard Island	24	0.049–0.295	0.083	0.068
Natomas East Main Drainage Canal (NEMDC)	47	0.096–0.666	0.204	0.164

Table 4-3 Summary of SUVA$_{254}$ at 11 MWQI stations

Station	Sample number	Range	Average	Median
		(units in cm-1)		
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	59	0.016–0.033	0.025	0.025
West Sacramento WTP Intake	61	0.022–0.081	0.033	0.030
Sacramento River at Hood	100	0.021–0.083	0.029	0.027
San Joaquin River stations				
San Joaquin River near Vernalis	102	0.019–0.061	0.030	0.029
Delta channel stations				
Old River at Station 9	62	0.029–0.068	0.037	0.035
Old River at Bacon Island	60	0.028–0.066	0.037	0.036
Diversion stations				
Banks Pumping Plant	22	0.023–0.042	0.034	0.034
Contra Costa Pumping Plant	21	0.027–0.037	0.033	0.033
Other stations				
Sacramento River at Mallard Island	24	0.030–0.060	0.037	0.037
Natomas East Main Drainage Canal (NEMDC)	47	0.018–0.041	0.031	0.029

Chapter 5 Bromide

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Chapter 5 Bromide

American and Sacramento Rivers

During the reporting period, the Municipal Water Quality Investigations Unit (MWQI) sampled one station on the American River at the E.A. Fairbairn Water Treatment Plant, and 2 stations, West Sacramento WTP Intake and Hood, on the Sacramento River. Both the E.A. Fairbairn WTP and the West Sacramento WTP Intake stations were sampled monthly during the dry months, and weekly during the wet months; the Hood station was sampled weekly throughout each water year.

Bromide was not detected at the American River at E.A. Fairbairn WTP station (Table 5-1). Water inflow to the American River mostly comes from snowmelt, which is stored in Folsom Lake, and it is very low in bromide. At the West Sacramento WTP Intake, 64% of the samples had bromide above the method detection limit (MDL) of 0.01 mg/L. Concentrations ranged from 0.01 to 0.03 mg/L with both an average and a median of 0.02 mg/L (Table 5-1).

Table 5-1 Summary of bromide at 11 MWQI stations

Bromide concentrations at the Sacramento River at Hood and at the West Sacramento WTP Intake stations were near the MDL of bromide (Table 5-1). At Hood, bromide was found below the MDL in 27% of the 101 weekly grab samples. For the positive samples, bromide concentrations ranged from 0.01 to 0.05 mg/L (Table 5-1). The average and median bromide concentrations were 0.02 and 0.01 mg/L, respectively (Table 5-1). Bromide concentrations at both stations were comparable to those found during the 1998–2001 summary period (DWR 2003a).

San Joaquin River Station near Vernalis

The San Joaquin River (SJR) near Vernalis was monitored weekly during the 2-year reporting period. Of the 103 samples, bromide concentrations ranged from 0.12 to 0.60 mg/L with average and median bromide concentrations of 0.31 and 0.30 mg/L, respectively (Table 5-1). Bromide concentrations increased considerably during this 2-year reporting period compared with those during the 1998–2001 summary period when average and median concentrations were 0.2 mg/L (DWR 2003a). This was due to the difference in runoff in the contributing watersheds between the 2 summary periods. The 1998–2001 summary period was relatively wetter runoff years than the current reporting period (Table 3-3).

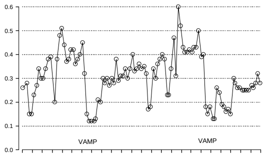

Figure 5-1 Bromide concentrations at San Joaquin River near Vernalis

Bromide was highest during January and February of the wet months when precipitation or intentional winter flooding caused surface runoff with high bromide from agricultural lands of the San Joaquin Valley to the SJR (Figure 5-1). The January and February runoff represented the first wash of accumulated salts and bromide in the soils, thus causing a surge in bromide detection. Bromide concentrations were the lowest between mid-April and mid-May (Figure 5-1), which coincides with the Vernalis Adaptive Management Plan period (see Chapter 3) when SJR flow was increased by additional reservoir releases to the Merced, Stanislaus, and Tuolumne rivers. The seasonal pattern of bromide differed from that of organic carbon at the

Vernalis station. Organic carbon concentrations at Vernalis were generally lower and less variable during the dry months than during the wet months (see Chapter 4); however, bromide concentrations remained relatively high throughout the dry months (Figure 5-1).

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 comes from the Delta-Mendota Canal (DMC), a Delta diversion station, and contains considerable bromide (Table 5-1) and recirculates within the San Joaquin Valley. When irrigation water is applied, bromide concentrates on the soil surface through evapotranspiration. Following either irrigation or rainfall, runoff water carries previously accumulated bromide on the soil surface and moves it into the SJR. Soils in some areas were developed from old marine deposits that contain high levels of bromide, which may be concentrated on the soil surface and washed into the river during wet months of low to moderate rainfall. In some areas, shallow groundwater also carries high levels of bromide and moves into the SJR through seepage. On the other hand, inflow water in the upstream watershed with low bromide is mostly trapped in upstream reservoirs for flood control or storage purposes during the wet months resulting in less dilution downstream; therefore, bromide concentrations in the lower part of the river are high during the wet months.

During the dry months, irrigation return waters containing elevated levels of bromide are discharged into the SJR. Thus, bromide concentrations generally increased during periods of peak irrigation (May through September) and decreased at the end of the irrigation season prior to increases in the wet months (Figure 5-1).

During the reporting period, 2002 Water Year was a “dry runoff year,” whereas 2003 WY was considered a “below normal year” in the SJR watershed (refer to Chapter 3). Median bromide concentrations between the 2 water years were not statistically different (p=0.5683), nor was the difference in median bromide concentrations between the wet months of the 2 water years (p=0.2223). However, the median bromide concentration (0.30 mg/L) during the dry months of 2002 WY was significantly higher than that (0.25 mg/L) of the dry months of 2003 WY (p=0.0006), according to the nonparametric Mann-Whitney test. This was attributable to irrigation returns with modest bromide concentrations and decreased inflows with low bromide levels from the tributaries on the east side of the upper SJR.

Channel Stations

MWQI monitored bromide at 2 channel stations—Old River at Station 9 and Old River at Bacon Island. The 2 monitoring stations are approximately 9 miles apart along Old River. The Woodward and North Victoria canals and Indian Slough join this section of the river. Although about 10 agricultural return sites drain to this section of Old River from Holland, Bacon, Orwood, Woodward, and Victoria islands/tracts, water quality between the 2 sites does not differ significantly.

During the 2-year reporting period, bromide was always above the reporting limit (Table 5-1). Median concentrations of bromide were 0.10 mg/L at

Station 9 and 0.09 mg/L at the Bacon Island station (Table 5-1), which were not statistically different (*p*=0.2929) according to the nonparametric Mann-Whitney test. These median bromide concentrations were similar to those found during the 1998–2001 summary period (DWR 2003a).

Temporal patterns of bromide were similar for both channel stations (Figure 5-2) and were similar to those of organic carbon. Concentrations were higher from October to February and decreased and remained relatively unchanged from February to July during the 2 water years (Figure 5-2). This seasonality pattern differed from that of the SJR station near Vernalis (Figure 5-1). At both stations (Figure 5-2), bromide concentrations were as elevated from July to October of 2002 WY as during the wet months. This was because 2002 WY was a dry runoff year. Total Delta outflows reached the lowest from July to October of 2002 WY (see Figure 3-5). The tides brought in seawater to the Delta, which increased bromide concentrations. The 2003 WY was a relatively wetter year, and thus total Delta outflow was greater (see Figure 3-5). Therefore, an increase in bromide concentrations around July 2003 was not as great as from July to October of 2002 WY.

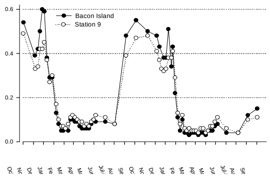

Figure 5-2 Bromide concentrations at two Old River stations

Precipitation and runoff in the watershed had a significant impact on bromide concentrations at the 2 stations. Median bromide concentrations at Station 9 were 0.11 and 0.09 mg/L for 2002 WY and 2003 WY, respectively; median bromide concentrations at Bacon Island were 0.09 and 0.05 mg/L for 2002 WY and 2003 WY, respectively. For both stations, median bromide concentrations were significantly higher during 2002 WY than in 2003 WY (*p* was 0.0447 and 0.0213 for Station 9 and Bacon Island, respectively).

The effect of runoff in the watershed on bromide concentration was also clearly demonstrated during the dry months (Figure 5-2). The 2002 WY was considered a dry runoff year in the SJR watershed (refer to Chapter 3). Bromide concentrations increased from about 0.10 mg/L at the end of June 2002 to more than 0.40 mg/L from July to September 2002. The 2003 WY was a wetter year and classified as a “below normal year” in the SJR watershed (refer to Chapter 3). The sudden increase in bromide levels from July to September 2002 did not occur from July to September 2003 (Figure 5-2). The lower bromide concentration from July to September 2003 was attributable to more reservoir releases and subsequently increased river flows from the Sacramento River and upper SJR (see Figures 3-3 and 3-4).

Diversion Stations

Samples from 3 Delta diversion stations—Banks Pumping Plant, DMC, and Contra Costa Pumping Plant #1—were collected during the reporting period. The median bromide concentrations varied from 0.15 to 0.22 mg/L (Table 5-1). Average bromide concentrations ranged from 0.19 to 0.31 mg/L (Table 5-1). Both median and average bromide concentrations during the current summary period were higher than those of the previous summary period (Table 5-2). The lower bromide levels at the diversion stations during the previous summary period were very likely due to that period’s greater runoff in the watersheds (DWR 2003a).

Table 5-2 Bromide at diversion stations: current vs. previous summary period

Seasonal patterns were similar for all 3 stations (Figure 5-3). In general, bromide reached its highest value from October through February of each water year. Bromide concentrations were lower from April through July (Figure 5-3). These seasonal patterns were different from those observed at the SJR station near Vernalis (Figure 5-2), reflecting the influences of multiple sources at the diversion pumps.

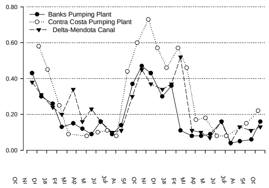

Figure 5-3 Bromide concentrations at three diversion stations

Because the Contra Costa Pumping Plant #1 had a different sampling frequency, statistical comparisons of all 3 stations cannot be performed. However, because both Banks and DMC stations were sampled mostly on the same day, a Mann-Whitney test of median bromide concentration can be made. Results suggested that median bromide concentrations at Banks and DMC were not significantly different during the 2 water years (p=0.2745).

Among the 3 diversion stations, both average and median bromide concentrations were highest at the Contra Costa Pumping Plant #1, perhaps due to the station's proximity to seawater influence (see Figure 1-1). Seawater influence is related to Delta outflows. The 2002 WY was a dry runoff year for both the Sacramento and San Joaquin valleys, but 2003 WY was a wetter year compared with 2002 WY (Table 3-3). Outflow in 2002 WY was lower than in 2003 WY. Delta outflow was lower in 2002 WY (see Figure 3-5) due to reduced reservoir releases (see figures 3-3 and 3-4). Reduced outflows resulted in greater seawater influence to the western part of the Delta during 2002 WY. Therefore, bromide levels at all 3 stations were much higher during the latter part of the dry months (July to October) of 2002 WY (Figure 5-3). This July to October increase in bromide did not occur in the relatively wetter 2003 WY (Figure 5-3). The July to October increase in bromide in response to runoff year type was more pronounced at Contra Costa Pumping Plant than at the other 2 diversion stations due to its proximity to seawater influence.

Other Stations

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 2-year period. Bromide was always above the reporting limit (Table 5-1). Concentrations ranged from 0.03 to 17.9 mg/L, making it the most widely variable of all 11 stations (Table 5-1). The average and median bromide concentrations were 4.06 and 2.00 mg/L, respectively, which were similar to those found during the previous summary period (DWR 2003a).

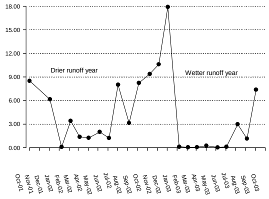

Figure 5-4 Bromide concentrations at the Mallard Island stations

Bromide at the Mallard Island station was much higher during the drier 2002 WY than during the relatively wetter 2003 WY (Figure 5-4). Higher bromide concentrations at Mallard during 2002 WY appear to have been directly related to runoff in the contributing watersheds. In 2002 WY, runoff was lower from both the Sacramento and San Joaquin watersheds than in 2003 WY (Table 3-3), reservoir releases and total Delta outflow were lower in 2002 WY than 2003 WY (Figures 3-3, 3-4, and 3-5). Consequently, bromide concentrations increased rapidly from July to December as Delta outflow decreased (Figure 5-4). In contrast, bromide concentrations remained low during most of 2003 WY (Figure 5-4) due to increased Delta outflow (see Figure 3-5). The bromide increase during the latter half of the dry months was smaller compared to that of 2002 WY (Figure 5-4).

Urban Drainage

Bromide at Natomas East Main Drainage Canal (NEMDC) was monitored monthly or weekly during the 2-year reporting period. Bromide ranged between 0.01 and 0.12 mg/L with a median concentration of 0.05 mg/L (Table 5-1), which was comparable to those found during the previous summary period (DWR 2003a). Although bromide concentrations fluctuate, no apparent seasonal or temporal trend was observed during the 2-year period (Figure 5-5).

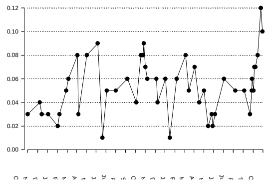

Figure 5-5 Bromide concentrations at the Natomas East Main Drainage Canal

Sources of Bromide in Delta Waters

Direct Seawater influence

MWQI data collected during the past 5 water years suggested that bromide in Delta waters mostly came from seawater either directly or indirectly. Waters from the Sierra, the Cascade Range, and in the watersheds of the Sacramento and San Joaquin valleys contain very low levels of bromide. Bromide in water samples collected from the American River and the upper Sacramento River (West Sacramento WTP Intake and Hood) were mostly below or at the MDL (DWR 2003a and Table 5-1). Based on the data, urban drainage did not appear to be a major contributor of bromide, which was evident from bromide data collected from NEMDC (DWR 2003a and Figure 5-5).

Seawater contains approximately 65 mg/L of bromide and 19,000 mg/L of chloride; the bromide/chloride ratio in seawater is, therefore, roughly 0.0034. Like chloride, bromide is conservative. This ratio should hold in Delta waters if seawater is the sole source of bromide and chloride. The bromide/chloride ratio in waters of the central and western Delta resembled that of seawater.

During the 1998–2001 summary period, a total of 427 samples were collected from 10 Delta stations susceptible to direct or indirect seawater influence including 2 agricultural drainage stations. The relationship between bromide and chloride may be described by this linear regression equation (DWR 2003a):

$$\text{Bromide} = 0.0035 * \text{Chloride} - 0.019,\ [r^2 = 0.996,\ p < 0.0001]$$

Thus, the bromide/chloride ratio in Delta waters is 0.0035, which is close to the ratio of 0.0034 found in seawater.

During the current 2-year reporting period, 130 samples were collected from 6 Delta stations susceptible to direct or indirect seawater influence, the relationship between bromide and chloride may be described by this linear regression equation (Figure 5-6):

$$\text{Bromide} = 0.0032 * \text{Chloride} - 0.0096, \; [\, r^2 = 0.988, \; p<0.0001]$$

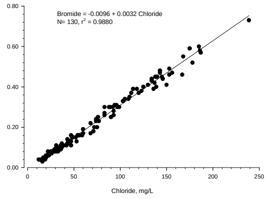

Figure 5-6 The relationship between bromide and chloride at six stations

A bromide/chloride ratio of 0.0032 is close to the bromide/chloride ratio of 0.0034 found in seawater. This analysis supports the hypothesis that the source of bromide in the Delta is primarily seawater.

Of the 11 stations studied, the Mallard Island station is most indicative of seawater influence among the stations. Bromide concentrations at this station reached as high as 18 mg/L during the reporting period (Figure 5-4). Such high concentrations can only be from seawater because rivers, channels, and urban drains of the Delta all had substantially lower bromide levels. In fact, when Delta outflows were high, bromide at Mallard Island decreased to levels similar to Delta river and channel stations, such as from January to June of 2003 (Figure 5-4).

Recirculation of Bromide within the San Joaquin Valley

Recirculation of bromide within the San Joaquin Valley represents effects of indirect seawater influence. The SJR contributes significant amounts of bromide to Delta waters. Median bromide concentration of the SJR near Vernalis was 0.30 mg/L (Table 5-1). Bromide from seawater enters the San Joaquin Valley as irrigation water taken from the Delta. Bromide in the irrigation water is concentrated in the agricultural lands and returned to the Delta through the SJR. Delta soils are peaty soils, which were formed when the area was a tidal wetland; therefore, soil bromide content was high. Bromide and salts also have accumulated in Delta island soils through irrigation and evapotranspiration. Some islands have shallow groundwater, which also contributes bromide through seepage. When island drainage water is pumped back into the Delta, bromide is released into Delta channels. As shown in MWQI's previous summary report, median bromide in island drainage waters ranged from 0.18 to 0.34 mg/L (DWR 2003a). Bromide concentrations in island drainage are even higher during the wet months when farmers apply water to their land to leach salts from the soil and then return the water to Delta channels during the winter. Heavy rainfall during the wet months also dissolves salts and carries these salts including bromide into the ditches, which are subsequently pumped into Delta channels. Most of the bromide in the San Joaquin Valley can be accounted for this way, but the valley also has intrinsic bromide sources, such as bromide from shallow groundwater or from soils developed from old marine deposits.

Chapter 5 Bromide

Figures

Tables

Figure 5-1 Bromide concentrations at San Joaquin River near Vernalis

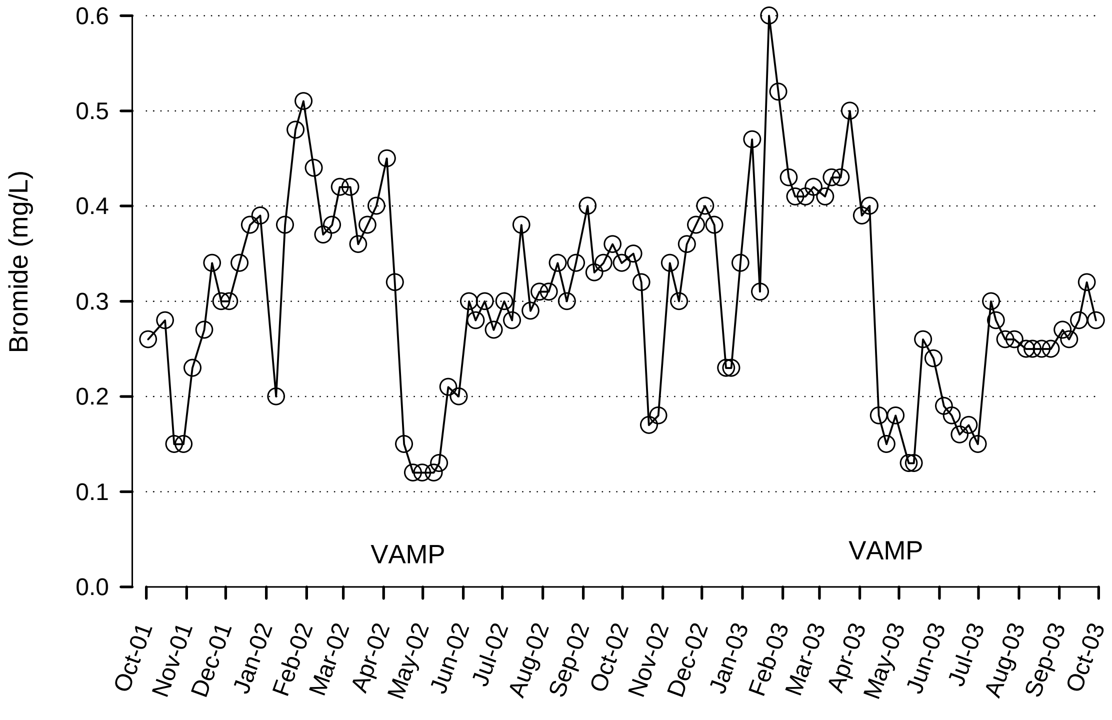

Figure 5-2 Bromide concentrations at two Old River stations

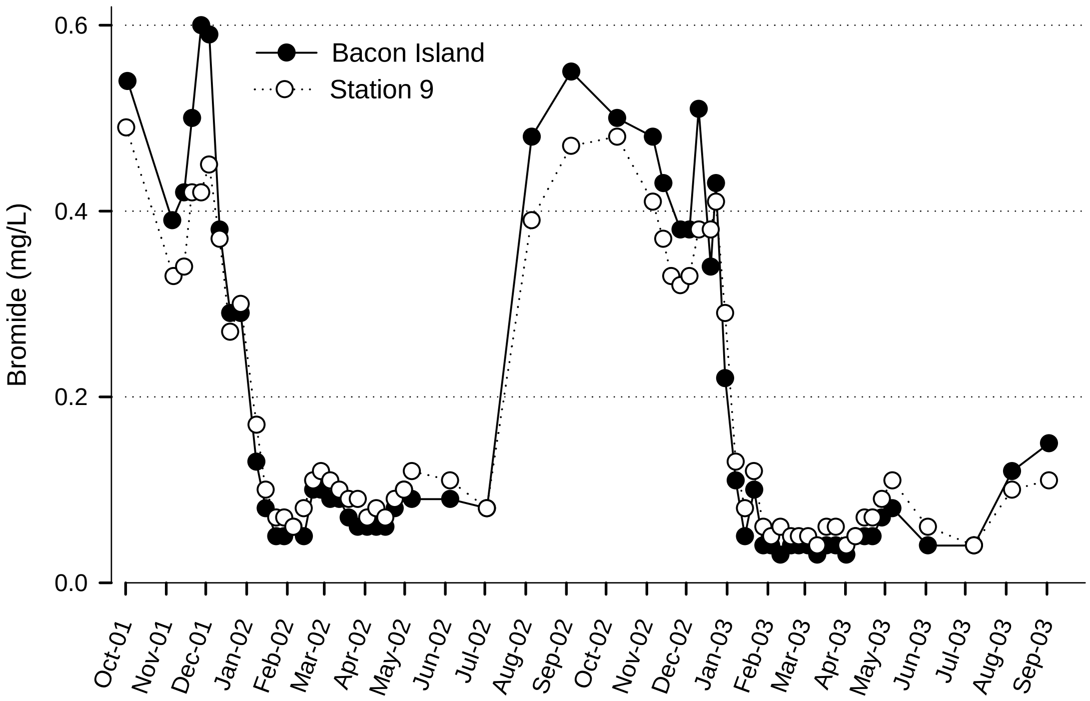

Figure 5-3 Bromide concentrations at three diversion stations

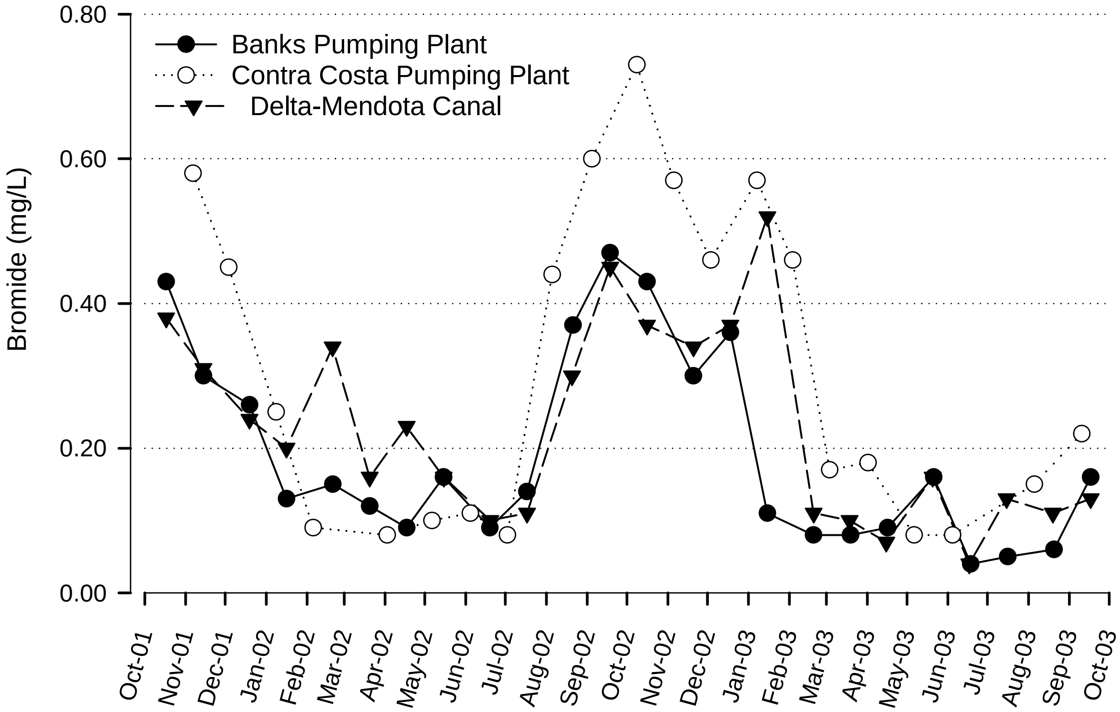

Figure 5-4 Bromide concentrations at the Mallard Island station

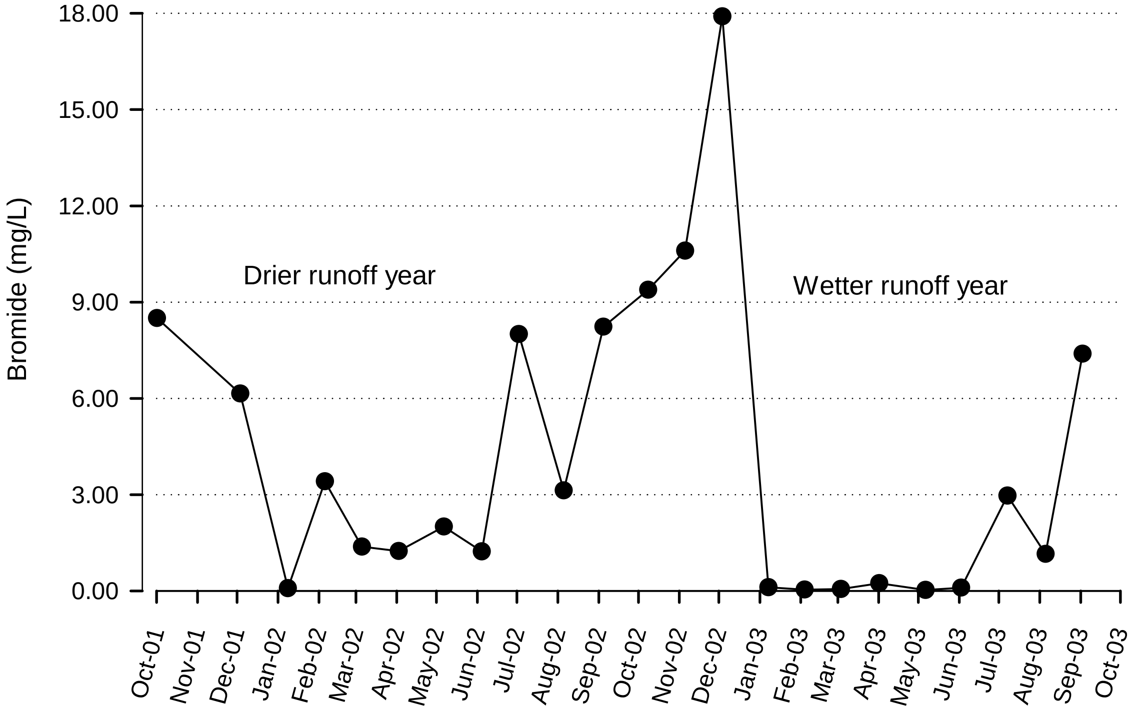

Figure 5-5 Bromide concentrations at the Natomas East Main Drainage Canal

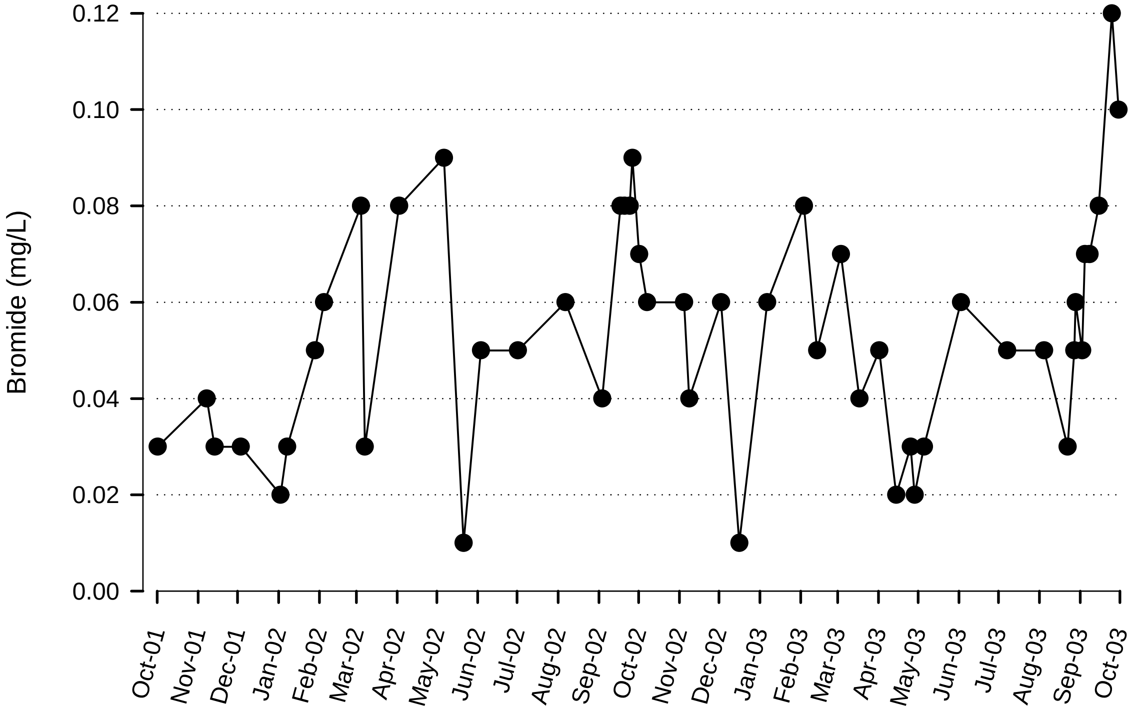

Figure 5-6 The relationship between bromide and chloride at six stations

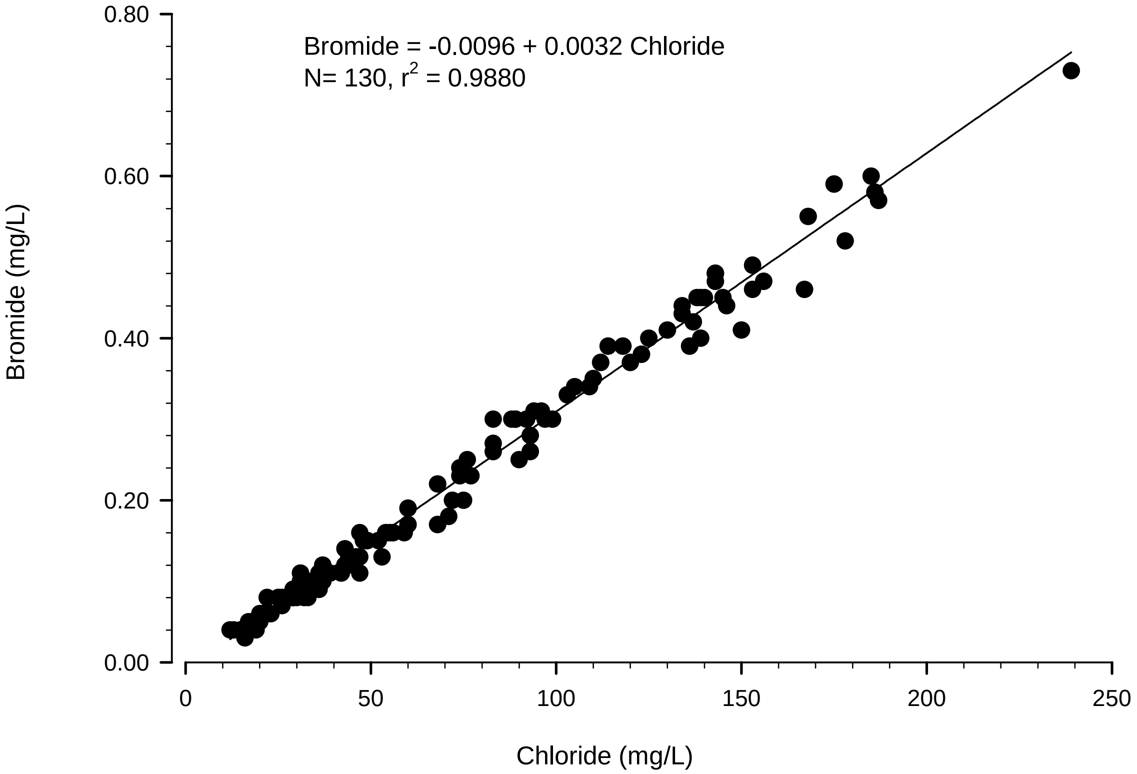

Table 5-1 Summary of bromide at 11 MWQI stations

Station	Positive detects/ Sample number	-------------------units in mg/L----------------- Range	Average	Median
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	0/59	<0.01		
West Sacramento WTP Intake	39/61	0.01–0.03	0.02	0.02
Sacramento River at Hood	74/101	0.01–0.05	0.02	0.01
San Joaquin River stations				
San Joaquin River near Vernalis	103/103	0.12–0.60	0.31	0.30
Delta channel stations				
Old River at Station 9	63/63	0.04–0.49	0.18	0.10
Old River at Bacon Island	62/62	0.03–0.60	0.19	0.09
Diversion stations				
Banks Pumping Plant	24/24	0.04–0.47	0.19	0.15
Delta-Mendota Canal (DMC)	24/24	0.04–0.52	0.23	0.18
Contra Costa Pumping Plant	21/21	0.08–0.73	0.31	0.22
Other stations				
Mallard Island	23/23	0.03–17.90	4.06	2.00
Natomas East Main Drainage Canal (NEMDC)	49/49	0.01–0.12	0.05	0.05

Note: All statistics are calculated for positively detected samples; positive detects are samples with concentrations equal to or greater than the reporting limit of 0.01 mg/L.

Table 5-2 Bromide at diversion stations: current vs. previous summary period

Station	Summary period[a]	Range	Average	Median
Banks Pumping Plant	10/01–9/03	0.04–0.47	0.19	0.15
	8/98–9/01	0.05–0.52	0.17	0.14
Delta-Mendota Canal (DMC)	10/01–9/03	0.04–0.52	0.23	0.18
	8/98–9/01	0.05–0.47	0.18	0.15
Contra Costa Pumping Plant	10/01–9/03	0.08–0.73	0.31	0.22
	8/98–9/01	0.03–0.77	0.22	0.11

a. Current summary period (Oct 2001-Sep 2003); previous summary period, Aug 1, 1998, to Sep 30, 2001 (see DWR 2003).

Chapter 6 Salinity

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Chapter 6 Salinity

Waters with highly elevated salinity and electrical conductivity (EC) are not suitable for drinking purposes. Salinity was originally conceived as a measure of the mass of dissolved salts in a given mass of solution (Eaton and others 1995). However, measuring every constituent in the water is time-consuming and cannot yield the precision necessary for accurate, routine assessment of water quality (Eaton and others 1995). The total quantity of dissolved salts, referred to as total dissolved solids (TDS), is estimated by increase in weight of a filtrate evaporated to dryness in a previously weighted dish and dried to constant weight at 180 ^oC after filtering through a standard glass fiber filter (Eaton and others 1995). The TDS results may not agree with the theoretical value for solids calculated from chemical analysis of sample. Therefore, an alternative and indirect method of observing salinity is often used, which is the measurement of the electrical conductivity of the water.

General Relationships between EC and TDS in Delta Waters

In the previous summary report by the Municipal Water Quality Investigations Program, 694 samples were collected from 14 MWQI stations from August 1998 to September 2001 (DWR 2003a). The 14 stations included 2 Delta island drainage stations. The report found that the relationship between EC and TDS in Delta waters was linear, and that TDS in milligrams per liter (mg/L) can be estimated numerically as 58% of the value of EC in µS/cm (DWR 2003a).

During this reporting period (September 2001 through October 2003), a total of 285 samples were collected from 11 MWQI stations and analyzed. The relationship between EC and TDS was also linear (Figure 6-1) and can be described by the following equation:

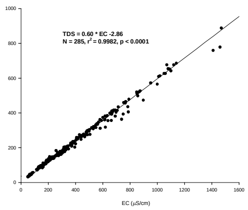

Figure 6-1 The relationship between EC and TDS at all 11 stations

$$\text{TDS} = 0.60*\text{EC} - 3, (r^2 = 0.9982, p < 0.0001).$$

The equation suggests that TDS in mg/L can be estimated numerically as 60% of the value of EC in microsiemens per centimeter (µS/cm).

Ranges and Seasonality

The range, average, and median EC and TDS for each station are presented in Table 6-1. Despite similar spatial patterns of EC and TDS among the 11 stations (Table 6-1), median EC and TDS at San Joaquin River (SJR) near Vernalis and Contra Costa Pumping Plant #1 were much higher during the the reporting period (Table 6-1) than during the previous summary period (DWR 2003a). The cause of such increases will be discussed in more detail. As noted above, the relationship between EC and TDS is linear and numerically predictable from each other (Figure 6-1). The following sections discuss EC alone at each individual station.

Table 6-1 Summary of EC and TDS data, Oct 2001 through Sep 2003

American River at the Fairbairn WTP Intake

Among all MWQI stations, E.A. Fairbairn Water Treatment Plant (WTP) intake on the American River has the lowest EC and TDS. During this reporting period, EC ranged from 51 to 92 µS/cm with an average of 69 µS/cm and a median of 66 µS/cm. TDS varied from 32 to 57 mg/L. Both the average and median TDS were 41 mg/L (Table 6-1), which were the lowest among all 11 stations. These EC and TDS concentrations were only slightly higher than those observed during the previous summary period (DWR 2003a).

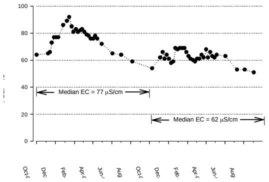

Figure 6-2 EC at the American River WTP Intake

The 2002 Water Year was a drier runoff year than 2003 WY in the Sacramento Valley (see Table 3-3). Runoff and releases from Folsom Lake were less during 2002 WY than during 2003 WY (see Figure 3-3). As a result, EC was higher in 2002 WY than in 2003 WY (Figure 6-2) Median EC was 77 µS/cm during 2002 WY and 62 µS/cm in 2003 WY; the difference in median EC was statistically significant (Mann-Whitney test *p*<0.00001).

Sacramento River Stations

The ranges for EC were 117 to 245 µS/cm at the West Sacramento WTP Intake and 114 to 239 µS/cm at Hood. The median EC was 167 and 160 µS/cm for West Sacramento WTP Intake and Hood, respectively (Table 6-1). TDS at these stations ranged from 80 to 138 mg/L and from 72 to 138 mg/L, respectively; median TDS was 104 mg/L for West Sacramento WTP Intake and 102 mg/L for Hood (Table 6-1). Median EC and TDS were not statistically different from those found during the 1998–2001 summary period (DWR 2003a).

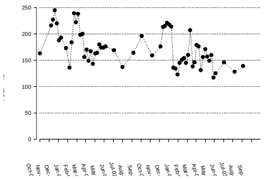

Figure 6-3 EC at the West Sacramento WTP Intake

EC at these 2 stations was dependent on the amount of runoff in the contributing watershed. EC was higher during the drier runoff year and lower during the wetter runoff year (Figures 6-3 and 6-4). At West Sacramento WTP Intake, median EC was 175 µS/cm during the relatively drier 2002 WY, and 154 µS/cm during the wetter 2003 WY. The difference was statistically significant with a *p* value of 0.0022. At Hood, median EC was 165 µS/cm during 2002 WY, and 152 µS/cm during 2003 WY. The difference was also significant with a *p* value of 0.0017.

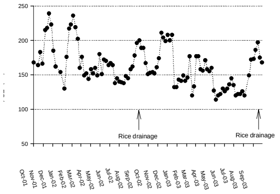

Figure 6-4 EC at the Hood station

Values of EC were elevated and variable in response to rainfall events during the wet months (Figures 6-3 and 6-4). EC fluctuated during the dry months in response to urban and agricultural drainages. For example, EC at both stations increased during August and September of each water year (Figures 6-3 and 6-4), probably due to rice drainage from the Sacramento Valley.

Despite differences in sampling frequency, seasonal patterns of EC at Hood were similar to those at the West Sacramento WTP Intake (Figures 6-3 and 6-4). Although low mineral water from the American River enters the Sacramento River between the West Sacramento WTP Intake and Hood, inflows were generally small compared to the inflows from the upper Sacramento River. Two wastewater treatment plants also discharge to the Sacramento River between the West Sacramento WTP Intake and Hood (see

Figure 4-1). Wastewater discharges may counter the effect of dilution from the American River water inflows.

San Joaquin River near Vernalis

Both EC and TDS of the SJR near Vernalis were among the highest of all 11 stations monitored during the reporting period and were only exceeded by those found at the Mallard Island station (Table 6-1), which is influenced by seawater. Salinity of water in the SJR is the highest of monitored rivers, channels, diversion points, and an urban drainage canal.

At the SJR near Vernalis, EC ranged from 352 to 1,180 µS/cm (Table 6-1). Median EC was 715 µS/cm (Table 6-1). Median EC in water years from 1998 through 2001 was 549 µS/cm (DWR 2003a); according to the Mann-Whitney test, median EC during the reporting period was significantly higher (*p*<0.0001). Higher EC and salinity at this station was attributable to reduced inflows to the SJR. The previous summary period (1998–2001) was preceded by 2 wet runoff years, and started with 2 above normal runoff years (1999 and 2000), followed by a dry runoff year (2001). In contrast, this reporting period was preceded by a dry runoff year (2001) and began with a dry runoff year (2002), which was followed by a below normal runoff year (2003). Consequently, inflows to the SJR above Vernalis were higher during the previous summary period than during this reporting period (data not shown). The median EC was higher during this reporting period than during the previous summary period.

EC was generally higher during the wet months than during the dry months of each water year; the highest EC values occurred during the wet months of the 2 water years (Figure 6-5). Median EC was 857 µS/cm during the wet months of 2002 WY, which was a dry runoff year in the San Joaquin Valley. Median EC was 935 µS/cm during the wet months of 2003 WY, which was a below normal runoff year. Although median EC was about 9% higher during the wet months of the wetter 2003 WY than during 2002 WY, these median EC levels were not significantly different (*p*=0.1871) according to the Mann-Whitney test.

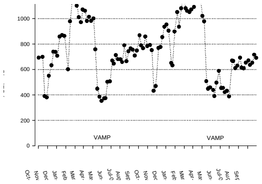

Figure 6-5 EC at San Joaquin River near Vernalis

In contrast, EC during the dry months of the 2 water years demonstrated a stronger response (16%) to the differences in watershed runoff (Figure 6-5). Median EC during the dry months of 2002 WY and 2003 WY were 710 and 611 µS/cm, respectively. The difference in median EC were statistically significant (*p*=0.0023).

The lowest EC values were found from April through June of the 2 water years (Figure 6-5). This lowering in EC was attributable to the implementation of the Vernalis Adaptive Management Plan, which is mandated by State Water Resources Control Board Decision 1641 (SWRCB 2000). VAMP requires an increase in inflows to the SJR from the Stanislaus River, Merced River, and Tuolumne River from the east side, which increases the percentages of low EC water from the Sierra Nevada. During high inflows from the eastern tributaries with increased reservoir releases, the SJR near Vernalis shows lower EC. This happens during the months of April and May when VAMP's measures are carried out (Figure 6-5). Because of VAMP, a pulse of fresh water is maintained for a minimum of 31 days from the rivers that bring in water from the Sierra (DWR 2003a). This was performed from mid-April to mid-May in both 2002 and 2003. A corresponding drop in EC and all charged ions were seen in May of those 2 years (Figure 6-5).

Salinity of the water in the SJR is the result of a combination of factors: (1) limited low EC water inflows into the SJR, (2) irrigation with Delta-Mendota Canal (DMC) water, which is recirculated water with considerable salinity both from the bay and from island drainages, and (3) geological sources of salinity such as soils and groundwater.

Because of these contributing factors, EC at the Vernalis station varied at an elevated level even during the dry months (Figure 6-5), which were higher than median EC at most stations except for the Mallard Island station (Figure 6-5 and Table 6-1). The elevated EC during the dry months coincided with the increased agricultural activity and drainage returns from the San Joaquin Valley.

Channel Stations

MWQI sampled 2 channel stations along Old River. One station was at Bacon Island and the other at Station 9 near Highway 4. They are approximately 9 miles apart. Due to their proximity, salinity levels and seasonality were similar (Figure 6-6). Although EC and TDS ranges differed slightly and median EC at Station 9 was about 14% higher than that at Bacon Island, these median EC levels were not statistically different according to the Mann-Whitney test (*p*=0.2161). Average EC and TDS levels at the 2 stations were nearly the same (Table 6-1).

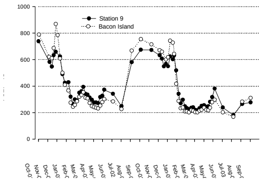

Figure 6-6 EC at Station 9 and Bacon Island on Old River

At both stations, EC and TDS levels were much lower than those at the SJR near Vernalis. However, they were nearly twice as high as the levels at the upper Sacramento River stations (Table 6-1), suggesting that channel waters came from multiple sources.

The majority of the water in Old River is a mixture from the 2 major river systems flowing into the Delta. However, seasonality and variability patterns of EC at the 2 channel stations (Figure 6-6) differed from those at the SJR near Vernalis and at the stations on the Sacramento River (Figures 6-3 and 6-4). Seasonality is directly related to Delta outflow, which is related to runoff year type in the contributing watersheds.

The relative contribution from either the Sacramento River or the SJR varies with hydrologic conditions in the rivers and pumping regimes at the diversion stations along Old River. In addition, a small fraction of the water is Delta drainage from various Delta islands. When Delta outflows are low, tides can bring in water from the bay. The biological processes in nutrient-rich channel waters also affect water quality. Consequently, seasonal patterns of EC and TDS at Old River stations resembled, but were not the same as, those of the SJR and Sacramento River.

Similar to the stations along both the SJR and Sacramento River, EC at the 2 channel stations were generally higher early in the wet months than during the dry months (Figure 6-6). During the reporting period, EC levels increased during November to January of both water years (Figure 6-6), probably in response to watershed flush by the first few rainfall events. As precipitation in the watershed continued from January to April, EC levels decreased (Figure 6-6). This was probably attributable to increased Delta outflow during the wet months, which prevented seawater from coming into the Delta, and, to a less extent, to the dilutional effect of relatively low salinity water from the Sacramento River Valley.

As mentioned above, seasonality of the channel stations was directly related to Delta outflows, which is related to runoff year type. During the 2-year reporting period, 2002 WY was a dry runoff year at both contributing watersheds (see Table 3-3); therefore, Delta outflows were the lowest between July 2002 and November 2002 (see Figure 3-5). In response, EC at the 2 channels stations increased to near peak levels of the 2 water years between July 2002 and November 2002 (Figure 6-6). In contrast, 2003 WY was a wetter runoff year. Delta outflows were greater (see Figure 3-5); therefore, an increase in EC during the dry months was not observed (Figure 6-6).

Diversion Stations

Median EC and TDS were 616 µS/cm and 361 mg/L, respectively, at Contra Costa Pumping Plant #1, which were the highest among the 3 diversion stations (Table 6-1). The Banks Pumping Plant station had the lowest EC and TDS among the diversion stations. Both EC and TDS were higher at the diversion stations than at the 2 Old River stations (Table 6-1).

Median EC and TDS at both Banks and DMC were comparable to those found during the previous summary period, 1998–2001 (DWR 2003a). However, median EC at the Contra Costa Pumping Plant #1 during this reporting period was about 68% higher than that of the previous period. The increase in EC is directly related to Delta outflows, which were less in this reporting period than during the previous summary period. See Table 3-3 for runoff year types in the 2 major contributing watersheds during both summary periods.

Of the 3 diversion stations, Contra Costa Pumping Plant #1 is closer to the Suisun Bay, where seawater intrusion to the Delta occurs, making the water at the Contra Costa Pumping Plant #1 more susceptible to seawater intrusion than the waters at Banks Pumping Plant and the DMC. Consequently, median EC levels were lower at Banks and at the DMC than at Contra Costa Pumping Plant #1 (Table 6-1).

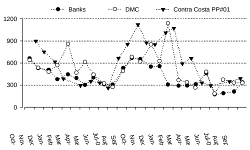

Figure 6-7 EC at three Delta diversion stations

Seasonal patterns of EC (Figure 6-7) at the diversion stations were similar to those at the Old River stations (Figure 6-6), which depend on Delta outflows. EC values were generally higher during the early days of the wet months of each water year. As Delta outflows increased with precipitation in the contributing watersheds, EC decreased during the wet months (Figure 6-7). During the dry months, EC could be as high as during the wet months if Delta outflows were reduced and seawater intrusion occurred. The increase in EC response to reduced Delta outflows was evident between July 2002 and November 2002 (Figure 6-7) when Delta outflows were the lowest (see Figure 3-5).

Other stations

Mallard Island

Of all 11 MWQI sampling stations, the Mallard Island station is the closest to Suisun Bay where tidal events and seawater intrusion can influence the western Delta. Water quality data collected at the Mallard Island station affect operations of the State Water Project and reservoir release controls for maintaining drinking water quality and ecological health purposes.

During the 2 water years, a total of 24 monthly grab samples were taken. The general range of EC was from 188 to 15,900 µS/cm, while average and median EC were 4,502 and 2,615 µS/cm, respectively (Table 6-1). Average and median TDS were 2,670 and 1,503 mg/L, respectively (Table 6-1). These EC and TDS concentrations were the most elevated for the 11 stations (Table 6-1), and were not significantly different than those found during the previous summary period (DWR 2003a).

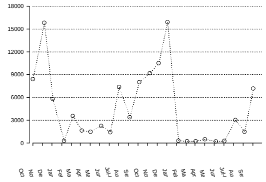

Figure 6-8 EC at the Mallard Island station

As with the Delta channel and diversion stations, EC was higher at the beginning of the wet months during each water year, but EC decreased as precipitation in the contributing watersheds continued (Figure 6-8).

Between the 2 water years, 2003 WY was a relatively wetter runoff year than 2002 WY (see Table 3-3). Consequently, there were more Delta outflows in 2003 WY (see Figure 3-5). In response, EC levels between January and September were much lower in the 2003 WY than in 2002 WY (Figure 6-8).

Natomas East Main Drainage Canal

The Delta receives inflows from urban drainages from the watersheds that contribute runoff to the Delta. Loads of salts and other water quality constituents have not been quantified. An MWQI special study is under way to investigate discharge and loads of various water quality constituents at the Natomas East Main Drainage Canal at El Camino, which collects urban runoff from a heavily populated and rapidly expanding watershed adjacent to the northern boundary of the legal Delta in northern Sacramento. Although NEMDC is outside the legal Delta, its mouth is less than 2 miles from the I Street Bridge, which is the upstream end of the legal Delta. NEMDC discharges to the Sacramento River.

EC and TDS ranged from 128 to 562 µS/cm and from 85 to 334 mg/L, respectively (Table 6-1). Average and median EC and TDS at NEMDC were considerably higher than in the American River at the E.A. Fairbairn WTP and in the Sacramento River at the West Sacramento WTP Intake, both of which are close to NEMDC (Table 6-1). EC and TDS at NEMDC were comparable to those found at the channel stations and at the Banks Pumping Plant, which are influenced by Delta drainage, flow from the SJR, and seawater.

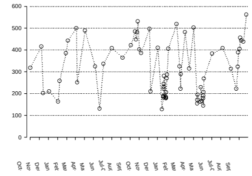

Figure 6-9 EC at the NEMDC station

There was no clear and persistent seasonal pattern of EC at NEMDC (Figure 6-9). However, EC and TDS may be significantly lower during or immediately after a sustained heavy rainfall and runoff such as those in

December 2002 and January 2003 (Figure 6-9). Also, no clear differences were observed in EC between the dry months and wet months. Sample collection for the ongoing MWQI special study is more frequent, and sometimes event-based. More detailed discussion on seasonality and loads of water quality constituents at NEMDC may be found in a recent report (DWR 2003b).

Chloride and Sulfate

Chloride and sulfate affect the taste and odor of finished drinking water. The maximum contaminant level (MCL) for chloride and for sulfate is the same: 250 mg/L. Drinking water providers report increased taste and odor complaints from customers when chlorides are greater than 100 mg/L (Holm 2003 pers comm). Although concentrations of chloride and sulfate in source waters of the Delta do not represent those of finished drinking waters, chloride and sulfate data are briefly summarized here for reference purposes.

Chloride and sulfate levels were generally low in most stations except at the Mallard Island station (Table 6-2). Chloride at the Mallard Island station was high and frequently exceeded the MCL because of seawater influence. The chloride ranged from 13 to 5,510 mg/L with a median of 394 mg/L. Sulfate occasionally was also above the MCL at Mallard Island station. The range for sulfate was from 12 to 767 mg/L with a median of 60 mg/L (Table 6-2). Contra Costa Water District has an intake adjacent to Mallard Island but only uses the intake when chlorides are less than 65 mg/L (Holm and Denton 2003 pers comm).

Table 6-2 Summary of chloride and sulfate data, Oct 2001 through Sep 2003

The Contra Costa Pumping Plant #1, which is adjacent to Mallard Island, is also affected by seawater influence. During the reporting period, both chloride and sulfate were low at this station: Average chloride and sulfate were 94 and 68 mg/L, respectively; median chloride and sulfate were 68 and 36 mg/L, respectively (Table 6-2), which were below the MCLs of chloride and sulfate.

Agricultural drainage waters, which often contain higher levels of chloride and sulfate, affect the stations on the SJR and Old River, but it doesn’t appear that they raised the concentrations of chloride and sulfate above their MCLs. Agricultural return water is a relatively small fraction of the water in the SJR and Old River; therefore, chloride and sulfate in these river stations remained low despite the discharges from Delta drainage. Chloride and sulfate at the other 2 diversion stations never exceeded the MCL of 250 mg/L.

Both concentrations of chloride and sulfate at the urban drainage NEMDC were low (Table 6-2). Sulfate concentrations were higher at NEMDC than at the American River at E.A. Fairbairn WTP, the Sacramento River at Hood, and the West Sacramento WTP Intake, but lower than at all other stations (Table 6-2).

Chapter 6 Salinity

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Figure 6-1 The relationship between EC and TDS at all 11 stations

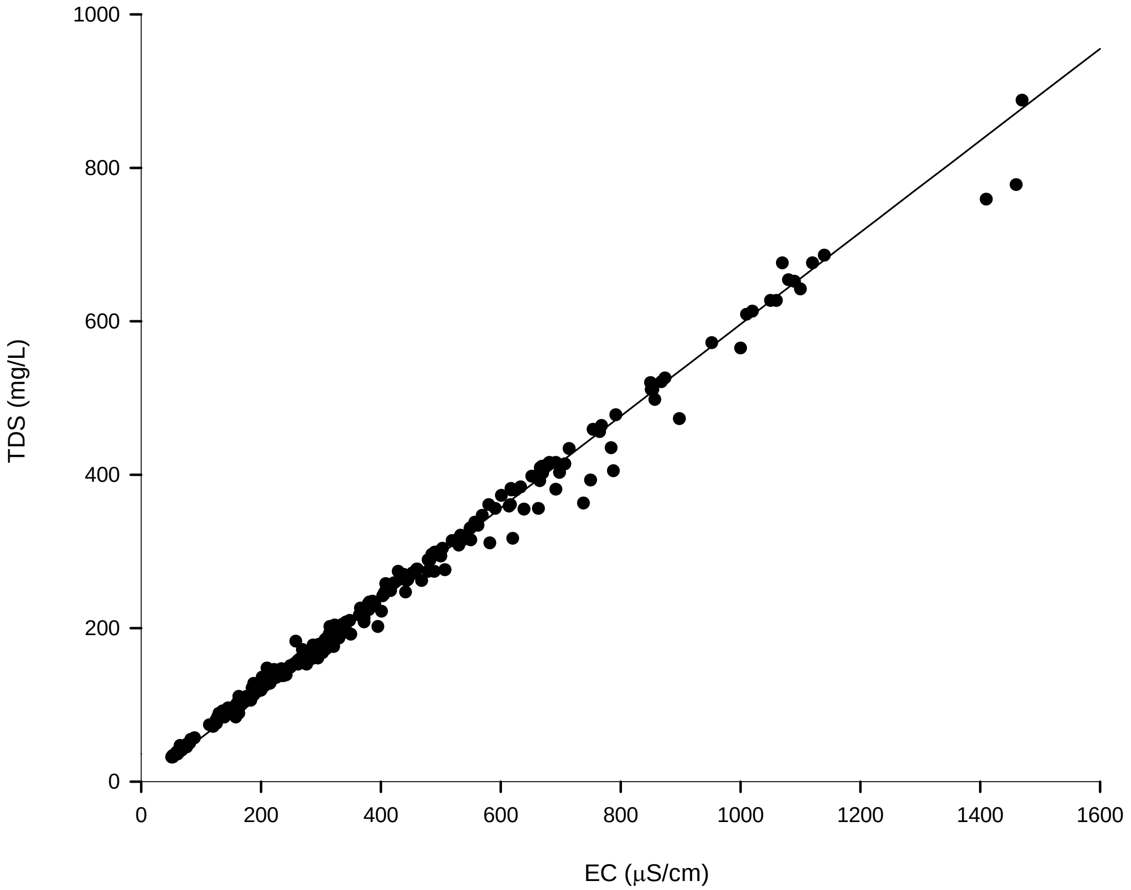

Figure 6-2 Electrical conductivity at the American River WTP Intake

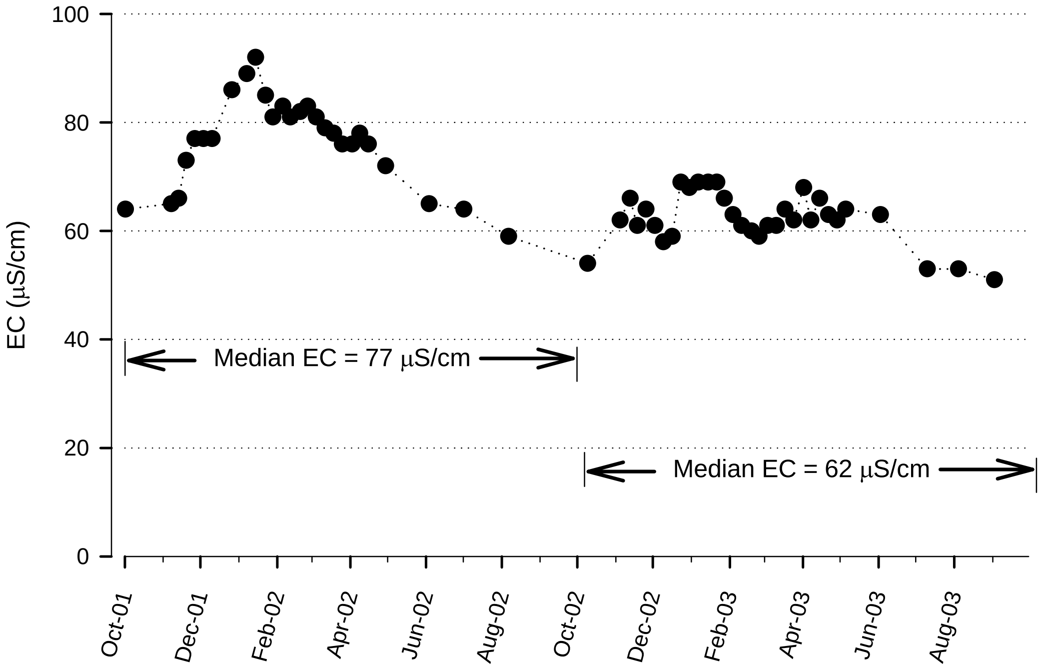

Figure 6-3 Electrical conductivity at the West Sacramento WTP Intake

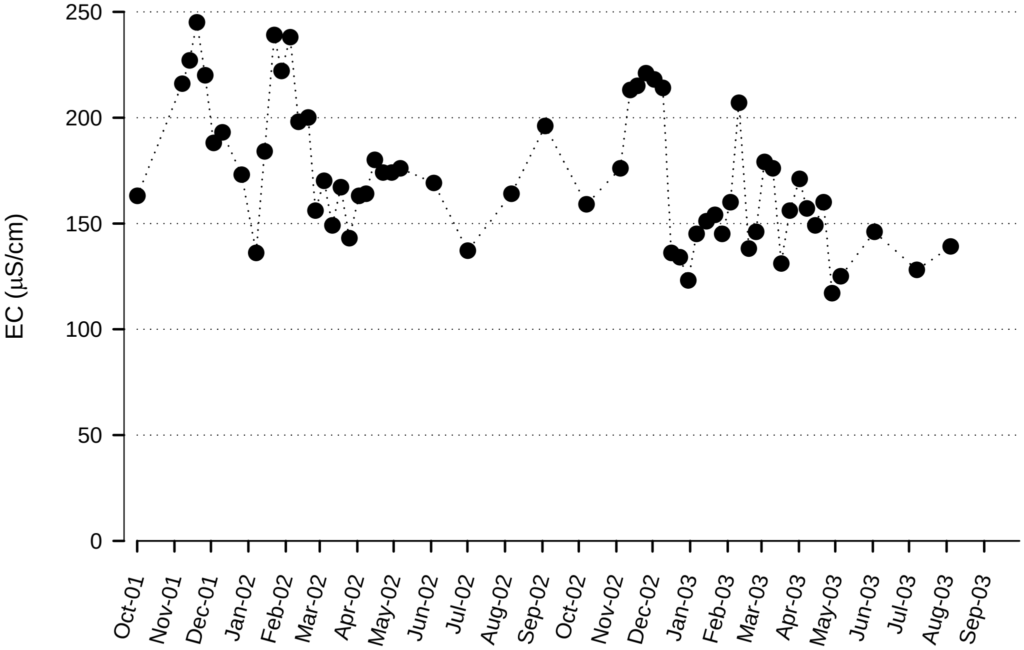

Figure 6-4 Electrical conductivity at the Hood station

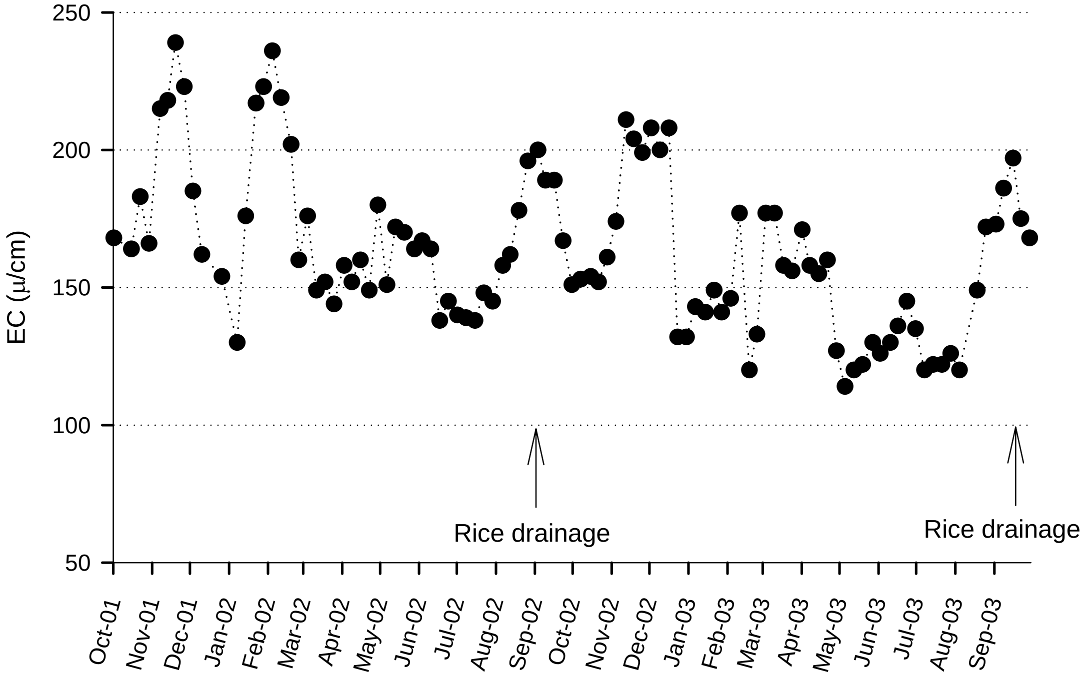

Figure 6-5 Electrical conductivity at San Joaquin River near Vernalis

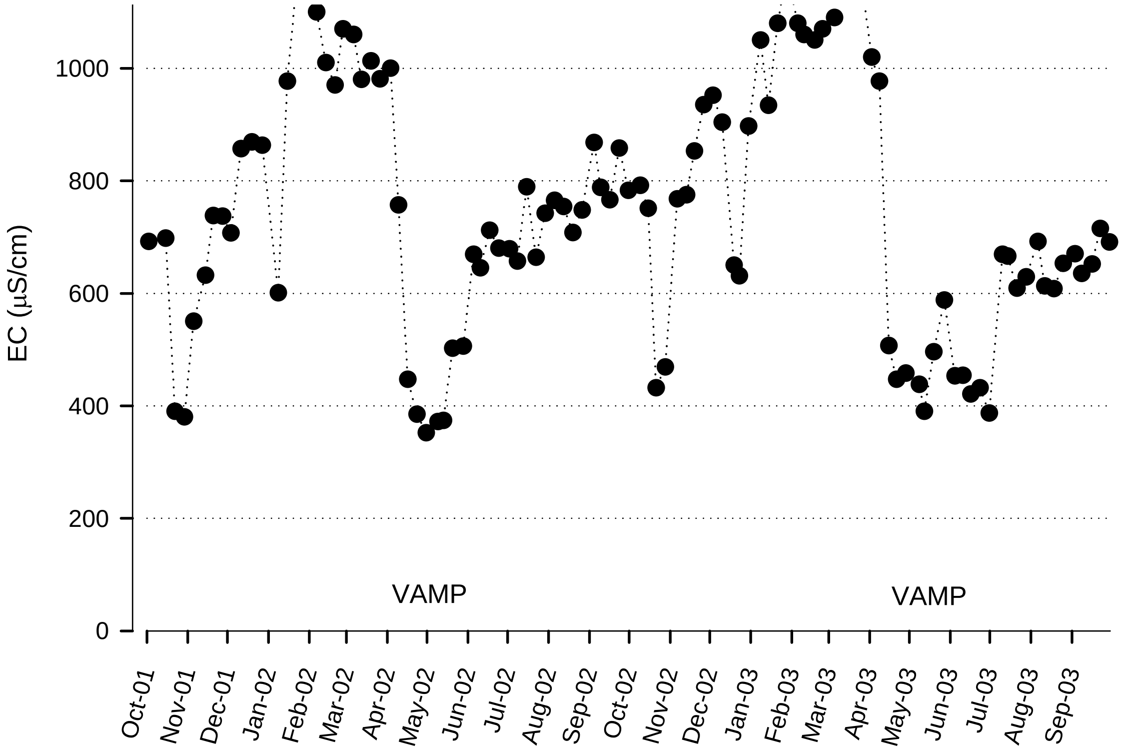

Figure 6-6 Electrical conductivity at Station 9 and Bacon Island on Old River

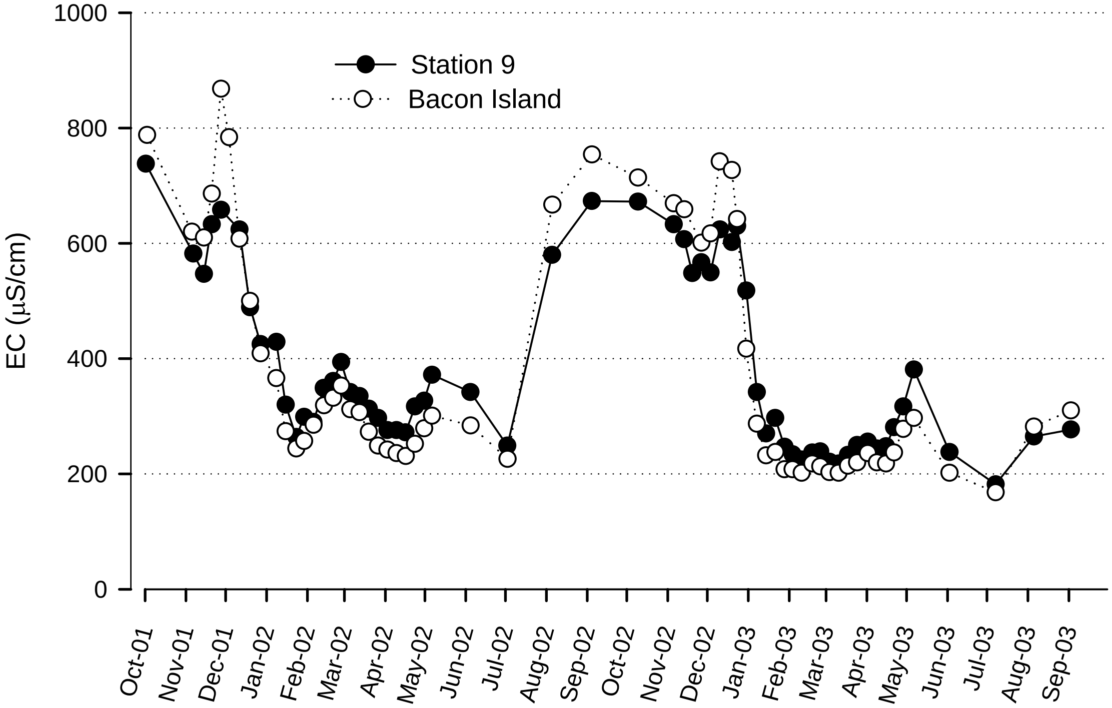

Figure 6-7 Electrical conductivity at three Delta diversion stations

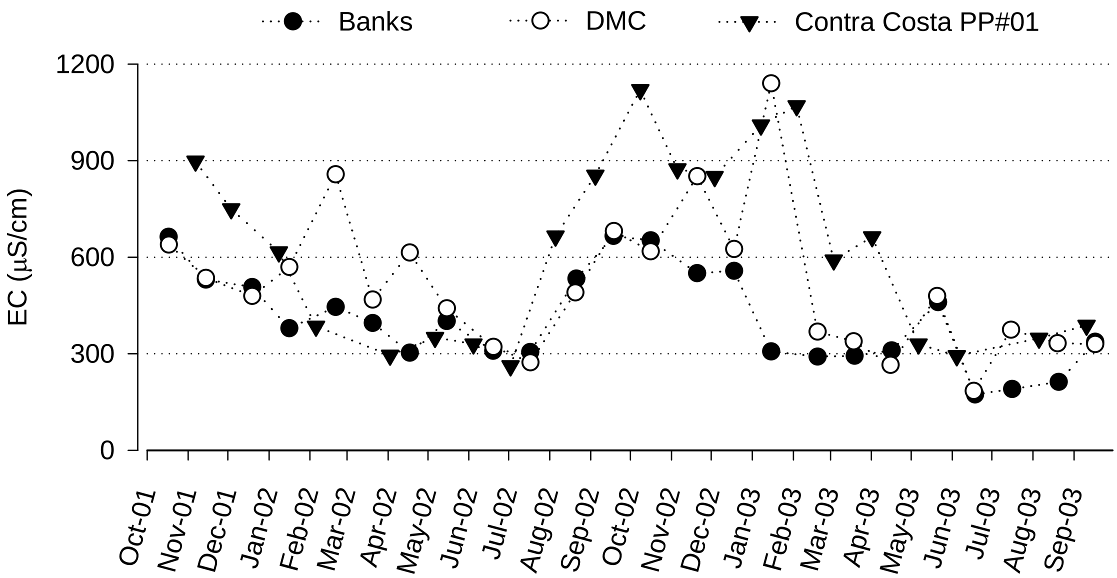

Figure 6-8 Electrical conductivity at the Mallard Island station

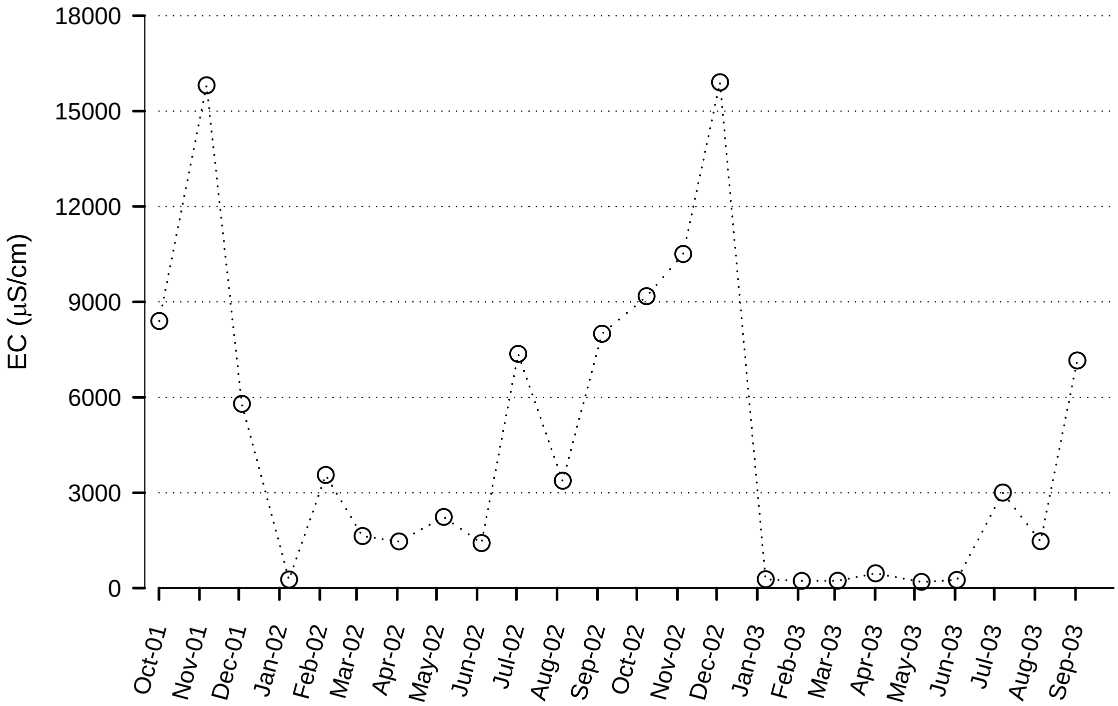

Figure 6-9 Electrical conductivity at the NEMDC station

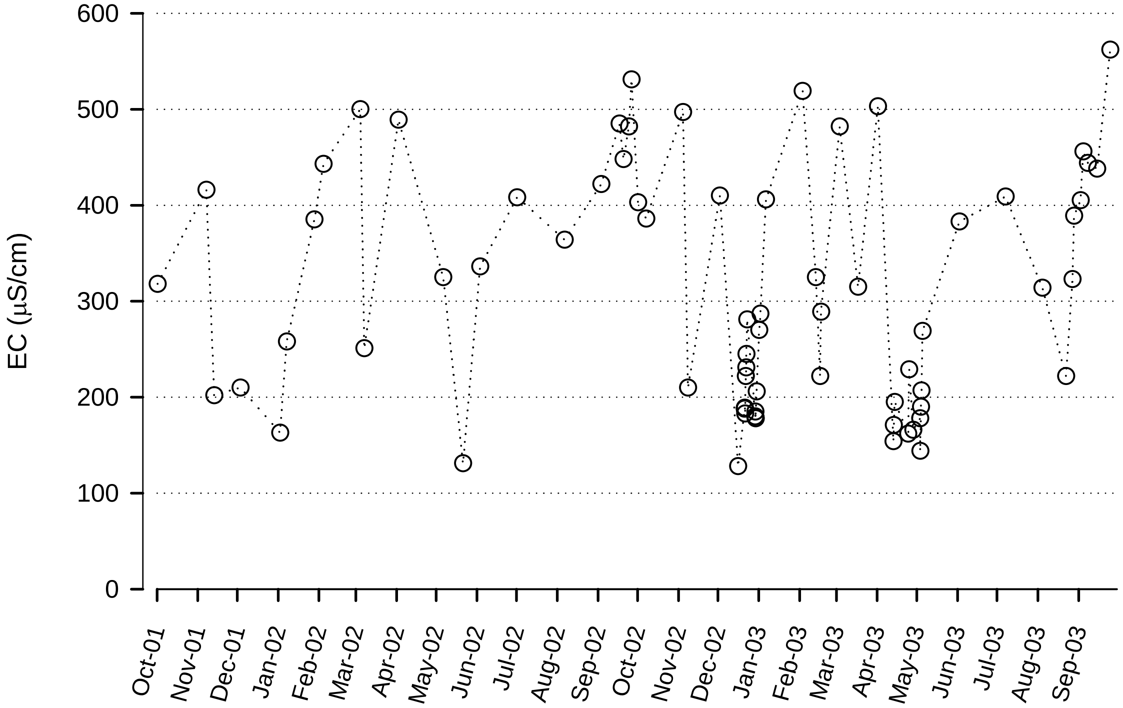

Table 6-1 Summary of EC and TDS data, Oct 2001 through Sep 2003

	EC (uS/cm)				TDS (mg/L)			
Station	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
American and Sacramento River stations								
American River at E.A. Fairbairn WTP	59	51–92	69	66	22	32–57	41	41
West Sacramento WTP Intake	61	117–245	172	167	23	80–138	104	104
Sacramento River at Hood	101	114–239	163	160	27	72–138	100	102
San Joaquin River station								
San Joaquin River near Vernalis	103	352–1,180	748	715	27	208–654	445	414
Delta channel stations								
Old River at Station 9	62	182–738	388	324	24	110–411	240	203
Old River at Bacon Island	62	168–868	384	285	22	101–459	240	179
Diversion stations								
Banks Pumping Plant	24	173–666	407	387	24	104–409	239	212
Delta-Mendota Canal	24	184–1,140	511	479	24	111–686	303	282
Contra Costa Pumping Plant	21	262–1,120	616	616	21	158–676	363	361
Other Stations								
Sacramento River at Mallard Island	24	188–15,900	4,502	2,615	24	113–9,840	2,670	1,503
Natomas East Main Drainage Canal	70	128–562	313	302	47	85–334	220	234

Table 6-2 Summary of chloride and sulfate data, Oct 2001 through Sep 2003

Station	Chloride (mg/L)				Sulfate (mg/L)			
	Number of samples	Range	Average	Median	Number of samples	Range	Average	Median
American and Sacramento River stations								
American River at E.A. Fairbairn WTP	22	1–3	2	2	22	2–4	2	2
West Sacramento WTP Intake	23	2–10	5	5	23	5–11	7	7
Sacramento River at Hood	27	2–10	6	6	27	4–12	7	7
San Joaquin River station								
San Joaquin River near Vernalis	26	44–156	98	93	21	40–157	89	85
Delta channel stations								
Old River at Station 9	23	15–153	62	39	23	10–44	26	25
Old River at Bacon Island	20	12–175	52	32	24	8–40	22	23
Diversion stations								
Banks Pumping Plant	20	13–134	52	43	22	10–52	29	30
Delta-Mendota Canal	22	15–178	70	57	22	13–167	47	34
Contra Costa Pumping Plant	19	26–239	94	68	18	15–163	51	36
Other stations								
Sacramento River at Mallard Island	20	13–5,510	1,264	394	16	12–767	151	60
Natomas East Main Drainage Canal	47	7–64	32	35	47	8–37	21	21

Chapter 7 Nutrients

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Chapter 7 Nutrients

For discussion purposes in this report, nutrients refer to various forms of nitrogen and phosphorus in the water. Among many compounds of nutrients, nitrate and nitrite are mandatory health-related constituents with established drinking water standards that require monitoring. The primary maximum contaminant levels (MCLs) for nitrate and combined nitrate and nitrite are 45 mg nitrate/L or 10 mg N/L (DWR 2001). To date no federal or State drinking water standards have been developed for phosphorus. However, high levels of nitrogen and phosphorus act collectively to promote growth of algae and, subsequently, degrade water quality by increasing organic carbon, turbidity, and by forming taste and odor-producing compounds. Excessive growth of algae can also clog filters in water treatment plants (WTPs). The US Environmental Protection Agency (EPA) released information supporting the development of State and tribal nutrient criteria in California rivers, streams, and reservoirs (EPA 2000). The final guidelines have not yet been developed for implementation.

Because of the adverse effect of nutrient-rich source waters on finished drinking water, the Municipal Water Quality Investigations Program (MWQI) resumed exploratory nutrient monitoring at most stations in November 2002. Monitoring frequency was monthly. Monitored nutrients include dissolved nitrate, combined nitrate and nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, and orthophosphates. This chapter summarizes data collected during the reporting period.

Stations on American and Sacramento Rivers

Among all stations, except for ammonia, the lowest median concentrations of nutrients were found at the 3 stations on American and Sacramento Rivers (Tables 7-1 to 7-6). Levels of nitrate and combined nitrate and nitrite never approached the primary MCL of 45 mg/L despite some seasonal variations.

The highest median ammonia level was observed at Sacramento River at Hood (Table 7-1); average and median ammonia concentrations at the Hood station were 0.23 and 0.17 mg N/L. High ammonia concentrations at Hood apparently did not come from upper river inflows because the lowest median ammonia levels were found at both the American River and at West Sacramento WTP Intake (Table 7-1). Ammonia at Hood probably came from wastewater discharges and possibly urban runoff. Upstream from the Hood station, 2 wastewater treatment plants—the Sacramento Regional Wastewater Treatment Plant and West Sacramento Wastewater Treatment Plant—and the Morrison Creek outfall pump discharge water into the Sacramento River between the West Sacramento WTP Intake and the Hood station. Morrison Creek discharges urban drainage water into the Sacramento River. An active marina also is upstream of the Hood station; therefore, elevated concentrations of ammonia detected at the Hood station could be due to the inflows of wastewater and urban drainage into this section of the Sacramento River.

Table 7-1 Summary of ammonia data at 10 MWQI stations

Apparent seasonality was observed with nutrients at the Hood station. For all nutrients, concentrations were higher during the wet months than during the dry months (Figure 7-1). From May to August of each water year, concentrations of nitrate, TKN, and total phosphorus decreased with time or remained constantly low (Figure 7-1). This decrease in nutrient concentrations coincided with atmospheric temperature increases during the summer months and aquatic vegetation growth in the Sacramento River. TKN and total phosphorus in 2002 WY appeared to increase from August to September (Figure 7-1), which probably was attributable to rice drainage from the Sacramento Valley.

San Joaquin River near Vernalis

Among all stations, the highest median nitrate and combined nitrate and nitrite concentrations were found at the San Joaquin River near Vernalis (Tables 7-2 and 7-3). Nitrogen fertilizers were applied on agricultural lands along the SJR and its tributaries. Nitrogen mostly in the form of nitrates or bound with organic carbon is mobile in organic rich soils and enters the SJR mostly through surface runoff and seepage. Because a considerable portion of nitrogen is bound with organic carbon, TKN at the SJR near Vernalis was the highest among all river, channel, and diversion stations; however, TKN at Natomas East Main Drainage Canal was higher than at Vernalis (Table 7-4). Like TKN, orthophosphates and total phosphorus concentrations at this station were among the highest, and were only lower than those found at NEMDC (Tables 7-5 and 7-6). However, ammonia at the SJR near Vernalis was among the lowest (Table 7-1).

The seasonality pattern of nutrients, nitrate in particular, at the SJR near Vernalis was different from that at the Hood station. In addition to occasional spikes in concentration, nitrate concentrations remained high during both water years except during May to June when nitrate levels dropped to their lowest due to Vernalis Adaptive Management Plan (VAMP) measures in April and May (Figure 7-2). An apparent decrease in nutrients due to aquatic activity during the dry months was observed for nitrate; nitrate concentrations were generally lower from May to August during each water year (Figure 7-2). However, changes in concentrations of TKN and phosphorus appeared to follow drainage discharge pattern of the San Joaquin Valley. TKN and phosphorus increased during the growing season in the San Joaquin Valley, generally from April to September (Figure 7-2) when drainage was high. During and right after the VAMP period, however, TKN remained unchanged, and nitrate and phosphorus decreased, apparently because of the dilutional effects of water releases from reservoirs.

Channel and Diversion Stations

The water at channel and diversion stations came from multiple sources. Consequently, except for ammonia, the ranges and median concentrations of nutrients at both channel and diversion stations were between those at the American and Sacramento River stations and the San Joaquin River station (Tables 7-1 to 7-6). Median concentrations of nitrate and combined nitrate and nitrite at the diversion stations were generally higher than those from the two channel stations (Tables 7-2 and 7-3). The Delta-Mendota Canal station had the highest nitrate concentration (Table 7-2) because the DMC draws

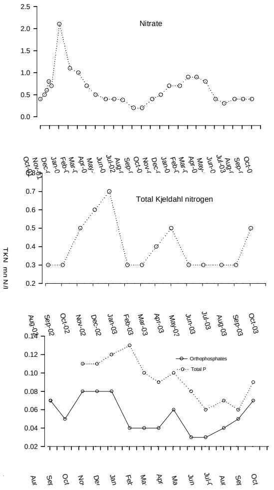

Figure 7-1 Nutrient concentrations at the Hood station

Table 7-2 Summary of nitrate data at 11 MWQI stations

Table 7-3 Summary of combined nitrite and nitrate data at 10 MWQI stations

Table 7-4 Summary of Kjeldahl nitrogen data at 10 MWQI stations

Table 7-5 Summary of orthophosphate data at 10 MWQI stations

Table 7-6 Summary of total phosphorus data at 10 MWQI stations

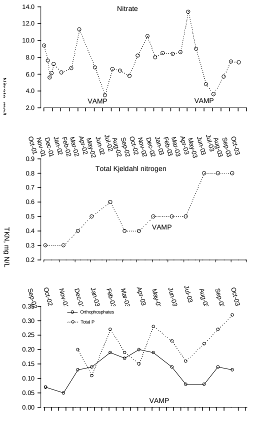

Figure 7-2 Nutrient concentrations at the San Joaquin River near Vernalis

more water from the SJR. However, concentrations never approached the primary MCLs of nitrate and combined nitrate and nitrite.

Median TKN concentrations at the diversion stations were also higher than those at the 2 channel stations (Table 7-4). However, such a consistent pattern was not observed for phosphorus (Tables 7-5 and 7-6). Concentrations of ammonia at both the channel and diversion stations were among the lowest of all stations (Table 7-1).

Despite the fact that water at channel and diversion stations came from multiple sources, seasonality of nutrients at the channel and diversion stations resembled that at the Sacramento River at Hood station (Figures 7-1 7-3, 7-4, 7-5, and 7-6). Concentrations of nutrients were generally higher from December to February in response to heavy rainfall events at the beginning of the wet months in the watersheds (Figures 7-3, 7-4, 7-5, and 7-6), which occurred before December. As precipitation increased, concentrations of nutrients gradually decreased and reached the lowest around April (Figures 7-3, 7-4, 7-5, and 7-6). Between June and September, concentrations of nitrogen and phosphorus decreased farther (Figures 7-3, 7-4, 7-5, and 7-6), presumably in response to nutrient demands of aquatic vegetation growth during the summer.

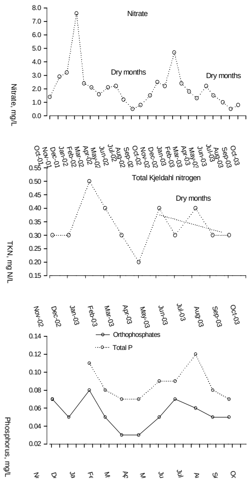

Figure 7-3 Nutrient concentrations at Old River at Station 9

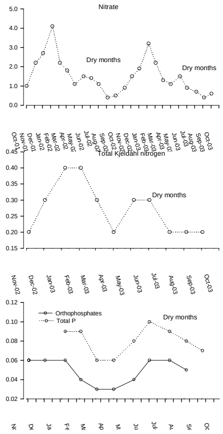

Figure 7-4 Nutrient concentrations at Old River at Bacon Island station

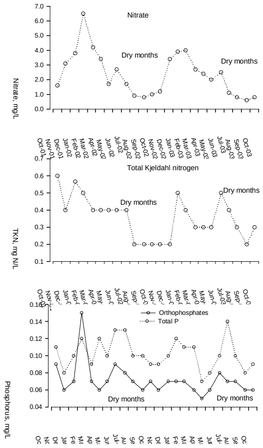

Figure 7-5 Nutrient concentrations at Banks

Mallard Island

Except for ammonia, concentrations of nutrients at the Mallard Island station were comparable to those at the 2 channel stations (Tables 7-1 to 7-6). Concentrations of nitrate and combined nitrate and nitrite never approached the MCL of 45 mg/L. Low nutrient concentrations at the Mallard Island station may be attributable to several factors, including seawater influence, water diversion through pumping, and biological consumption of nutrients within the Delta.

Mallard Island is the most susceptible to tidal and seawater influence from the bay. Low-nitrogen seawater causes a dilutional effect on nitrogen concentrations. The Banks Pumping Plant and DMC are in operation most of the time during each water year. The DMC diverts water from Old River, a bifurcation from the SJR. The SJR near Vernalis had the highest nitrogen levels among all stations measured. The DMC sometimes pumps water mostly from the SJR, possibly reducing the amount of nitrogen reaching the Mallard Island station. In addition, when water passes the biologically diverse and complex Delta, much of the nitrogen may be consumed before it reaches the Mallard Island station. Despite low nutrient concentrations at Mallard Island, median ammonia at this station was 0.08 mg/L as N (Table 7-1). The source of ammonia remains unknown and warrants further monitoring.

Natomas East Main Drainage Canal

Median nitrate and combined nitrate and nitrite concentrations at NEMDC were nearly as high as the SJR near Vernalis (Tables 7-2 and 7-3). Elevated inorganic nitrogen may be attributable to nitrogen fertilizers used in some areas of the watershed. Concentrations of TKN and phosphorus at NEMDC were the highest among all monitored stations (Tables 7-4 to 7-6). NEMDC collects water from a heavily populated watershed, agricultural drainage pumps, and a wastewater treatment plant. Consequently, organic carbon concentrations in the water were also the highest of all stations (see Chapter 4). Because ammonia concentrations at NEMDC were low (Table 7-1), most nitrogen in the water at NEMDC may be bound with organic carbon; therefore, the highest TKN was found at this station (Table 7-4).

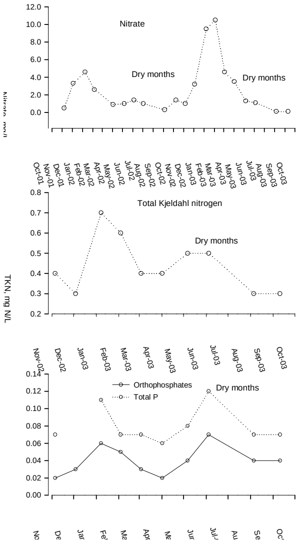

Figure 7-6 Nutrient concentrations at Contra Costa Pumping Plant #1

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Figure 7-1 Nutrient concentrations at the Hood station

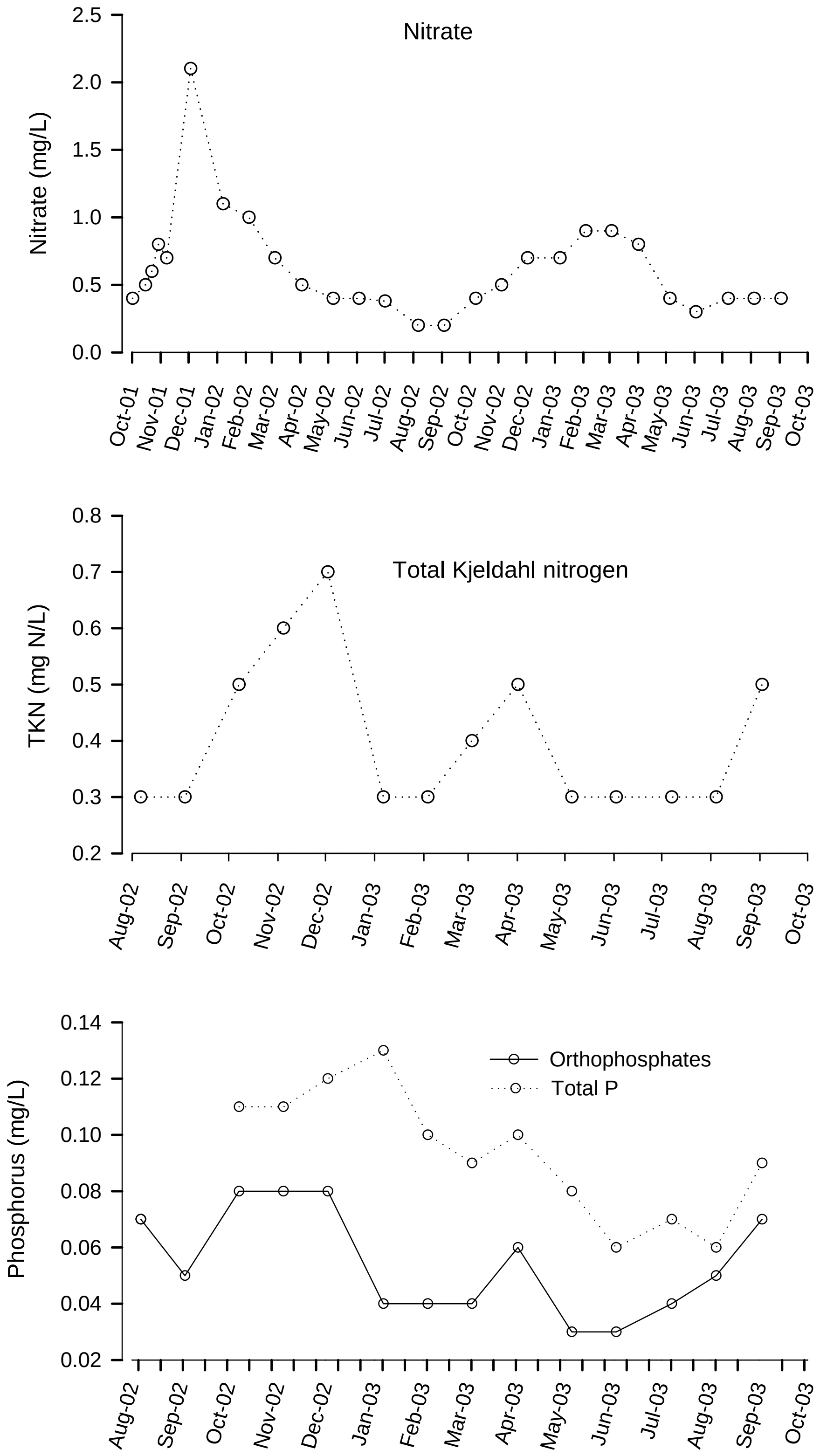

Figure 7-2 Nutrient concentrations at the San Joaquin River near Vernalis

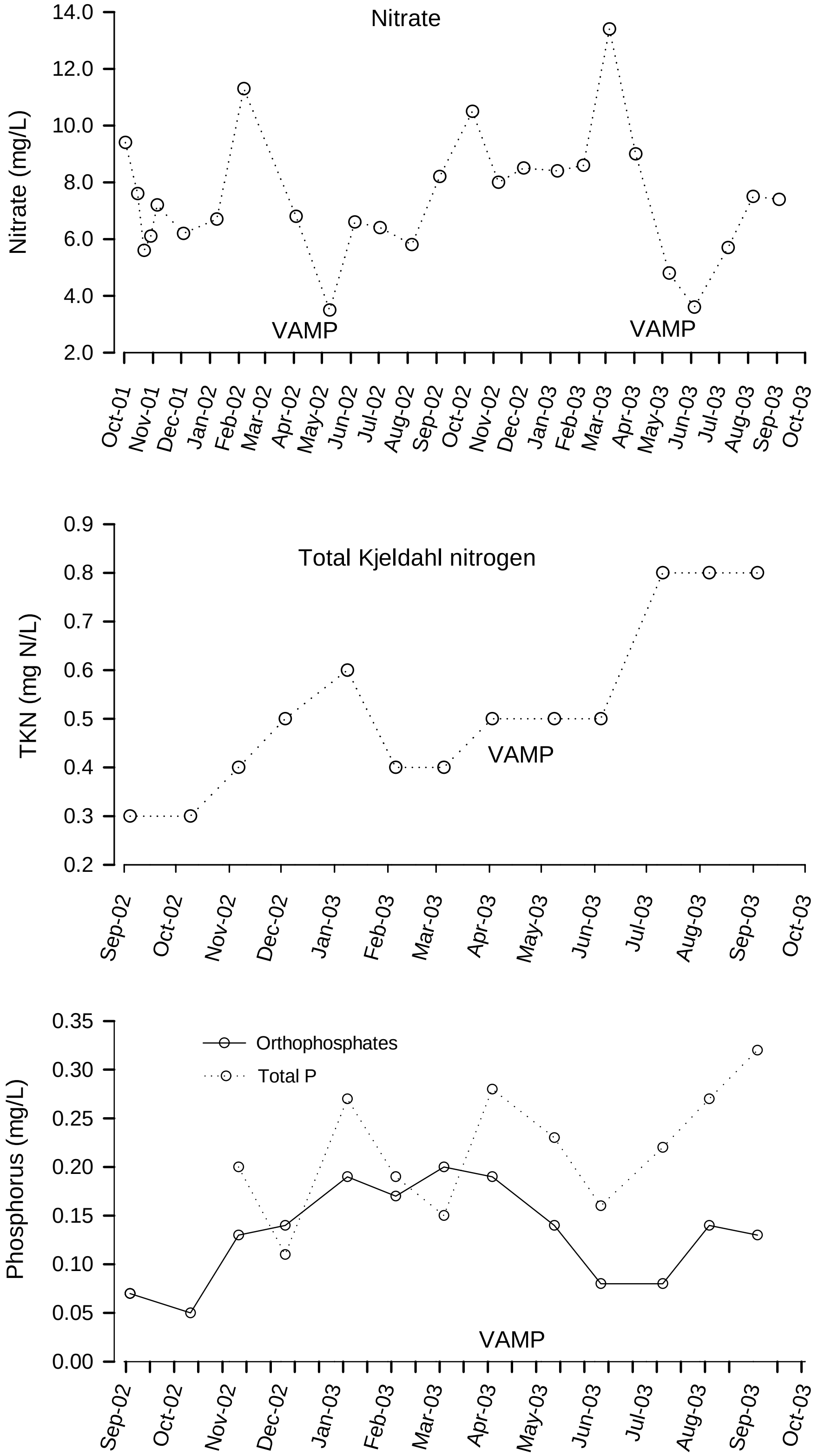

Figure 7-3 Nutrient concentrations at Old River at Station 9

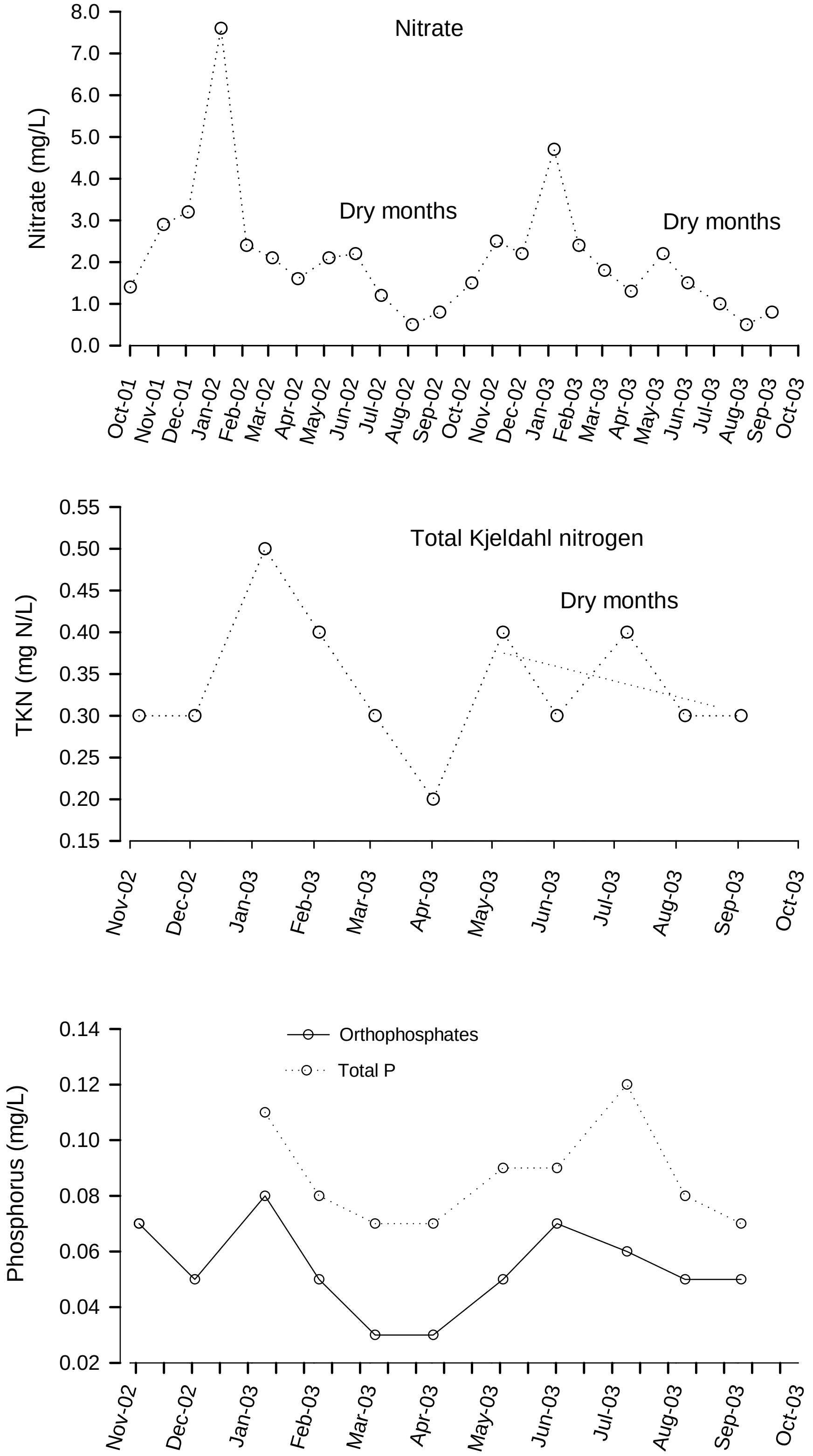

Figure 7-4 Nutrient concentrations at Old River at Bacon Island station

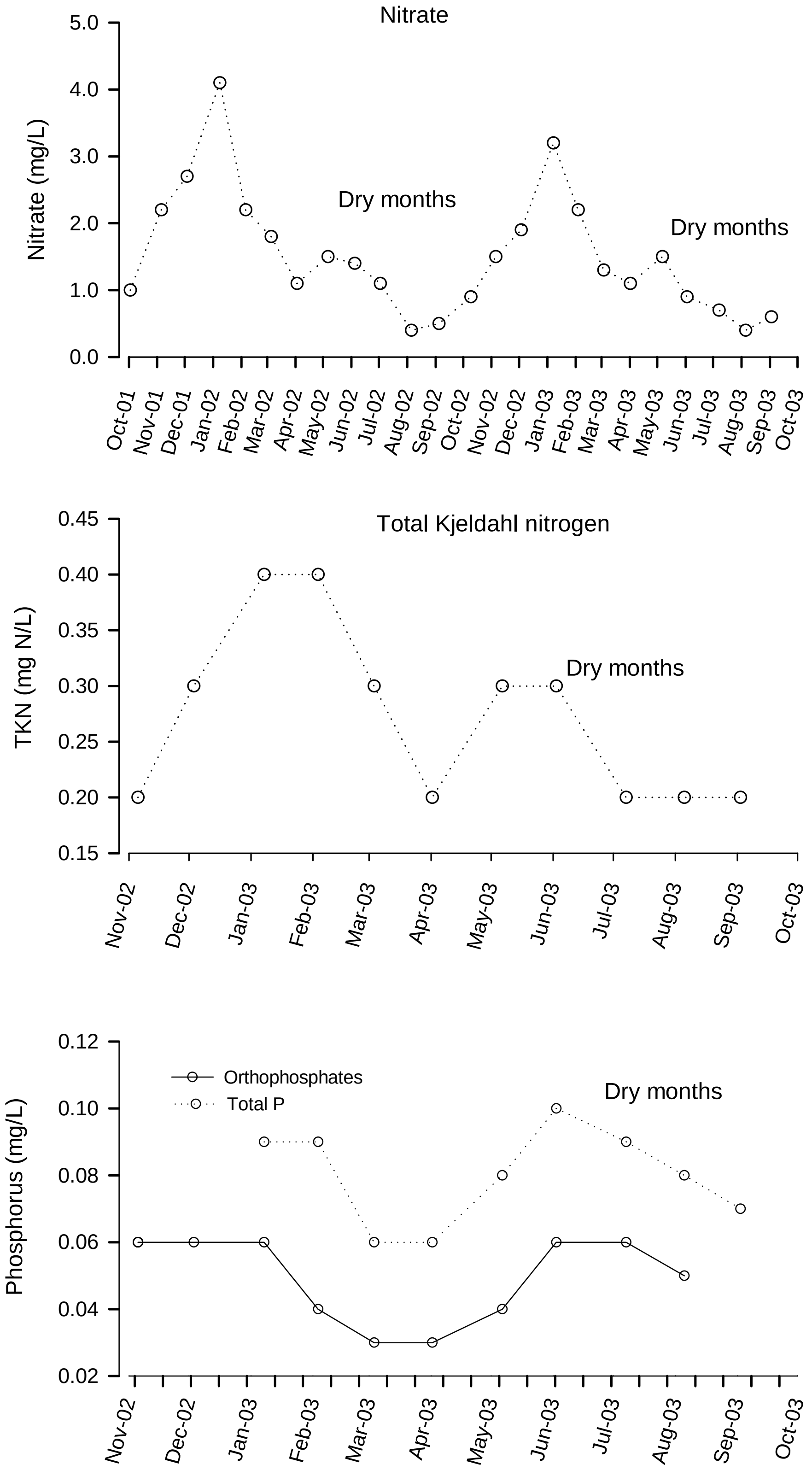

Figure 7-5 Nutrient concentrations at Banks

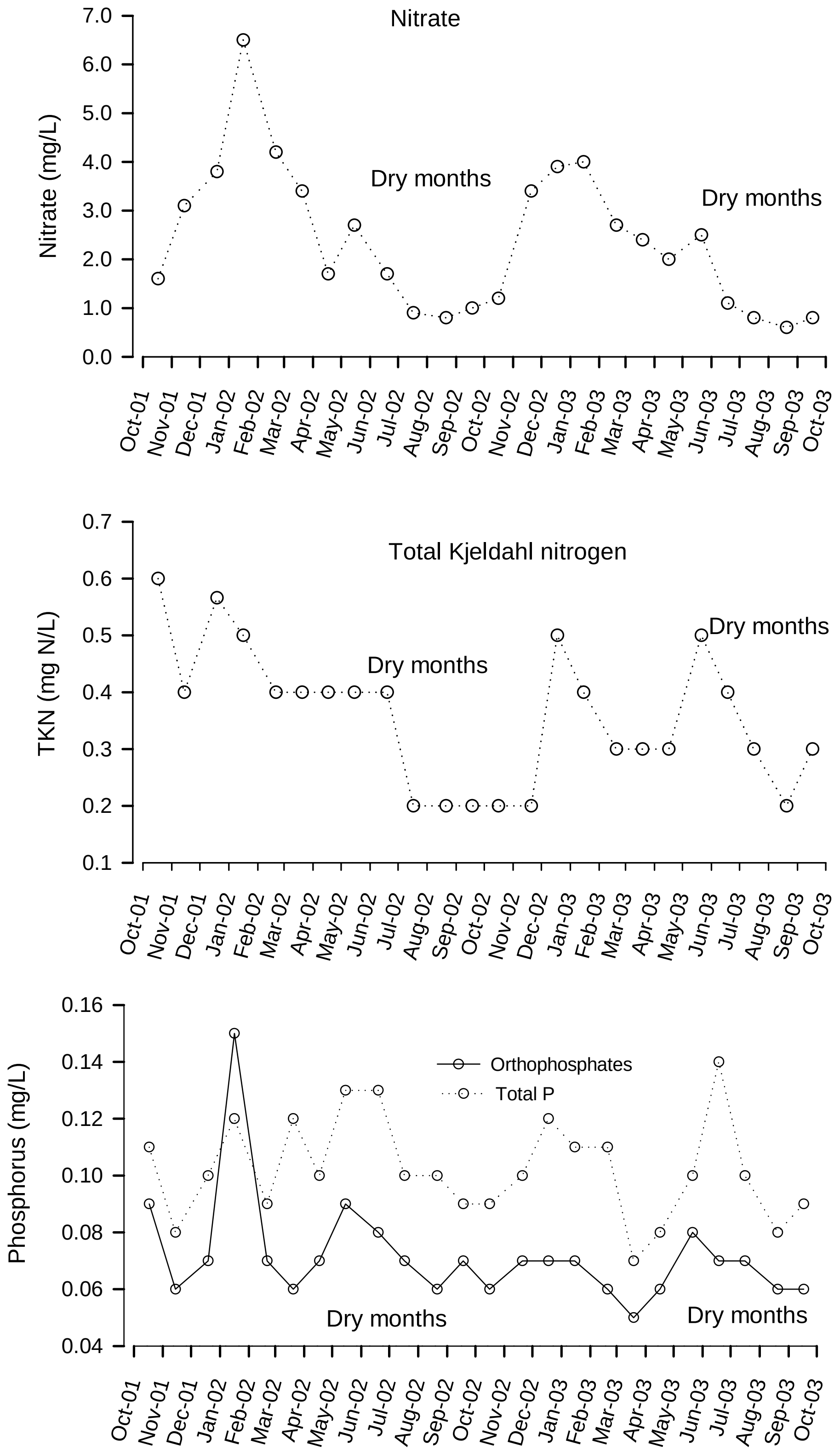

Figure 7-6 Nutrient concentrations at Contra Costa Pumping Plant #1

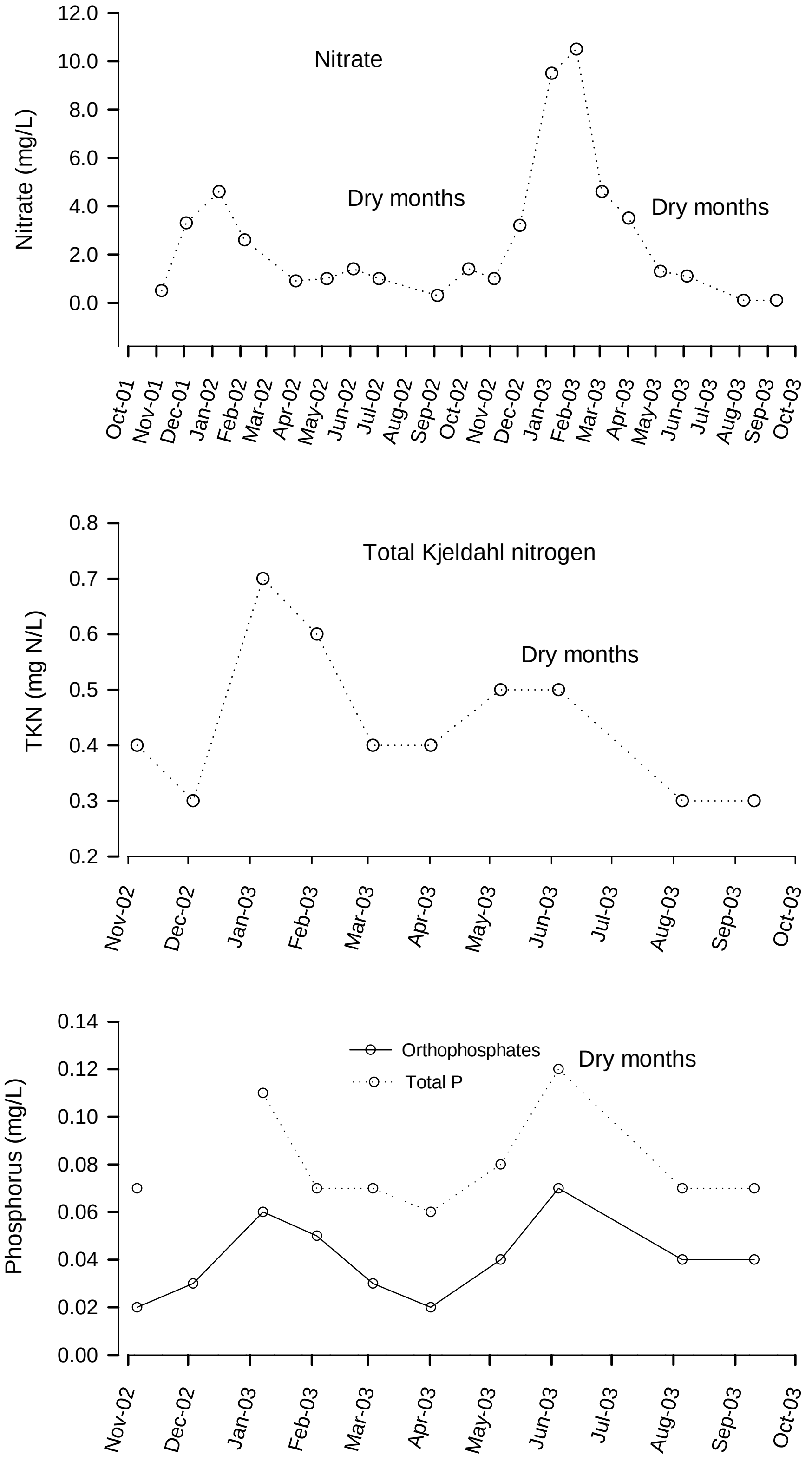

Table 7-1 Summary of ammonia data at 10 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		------------------- mg/L as N-------------------		
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	2/11	0.01–0.03	0.02	0.02
West Sacramento WTP Intake	2/10	0.01–0.03	0.02	0.02
Sacramento River at Hood	11/11	0.06–0.57	0.23	0.17
San Joaquin River station				
San Joaquin River near Vernalis	9/11	0.01–0.07	0.03	0.03
Delta channel stations				
Old River at Station 9	11/11	0.02–0.11	0.04	0.03
Old River at Bacon Island	10/11	0.02–0.08	0.03	0.02
Diversion stations				
Banks Pumping Plant	23/24	0.02–0.14	0.06	0.04
Contra Costa Pumping Plant	8/10	0.01–0.05	0.03	0.03
Other Stations				
Mallard Island	11/11	0.03–0.15	0.08	0.08
Natomas East Main Drainage Canal	42/46	0.01–0.18	0.05	0.04

Table 7-2 Summary of nitrate data at 11 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		-------------------- mg/L	-------------------	
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	12/22	0.1–1.2	0.3	0.2
West Sacramento WTP Intake	22/22	0.1–2.6	0.6	0.4
Sacramento River at Hood	27/27	0.2–2.1	0.6	0.5
San Joaquin River station				
San Joaquin River near Vernalis	26/27	3.5–13.4	7.4	7.3
Delta channel stations				
Old River at Station 9	24/24	0.5–7.6	2.1	2.0
Old River at Bacon Island	24/24	0.4–4.1	1.5	1.4
Diversion stations				
Banks Pumping Plant	24/24	0.6–6.5	2.3	2.2
Contra Costa Pumping Plant	20/21	0.1–10.5	2.6	1.4
Delta-Mendota Canal	24/24	1.2–11.4	3.7	3.3
Other Stations				
Mallard Island	24/24	0.7–2.1	1.5	1.5
Natomas East Main Drainage Canal	47/47	2.7–25.2	8.3	6.4

Table 7-3 Summary of combined nitrite and nitrate data at 10 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		-------------------- mg/L as N	--------------------	
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	8/11	0.01–0.09	0.04	0.04
West Sacramento WTP Intake	10/10	0.06–0.25	0.14	0.13
Sacramento River at Hood	11/11	0.06–0.25	0.14	0.13
San Joaquin River station				
San Joaquin River near Vernalis	11/11	0.85–3.1	1.83	1.97
Delta channel stations				
Old River at Station 9	11/11	0.15–1.1	0.46	0.42
Old River at Bacon Island	11/11	0.12–0.77	0.33	0.31
Diversion stations				
Banks Pumping Plant	24/24	0.13–1.7	0.58	0.53
Contra Costa Pumping Plant	10/10	0.03–2.5	0.73	0.55
Other Stations				
Mallard Island	11/11	0.23–0.47	0.32	0.31
Natomas East Main Drainage Canal	46/46	0.63–5.7	1.89	1.49

Table 7-4 Summary of Kjeldahl nitrogen data at 10 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		------------------- mg/L as N	-------------------	-------------------
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	7/10	0.1–0.2	0.1	0.1
West Sacramento WTP Intake	9/10	0.1–0.2	0.2	0.2
Sacramento River at Hood	11/11	0.3–0.7	0.4	0.3
San Joaquin River station				
San Joaquin River near Vernalis	11/11	0.4–0.8	0.6	0.5
Delta channel stations				
Old River at Station 9	11/11	0.2–0.5	0.3	0.3
Old River at Bacon Island	11/11	0.2–0.4	0.3	0.3
Diversion stations				
Banks Pumping Plant	24/24	0.2–0.6	0.4	0.4
Contra Costa Pumping Plant	10/10	0.3–0.7	0.4	0.4
Other Stations				
Mallard Island	11/11	0.2–0.7	0.3	0.3
Natomas East Main Drainage Canal	46/46	0.5–4.0	0.9	0.8

Table 7-5 Summary of orthophosphate data at 10 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		------------------- mg/L-------------------		
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	2/11	0.01–0.01	0.01	0.01
West Sacramento WTP Intake	10/10	0.02–0.04	0.03	0.03
Sacramento River at Hood	11/11	0.03–0.08	0.05	0.04
San Joaquin River station				
San Joaquin River near Vernalis	11/11	0.08–.2	0.14	0.14
Delta channel stations				
Old River at Station 9	11/11	0.03–0.08	0.05	0.05
Old River at Bacon Island	11/11	0.03–0.09	0.05	0.06
Diversion stations				
Banks Pumping Plant	24/24	0.05–0.15	0.07	0.07
Contra Costa Pumping Plant	10/10	0.02–0.07	0.04	0.04
Other Stations				
Mallard Island	11/11	0.04–0.1	0.06	0.06
Natomas East Main Drainage Canal	46/46	0.08–1.3	0.39	0.31

Table 7-6 Summary of total phosphorus data at 10 MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		-------------------- mg/L		--------------------
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	7/10	0.01–0.02	0.02	0.02
West Sacramento WTP Intake	10/10	0.04–0.11	0.07	0.06
Sacramento River at Hood	11/11	0.06–0.13	0.09	0.09
San Joaquin River station				
San Joaquin River near Vernalis	10/11	0.15–0.32	0.23	0.23
Delta channel stations				
Old River at Station 9	10/11	0.07–0.12	0.09	0.08
Old River at Bacon Island	10/11	0.06–0.10	0.08	0.08
Diversion stations				
Banks Pumping Plant	24/24	0.07–0.14	0.10	0.10
Contra Costa Pumping Plant	9/10	0.06–0.12	0.08	0.07
Other Stations				
Mallard Island	10/11	0.07–0.3	0.12	0.10
Natomas East Main Drainage Canal	44/46	0.18–1.5	0.51	0.44

Chapter 8 pH, Alkalinity, Hardness, and Turbidity

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Chapter 8 pH, Alkalinity, Hardness, and Turbidity

By **Sarojini Balachandra**

This chapter summarizes data for pH, alkalinity, hardness, and turbidity during the reporting period. A brief overview of the general ranges of these water quality parameters is presented.

pH

Source waters in the Delta were slightly alkaline with median pH ranging from 7.4 to 7.9 (Table 8-1). Seawater influence slightly increases pH of the water directly, and phytoplankton activity indirectly increases water pH by consumption of dissolved carbon dioxide in the water.

Table 8-1 Summary of pH at 11 MWQI monitoring stations, 2002 and 2003

Alkalinity

Alkalinity is defined as the acid-neutralizing capacity of water. Alkalinity is a function of dissolved carbonates, bicarbonates, and hydroxides of the water. These compounds in high concentrations act as pH buffers in the water. The measure of alkalinity is important for water treatment processes. According to the federal Disinfectants and Disinfection Byproducts (D/DBP) Rule (EPA 1998), alkalinity is one of the criteria used for removal of total organic carbon (TOC) by enhanced coagulation and enhanced softening. Adequate alkalinity is needed to aid coagulation and flocculation (Breuer 2002 pers comm). Although alkalinity is unregulated, waters with high alkalinity have an unpleasant taste.

Table 8-2 Summary of alkalinity at 11 MWQI monitoring stations

The lowest average and median alkalinity was seen in the American River (Table 8-2). Alkalinity decreased at this station during the dry months (Figure 8-1). Such seasonal variation in alkalinity is not seen in the Sacramento River. In the San Joaquin River, alkalinity was lowest in the month of May. This may be due to the dilutional effect of the freshwater pulse introduced into the SJR between April and May when the Vernalis Adaptive Management Plan (VAMP) was implemented. After this period, alkalinity in the SJR increased in both years.

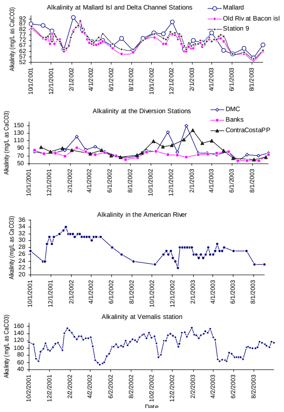

Figure 8-1 Alkalinity in eight MWQI stations

The highest mean and median alkalinity was observed at the Vernalis station (Table 8-2). Although 2002 WY was considered a dry runoff year compared to 2003 WY, median alkalinity was the same in both years at the Vernalis station.

Changes in alkalinity at the Bacon Island station and Station 9 were very similar in both years (Figure 8-1). Alkalinity at the Mallard Island station was similar to that of the channel stations (Figure 8-1).

Alkalinity at the diversion stations did not show large seasonal variations. However, alkalinity reached its lowest levels in June, July, and August of each water year. The VAMP measures implemented between April and May and opening of the Delta Cross Channel gates to bring in Sacramento River water at the end of May could have led to lower alkalinity in the south and central Delta. The relatively drier runoff year of 2002 had higher median alkalinity at all stations except at Vernalis, Contra Costa Pumping Plant #1, and Natomas East Main Drainage Canal (Table 8-2). The higher runoff in 2003 seemed to have brought in more carbonates, bicarbonates, and hydroxides to Contra Costa Pumping Plant #1 and the NEMDC, and increased median alkalinity at both stations.

Hardness

Total hardness is defined as the sum of calcium and magnesium concentrations expressed as calcium carbonate in milligrams per liter. During the reporting period, hardness was monitored at all 11 MWQI stations, and temporal data for 7 of the 11 stations are presented in Figure 8-2. Of the 7 stations, American River water had the lowest hardness, and water at the Mallard Island station had the greatest hardness (Table 8-3), which is heavily influenced by seawater.

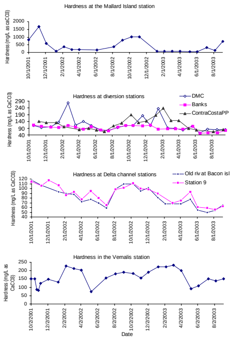

Figure 8-2 Hardness in seven MWQI stations

The drier 2002 WY and the wetter 2003 WY were compared in 11 MWQI stations to establish whether the changes in unimpaired runoff in these 2 years affected the hardness (Table 8-3). Hardness increased in 2003 WY compared to 2002 WY at the SJR station, Contra Costa Pumping Plant #1, and NEMDC. The increased hardness may be associated with increased watershed runoff and drainage discharges during wet years. For example, Rock Slough, which delivers water to the Contra Costa Pumping Plant #1, may get more Delta drainage water during a wetter runoff year as compared to a dry runoff year. This could be a reason for the increase in hardness at Contra Costa Pumping Plant #1 during 2003 WY.

Table 8-3 Summary of hardness at 11 MWQI monitoring stations

At all other stations, the increased runoff reduced the hardness of water in 2003. The dilutional effect of wetter conditions was seen mostly at the Mallard Island station where the hardness decreased by 75% in 2003 WY compared to 2002 WY (Table 8-3).

Turbidity

Turbidity in water is caused by suspended particulate matter in the water. Fine particles such as clay, silt, microorganisms, and organic and inorganic matter cause turbidity and reduce clarity in the water. Water with few suspended particles is said to have low turbidity.

Total suspended solids are determined by pouring water through a filter and weighing the filter before and after filtration to determine the increase in weight. This increase in weight measures the amount of the particles trapped in the filter and is recorded as the total suspended solids. Turbidity changes at Banks Pumping Plant and NEMDC were similar to the variations in total suspended solids at these locations during the 2 water years (Figure 8-3).

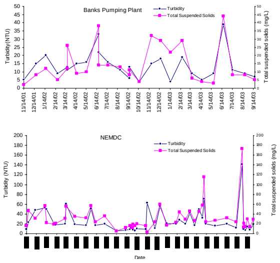

Figure 8-3 Relationship between turbidity and total suspended solids

Turbidity in the Rivers

It was observed in previous wet years that the rivers brought in water that made the bay more turbid. Therefore, at 11 MWQI stations, turbidity was compared between the drier 2002 WY and the wetter 2003 WY.

As expected, turbidity at West Sacramento WTP Intake, the Hood station, and the SJR near Vernalis station showed an increase in average and median turbidity in 2003 WY compared to 2002 WY (Table 8-4). However, the American River did not show an increase in median turbidity in 2003 WY. The lowest turbidity readings were observed in the American River (Table 8-4) during both years. However, the range in turbidity readings at this station was greater during 2003 WY compared to 2002 WY.

Table 8-4 Summary of turbidity at 11 MWQI monitoring stations

Of the river, channel, and diversion stations, the highest turbidity readings were recorded at West Sacramento WTP Intake and Sacramento River at Hood in 2003 after the first rainfall events in the watersheds (Figure 8-4 and Table 8-4).

It was also observed that turbidity in the American River increased during the first rains in the winter of 2003 WY (Figure 8-4). Similarly, the West Sacramento WTP Intake station, the Hood, and the Mallard Island stations, all on the Sacramento River, experienced an increase in turbidity after the first rainfall events. These increases were greater during 2003 WY than in 2002 WY (Figure 8-4). A similar phenomenon was observed in both channel stations (Figure 8-4). These increases could be due to runoff entering the rivers with large amounts of particulate matter from the watershed accumulated during a dry summer.

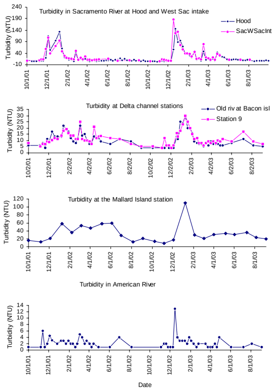

Figure 8-4 Turbidity in the rivers and Delta channels

Turbidity at Channel and Diversion Stations

An increase in median turbidity in 2003 WY was also observed at the Contra Costa Pumping Plant (Table 8-4). Mallard Island station, Old River at Station 9, Old River at Bacon Island, and Banks Pumping Plant had lower median turbidity in 2003 WY than in 2002 WY (Table 8-4).

Chapter 8 pH, Alkalinity, Hardness, and Turbidity

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Figure 8-1 Alkalinity in eight MWQI stations

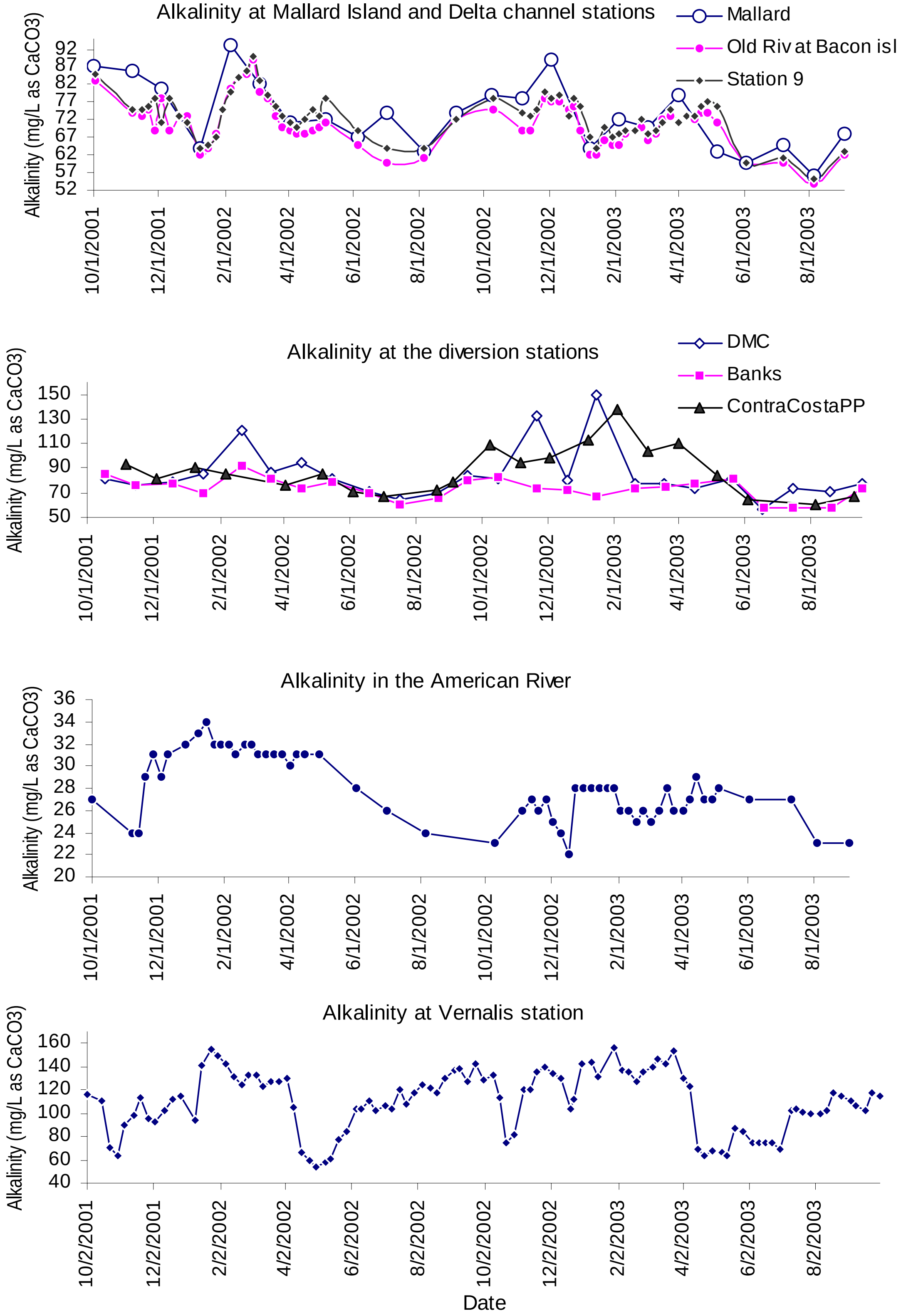


Figure 8-2 Hardness in seven MWQI stations

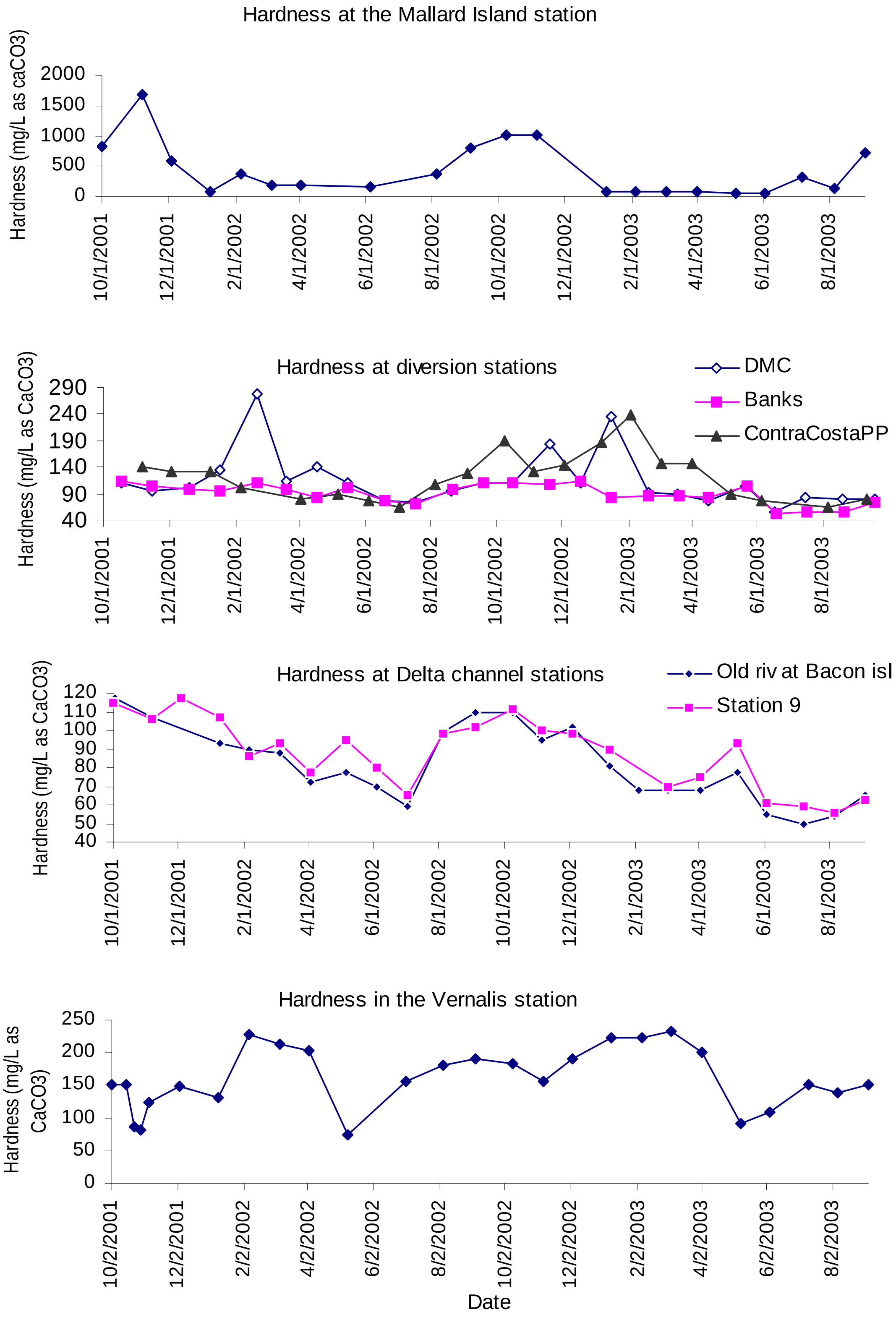
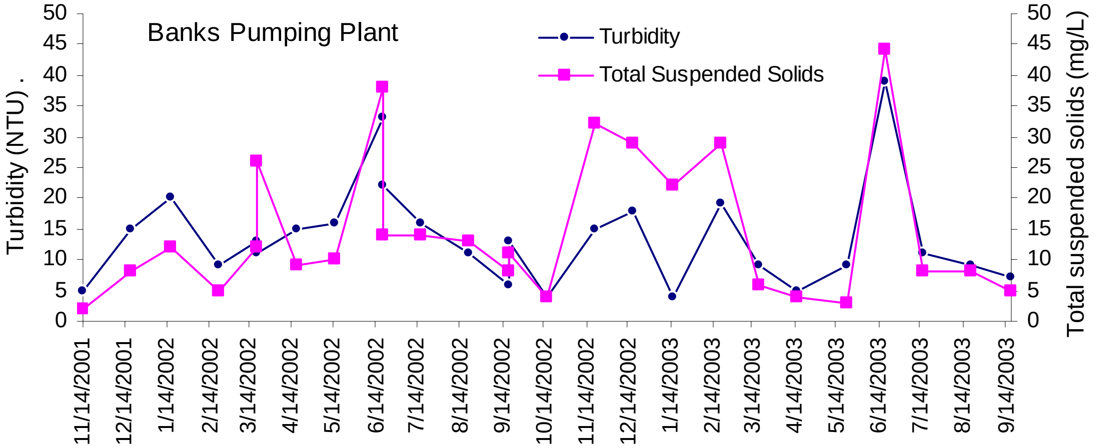


Figure 8-3 Relationship between turbidity and total suspended solids



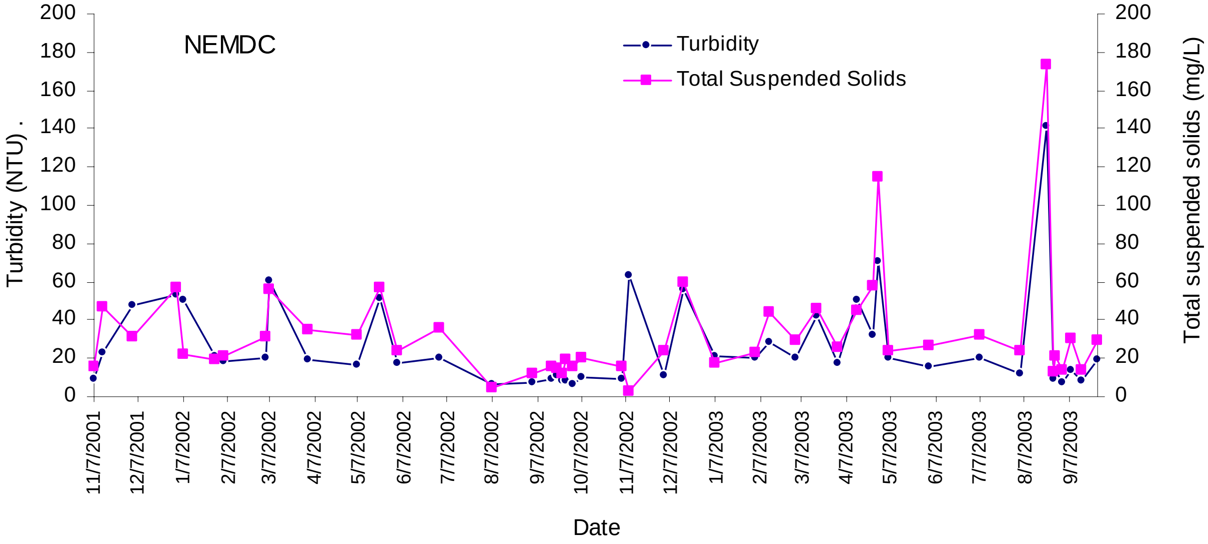


Figure 8-4 Turbidity in the rivers and Delta channels

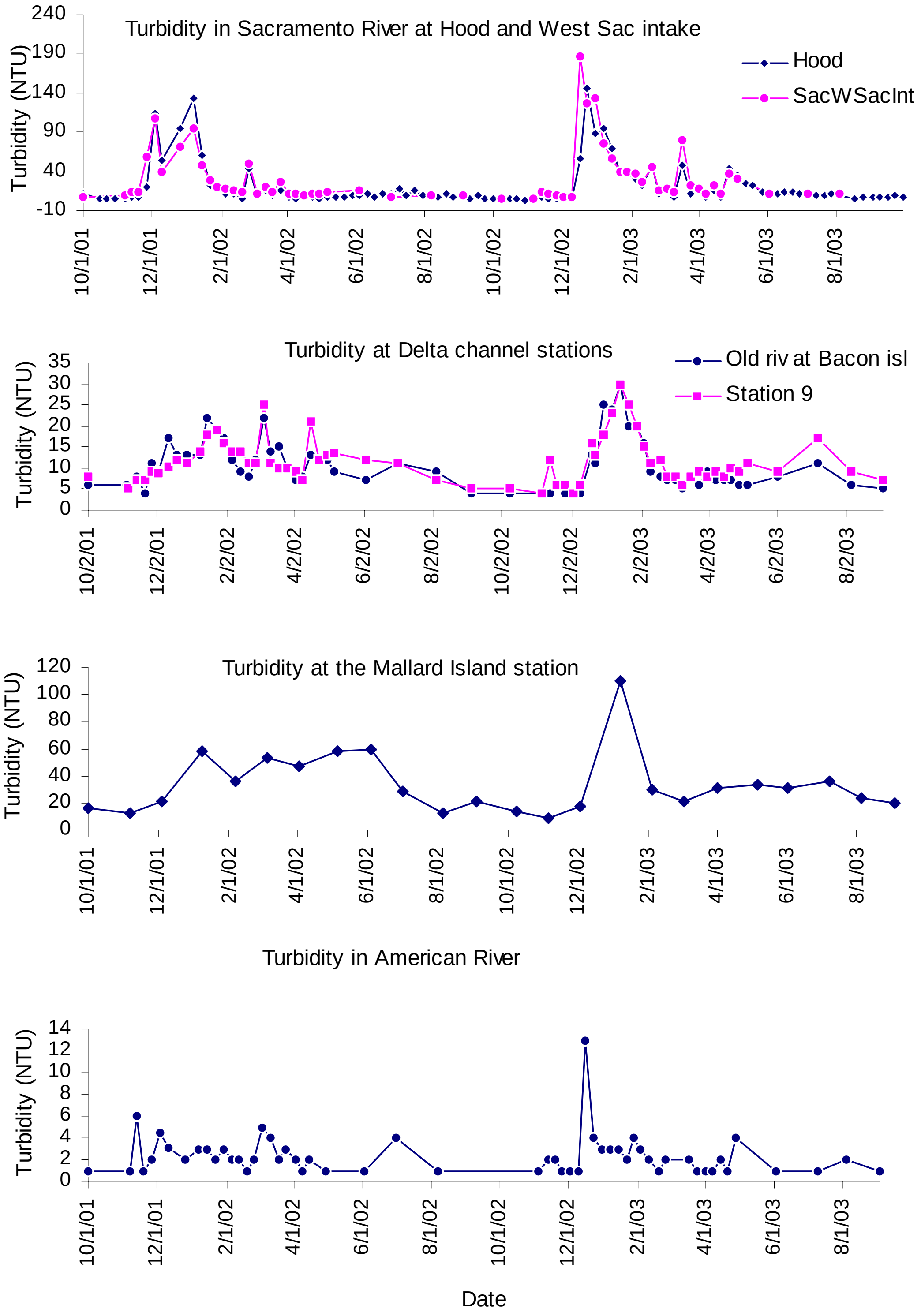


Table 8-1 Summary of pH at 11 MWQI monitoring stations

Station	Sample number	Range (pH units)	Median
American and Sacramento River stations			
American River at E.A. Fairbairn WTP[a]	59	5.9–8.0	7.4
West Sacramento WTP Intake	60	6.6–8.3	7.6
Sacramento River at Hood	97	6.9–8.5	7.5
San Joaquin River stations			
San Joaquin River near Vernalis	100	7.0–9.0	7.8
Delta channel stations			
Old River at Station 9	63	6.9–8.8	7.6
Old River at Bacon Island	61	6.7–8.5	7.8
Diversion stations			
Banks Pumping Plant	20	7.3–8.3	7.8
Delta-Mendota Canal	23	7.5–8.4	7.8
Contra Costa Pumping Plant	21	7.5–8.8	7.9
Other stations			
Sacramento River at Mallard Island	23	7.2–8.0	7.6
Natomas East Main Drainage Canal	46	6.4–8.5	7.4

a. Field pH except for the American River station where lab pH was used.

Table 8-2 Summary of alkalinity at 11 MWQI monitoring stations

	2002 Water Year				2003 Water Year				
Station	Sample number	Range (mg/L as $CaCO_3$)	Average (mg/L as $CaCO_3$)	Median (mg/L as $CaCO_3$)	Sample number	Range (mg/L as $CaCO_3$)	Average (mg/L as $CaCO_3$)	Median (mg/L as $CaCO_3$)	% difference in median[a]
American and Sacramento River stations									
American River at E.A. Fairbairn WTP	27	24–34	30	31	32	22–29	26	27	-13
West Sacramento WTP Intake	30	54–99	72	70	31	50–94	69	66	-6
Sacramento River at Hood	50	52–93	66	63	51	51–84	64	62	-2
San Joaquin River stations									
San Joaquin River near Vernalis	51	54–155	110	113	52	29–156	108	113	0
Delta channel stations									
Old River at Station 9	31	64–90	75	75	32	55–80	71	73	-3
Old River at Bacon Island	31	60–89	73	72	31	54–78	69	69	-4
Diversion stations									
Banks Pumping Plant	12	60–92	76	77	12	58–83	71	73	-5
Delta-Mendota Canal	11	56–65	83	81	13	57–150	86	78	-4
Contra Costa Pumping Plant	10	67–93	80	81	11	60–138	95	98	20
Other stations									
Sacramento River at Mallard Island	12	63–93	76	74	12	56–89	70	69	-7
Natomas East Main Drainage Canal	21	38–178	96	76	26	32–209	104	102	34

a. Negative sign denotes a decrease in median

Table 8-3 Summary of hardness at 11 MWQI monitoring stations

	2002 Water Year				2003 Water Year				
Station	Sample number	Range ----------(mg/L as $CaCO_3$)----------	Average	Median	Sample number	Range ----------(mg/L as $CaCO_3$)----------	Average	Median	% difference in median[a]
American and Sacramento River stations									
American River at E.A. Fairbairn WTP	10	21–34	26	26	10	21–26	23	23	-12
West Sacramento WTP Intake	12	46–77	62	61	11	46–75	58	59	-3
Sacramento River at Hood	15	43–75	58	55	11	43–68	55	55	0
San Joaquin River stations									
San Joaquin River near Vernalis	14	75–227	152	151	12	91–141	171	170	13
Delta channel stations									
Old River at Station 9	12	52–65	95	97	11	56–111	80	75	-23
Old River at Bacon Island	11	59–117	89	90	12	50–110	74	68	-24
Diversion stations									
Banks Pumping Plant	12	72–113	97	99	12	52–112	84	85	-14
Delta-Mendota Canal	12	75–277	120	109	12	55–234	108	91	-17
Contra Costa Pumping Plant	10	65–141	105	104	11	63–237	135	144	38
Other stations									
Sacramento River at Mallard Island	10	75–1688	526	366	11	56–1010	328	91	-75
Natomas East Main Drainage Canal	21	41–171	93	75	26	35–179	95	88	17

a. Negative sign denotes a decrease in median

Table 8-4 Summary of turbidity at 11 MWQI monitoring stations

Station	2002 Water Year Sample number	2002 Water Year Range	2002 Water Year Average	2002 Water Year Median	2003 Water Year Sample number	2003 Water Year Range	2003 Water Year Average	2003 Water Year Median	% difference in median[a]
		------------------NTU----------------				------------------NTU----------------			
American and Sacramento River stations									
American River at E.A. Fairbairn WTP	27	1–6	2	2	29	1–13	2	2	0
West Sacramento WTP Intake	29	7–107	27	14	32	5–186	36	17	21
Sacramento River at Hood	50	4–134	19	9	51	3–145	22	11	22
San Joaquin River stations									
San Joaquin River near Vernalis	51	8–50	21	20	52	11–64	24	23	15
Delta channel stations									
Old River at Station 9	31	5–25	12	11	32	4–30	11	9	-18
Old River at Bacon Island	31	4–22	11	11	31	4–30	10	7	-36
Division stations									
Banks Pumping Plant	12	5–33	14	13	12	4–39	14	10	-23
Delta-Mendota Canal	12	9–24	15	13	12	6–35	16	16	23
Contra Costa Pumping Plant	10	5–23	12	11	11	4–21	12	13	18
Other stations									
Sacramento River at Mallard Island	12	12–59	35	33	12	9–110	31	27	-18
Natomas East Main Drainage Canal	21	6–61	23	18	49	6–141	31	27	50

a. Negative sign denotes a decrease in median

Chapter 9 Other Water Quality Constituents

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Chapter 9 Other Water Quality Constituents

By **Sarojini Balachandra**

This chapter discusses metallic and nonmetallic constituents monitored in Delta source waters. These constituents include aluminum, boron, copper, iron, manganese, silver, zinc, antimony, arsenic, barium, cadmium, chromium, lead, mercury, nickel, and selenium, which can be harmful to human health when present in drinking waters at high concentrations. Except for boron, these constituents were monitored only at Delta diversion points. Boron was monitored at all 11 MWQI stations.

Many of the metals reaching the Sacramento and San Joaquin rivers came from abandoned mines, wastewater treatment plants, and surface flows from agricultural and urban areas. These constituents are either regulated by national and State law or are of current regulatory interests. Federal or California drinking water standards have been established for most of these parameters in the form of primary or secondary maximum contaminant levels. Primary MCLs established by the federal government are enforceable; secondary standards are nonenforceable. The California Department of Health Services (DHS) is given the responsibility for implementing the federal Clean Water Act, which requires the State to establish MCLs that are at least as stringent as the federal standards. California has adopted primary and secondary MCLs meeting this requirement. Secondary MCLs established by California are enforceable. These standards affect characteristics such as taste, odor, and color of drinking water.

Metallic constituents that can affect the health of human beings when present above their MCLs are aluminum, antimony, arsenic, barium, beryllium, cadmium, copper, lead, mercury, nickel, selenium, and thalium.

Article 19 of the Standard Provisions for Water Supply Contract established water quality objectives for concentrations of copper, zinc, arsenic, chromium, lead, and selenium that should not be exceeded in waters of the State Water Project (DWR 1962). During this reporting period, the concentrations of all these constituents never exceeded the objectives.

The concentrations of all these elements reported in this chapter are similar to those from the previous summary period, 1998 to 2001 (DWR 2003a) at the same stations.

Table 9-1 Summary of data for metallic constituents

Metallic Constituents

Historical data indicate that metallic constituents (aluminum, copper, iron, manganese, silver, and zinc) were not a serious concern for Delta source waters. Therefore, regular monitoring of these constituents is not considered to be necessary at all stations. Thus, only 3 stations were monitored: Banks Pumping Plant, Delta-Mendota Canal (DMC) at McCabe Road, and Natomas East Main Drainage Canal, (NEMDC) (Tables 9-1 and 9-2). Data collected during the reporting period suggested that concentrations of antimony, arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, and copper were never above their respective MCLs (Tables 9-1 and 9- 2).

Table 9-2 Summary of regulated constituents in drinking water having federal and State primary MCLs

Neither silver nor zinc was monitored at NEMDC. Silver and zinc were not detected at DMC at McCabe Road (Table 9-1). Silver was not detected, and zinc was less than the MCL at the Banks Pumping Plant (Table 9-1).

Constituents Affecting Taste, Odor, and Appearance

Turbidity, aluminum, copper, iron, manganese, silver, and zinc affect taste, odor, and appearance of drinking water. Corrosion of iron and copper may stain household fixtures and impart a metallic taste and give a red, blue, or green color to the water (EPA 1992). Iron above 0.3 mg/L can have a metallic taste and cause staining (EPA 1992). Manganese concentrations above 0.05 mg/L can produce a bitter metallic taste to the water and brown-black staining of fixtures (EPA 1992). Aluminum above 0.2 mg/L can color the water (EPA 1992).

Aluminum, Iron, and Manganese at Diversion Stations

Aluminum was not detected at Banks Pumping Plant and DMC at McCabe Road (Table 9-1). Iron and manganese were found at Banks Pumping Plant and DMC at McCabe Road, but the concentrations never exceeded their respective MCLs (Table 9-1).

Aluminum, Iron, and Manganese at NEMDC

Aluminum was detected at NEMDC in most of the water samples collected during the 2 water years (Table 9-1). The amounts were above the MCL in some samples collected during the rainy season (Figure 9-1). During the dry months of June, July, and August, concentrations of aluminum, iron, and manganese were below their respective MCLs at this station (Figure 9-1).

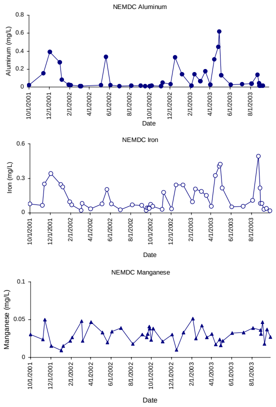

Figure 9-1 Aluminum, iron, and manganese at NEMDC

In some samples, manganese and iron were above the MCL at NEMDC (Figure 9-1). The US Geological Survey also recorded a manganese concentration above the MCL in the Arcade Creek in 1997. Arcade Creek receives runoff from an urban district and discharges into NEMDC (DWR 2003).

Inflow from NEMDC is relatively small. Water from NEMDC discharges into the Sacramento River, and the dilutional effect of the river reduces the aluminum, manganese, and iron concentrations. Therefore, concentrations of these metals never increase to levels above the MCLs at the diversion points.

Boron

Dissolved boron compounds do not produce taste or smell in the drinking water. Seawater has about 5 mg/L of boron as boric acid and boric acid salts. California has boron-rich groundwater in the western San Joaquin Valley. Boron is currently not regulated but generally monitored in drinking water. The DHS action level for boron is 1 mg/L. ALs are based on health advisory levels of contaminants that have no primary MCLs. ALs are not enforceable, but exceeding them prompts statutory requirements and recommendations by DHS for consumer notices. At higher levels, source removal may be recommended.

During the reporting period, boron was never detected in the American River at E.A. Fairbairn Water Treatment Plant or at Sacramento River at Hood (Table 9-3). Although boron was detected in the water samples from the San Joaquin River station, Delta channel stations, diversion stations, and NEMDC, the concentrations were always below the DHS AL of 1 mg/L (Table 9-3). At the diversion stations, average boron concentration was from 0.1 to 0.2 mg/L, which was below boron's AL (Table 9-3). Boron concentrations at the diversion stations did not exceed objective levels specified in Standard Provisions for Water Supply Contract Article 19, which was established to protect agriculture (monthly average of 0.6 mg/L). However, one sample out of 24 collected from the DMC at McCabe Road, contained a boron concentration of 0.6 mg/L.

Table 9-3 Summary of boron data at MWQI stations

Boron was at or above 0.6 mg/L in 6 out of 24 samples collected from the Mallard Island station. Elevated boron at this location came from seawater.

Chapter 9 Other Water Quality Constituents

Figure

Tables

Figure 9-1 Aluminum, iron, and manganese at NEMDC

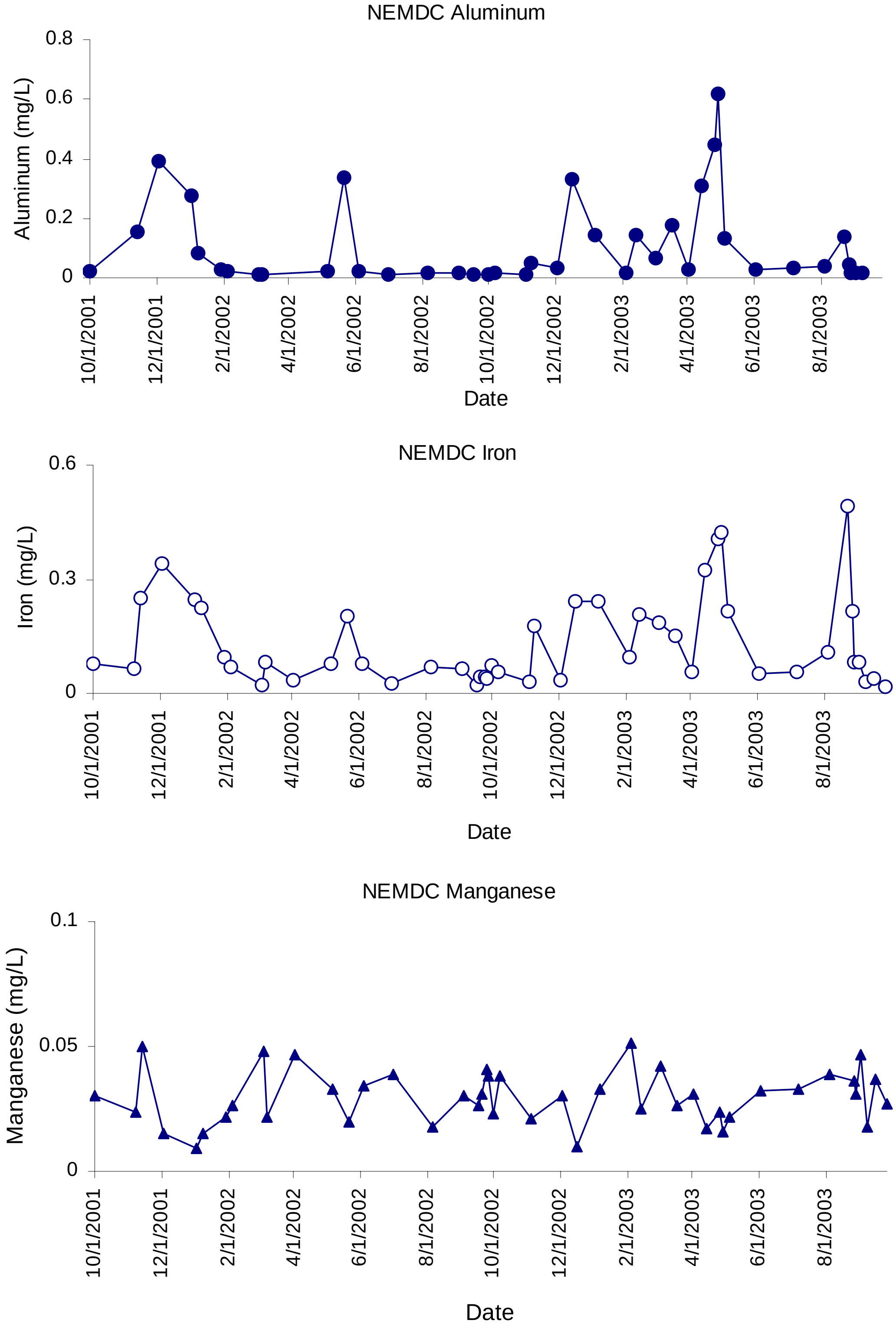

Table 9-1 Summary of data for metallic constituents

		Station		
	MCL	Banks	DMC	NEMDC
Constituent	mg/L			
Aluminum	0.2			
Detects/sample number		0/23	0/17	40/51
Range		<0.01	<0.01	0.01–0.62
Average				0.11
Median				0.03
Copper	1.0			
Detects/sample number		24/24	24/24	47/51
Range		0.002–0.009	0.001–0.007	0.002–0.005
Average		0.003	0.002	0.003
Median		0.002	0.002	0.003
Iron	0.3			
Detects/sample number		14/24	10/24	47/51
Range		0.005–0.085	0.005–0.06	0.018–0.493
Average		0.032	0.021	0.133
Median		0.024	0.016	0.078
Manganese	0.05			
Detects/sample number		20/24	2/24	46/51
Range		0.007–0.028	0.006–0.025	0.009–0.372*
Average		0.012	0.016	0.037
Median		0.01		0.03
Silver	0.1			
Detects/sample number		0/23	0/17	–
Range		<0.001	<0.001	
Zinc				
Detects/sample number	5.0	2/26	0/24	–
Range		0.005–0.015	<0.005	
Average		0.01		

* The highest value recorded may not be true as the next highest value for the 2-year period was 0.051

Table 9-2 Summary of regulated constituents in drinking water having federal and State primary MCLs

		Station		
	MCL	Banks	DMC	NEMDC
Constituent	mg/L			
Antimony	0.006			
Detects/sample number		0/26	0/24	_
Range		<0.005/<0.001*	<0.005/<0.001*	
Arsenic	0.01			
Detects/sample number		24/24	24/24	47/51
Range		0.001–0.003	0.001–0.003	0.002–0.006
Average		0.002	0.002	0.003
Median		0.002	0.002	0.003
Barium	2.0 or 1.0 (DHS)			
Detects/sample number		0/23	15/17	_
Range		<0.05	0.05–0.06	
Average			0.06	
Median				
Cadmium	0.005			
Detects/sample number		0/17	0/24	_
Range		<0.001	<0.001	
Chromium	0.1 or 0.05 (DHS)			
Detects/sample number		21/24	23/24	_
Range		0.001–0.007	0.001–0.009	
Average		0.004	0.004	
Median		0.003	0.003	
Lead	0.015[a]			
Detects/sample number		0/24	0/24	_
Range		<0.001	<0.001	
Mercury	0.002			
Detects/sample number		0/24	0/17	_
Range		<0.0002	<0.0002	
Nickel	0.1 (DHS)			
Detects/sample number		22/24	22/22	_
Range		0.001–0.002	0.001–0.003	
Average		0.001	0.001	
Median		0.001	0.001	
Selenium	0.05			
Detects/sample number		9/24	_	_
Range		0.001–0.002		
Average		0.001		
Median		0.001		

* From July 2002 the lab detection limit was improved to 0.001. The previous detection limit was 0.005.

a. Action level that triggers treatment actions if exceeded in more than 10% of tap water samples.

Table 9-3 Summary of boron data at MWQI stations

Station	Positive detects/ sample number	Range	Average	Median
		---------------------mg/L---------------		
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	0/22	–	–	–
West Sacramento WTP Intake	1/23	<0.1–1.0	–	–
Sacramento River at Hood	0/27	–	–	–
San Joaquin River stations				
San Joaquin River near Vernalis	26/27	0.2–0.8	0.4	0.4
Delta channel stations				
Old River at Station 9	11/26	0.1–0.3	0.2	0.1
Old River at Bacon Island	7/24	0.1–0.1	0.1	0.1
Diversion stations				
Banks Pumping Plant	18/24	0.1–0.3	0.1	0.1
Delta-Mendota Canal	22/24	0.1–0.6	0.2	0.2
Contra Costa Pumping Plant	15/21	0.1–0.5	0.2	0.2
Other stations				
Sacramento River at Mallard Island	17/24	0.1–1.4	0.5	0.3
Natomas East Main Drainage Canal	36/49	0.1–0.3	0.2	0.2

Note: Boron is currently an unregulated constituent that requires monitoring.

Chapter 10 Data Quality Control

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Overview

This data quality review covers the reporting period from October 1, 2001, through September 30, 2003. The Municipal Water Quality Investigations (MWQI) Program monitored and collected data from 11 stations during this reporting period.

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

The data quality review indicated that overall the 2001–2003 MWQI project data were of acceptable quality. A few analyses were outside the control limits, but they were not considered to have a significant impact on the overall data quality of 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 precision of field and laboratory procedures. The results of field duplicate analyses are evaluated by calculating relative percent differences 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, 2,066 field duplicate analyses were performed and 134 (6.5%) of the RPDs exceeded the acceptable control limits (Table 10-1). The results indicate that field and laboratory procedures were of acceptable precision for the project.

Table 10-1 Field duplicates

Field Blanks

Field blanks are purified water samples taken to the field and filtered or left unfiltered. Filtered blanks help check for contamination from field sample processing procedures. Unfiltered blanks check for contamination from containers and preservatives. In the study period, 569 field blank analyses were performed, and 9 of the field blanks (1.6%) exceeded the control limit (Table 10-2).

Table 10-2 Field blanks exceeding control limits

Internal Quality Controls

Internal QCs are procedures used in the laboratory to ensure that the analytical methods are in control. Environmental samples are grouped in “batches,” with approximately 20 samples per batch. Generally, one of each

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 10-3. The following is a review of the internal QC for the project.

Table 10-3 Total internal QC batches grouped by analyte

Sample Holding Times

Holding time is the period during which a sample can be stored after collection and preservation without significantly affecting the accuracy of its analysis. During the 2001-2003 study period, approximately 8,904 environmental analyses were conducted and 12 analyses (0.13 %) exceeded the holding time. The analyses that exceeded the holding times are listed in Table 10-4. The analytes that exceeded holding times were chromium, orthophosphate, and ultraviolet absorbance (UVA). Chromium has a holding time limit of 24 hours and orthophosphate 48 hours, whereas UVA has a holding time limit of 14 days. The table shows the number of hours or days that the samples were held by the laboratory compared to their holding time limits. The analytes in the table exceeded holding time limits from a few hours to several days. Although the frequency of these exceedances was low, the results of the specific analyses should be interpreted with caution.

Table 10-4 Holding time exceedances

Method Blanks

The purpose of method blanks is to detect and quantify contamination introduced through sample preparation or analytical procedures in the laboratory (some "background noise" is allowed). A total of 2,978 method blanks were performed from October 2001 through September 2003, and 17 (0.6%) exceeded the control limits.

Table 10-5 Method blank exceedances

Table 10-5 shows the number of method blanks outside the control limits. The analytes were dissolved organic carbon (DOC) and total organic carbon (TOC). Table 10-6 shows the frequency of method blank contamination for these analytes. The frequency of method blanks out of the control limits was 4.2% for DOC by method EPA 415.1 (D) Ox and 4.7% for TOC by method EPA 415.1 (T) Ox. The samples affected by method blank contamination are shown in Table 10-7.

Table 10-6 Number of batches with method blank exceedances

Table 10-7 Environmental samples associated with method blank exceedances

Laboratory Control Samples (LCS)

Laboratory control sample recoveries are used to assess the accuracy of the analytical method especially when matrix interference occurs in the analyses of the environmental samples. LCSs are prepared by adding a known concentration of analyte of interest into a clean medium. The LCS is then analyzed, and the results are compared to the laboratory's control limits. During the period of October 2001 through September 2003, 5,080 LCS analyses were performed (Table 10-3). Only 1 LCS exceeded the control limits (Table10-8).

Table 10-8 LCS recovery exceedances

Table 10-9 Frequency of QC batches with LCS recovery exceedances

Therefore, the laboratory analyses for the project were of acceptable accuracy. Table 10-9 shows the frequency of exceedance and Table 10-10 shows the environmental samples associated with this batch.

Table 10-10 Samples with LCS recovery exceedances

Matrix Spike Recovery

Matrix spike recoveries indicate the accuracy of recovering a known concentration of substance in a matrix of interest. 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 method analytes to an environmental sample with known background concentration. The percent recovery must fall within acceptable limits. During the study period, 6,801 matrix spike recoveries were performed, and 49 (0.7%) exceeded the control limits. The batches with matrix spike recoveries outside the control limits are shown in Table 10-11. The analytes that had matrix spike exceedances were boron, calcium, chromium, Kjeldahl nitrogen, magnesium, phosphorus, sodium, and sulfate. Phosphorus had a frequency of exceedance of 7.1% and sodium 6.3% (Table 10-12). Some of the recoveries were high, but the RPDs and LCS 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 those batches were in control.

Table 10-11 Matrix spike recovery exceedances

Table 10-12 Frequency of QC batches with matrix spike recovery exceedances

The analytes with the highest frequency of exceedance were Kjeldahl nitrogen, phosphorus and sodium (Table 10-8). Calcium, Kjeldahl nitrogen and phosphorus were out of recovery limits for both matrix spikes and spike duplicate, which suggests matrix interference. The LCS and RPDs were within limits for all of these analytes; therefore, the batch was considered in control.

The low frequency of recoveries outside the control limits for the remaining analytes was considered insignificant to the overall data quality of the project. Therefore, the laboratory analyses were of acceptable accuracy, and matrix interference did not have significant effects on the analyses. The environmental samples in these batches are shown in Table 10-13.

Table 10-13 Samples 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, 3,380 matrix spike duplicates were performed. Six matrix spike duplicate batches exceeded the control limits (0.2%), shown in Table 10-14. The analytes were calcium, Kjeldahl nitrogen, and phosphorus and the frequency of exceedance is shown in Table 10-15. These analytes were out of recovery limits for the matrix spikes as well as the spike duplicates, which suggests matrix interference. The LCS recoveries are within limits for these analytes; therefore the batch is considered in control. The environmental samples are shown in Table 10-16.

Table 10-14 Matrix spike duplicate recovery exceedances

Table 10-15 Number of matrix spike duplicate recovery exceedances

Table 10-16 Samples with matrix spike duplicate exceedances

Sample Duplicates

Sample duplicates are environmental samples that are divided into 2 aliquots in the laboratory and analyzed independently to determine the repeatability of the analytical method. The RPD for the duplicate results must fall within the established control limits. During the study period, there were 760 RPD sample duplicate analyses performed, and only 1 sample duplicate (0.1%) exceeded the control limits. The sample duplicate batch outside of the control limits is shown in Table 10-17. The analyte was turbidity and the frequency of exceedance was 0.4% (Table 10-18). These results indicate the laboratory had acceptable precision in its analysis of the project samples. The environmental samples are shown in Table 10-19.

Table 10-17 Sample duplicate exceedances

Table 10-18 Number of sample duplicate exceedances

Table 10-19 Samples with sample duplicate exceedances

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Tables

Table 10-1 Field duplicates

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	RPD %	Units	RPD limit
Conductance (EC)	9/3/2002	CB0902B0639	CB0902B0643	277	196	34.25%	µS/cm	15
Conductance (EC)	11/4/2002	CB1102B0817	CB1102B0820	172	62	94.02%	µS/cm	15
Conductance (EC)	5/19/2003	CB0503B0429	CB0503B0431	588	496	16.97%	µS/cm	15
Conductance (EC)	8/11/2003	CC0803B0691	CC0803B0693	141	613	125.20%	µS/cm	15
Dissolved Ammonia	11/4/2002	CB1102B0817	CB1102B0820	0	0.01	200.00%	mg/L as N	20
Dissolved Ammonia	9/2/2003	CB0903B0589	CB0903B0590	0.04	0.03	28.57%	mg/L as N	20
Dissolved Boron	10/2/2001	CB1001B1002	CB1001B1004	0	0.1	200.00%	mg/L	25
Dissolved Boron	2/5/2002	CB0202B0012	CB0202B0013	0.4	0.3	28.57%	mg/L	25
Dissolved Boron	12/3/2002	CB1202B0883	CB1202B0885	0.2	0	200.00%	mg/L	25
Dissolved Boron	5/6/2003	CB0503B0400	CB0503B0401	0.1	0	200.00%	mg/L	25
Dissolved Bromide	10/15/2001	CB1001B1032	CB1001B1034	0	0.01	200.00%	mg/L	20
Dissolved Bromide	11/13/2001	CB1101B1104	CB1101B1107	0.03	0.02	40.00%	mg/L	20
Dissolved Bromide	11/19/2001	CB1101B1138	CB1101B1141	0.02	0.03	40.00%	mg/L	20
Dissolved Bromide	12/26/2001	CB1201B1276	CB1201B1279	0.02	0.01	66.67%	mg/L	20
Dissolved Bromide	12/27/2001	CB1201B1280	CB1201B1282	0.23	0.3	26.42%	mg/L	20
Dissolved Bromide	1/7/2002	CC0102B0032	CC0102B0033	0.01	0	200.00%	mg/L	20
Dissolved Bromide	2/13/2002	CB0102B0101	CB0102B0104	0.09	0.05	57.14%	mg/L	20
Dissolved Bromide	2/19/2002	CB0202B0111	CB0202B0112	0	0.02	200.00%	mg/L	20
Dissolved Bromide	5/6/2002	CC0502B1820	CC0502B1821	0.01	0.02	66.67%	mg/L	20
Dissolved Bromide	6/3/2002	CB0602B0449	CB0602B0453	0.01	0.02	66.67%	mg/L	20
Dissolved Bromide	11/12/2002	CC1102B3651	CC1102B3654	0.02	0.01	66.67%	mg/L	20
Dissolved Bromide	12/19/2002	CB1202B0923	CB1202B0926	0.51	0.34	40.00%	mg/L	20
Dissolved Bromide	12/30/2002	CC1202B4258	CC1202B4259	0	0.01	200.00%	mg/L	20
Dissolved Bromide	1/14/2003	CC0103B0045	CC0103B0048	0.01	0	200.00%	mg/L	20
Dissolved Bromide	2/10/2003	CB0203B0096	CB0203B0099	0.04	0.03	28.57%	mg/L	20
Dissolved Bromide	4/15/2003	CB0403B0304	CB0403B0307	0.04	0.05	22.22%	mg/L	20
Dissolved Bromide	8/11/2003	CC0803B0691	CC0803B0693	0.01	0.25	184.62%	mg/L	20
Dissolved Calcium	11/4/2002	CB1102B0817	CB1102B0820	13	5	88.89%	mg/L	20

Table 10-1 continued on next page

Table 10-1 Field duplicates (continued)

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	RPD %	Units	RPD limit
Dissolved Chloride	11/4/2002	CB1102B0817	CB1102B0820	5	2	85.71%	mg/L	20
Dissolved Chloride	1/6/2003	CC0103B0019	CC0103B0020	5	3	50.00%	mg/L	20
Dissolved Magnesium	11/4/2002	CB1102B0817	CB1102B0820	7	3	80.00%	mg/L	20
Dissolved Nitrate	11/6/2001	CB1101B1079	CB1101B1081	0.4	0.5	22.22%	mg/L	20
Dissolved Nitrate	8/6/2002	CB0802B0584	CB0802B0588	0.1	0	200.00%	mg/L	20
Dissolved Nitrate	1/6/2003	CC0103B0019	CC0103B0020	1	0.7	35.29%	mg/L	20
Dissolved Nitrate	6/2/2003	CB0603B0452	CB0603B0453	0.4	0.3	28.57%	mg/L	20
Dissolved Organic Carbon	12/3/2001	CB1201B1185	CB1201B1189	11.6	4.6	86.42%	mg/L as C	30
Dissolved Organic Carbon	3/18/2002	CB0302B0278	CB0302B0280	2	3.3	49.06%	mg/L as C	30
Dissolved Organic Carbon	3/19/2002	CB0302B0288	CB0302B0291	5.6	4	33.33%	mg/L as C	30
Dissolved Organic Carbon	4/2/2002	CB0402B0349	CB0402B0351	6.7	4.9	31.03%	mg/L as C	30
Dissolved Organic Carbon	11/4/2002	CB1102B0817	CB1102B0820	1.8	1.3	32.26%	mg/L as C	30
Dissolved Organic Carbon	3/17/2003	CB0303B0195	CB0303B0198	4.5	2.9	43.24%	mg/L as C	30
Dissolved Sodium	11/4/2002	CB1102B0817	CB1102B0820	10	2	133.33%	mg/L	20
Dissolved Sulfate	11/4/2002	CB1102B0817	CB1102B0820	7	2	111.11%	mg/L	20
Dissolved Sulfate	1/6/2003	CC0103B0019	CC0103B0020	7	4	54.55%	mg/L	20
Hardness	11/4/2002	CB1102B0817	CB1102B0820	61	21	97.56%	mg/L as CaCO3	20
Orthophosphate	11/4/2002	CB1102B0817	CB1102B0820	0.03	0.01	100.00%	mg/L as P	20
Orthophosphate	2/3/2003	CB0203B0066	CB0203B0069	0	0.01	200.00%	mg/L as P	20
Orthophosphate	3/3/2003	CB0303B0159	CB0303B0161	0.02	0.03	40.00%	mg/L as P	20
Orthophosphate	9/2/2003	CB0903B0589	CB0903B0590	0.08	0.06	28.57%	mg/L as P	20
pH	4/2/2002	CB0402B0340	CB0402B0343	7.9	6.6	17.93%	pH Units	3
pH	7/29/2002	CB0702B0558	CB0702B0559	5.4	6.5	18.49%	pH Units	3
pH	8/5/2002	CB0802B0576	CB0802B0579	6.5	6.7	3.03%	pH Units	3
pH	11/4/2002	CB1102B0817	CB1102B0820	6.5	6.2	4.72%	pH Units	3
pH	11/12/2002	CC1102B3651	CC1102B3654	7.7	6.6	15.38%	pH Units	3
pH	11/18/2002	CC1102B3674	CC1102B3675	6.5	6.7	3.03%	pH Units	3
pH	11/25/2002	CB1102B0846	CB1102B0849	7.1	6.7	5.80%	pH Units	3

Table 10-1 continued on next page

Table 10-1 Field duplicates (continued)

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	RPD %	Units	RPD limit
pH	12/2/2002	CB1202B0873	CB1202B0877	5.4	6.7	21.49%	pH Units	3
pH	1/21/2003	CC0103B0073	CC0103B0074	7.5	5.1	38.10%	pH Units	3
pH	1/27/2003	CC0103B0084	CC0103B0087	6.4	6.6	3.08%	pH Units	3
pH	2/3/2003	CB0203B0066	CB0203B0069	6	6.2	3.28%	pH Units	3
pH	2/10/2003	CB0203B0092	CB0203B0095	6.5	6.7	3.03%	pH Units	3
pH	6/2/2003	CB0603B0452	CB0603B0453	6.4	6.2	3.17%	pH Units	3
pH	6/10/2003	CB0603B0488	CB0603B0489	6.3	5.9	6.56%	pH Units	3
pH	6/23/2003	CB0603B0511	CB0603B0513	6	6.2	3.28%	pH Units	3
pH	7/21/2003	CC0703B0617	CC0703B0618	5.8	6	3.39%	pH Units	3
pH	8/11/2003	CC0803B0691	CC0803B0693	5.8	6.3	8.26%	pH Units	3
Total Alkalinity	4/2/2002	CB0402B0340	CB0402B0343	35	30	15.38%	mg/L as CaCO3	15
Total Alkalinity	11/4/2002	CB1102B0817	CB1102B0820	75	26	97.03%	mg/L as CaCO3	15
Total Alkalinity	1/21/2003	CC0103B0073	CC0103B0074	155	29	136.96%	mg/L as CaCO3	15
Total Alkalinity	8/11/2003	CC0803B0691	CC0803B0693	60	102	51.85%	mg/L as CaCO3	15
Total Dissolved Solids	9/3/2002	CB0902B0639	CB0902B0643	168	118	34.97%	mg/L	15
Total Dissolved Solids	11/4/2002	CB1102B0817	CB1102B0820	105	38	93.71%	mg/L	15
Total Kjeldahl Nitrogen	11/4/2002	CB1102B0817	CB1102B0820	0.2	0.1	66.67%	mg/L as N	25
Total Kjeldahl Nitrogen	1/6/2003	CC0103B0019	CC0103B0020	0.4	0.3	28.57%	mg/L as N	25
Total Kjeldahl Nitrogen	6/2/2003	CB0603B0452	CB0603B0453	0.2	0.3	40.00%	mg/L as N	25
Total Kjeldahl Nitrogen	7/7/2003	CC0703B0588	CC0703B0592	0.3	0.4	28.57%	mg/L as N	25
Total Organic Carbon	1/14/2002	CC0102B0064	CC0102B0067	3.2	5.2	47.62%	mg/L as C	30
Total Organic Carbon	3/12/2002	CB0302B0266	CB0302B0268	7.2	10.1	33.53%	mg/L as C	30
Total Organic Carbon	3/19/2002	CB0302B0288	CB0302B0291	7.5	4.6	47.93%	mg/L as C	30
Total Organic Carbon	4/2/2002	CB0402B0349	CB0402B0351	9.6	6.7	35.58%	mg/L as C	30
Total Organic Carbon	9/3/2002	CB0902B0639	CB0902B0643	6.2	2.4	88.37%	mg/L as C	30
Total Organic Carbon	9/4/2002	CB0902B0657	CB0902B0659	3.5	2.4	37.29%	mg/L as C	30
Total Organic Carbon	11/4/2002	CB1102B0817	CB1102B0820	2	1.4	35.29%	mg/L as C	30
Total Organic Carbon	3/17/2003	CB0303B0195	CB0303B0198	5.3	3.9	30.43%	mg/L as C	30

Table 10-1 continued on next page

Table 10-1 Field duplicates (continued)

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	RPD %	Units	RPD limit
Total Phosphorus	11/4/2002	CB1102B0817	CB1102B0820	0.06	0.02	100.00%	mg/L	25
Total Phosphorus	11/5/2002	CB1102B0827	CB1102B0829	0.05	0.07	33.33%	mg/L	25
Total Phosphorus	2/3/2003	CB0203B0066	CB0203B0069	0	0.01	200.00%	mg/L	25
Turbidity	10/1/2001	CB1001B0993	CB1001B0996	0	1	200.00%	N.T.U.	15
Turbidity	10/29/2001	CB1001B1068	CB1001B1070	5	4	22.22%	N.T.U.	15
Turbidity	11/5/2001	CC1101B0790	CC1101B0792	5	6	18.18%	N.T.U.	15
Turbidity	11/13/2001	CB1101B1104	CB1101B1107	17	13	26.67%	N.T.U.	15
Turbidity	11/19/2001	CB1101B1138	CB1101B1141	17	14	19.35%	N.T.U.	15
Turbidity	11/26/2001	CB1101B1159	CB1101B1161	1	2	66.67%	N.T.U.	15
Turbidity	12/3/2001	CB1201B1185	CB1201B1189	140	107	26.72%	N.T.U.	15
Turbidity	12/27/2001	CB1201B1280	CB1201B1282	13	11	16.67%	N.T.U.	15
Turbidity	1/7/2002	CC0102B0032	CC0102B0033	110	134	19.67%	N.T.U.	15
Turbidity	2/20/2002	CB0202B0199	CB0202B0202	6	8	28.57%	N.T.U.	15
Turbidity	2/26/2002	CB0202B0213	CB0202B0216	10	12	18.18%	N.T.U.	15
Turbidity	3/18/2002	CB0302B0278	CB0302B0280	3	2	40.00%	N.T.U.	15
Turbidity	3/26/2002	CB0302B0316	CB0302B0319	12	10	18.18%	N.T.U.	15
Turbidity	4/15/2002	CB0402B0393	CB0402B0395	1	2	66.67%	N.T.U.	15
Turbidity	4/16/2002	CB0402B0397	CB0402B0399	10	21	70.97%	N.T.U.	15
Turbidity	4/23/2002	CB0402B0419	CB0402B0422	20	12	50.00%	N.T.U.	15
Turbidity	4/29/2002	CB0402B0441	CB0402B0443	2	1	66.67%	N.T.U.	15
Turbidity	6/17/2002	CC0602B1926	CC0602B1927	6	7	15.38%	N.T.U.	15
Turbidity	7/1/2002	CC0702B2047	CC0702B2051	11	7	44.44%	N.T.U.	15
Turbidity	8/12/2002	CB0802B0615	CB0802B0616	6	7	15.38%	N.T.U.	15
Turbidity	8/26/2002	CB0802B0636	CB0802B0637	11	8	31.58%	N.T.U.	15
Turbidity	9/9/2002	CB0902B0680	CB0902B0681	5	6	18.18%	N.T.U.	15
Turbidity	9/16/2002	CB0902B0698	CB0902B0699	5	9	57.14%	N.T.U.	15
Turbidity	9/30/2002	CC0902B3322	CC0902B3323	8	6	28.57%	N.T.U.	15
Turbidity	10/8/2002	CB1002B0725	CB1002B0727	5	13	88.89%	N.T.U.	15

Table 10-1 continued on next page

Table 10-1 Field duplicates (continued)

Analyte	Collection date	Sample number	Sample duplicate	Result 1	Result 2	RPD %	Units	RPD limit
Turbidity	10/15/2002	CB1002B0733	CB1002B0734	3	5	50.00%	N.T.U.	15
Turbidity	10/21/2002	CB1002B0751	CB1002B0753	36	25	36.07%	N.T.U.	15
Turbidity	10/28/2002	CB1002B0793	CB1002B0794	2	3	40.00%	N.T.U.	15
Turbidity	11/4/2002	CB1102B0817	CB1102B0820	4	1	120.00%	N.T.U.	15
Turbidity	11/18/2002	CC1102B3674	CC1102B3675	6	5	18.18%	N.T.U.	15
Turbidity	11/19/2002	CC1102B3678	CC1102B3680	5	6	18.18%	N.T.U.	15
Turbidity	11/26/2002	CB1102B0850	CB1102B0852	7	6	15.38%	N.T.U.	15
Turbidity	12/3/2002	CB1202B0883	CB1202B0885	5	6	18.18%	N.T.U.	15
Turbidity	12/10/2002	CB1202B0904	CB1202B0907	3	4	28.57%	N.T.U.	15
Turbidity	2/3/2003	CB0203B0066	CB0203B0069	2	3	40.00%	N.T.U.	15
Turbidity	2/10/2003	CB0203B0096	CB0203B0099	11	9	20.00%	N.T.U.	15
Turbidity	3/24/2003	CB0303B0262	CB0303B0263	14	11	24.00%	N.T.U.	15
Turbidity	4/1/2003	CB0403B0362	CB0403B0363	13	16	20.69%	N.T.U.	15
Turbidity	4/15/2003	CB0403B0304	CB0403B0307	6	7	15.38%	N.T.U.	15
Turbidity	4/21/2003	CB0403B0329	CB0403B0330	21	25	17.39%	N.T.U.	15
Turbidity	6/10/2003	CB0603B0488	CB0603B0489	13	11	16.67%	N.T.U.	15
Turbidity	7/28/2003	CC0703B0629	CC0703B0630	10	12	18.18%	N.T.U.	15
Turbidity	8/11/2003	CC0803B0691	CC0803B0693	9	25	94.12%	N.T.U.	15
UV Absorbance @254nm	7/29/2002	CB0702B0558	CB0702B0559	0.055	0.034	47.19%	absorbance/cm	10
UV Absorbance @254nm	10/28/2002	CB1002B0793	CB1002B0794	0.028	0.038	30.30%	absorbance/cm	10
UV Absorbance @254nm	11/4/2002	CB1102B0817	CB1102B0820	0.05	0.028	56.41%	absorbance/cm	10
UV Absorbance @254nm	8/11/2003	CC0803B0691	CC0803B0693	0.042	0.089	71.76%	absorbance/cm	10

Table 10-2 Field blanks exceeding control limits

Analyte	Collection date	Sample number	Result	Reporting limit	Units
Dissolved Organic Carbon	10/25/2002 11:06	CC1002B3648	0.9	0.1	mg/L as C
Dissolved Organic Carbon	10/25/2002 11:07	CC1002B3649	0.2	0.1	mg/L as C
Dissolved Organic Carbon	11/8/2002 11:00	CC1102B4051	0.2	0.1	mg/L as C
Orthophosphate	2/3/2003 10:40	CB0203B0084	0.03	0.01	mg/L as P
Total Organic Carbon	10/25/2002 11:03	CC1002B3647	0.2	0.1	mg/L as C
Total Organic Carbon	11/8/2002 11:00	CC1102B4050	0.2	0.1	mg/L as C
Total Organic Carbon	11/8/2002 11:00	CC1102B4049	0.2	0.1	mg/L as C
Total Phosphorus	6/2/2003 13:10	CB0603B0461	0.04	0.01	mg/L
Total Phosphorus	6/4/2003 11:20	CB0603B0470	0.05	0.01	mg/L

Table 10-3 Total internal QC batches grouped by analyte

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank	RPD sample duplicate
Minor elements							
Aluminum	EPA 200.8 (D)	106	53	172	86	53	
Arsenic	EPA 200.8 (D)	106	53	160	80	53	
Barium	EPA 200.8 (D)	84	42	140	70	42	
Boron	EPA 200.8 (D)	152	74	290	140	87	
Cadmium	EPA 200.8 (D)	66	33	122	61	33	
Chromium	EPA 200.8 (D)	72	36	130	65	36	
Copper	EPA 200.8 (D)	106	53	174	87	53	
Iron	EPA 200.8 (D)	106	53	174	87	53	
Lead	EPA 200.8 (D)	70	35	124	62	35	
Manganese	EPA 200.8 (D)	106	53	160	80	53	
Nickel	EPA 200.8 (D)	60	30	94	47	30	
Selenium	EPA 200.8 (D)	92	46	112	56	46	
silver	EPA 200.8 (D)	66	33	122	61	33	
Zinc	EPA 200.8 (D)	68	34	124	62	34	
Bromide	EPA 300.0 28d Hold	297	148	696	352	165	
Organic carbon							
Dissolved Organic Carbon (DOC)	EPA 415.1 (D) Ox	288	143			144	13
Dissolved Organic Carbon (DOC)		212	104			106	3
Total Organic Carbon (TOC)	EPA 415.1 (T) Ox	296	144			148	
Total Organic Carbon (TOC)	EPA 415_1 (T) Cmbst	246	123			123	
UV Absorbance @254nm	Std Method 5910B	136	67			129	160
EC and salts							
Conductance (EC)	Std Method 2510-B					125	20
Calcium	EPA 200.7 (D)	152	74	300	144	87	
Magnesium	EPA 200.7 (D)	152	74	300	144	87	
Chloride	Std Method 4500-Cl-E	319	159	1062	532	159	

Table 10-3 continued on next page

Table 10-3 Total internal QC batches grouped by analyte (continued)

Analyte	Method	LCS recovery	RPD-LCS duplicate	Matrix spike	RPD- Matrix spike duplicate	Method blank	RPD sample duplicate
Sulfate	EPA 300.0 28 day	309	154	972	487	154	
Sodium	200.7 ICP	152	74	300	144	87	
Nutrients							
Nitrate	Std Method 4500-NO3-F or EPA 353.2 28 day	114	56	168	84	56	
Ammonia	Std Method 4500-NH3 or EPA 350.1	166	82	215	106	80	
Kjeldahl nitrogen	EPA 351.2	134	67	80	40	66	
Orthophosphate		161	80	116	58	79	
Phosphorus	EPA 365.4	134	67	98	49	67	
Miscellaneous							
pH	pH - Std Method 2320 B					58	
pH	Std Method 5910 B						30
Hardness	Std Method 2340 B						
Alkalinity	Std Method 2320 B	246	121	396	196	123	
Methyl tert-butyl ether (MTBE)							
Turbidity							
Turbidity EPA 180.1	EPA 180.1	306	147			294	233
Turbidity	Std Method 2130 B						
Total Suspended Solids (TSS)	EPA 160.2						174
Solids (TDS)	Std Method 2540-C						127
Total		5080	2512	6801	3380	2978	760
		LCS	LCS dup	MS	MS dup	MB	Sample dup

Table 10-4 Holding time exceedances

Analyte	Collection date	Sample number	Holding time	Limit
Chromium, Hexavalent by Ion Chromatography	5/15/2002	DZ0502B7522	25 hours	24
Chromium, Hexavalent by Ion Chromatography	7/17/2002	DZ0702B0631	50 hours	24
Chromium, Hexavalent by Ion Chromatography	7/17/2002	DZ0702B0634	45 hours	24
Chromium, Hexavalent by Ion Chromatography	8/21/2002	DZ0802B2698	25 hours	24
Chromium, Hexavalent by Ion Chromatography	8/21/2002	DZ0802B2706	25 hours	24
Orthophosphate (Dissolved)	1/7/2002	CC0102B0034	164 hours	48
Orthophosphate (Dissolved)	1/2/2002	CC0102B0098	286 hours	48
Orthophosphate (Dissolved)	7/17/2002	DZ0702B0631	76 hours	48
Orthophosphate (Dissolved)	7/17/2002	DZ0702B0634	71 hours	48
UVA	10/29/2001	CB1001B1068	16 days	14
UVA	10/29/2001	CB1001B1069	16 days	14
UVA	10/29/2001	CB1001B1070	16 days	14

Table 10-5 Method blank exceedances

Analyte	Method	Batch number	Result	Reporting limit	Units
DOC	EPA 415.1 (D) Ox	BL02B10636	0.11	0.1	mg/L as C
DOC	EPA 415.1 (D) Ox	BL02B12647	0.16	0.1	mg/L as C
DOC	EPA 415.1 (D) Ox	BL01B9475	0.15	0.1	mg/L as C
DOC	EPA 415.1 (D) Ox	BL02B10066	0.2	0.1	mg/L as C
DOC	EPA 415.1 (D) Ox	BL02B12541	0.46	0.1	mg/L as C
DOC	EPA 415.1 (D) Ox	BL02B12602	0.18	0.1	mg/L as C
DOC	EPA 415.1 (D) Cmbst	BL02B11049	0.6	0.5	mg/L as C
DOC	EPA 415.1 (D) Cmbst	BL02B11073	0.7	0.5	mg/L as C
TOC	EPA 415.1 (T) Ox	BL02B10637	0.11	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL02B12648	0.16	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL01B9476	0.15	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL01B9605	0.2	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL02B10067	0.2	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL02B12542	0.46	0.1	mg/L as C
TOC	EPA 415.1 (T) Ox	BL02B12603	0.18	0.1	mg/L as C
TOC	EPA 415.1 (T) Cmbst	BL02B11048	0.6	0.5	mg/L as C
TOC	EPA 415.1 (T) Cmbst	BL02B11072	0.7	0.5	mg/L as C

Table 10-6 Number of batches with method blank exceedances

Analyte	Method	Total batches	Batches with method blanks out of limits	Frequency of samples out of limits (%)
DOC	EPA 415.1 (D) Ox	144	6	4.2
DOC	EPA 415.1 (D) Cmbst	106	2	1.9
TOC	EPA 415.1 (T) Ox	148	7	4.7
TOC	EPA 415.1 (T) Cmbst	123	2	1.6

Table 10-7 Environmental samples associated with method blank exceedances

Analyte	Method	Batch number	Sample number	Collection date
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1069	10/29/2001
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1070	10/29/2001
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1037	10/22/2001
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1068	10/29/2001
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1037	10/22/2001
DOC	EPA 415.1 (D) Ox	BL01B9475	CB1001B1069	10/29/2001
DOC	EPA 415.1 (D) Ox	BL02B10636	CB0402B0415	4/22/2002
DOC	EPA 415.1 (D) Ox	BL02B10636	CB0402B0416	4/22/2002
DOC	EPA 415.1 (D) Ox	BL02B10636	CB0402B0418	4/22/2002
DOC	EPA 415.1 (D) Ox	BL02B10066	CB0202B0089	2/11/2002
DOC	EPA 415.1 (D) Ox	BL02B10066	CB0202B0090	2/11/2002
DOC	EPA 415.1 (D) Ox	BL02B10066	CB0202B0091	2/11/2002
DOC	EPA 415.1 (D) Ox	BL02B10066	CB0202B0092	2/11/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0888	12/3/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0900	12/9/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0901	12/9/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0902	12/9/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0903	12/9/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0904	12/10/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0905	12/10/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0906	12/10/2002
DOC	EPA 415.1 (D) Ox	BL02B12541	CB1202B0907	12/10/2002
DOC	EPA 415.1 (D) Ox	BL02B12602	DZ1202B0259	12/18/2002
DOC	EPA 415.1 (D) Ox	BL02B12602	SLA1202B0236	12/18/2002
DOC	EPA 415.1 (D) Ox	BL02B12602	DZ1202B0262	12/18/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0918	12/16/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0915	12/16/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0916	12/16/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0917	12/16/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0923	12/19/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0924	12/19/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0925	12/19/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CB1202B0926	12/19/2002
DOC	EPA 415.1 (D) Ox	BL02B12647	CC1202B4231	12/16/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CC0502B1867	5/28/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CC0502B1868	5/28/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CC0502B1869	5/28/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CB0602B0449	6/3/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CB0602B0450	6/3/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CB0602B0451	6/3/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CB0602B0452	6/3/2002

Table 10-7 continued on next page

Table 10-7 Environmental samples associated with method blank exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
DOC	EPA 415.1 (D) Cmbst	BL02B11049	CB0602B0453	6/3/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0459	6/4/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0460	6/4/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0461	6/4/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0462	6/4/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0458	6/4/2002
DOC	EPA 415.1 (D) Cmbst	BL02B11073	CB0602B0463	6/5/2002
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1068	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1069	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1070	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1037	10/22/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1037	10/22/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1069	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1069	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9476	CB1001B1069	10/29/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0918	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0919	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0920	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0921	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0922	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0923	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0924	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0925	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0926	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0927	11/7/2001
TOC	EPA 415.1 (T) Ox	BL01B9605	CC1101B0928	11/7/2001
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0862	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0863	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0864	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0865	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0866	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0867	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0868	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0869	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0870	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0871	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CC0202B0872	2/7/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CB0202B0089	2/11/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CB0202B0090	2/11/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CB0202B0091	2/11/2002
TOC	EPA 415.1 (T) Ox	BL02B10067	CB0202B0092	2/11/2002

Table 10-7 continued on next page

Table 10-7 Environmental samples associated with method blank exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
TOC	EPA 415.1 (T) Ox	BL02B10637	CB0402B0415	4/22/2002
TOC	EPA 415.1 (T) Ox	BL02B10637	CB0402B0416	4/22/2002
TOC	EPA 415.1 (T) Ox	BL02B10637	CB0402B0418	4/22/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0888	12/3/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0900	12/9/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0901	12/9/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0902	12/9/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0903	12/9/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0904	12/10/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0905	12/10/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0906	12/10/2002
TOC	EPA 415.1 (T) Ox	BL02B12542	CB1202B0907	12/10/2002
TOC	EPA 415.1 (T) Ox	BL02B12603	DZ1202B0259	12/18/2002
TOC	EPA 415.1 (T) Ox	BL02B12603	DZ1202B0262	12/18/2002
TOC	EPA 415.1 (T) Ox	BL02B12603	SLA1202B0236	12/18/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0917	12/16/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0918	12/16/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0915	12/16/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0916	12/16/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0923	12/19/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0924	12/19/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0925	12/19/2002
TOC	EPA 415.1 (T) Ox	BL02B12648	CB1202B0926	12/19/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CC0502B1867	5/28/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CC0502B1868	5/28/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CC0502B1869	5/28/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CB0602B0449	6/3/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CB0602B0450	6/3/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CB0602B0451	6/3/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CB0602B0452	6/3/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11048	CB0602B0453	6/3/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0460	6/4/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0461	6/4/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0462	6/4/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0458	6/4/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0459	6/4/2002
TOC	EPA 415.1 (T) Cmbst	BL02B11072	CB0602B0463	6/5/2002

Table 10-8 LCS recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Kjeldahl nitrogen	EPA 351.2	BL02B9841	124	80-120

Table 10-9 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	134	1	0.75

Table 10-10 Samples with LCS recovery exceedances

Analyte	Method	Batch number	Sample number	Collection date
Kjeldahl nitrogen	EPA 351.2	BL02B9841	CC0102B0098	1/2/2002

Table 10-11 Matrix spike recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Boron	EPA 200.7 (D)	BL02B12193	128.7	80–120
Calcium	EPA 200.7 (D)	BL01B9580	70.7	80–120
Calcium	EPA 200.7 (D)	BL02B12193	129.3	80–120
Calcium	EPA 200.7 (D)	BL02B12193	128.3	80–120
Calcium	EPA 200.7 (D)	BL02B12275	120.9	80–120
Calcium	EPA 200.7 (D)	BL02B9810	135.77	80–120
Calcium	EPA 200.7 (D)	BL02B9810	132.77	80–120
Calcium	EPA 200.7 (D)	BL03B14698	130	80–120
Chromium, hexavalent (Cr6+)	EPA 218.6	BL01B9383	80.6	85–115
Chromium, hexavalent (Cr6+)	EPA 218.6	BL01B9383	83	85–115
Kjeldahl Nitrogen	EPA 351.2	BL01B9460	147.25	70–130
Kjeldahl Nitrogen	EPA 351.2	BL01B9460	149.5	70–130
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	138.5	70–130
Kjeldahl Nitrogen	EPA 351.2	BL02B9901	52.13	70–130
Magnesium	EPA 200.7 (D)	BL02B12275	79.6	80–120
Magnesium	EPA 200.7 (D)	BL02B12275	79.6	80–120
Magnesium	EPA 200.7 (D)	BL02B9810	126.54	80–120
Phosphorus	EPA 365.4	BL02B10072	79	80.7–120.7
Phosphorus	EPA 365.4	BL02B10072	74	80.7–120.7
Phosphorus	EPA 365.4	BL02B10431	39	80.7–120.7
Phosphorus	EPA 365.4	BL02B10431	42	80.7–120.7
Phosphorus	EPA 365.4	BL03B14018	125	80.7–120.7
Phosphorus	EPA 365.4	BL02B9900	52	80.7–120.7
Phosphorus	EPA 365.4	BL02B9900	133	80.7–120.7
Sodium	EPA 200.7 (D)	BL01B9580	70.88	80–120
Sodium	EPA 200.7 (D)	BL02B10000	121	80–120
Sodium	EPA 200.7 (D)	BL02B10615	123.3	80–120
Sodium	EPA 200.7 (D)	BL02B11132	77.3	80–120
Sodium	EPA 200.7 (D)	BL02B11768	75	80–120
Sodium	EPA 200.7 (D)	BL02B11768	79	80–120
Sodium	EPA 200.7 (D)	BL02B12193	135.9	80–120
Sodium	EPA 200.7 (D)	BL02B12193	120.9	80–120
Sodium	EPA 200.7 (D)	BL02B12196	72.9	80–120
Sodium	EPA 200.7 (D)	BL02B12275	70	80–120
Sodium	EPA 200.7 (D)	BL02B12513	40	80–120
Sodium	EPA 200.7 (D)	BL02B12513	50	80–120
Sodium	EPA 200.7 (D)	BL02B9810	129.85	80–120
Sodium	EPA 200.7 (D)	BL02B9810	122.85	80–120
Sodium	EPA 200.7 (D)	BL02B12513	172.9	80–120
Sodium	EPA 200.7 (D)	BL03B13176	142.9	80–120

Table 10-11 continued on next page

Table 10-11 Matrix spike recovery exceedances (continued)

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Sodium	EPA 200.7 (D)	BL03B13270	149.5	80–120
Sodium	EPA 200.7 (D)	BL03B13270	69.5	80–120
Sodium	EPA 200.7 (D)	BL03B13720	72.4	80–120
Sulfate	EPA 300.0 28d Hold	BL02B11412	127.88	80–120
Sulfate	EPA 300.0 28d Hold	BL02B11412	127.88	80–120
Sulfate	EPA 300.0 28d Hold	BL03B13681	160.8	80–120
Sulfate	EPA 300.0 28d Hold	BL03B13681	160.8	80–120
Sulfate	EPA 300.0 28d Hold	BL03B14318	122.1	80–120
Sulfate	EPA 300.0 28d Hold	BL03B14318	123	80–120

Table 10-12 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 (%)
Boron	290	1	0.34
Calcium	300	7	2.3
Chromium	130	2	1.5
Kjeldahl Nitrogen	80	4	5
Magnesium	300	3	1
Phosphorus	98	7	7.1
Sodium	300	19	6.3
Sulfate	972	6	0.6

Table 10-13 Samples with matrix spike recovery exceedances

Analyte	Method	Batch number	Sample number	Collection date
Boron	EPA 200.8 (D)	BL02B12193	CC0902B3419	9/26/2002 11:00
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1210	12/3/2001 12:15
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1193	12/3/2001 15:15
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1192	12/3/2001 13:55
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1212	12/3/2001 12:15
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1187	12/3/2001 10:50
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1213	12/3/2001 13:00
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1211	12/3/2001 11:00
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1186	12/3/2001 10:05
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1189	12/3/2001 9:20
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1194	12/3/2001 13:55
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1188	12/3/2001 11:40
Calcium	EPA 200.8 (D)	BL02B9810	CB1201B1185	12/3/2001 13:10
Calcium	EPA 200.8 (D)	BL01B9580	CB1101B1181	11/13/2001 13:45
Calcium	EPA 200.8 (D)	BL01B9580	DZ1101B0889	11/14/2001 10:00
Calcium	EPA 200.8 (D)	BL01B9580	DZ1101B0892	11/14/2001 12:40
Calcium	EPA 200.8 (D)	BL01B9580	SLA1101B0838	11/14/2001 10:00
Calcium	EPA 200.8 (D)	BL02B12193	CC0902B3419	9/26/2002 11:00
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0830	11/5/2002 14:10
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0827	11/5/2002 12:05
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0819	11/4/2002 13:00
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0832	11/6/2002 10:50
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0831	11/5/2002 13:10
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0829	11/5/2002 12:05
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0821	11/4/2002 9:40
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0818	11/4/2002 10:45
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0817	11/4/2002 9:40
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0818	11/4/2002 10:45
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0817	11/4/2002 9:40
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0820	11/4/2002 12:10
Calcium	EPA 200.8 (D)	BL02B12275	CB1102B0828	11/5/2002 10:45
Calcium	EPA 200.8 (D)	BL03B14698	CB0903B0591	9/10/2003 9:30
Chromium, hexavalent (Cr6+)	EPA 218.6	BL01B9383	DZ1001B0742	10/17/2001 14:35
Chromium, hexavalent (Cr6+)	EPA 218.6	BL01B9383	DZ1001B0739	10/17/2001 7:45
Kjeldahl Nitrogen	EPA 351.2	BL01B9460	DZ1001B0739	10/17/2001 7:45
Kjeldahl Nitrogen	EPA 351.2	BL01B9460	DZ1001B0742	10/17/2001 14:35
Kjeldahl Nitrogen	EPA 351.2	BL02B9901	CC0102B0034	1/7/2002 14:25
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0828	11/5/2002 10:45

Table 10-13 continued on next page

Table 10-13 Samples with matrix spike recovery exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0821	11/4/2002 9:40
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0829	11/5/2002 12:05
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0830	11/5/2002 14:10
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0827	11/5/2002 12:05
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0832	11/6/2002 10:50
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0819	11/4/2002 13:00
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0818	11/4/2002 10:45
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0817	11/4/2002 9:40
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0831	11/5/2002 13:10
Magnesium	EPA 200.7 (D)	BL02B12275	CB1102B0820	11/4/2002 12:10
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1212	12/3/2001 12:15
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1211	12/3/2001 11:00
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1189	12/3/2001 9:20
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1187	12/3/2001 10:50
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1194	12/3/2001 13:55
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1188	12/3/2001 11:40
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1193	12/3/2001 15:15
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1210	12/3/2001 12:15
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1185	12/3/2001 13:10
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1192	12/3/2001 13:55
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1186	12/3/2001 10:05
Magnesium	EPA 200.7 (D)	BL02B9810	CB1201B1213	12/3/2001 13:00
Phosphorus	EPA 365.4	BL02B9900	CC0102B0034	1/7/2002 14:25
Phosphorus	EPA 365.4	BL02B10072	CC0102B0665	1/28/2002 13:50
Phosphorus	EPA 365.4	BL02B10072	CB0202B0003	2/4/2002 12:30
Phosphorus	EPA 365.4	BL02B10431	CB0302B0233	3/4/2002 12:45
Phosphorus	EPA 365.4	BL02B10431	CB0302B0328	3/7/2002 12:20
Phosphorus	EPA 365.4	BL03B14018	CB0603B0465	6/2/2003 12:30
Phosphorus	EPA 365.4	BL03B14018	CB0603B0467	6/4/2003 13:00
Phosphorus	EPA 365.4	BL03B14018	CB0603B0470	6/4/2003 11:20
Phosphorus	EPA 365.4	BL03B14018	CB0603B0464	6/4/2003 11:00
Phosphorus	EPA 365.4	BL03B14018	CB0603B0466	6/2/2003 11:40
Phosphorus	EPA 365.4	BL03B14018	CB0603B0462	6/2/2003 10:30
Phosphorus	EPA 365.4	BL03B14018	CB0603B0463	6/2/2003 10:00
Phosphorus	EPA 365.4	BL03B14018	CB0603B0461	6/2/2003 13:10
Phosphorus	EPA 365.4	BL03B14018	CB0603B0454	6/2/2003 13:10
Sodium	EPA 200.7 (D)	BL02B10000	CC0102B0665	1/28/2002 13:50
Sodium	EPA 200.7 (D)	BL02B10615	SLA0402B0135	4/17/2002 7:35
Sodium	EPA 200.7 (D)	BL02B10615	DZ0402B6068	4/17/2002 7:10
Sodium	EPA 200.7 (D)	BL02B10615	DZ0402B6071	4/17/2002 12:40
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0460	6/4/2002 12:45

Table 10-13 continued on next page

Table 10-13 Samples with matrix spike recovery exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0461	6/4/2002 13:45
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0462	6/4/2002 12:45
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0452	6/3/2002 11:00
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0453	6/3/2002 8:50
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0458	6/4/2002 12:45
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0459	6/4/2002 10:15
Sodium	EPA 200.7 (D)	BL02B11132	SLB0602B0010	6/19/2002 12:00
Sodium	EPA 200.7 (D)	BL02B11132	DZ0602B9305	6/19/2002 7:00
Sodium	EPA 200.7 (D)	BL02B11132	DZ0602B9308	6/19/2002 0:05
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0459	6/4/2002 10:15
Sodium	EPA 200.7 (D)	BL02B11132	CB0602B0463	6/5/2002 9:40
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0657	9/4/2002 11:40
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0662	9/4/2002 9:50
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0639	9/3/2002 9:05
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0640	9/3/2002 10:15
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0641	9/3/2002 12:15
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0643	9/3/2002 9:05
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0658	9/4/2002 10:30
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0660	9/4/2002 13:45
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0661	9/4/2002 12:45
Sodium	EPA 200.7 (D)	BL02B11768	CB0902B0659	9/4/2002 11:40
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0814	10/1/2002 11:45
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0717	10/7/2002 10:30
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0718	10/7/2002 12:30
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0726	10/8/2002 10:40
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0720	10/7/2002 9:25
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0725	10/8/2002 11:45
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0727	10/8/2002 11:45
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0719	10/9/2002 9:00
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0728	10/9/2002 12:50
Sodium	EPA 200.7 (D)	BL02B12196	SLB1002B0157	10/16/2002 6:30
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0729	10/9/2002 12:00
Sodium	EPA 200.7 (D)	BL02B12196	CB1002B0730	10/9/2002 10:45
Sodium	EPA 200.7 (D)	BL02B12196	DZ1002B7414	10/16/2002 6:40
Sodium	EPA 200.7 (D)	BL02B12196	DZ1002B7418	10/16/2002 10:50
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0886	12/3/2002 10:15
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0887	12/3/2002 11:25
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0883	12/3/2002 12:15
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0884	12/3/2002 12:15
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0888	12/3/2002 10:20
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0883	12/3/2002 12:15

Table 10-13 continued on next page

Table 10-13 Samples with matrix spike recovery exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0888	12/3/2002 10:20
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0885	12/3/2002 12:15
Sodium	EPA 200.7 (D)	BL02B12513	CB1202B0884	12/3/2002 12:15
Sodium	EPA 200.7 (D)	BL03B13176	CB0303B0164	3/5/2003 11:18
Sodium	EPA 200.7 (D)	BL03B13270	CC0303B0408	3/17/2003 13:30
Sodium	EPA 200.7 (D)	BL01B9580	CB1101B1181	11/13/2001 13:45
Sodium	EPA 200.7 (D)	BL01B9580	DZ1101B0892	11/14/2001 12:40
Sodium	EPA 200.7 (D)	BL01B9580	DZ1101B0889	11/14/2001 10:00
Sodium	EPA 200.7 (D)	BL01B9580	SLA1101B0838	11/14/2001 10:00
Sodium	EPA 200.7 (D)	BL02B12193	CC0902B3419	9/26/2002 11:00
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0820	11/4/2002 12:10
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0828	11/5/2002 10:45
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0832	11/6/2002 10:50
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0818	11/4/2002 10:45
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0817	11/4/2002 9:40
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0830	11/5/2002 14:10
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0821	11/4/2002 9:40
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0829	11/5/2002 12:05
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0831	11/5/2002 13:10
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0827	11/5/2002 12:05
Sodium	EPA 200.7 (D)	BL02B12275	CB1102B0819	11/4/2002 13:00
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1188	12/3/2001 11:40
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1194	12/3/2001 13:55
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1211	12/3/2001 11:00
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1193	12/3/2001 15:15
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1189	12/3/2001 9:20
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1186	12/3/2001 10:05
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1212	12/3/2001 12:15
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1192	12/3/2001 13:55
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1187	12/3/2001 10:50
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1213	12/3/2001 13:00
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1210	12/3/2001 12:15
Sodium	EPA 200.7 (D)	BL02B9810	CB1201B1185	12/3/2001 13:10
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0400	5/6/2003 10:15
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0404	5/6/2003 12:55
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0403	5/6/2003 13:35
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0401	5/6/2003 10:15
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0405	5/8/2003 13:05
Sodium	EPA 200.7 (D)	BL03B13720	CB0503B0402	5/6/2003 12:05
Sulfate	EPA 300.0 28d Hold	BL02B11412	CB0702B0558	7/29/2002 9:25
Sulfate	EPA 300.0 28d Hold	BL02B11412	CB0702B0559	7/29/2002 9:25

Table 10-13 continued on next page

Table 10-13 Samples with matrix spike recovery exceedances (continued)

Analyte	Method	Batch number	Sample number	Collection date
Sulfate	EPA 300.0 28d Hold	BL02B11412	CB0702B0560	7/29/2002 11:00
Sulfate	EPA 300.0 28d Hold	BL03B13681	CB0503B0405	5/8/2003 13:05
Sulfate	EPA 300.0 28d Hold	BL03B13681	CB0503B0405	5/8/2003 13:05
Sulfate	EPA 300.0 28d Hold	BL03B13681	CB0503B0405	5/8/2003 13:05
Sulfate	EPA 300.0 28d Hold	BL03B14318	CC0703B0629	7/28/2003 9:05
Sulfate	EPA 300.0 28d Hold	BL03B14318	CC0703B0630	7/28/2003 9:05
Sulfate	EPA 300.0 28d Hold	BL03B14318	CC0703B0631	7/28/2003 11:40

Table 10-14 Matrix spike duplicate recovery exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Calcium	EPA 200.7 (D)	BL01B9580	24.783	0–20
Calcium	EPA 200.7 (D)	BL03B14698	36.36	0–20
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	44.86	0–25
Kjeldahl Nitrogen	EPA 351.2	BL02B9901	52.128	0–25
Phosphorus	EPA 365.4	BL03B14018	30.41	0–25
Phosphorus	EPA 365.4	BL02B9900	87.568	0–25

Table 10-15 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 (%)
Calcium	144	2	1.4
Kjeldahl Nitrogen	40	2	5
Phosphorus	49	2	4

Table 10-16 Samples with matrix spike duplicate exceedances

Analyte	Method	Batch number	Sample number	Collection date
Calcium	EPA 200.7 (D)	BL01B9580	DZ1101B0889	11/14/2001
Calcium	EPA 200.7 (D)	BL01B9580	SLA1101B0838	11/14/2001
Calcium	EPA 200.7 (D)	BL03B14698	CB0903B0591	9/10/2003
Calcium	EPA 200.7 (D)	BL01B9580	DZ1101B0892	11/14/2001
Calcium	EPA 200.7 (D)	BL01B9580	CB1101B1181	11/13/2001
Kjeldahl Nitrogen	EPA 351.2	BL02B9901	CC0102B0034	1/7/2002
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0465	6/2/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0467	6/4/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0470	6/4/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0464	6/4/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0466	6/2/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0462	6/2/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0463	6/2/2003
Kjeldahl Nitrogen	EPA 351.2	BL03B14019	CB0603B0461	6/2/2003
Phosphorus	EPA 365.4	BL02B9900	CC0102B0034	1/7/2002
Phosphorus	EPA 365.4	BL03B14018	CB0603B0465	6/2/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0467	6/4/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0470	6/4/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0464	6/4/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0466	6/2/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0462	6/2/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0463	6/2/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0461	6/2/2003
Phosphorus	EPA 365.4	BL03B14018	CB0603B0454	6/2/2003

Table 10-17 Sample duplicate exceedances

Analyte	Method	Batch number	Recovery (%)	Control limits (%)
Turbidity	EPA 180.1	BL03B13070	66.67	0-15

Table 10-18 Number of sample duplicate exceedances

Analyte	Total sample duplicates	Sample duplicates out of limits	Frequency of samples out of limits (%)
Turbidity	233	1	0.4

Table 10-19 Samples with sample duplicate exceedances

Analyte	Method	Batch number	Sample number	Collection date
Turbidity	EPA 180.1	BL03B13070	CB0203B0123	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0124	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0125	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0126	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0139	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0140	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0141	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0142	2/24/2003
Turbidity	EPA 180.1	BL03B13070	CB0203B0125	2/24/2003

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Appendix A

Find raw data files for this report on the CD version or on the Internet at