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Chapter 6
Electrical Conductivity and Salinity

General Relationships between EC and TDS in Delta Waters

In natural waters, the relationship between electrical conductivity (EC) and total dissolved solids (TDS) is linear. Waters at the 14 stations of Municipal Water Quality Investigations Program (MWQI) represent a wide spectrum of salinity varying from low salinity fresh waters to seawaters. A total of 694 samples were collected. The general EC range was from 40 to 17,600 µS/cm (Figure 6-1). Approximately 97% of the EC data were less than 1,500 µS/cm (Figure 6-1). The 3% of the samples with EC greater than 1,500 µS/cm were all collected from the Mallard Island station. Although EC and TDS varied widely among various stations, the relationship between EC and TDS is strongly linear (Figure 6-1), which can be described by this equation:

$$TDS = 0.58*EC–0.30, [r2 = 0.998]$$

This analysis further suggests that TDS (in milligrams per liter) at all 14 stations can be estimated numerically as 58% of the value of EC in µS/cm.

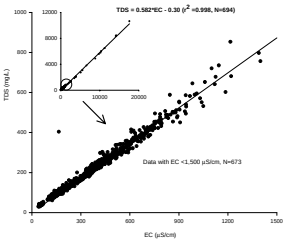


Figure 6-1 Relationship between EC and TDS at 14 MWQI stations

Ranges, Seasonality, and Differences among Stations

Table 6-1 summarizes the range, average, and median TDS/EC ratios for each station during the reporting period. The stations belong to either of 2 general categories separated by a TDS/EC ratio of 0.58. TDS/EC ratios in waters from the San Joaquin River (SJR), Delta channels, diversion stations, and the Sacramento River at Mallard Island station were equal or less than the empirical value of 0.58 (Table 6-1). TDS/EC ratios in the rest of the stations are greater than 0.58 (Table 6-1). Waters with low mineral content, such as water from the American River and Upper Sacramento River, are known to have higher TDS/EC ratios. Waters for the 2 agricultural drainage sites also had higher TDS/EC ratios. This may have been due to the presence of nonconducting organic residues, which will not evaporate significantly at the temperatures for the determination of TDS.

Table 6-1 Summary of TDS/EC ratios in 14 MWQI stations

Table 6-2 Summary of EC at 14 MWQI stations

Table 6-3 Summary of statistics for TDS

American River at the Fairbairn WTP Intake

At the E.A. Fairbairn Water Treatment Plant (WTP) intake on the American River, EC ranged from 40 to 71 µS/cm with an average of 55 µS/cm and a median of 54 µS/cm. TDS varied from 30 to 54 mg/L. Both the average and median TDS were 39 mg/L (Table 6-2 and Table 6-3). Both EC and TDS at this station are the lowest among all stations. The TDS/EC ratio at this station was higher than the ratio for all other stations.

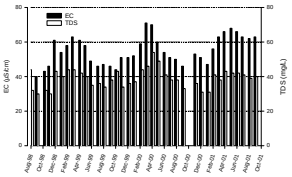


Figure 6-2 Monthly EC and TDS at the American River WTP Intake

EC and TDS were both higher during the wet months than during the dry months for the reporting period (Figure 6-2); however, these differences were not statistically significant (p=0.078 and 0.336 for EC and TDS,

respectively). Neither EC nor TDS varied significantly by water year (p=0.058 and 0.834 for EC and TDS, respectively), despite the 2001 water year being classified as a dry year as opposed to the wetter 1999 and 2000 water years, which were both classified as above normal years.

Sacramento River Stations

The ranges for EC were 112 to 241 µS/cm at the West Sacramento WTP Intake and 96 to 228 µS/cm at Hood (Table 6-2). TDS at these stations ranged from 71 to 148 mg/L and 61 to 137 mg/L, respectively (Table 6-3). The median EC was 155 µS/cm for both stations. The average EC of monthly samples were 161 and 158 µS/cm for West Sacramento WTP Intake and Hood, respectively, which were not statistically different (p=0.462). The median TDS was 97 mg/L for West Sacramento WTP Intake and 95 mg/L for Hood (Table 6-3). The average TDS from monthly samples were 100 and 97 mg/L for West Sacramento WTP Intake and Hood, respectively, which were not statistically different (p=0.791) according to the Wilcoxon Rank-sum test.

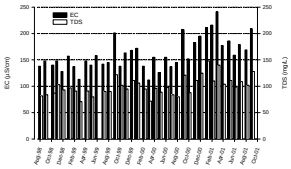


Figure 6-3 Monthly EC and TDS at West Sacramento WTP Intake

Seasonality of both EC and TDS appears to have been related to the amount of runoff in the contributing watershed. At the West Sacramento WTP Intake, average EC and TDS were the highest during the dry 2001 water year (Figure 6-3). Both EC and TDS were elevated during the wet months (Figure 6-3), but no statistically significant differences were found between the wet and dry months (p=0.121 and 0.200 for EC and TDS, respectively). The variations in EC and TDS were even smaller during the relatively wetter 1999 and 2000 water years. Regardless of the water years, EC and TDS increased in September. This increase is attributable to the rice drainage returns to the Sacramento River. Rice drainage effects on salinity in the Sacramento River are discussed in the section "Agricultural Drainage to the Sacramento River."

Seasonal patterns of EC and TDS at Hood were similar to those at the West Sacramento WTP Intake despite low mineral water entering the Sacramento River between the West Sacramento WTP and Hood. Although water from the American River is low in mineral content, inflows are 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. Weekly EC and TDS data collected at Hood are presented with Loess smoothing in Figure 6-4. EC and TDS appear to have increased over the reporting period with both parameters the highest during the 2001 water year and with little difference between the 1999 and 2000 water years (Figure 6-4).

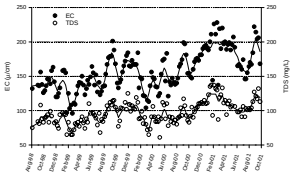


Figure 6-4 Weekly EC and TDS at the Hood station

A Kruskal-Wallis Test suggests that average EC and TDS were significantly different among the 3 water years (p<0.0001 for both EC and TDS). A multiple comparison analysis was performed using Duncan's Multiple Range Test on rank transformed data. Average EC was significantly higher in the 2001 water year than in the 1999 and 2000 water years. Average EC was statistically higher in the 2000 water year than in the 1999 water year. Similarly, average TDS was significantly higher in the 2001 water year than

in the 1999 and 2000 water years. However, no significant difference was found in average TDS between the 1999 and 2000 water years at the 5% significance level.

The years before the 1999 water year were classified as wet years (refer to Chapter 3). These conditions led to greater inflows of lower EC water into Shasta and Oroville reservoirs; furthermore, these reservoirs were nearly full in the late spring of 1998, which led to more carry-over of low EC water released to the Sacramento River during the 1999 and 2000 water years.

San Joaquin River Stations

At the SJR near Vernalis and the SJR at Highway 4 stations, the majority data ranges, average and median EC and TDS were similar (Table 6-2 and Table 6-3). The results of Wilcoxon Rank-sum test suggest that there was no significant difference in average monthly EC (p=0.573) and TDS (p=0.593) between the 2 stations. Despite the difference in sampling frequency, temporal patterns of both EC and TDS at both stations were similar (Figure 6-5 and Figure 6-6). This is due to their similarities in hydrology (refer to Chapter 4).

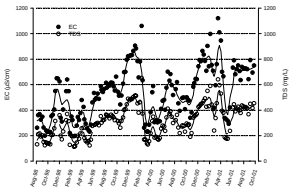


Figure 6-5 Weekly EC and TDS at San Joaquin River near Vernalis

Both EC and TDS were generally higher during the wet months than during dry months of each water year (Figure 6-5 and Figure 6-6). EC and TDS were higher during the 2001 water year than during the previous 2 water years due to lower watershed runoff in the 2001 water year. At Vernalis, water year average EC and TDS were highly significantly different ($p<0.0001$ for both EC and TDS). A Duncan's multiple comparison analysis on rank transformed EC and TDS data suggests that average EC and TDS were significantly higher in the 2001 water year than in the 1999 and 2000 water years. Average EC and TDS were statistically higher in the 2000 water year than in the 1999 water year. Lower EC and TDS during the 1999 water year may be the result of high watershed runoff during the previous 2 water years.

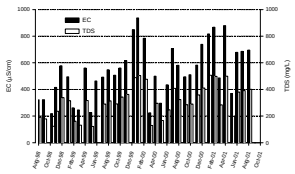


Figure 6-6 Monthly EC and TDS at San Joaquin River at Highway 4

At both stations, EC and TDS were generally higher during June, July, and August than during the other dry months of each water year (Figure 6-5 and Figure 6-6). This increase generally coincided with the increased agricultural activity in the lower San Joaquin watershed, reflecting the increases in irrigation return waters to the lower SJR watershed.

Channel Stations

The average and median of both EC and TDS were higher at Station 9 than at Bacon Island (Table 6-2 and Table 6-3); but these differences were not statistically significant at the 5% level (p values were 0.234 and 0.208 for EC and TDS, respectively). Although sampling dates were different, EC and TDS were much lower at the 2 Old River stations than at the 2 SJR stations (Table 6-2 and Table 6-3). EC and TDS were nearly twice as high in the channel stations as in the upper Sacramento River stations, reflecting that water quality in the channels are affected by inputs from multiple sources. As at the stations along both the SJR and Sacramento River, EC and TDS at the channel stations were generally higher during the wet months than during the dry months (Figure 6-7 and Figure 6-8).

Although the majority of the water in Old River is a mixture from the 2 major river systems flowing into the Delta, the relative contribution from either river varies with hydrologic conditions in the rivers and pumping regimes at the diversion stations along the Old River. In addition, a small fraction of the water is agricultural drainage from various Delta islands. When Delta outflows are low, the 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 the Old River stations not only had some resemblance to those of both the SJR and Sacramento River but also some of their own characteristics.

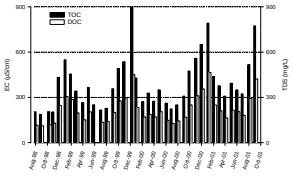


Figure 6-7 Monthly EC and TDS at Old River at Station 9

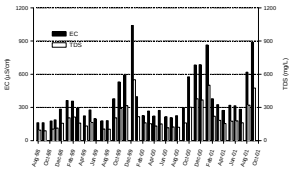


Figure 6-8 Monthly EC and TDS at the Bacon Island Station on Old River

Diversion Stations

Of the 3 diversion stations, the Banks Pumping Plant and the Delta-Mendota Canal (DMC) station were sampled on the same day each month, but the Contra Costa Pumping Plant was sampled on a different day. Therefore, data collected from Banks and DMC stations were not compared with data from the Contra Costa Pumping Plant. Samples at the Contra Costa Pumping Plant were collected at the pumping outlet. Samples were collected only when pumping was scheduled on a sampling date. Because of this, some data are not available for the Contra Costa Pumping Plant, especially during the 2001 water year.

The range and data dispersion were the greatest at the Contra Costa Pumping Plant, followed by the DMC (Table 6-2 and Table 6-3). Although average EC and TDS were the highest at the Contra Costa Pumping Plant, the highest median EC and TDS were found at the DMC. This inconsistency could be attributed to the differences in data collection dates and sampling frequency.

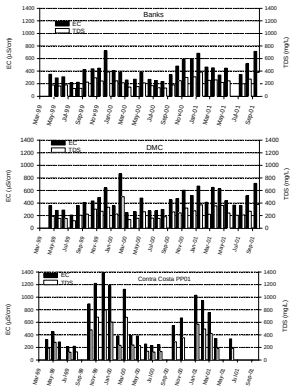


Figure 6-9 Monthly EC and TDS at three Delta diversion stations

Seasonal patterns of EC and TDS were similar to those at the Old River stations (Figure 6-9). EC and TDS were generally higher during the wet months than during the dry months. During the wet months, both EC and TDS were considerably higher at the Contra Costa Pumping Plant than at the other 2 diversion stations. Both the average and median EC and TDS were higher at DMC than at Banks (Table 6-2 and Table 6-3). However, the differences in EC and TDS at both stations were not statistically different (p values were 0.375 and 0.448 for EC and TDS, respectively).

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 summarized here for a brief overview of both parameters.

Chloride and sulfate levels were generally low in most Delta stations except at the Mallard Island station (Table 6-4). Chloride at the Mallard Island station was high and frequently exceeded the MCL of 250 mg/L due to seawater influence. Contra Costa Water District has an intake at Mallard Slough adjacent to Mallard Island but only uses the intake when chlorides are less than 65 mg/L (Holm and Denton 2003 pers comm). Sulfate occasionally was also above the MCL at Mallard Island. Chloride and sulfate at Mallard ranged from 10 to 4,660 mg/L and from 11 to 637 mg/L, respectively. In contrast, chloride and sulfate at the 3 diversion stations never exceeded the MCL of 250 mg/L.

Table 6-4 Chloride and sulfate at 14 MWQI monitoring stations (mg/L)

The Contra Costa Pumping Plant #1 is also affected by seawater influence. During the reporting period, both chloride and sulfate were low at this station: average chloride and sulfate were 65 and 54 mg/L, respectively; median chloride and sulfate were 36 and 38 mg/L, respectively (Table 6-4).

Agricultural drainage waters, which often contain higher levels of chloride and sulfate, affect the stations on the SJR and Old River, but they don't appear to have raised the concentrations of chloride and sulfate above their MCLs. Even in the 2 agricultural drainage stations, chloride never exceeded the MCL of 250 mg/L (Table 6-4). Although sulfate at the Bacon Island Pumping Plant reached 343 mg/L, average and median chloride and sulfate were low. Agricultural return water is a relatively small fraction of the water in the SJR system and in the Old River; therefore, chloride and sulfate in these river stations remained low despite the discharges from agricultural drainage sites.

Average and median concentrations of chloride were similar in the urban drainage Natomas East Main Drainage Canal (NEMDC) and in Old River stations, including the diversion stations. However, the ranges were narrower in the NEMDC than in the Old River (Table 6-4), suggesting that chloride was less variable in NEMDC than in Old River. 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.

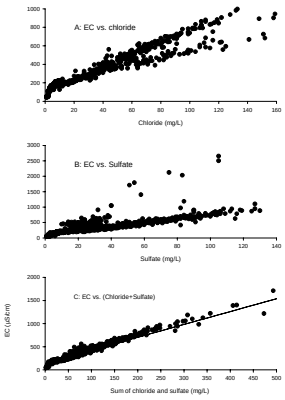


Figure 6-10 EC, Chloride, and sulfate relationships

Chloride and EC were highly correlated at the various stations; however, a single linear regression equation could not describe the relationship between chloride and EC at all 14 stations (Figure 6-10(a)). Instead, the stations fell into 3 major clusters. The first cluster represents waters with chloride concentrations less than 15 mg/L and EC of less than 250 mg/L; these are mostly waters collected from the American River, the West Sacramento WTP Intake, and the Sacramento River at Hood. The remainder of the stations belonged to the remaining 2 clusters, which are both linear. Therefore, at least 3 separate linear equations would be needed to describe the relationships between EC and chloride.

As with chloride, a single linear regression equation could not describe the relationship between sulfate concentration and EC for all stations. Although the majority of the data fell on a linear line, scattering occurred, especially where sulfate was from 10 to 40 mg/L, and EC was less than 600 µS/cm

(Figure 6-10(b)). The samples with high EC are mostly from the Mallard Island station.

Despite the lack of a single linear relationship between EC and chloride and sulfate individually for all 14 stations, a statistically significant linear equation,

$$EC=147.9+2.78*(\text{chloride}+\text{sulfate})$$

($p<0.0001$ for the overall regression and the regression coefficient), could be used to describe the relationship between EC and the sum of both chloride and sulfate with an r^2 of 0.995 (Figure 6-10(c)).

Relationships Between EC and Major Cations

The combined concentrations of chloride and sulfate can be used to predict EC of all 14 stations (see section "Chloride and Sulfate"). Anions such as chloride and sulfate do not exist alone in the water; they always pair in balance with cations. Among the various cations, sodium, calcium, and magnesium are the most abundant and contribute the most to EC. The other cations exist in much smaller quantities. Therefore, for cations only the relationships between EC and sodium, calcium, and magnesium are presented.

Like chloride and sulfate, concentrations of sodium, calcium, and magnesium at the 14 stations may be roughly divided into 3 groups. The group with the lowest concentrations is not affected by seawater influence. Stations of this group include the American River at E.A. Fairbairn WTP, the West Sacramento WTP Intake, and the Sacramento River at Hood. Within this group, sodium ranged from 2 to 17 mg/L, and the combined calcium and magnesium from 5.0 to 28.9 mg/L (Table 6-5). Seawater influences resulted in the detection of the highest concentrations of sodium, calcium, and magnesium at the Mallard Island station (Table 6-5). The remainder of the stations belongs to the third group, which except for the NEMDC station either directly or indirectly are affected by seawater. Concentrations of sodium, calcium, and magnesium in these stations were similar (Table 6-5).

Table 6-5 Summary of sodium, calcium, and magnesium at 14 MWQI monitoring stations

Like the anions (chloride and sulfate), EC was highly correlated with sodium, calcium, and magnesium individually at each station, but no single linear regression equation described relationships for all stations (data not shown). However, a strong linear relationship exists between EC and the sum of the cations (Figure 6-11). This figure shows the majority of the data with all 730 data points plotted in the inset. EC may be predicted by the equation,

$$EC = 39.5 + 5.0*(\text{sodium}+\text{calcium}+\text{magnesium}),\ [r^2 = 0.997],$$

with $p<0.0001$ for both the overall equation and regression constant.

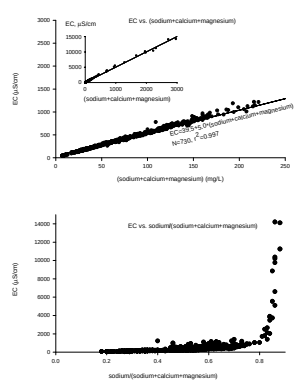


Figure 6-11 Relationships between EC and major cations at 14 MWQI stations

The data during the reporting period suggest that the relative percentage of sodium, as expressed by the ratio, sodium /(sodium+calcium+magnesium), was important (Figure 6-11). When sodium composed 80% of the cationic makeup—that is, when the sodium/(sodium+calcium+magnesium) ratio

reached 0.8—EC increased more rapidly, suggesting that sodium will be the dominant cation contributing to EC when a cation ratio is above 0.8.

The lowest sodium/(sodium+calcium+magnesium) among the 14 MWQI stations was found in the American River at E.A. Fairbairn WTP, followed by 2 Sacramento River stations at West Sacramento WTP Intake and at Hood (Table 6-5). Mallard Island is the only station that had a ratio that exceeded 0.8 (Table 6-5). The average and median ratios for NEMDC were 0.5, suggesting that sodium and the combined amounts of calcium and magnesium were roughly equal. The ratios for the remainder of the stations were around 0.6.

Factors that Affect EC and Salinity in Delta Waters

Seawater Influence

The Delta is strongly influenced by tidal events. Figure 6-12 presents a general picture of seawater influence in the western part of the Delta as indicated by the presence of high chloride concentrations from 1921 through 1943. Chloride levels as high as 1,000 mg/L were observed on the Sacramento River upstream of Rio Vista during 7 years of the 23-year period. This was before Shasta, Folsom, and Oroville dams were built. Reservoirs help reduce seawater influence by releasing low-salinity water that dilutes salt content and reduces seawater influence to Delta waters during the dry months of each year.

Figure 6-12 Seawater influence in the Delta, 1921-1943 (map)

The Mallard Island station is affected heavily by daily tides. Monitoring data for EC and TDS suggest that EC and TDS were widely variable (Figure 6-13, Table 6-2, and Table 6-3). The general range of EC was from 171 to 17,600 µS/cm, while average and median EC were 4,199 and 2,120 µS/cm, respectively. These high EC and TDS concentrations have not been observed at the other stations, including the 2 agricultural drainage stations (Table 6-2 and Table 6-3).

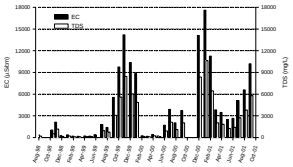


Figure 6-13 Monthly EC and TDS at Mallard Island station

Like bromide, both EC and TDS were higher during the wet months than during the dry months (Figure 6-13). This is perhaps attributable to lower Delta outflows, especially during dry runoff years. Delta outflows are generally higher during the dry months than during the wet months when dams, lakes, and reservoirs are storing water and releasing less. Delta outflows measured at Chipps Island near Mallard Island are summarized in Chapter 3 (Figure 3-3). When Delta outflows were strong such as during the 1998 and 1999 water years and from February to May of 2000 when the contributing Delta watersheds rainfall was delayed, EC and TDS were lower due to both dilution and suppression of seawater influence.

During the 3 water years, EC and TDS at Mallard were affected by runoff in the upper watersheds. EC and TDS levels were the lowest during the 1999 water year and highest in the 2001 water year (Figure 6-13). The 1999 water year was an above-normal year, and the 2 previous water years, 1997 and 1998, were wet years. Strong outflows (Figure 3-3) from 1997 and 1998 lowered both EC and TDS. In contrast, the 2001 water year was classified a dry year, and runoff in the contributing watersheds was the lowest among the

3 water years (Figure 3-3). Therefore, EC and TDS were highest during both the wet and the dry months of the 2001 water year.

In-Delta Agricultural Drainage

In-Delta agricultural drainage contributes salts and increases EC and TDS in Delta waters. Average and median EC and TDS were significantly higher in agricultural drainage waters than in the surrounding waters (Table 6-2 and Table 6-3). EC and TDS showed little variation among the water years (Figure 6-14). Within each water year, they were higher during the wet months than during the dry months. Increased EC and TDS during the wet months were due perhaps to annual salt leaching activities. Each winter, farmers flood the land to leach salts from the soil. The amount of salt drained to the ditches generally does not vary significantly from year to year; therefore, EC and TDS varied little during the 3 water years.

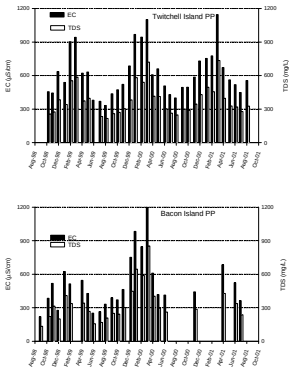


Figure 6-14 Monthly EC and TDS at the agricultural pumping plants at Bacon and Twitchell islands

The monitoring data for Bacon Island agricultural drainage were incomplete due to the amount of missing data for 2000 and 2001 water years. Although the average and median EC and TDS were lower at the Bacon Island agricultural drain than at the Twitchell Island drain station, the difference may not have existed if all the data had been available. A statistical comparison of EC and TDS between the 2 agricultural drainage sites could not be made.

Agricultural Drainage to the Sacramento River

Drainage from rice fields in the Sacramento Valley contributes considerable TDS to the Sacramento River during the drainage season of each water year. Figure 6-15 presents average daily EC data from the U.S. Bureau of Reclamation (USBR) station at Greenes Landing on the Sacramento River for the period July through October in water years 2000 and 2001. Greenes Landing is approximately 2 miles downstream from the Hood station (Figure 4-1). Rice drainage usually begins in August and continues until the end of September each year. In response to rice drainage, EC began to increase in mid-August and peaked in mid-September, then dropped close to normal levels after rice drainage was completed at the end of September. EC averages for September were 40% and 27% higher than July averages in 2000 and 2001, respectively.

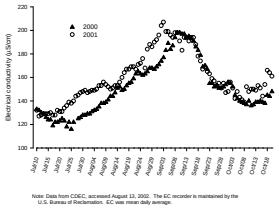


Figure 6-15 Effects of rice drainage on EC at Greenes Landing

The increase in EC in September was attributable presumably to rice drainage returns to the Sacramento River rather than to a reduction in the percent of water from the American River. Water at the Greenes Landing station is a mixture of water from both the upper Sacramento and American rivers. During each September of the reporting period, there was little variation in the amount of water released to the American River from Lake Natoma, and there were only minor changes of flow in the Sacramento River at Freeport (data not shown).

The Sacramento River also receives irrigation discharges from rice fields and row crops, which also increase salinity during June and July (see Chapter 4 section “The Hood Station”).

Agricultural Drainage to the San Joaquin River

As discussed, EC and TDS are higher in water collected at the SJR near Vernalis station (Figure 6-5) than at the Sacramento River at Hood. The high EC and TDS in the SJR may be attributable to intensive agricultural activities in the upper SJR watershed and the lack of large freshwater releases from dams, reservoirs, and tributaries to dilute summer runoff. Figure 6-16 is a watershed map showing the SJR and some non-MWQI stations where EC data were collected by the San Joaquin District of the California Department of Water Resources (DWR). A summary of mean daily EC for 2 stations on the SJR and 3 stations on 3 major tributaries are presented in Table 6-6. Although data periods varied, the data clearly demonstrate the differences among the stations.

Figure 6-16 Stations on the San Joaquin River from DMC to Vernalis (map)

Although agricultural return waters were not monitored for EC and TDS along the SJR from the Vernalis station to the upstream station near Stevinson during the reporting period, data suggest that additional loads of salts to the upper SJR existed (Table 6-6). Water inflows from the 3 major tributaries—Merced River near Stevinson, Tuolumne River at Modesto, and Stanislaus River at Ripon—were all low in EC (Table 6-6). Average EC for the waters of the 3 tributaries ranged from 102 to 180 µS/cm; the range for median EC was similar (Table 6-6). If there were no additional loads of salts, the EC of the SJR would have been low.

Table 6-6 EC at stations on the San Joaquin River and its major tributaries

The contributions of high EC from both the Salt Slough and Mud Slough inflows are clearly demonstrated by comparing mean daily EC at 3 stations—the SJR near Stevinson, the SJR near Patterson, and the Merced River near Stevinson. The SJR near Stevinson and the SJR near Patterson are about 38 stream miles apart; the mouth of the Merced River is between the 2 stations, approximately 24 miles upstream from the SJR near Patterson (Figure 6-16). At the SJR near Stevinson station, average daily EC was 1,142 µS/cm, and median was 1,200 µS/cm (Table 6-6). High EC at this station was due perhaps to both low flows and high salt concentration in inflows. During the reporting period, average flow at this station was 150 cubic feet per second (cfs) with a median of 57 cfs. In contrast, average flow at downstream SJR near Patterson was 1,262 cfs with a median of 913 cfs. These values were 8 to 16 times greater than those at the SJR near Stevinson station.

The SJR near Patterson station receives inflows from the Merced River, which is low in EC as indicated by low EC at the Merced River near Stevinson station (Table 6-6). Despite higher flows and dilutional inflows, average EC at SJR near Patterson was 1,128 µS/cm with a median of 1,168 µS/cm, which is similar to those at the upstream SJR near Stevinson station (Table 6-6). This is due to the fact that the Patterson station also receives inflows from both Salt Slough and Mud Slough.

Although monitoring data for both Salt Slough and Mud Slough were not available, EC in drainage waters of Salt and Mud sloughs would have to be high to counter the dilutional effects of low-EC inflows from the Merced River. Both Salt Slough and Mud Slough collect agricultural drainage returns from the watershed. The irrigation return waters are concentrated water from the DMC, which contains moderately high salts even before

condensation in agricultural lands. The soils in some of the areas were developed from geologic marine deposits, which also contribute salts to the drainage waters.

In addition to irrigated agriculture, many dairy farms are in the upper SJR watershed in Stanislaus and Merced counties. Although estimates for TDS loads are not available, discharges from these operations increase EC and TDS in both groundwater and surface water. The effects of dairies on water quality are discussed extensively in Chapter 4 of *Sanitary Survey Update 2001* (DWR 2001).

Urban Drainage in and near the Delta

Many wastewater treatment plants and urban drainage areas are scattered throughout the Delta and the watersheds that contribute runoff to the Delta. The amount of salts contributed by these wastewater treatment operations and other urban drainage to Delta source waters are discussed in *Sanitary Survey Update 2001*, especially in Chapter 4 (DWR 2001).

During the reporting period, MWQI monitored one urban drainage canal in the Sacramento River watershed—NEMDC at El Camino in north 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. The average and median EC and TDS were considerably higher in NEMDC 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 6-2 and Table 6-3). Instead, EC and TDS at NEMDC were quite similar to those of the channel stations, which are heavily influenced by agricultural drainage, inputs from the SJR, and (to a lesser extent) seawater influence.

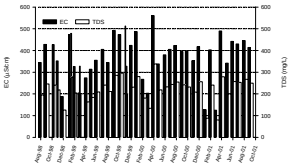


Figure 6-17 EC and TDS at NEMDC station

Average and median EC and TDS at NEMDC were similar to those of the channel stations (Table 6-2 and Table 6-3). A strong and persistent seasonal pattern was not observed. Episodic events could drastically alter this general pattern such as the increases in EC and TDS in September of 1998 and 1999 and in April 2000 and 2001 (Figure 6-17). However, EC and TDS may be significantly lower during or immediately after a sustained heavy rainfall and runoff such as those during January and March of 2001. Both EC and TDS increased slightly during the dry months, especially during the 2000 water year, but average EC and TDS during the dry months were not significantly different from those during the wet months of the reporting period (p was 0.215 and 0.200 for EC and TDS, respectively).

Table 6-1 Summary of TDS/EC ratios at 14 MWQI stations

Station	Sample number	Range	Average	Median
American and Sacramento River stations				
American River at E.A. Fairbairn WTP	37	0.60–0.97	0.71	0.71
West Sacramento WTP Intake	37	0.51–0.74	0.62	0.62
Sacramento River at Hood	157	0.49–0.80	0.62	0.61
Sacramento River at Mallard Island	34	0.51–0.64	0.56	0.57
San Joaquin River stations				
San Joaquin River near Vernalis	156	0.50–0.65	0.58	0.58
San Joaquin River at Highway 4	36	0.54–0.64	0.58	0.58
Channel stations				
Old River at Station 9	37	0.50–0.64	0.57	0.56
Old River at Bacon Island	37	0.52–0.71	0.57	0.57
Delta diversion stations				
Banks Pumping Plant	29	0.51–0.67	0.56	0.55
Delta-Mendota Canal	30	0.52–0.70	0.56	0.56
Contra Costa Pumping Plant	29	0.51–0.73	0.57	0.56
Agricultural drainage stations				
Bacon Island Pumping Plant	25	0.58–0.72	0.65	0.65
Twitchell Island Pumping Plant	34	0.56–0.68	0.61	0.60
Urban drainage station				
Natomas East Main Drainage Canal	41	0.54–0.69	0.60	0.60

Table 6-2 Summary of electrical conductivity at 14 MWQI stations (µS/cm)

Station	Sample number	Range	Majority data range	Data Dispersion (IQR)	Average	Median
American and Sacramento River stations						
American River at E.A. Fairbairn WTP	37	40–71	44–68	47–62	52	54
West Sacramento WTP Intake	38	112–241	124–212	140–179	161	155
Sacramento River at Hood	160	96–228	115–207	137–178	158	155
Sacramento River at Mallard Island	35	171–17,600	187–14,130	367–6,070	4,199	2,120
San Joaquin River Stations						
San Joaquin River near Vernalis	160	195–1,120	231–865	351–700	543	549
San Joaquin River at Highway 4	37	218–937	226–870	415–686	539	510
Delta channel stations						
Old River at Station 9	38	187–908	204–776	263–470	391	350
Old River at Bacon Island	38	162–1,040	175–868	223–393	372	290
Diversion stations						
Banks Pumping Plant	29	215–725	228–703	291–466	408	384
Delta-Mendota Canal	30	208–862	254–693	312–517	443	422
Contra Costa Pumping Plant	30	161–1,390	190–1,205	247–732	522	367
Agricultural drainage stations						
Bacon Island Pumping Plant	25	220–1,216	254–955	370–609	513	442
Twitchell Island Pumping Plant	35	332–1,145	377–1,008	464–708	621	561
Urban drainage station						
Natomas East Main Drainage Canal	41	125–561	188–492	328–430	374	397

Table 6-3 Summary of statistics for total dissolved solids (mg/L)

Station	Sample number	Range	Majority data range	Data dispersion (IQR)	Average	Median
American and Sacramento River stations						
American River at E.A. Fairbairn WTP	37	30–54	31–47	35–42	39	39
West Sacramento WTP Intake	37	71–148	78–130	89–110	100	97
Sacramento River at Hood	157	61–137	72–126	85–108	97	95
Sacramento River at Mallard Island	34	101–10,603	115–8,382	194–3,629	2,458	1,215
San Joaquin River stations						
San Joaquin River near Vernalis	156	113–652	137–505	203–409	315	318
San Joaquin River at Highway 4	36	122–507	129–501	227–394	313	315
Delta channel stations						
Old River at Station 9	37	112–465	118–428	151–277	223	204
Old River at Bacon Island	37	90–551	102–480	133–221	210	162
Diversion stations						
Banks Pumping Plant	29	123–388	128–385	170–262	228	220
Delta Mendota Canal	30	120–501	145–376	184–297	248	234
Contra Costa Pumping Plant	29	92–797	107–680	138–421	298	228
Agricultural drainage stations						
Bacon Island Pumping Plant	25	134–853	159–634	237–403	334	298
Twitchell Island Pumping Plant	34	216–735	243–633	281–426	383	344
Urban drainage station						
Natomas East Main Drainage Canal	41	80–338	126–296	200–256	224	233

Table 6-4 Chloride and sulfate at 14 MWQI monitoring stations (mg/L)

Station	Chloride				Sulfate			
	Sample number	Range	Average	Median	Sample number	Range	Average	Median
American and Sacramento River stations								
American River at E.A. Fairbairn WTP	37	1–2	2	2	31/37[a]	1–6	2	2
West Sacramento WTP Intake	38	2–12	5	4	38	3–15	7	6
Sacramento River at Hood	158	2–11	6	5	159	2–15	7	7
Sacramento River at Mallard Island	30	10–4,660	964	458	31	11–637	138	58
San Joaquin River stations								
San Joaquin River near Vernalis	153	16–139	64	65	153	23–164	67	68
San Joaquin River at Highway 4	35	19–128	64	60	35	22–130	65	65
Delta channel stations								
Old River at Station 9	34	13–190	48	39	38	12–71	29	26
Old River at Bacon Island	34	10–246	45	30	38	8–42	23	22
Diversion stations								
Banks Pumping Plant	35	18–151	48	43	38	14–60	33	31
Delta-Mendota Canal	28	19–122	55	51	31	14–125	40	33
Contra Costa Pumping Plant	27	9–224	65	36	30	11–195	54	38
Agricultural drainage stations								
Bacon Island Pumping Plant	25	18–132	62	49	24	10–343	71	44
Twitchell Island Pumping Plant	31	45–191	100	90	33	11–127	39	28
Urban drainage station								
Natomas East Main Drainage Canal	41	6–71	41	44	41	6–34	21	21

a. Positive detects/total sample number

Table 6-5 Summary of sodium, calcium, and magnesium at 14 MWQI monitoring stations[a]

Station	Sample number	Sodium			Calcium+ magnesium			Sodium/(sodium + calcium + magnesium)		
		Range	Average	Median	Range	Average	Median	Range	Average	Median
American and Sacramento River stations										
American River at E.A. Fairbairn WTP	37	2–3	2	2	5.0–10.0	7.2	7.0	0.18–0.29	0.24	0.23
West Sacramento WTP Intake	38	5–16	10	9	13.8–28.9	19.5	19.0	0.26–0.39	0.33	0.33
Sacramento River at Hood	159	5–17	10	10	11.9–26.1	18.0	18.0	0.25–0.42	0.35	0.35
Sacramento River at Mallard Island	35	11–3,060	697	314	17.0–501.1	121.4	64.0	0.38–0.88	0.73	0.83
San Joaquin River stations										
San Joaquin River near Vernalis	159	18–135	59	60	16.0–80.0	37.9	39.0	0.51–0.64	0.59	0.58
San Joaquin River at Highway 4	37	20–104	59	56	18.0–63.0	40.1	41.0	0.51–0.66	0.58	0.58
Delta channel stations										
Old River at Station 9	38	16–112	42	35	17.0–42.0	27.6	27.5	0.45–0.75	0.57	0.55
Old River at Bacon Island	38	13–147	41	27	15.3–41.0	25.1	24.0	0.42–0.78	0.56	0.53
Diversion stations										
Banks Pumping Plant	37	18–91	41	36	20.0–40.0	27.6	26.0	0.46–0.72	0.57	0.56
Delta-Mendota Canal	31	18–102	47	42	20.0–60.0	31.5	30.0	0.47–0.70	0.58	0.57
Contra Costa Pumping Plant	30	12–188	59	37	16.4–82.0	34.8	30.0	0.41–0.73	0.58	0.56
Agricultural drainage stations										
Bacon Island Pumping Plant	25	20–88	48	46	21.0–133.0	45.0	39.0	0.40–0.61	0.53	0.53
Twitchell Island Pumping Plant	35	38–132	72	64	23.0–86.0	40.7	36.0	0.53–0.71	0.64	0.64
Urban drainage station										
Natomas East Main Drainage Canal	41	8–50	35	38	12.0–53.0	32.6	30.0	0.36–0.65	0.51	0.50

a. Data unit is mg/L except for the unitless sodium/(sodium + calcium + magnesium) ratio.

Table 6-6 Electrical conductivity at stations on the San Joaquin River and its major tributaries (µS/cm)

Station	Sampling days	Summary period	Range	Majority data range	Data dispersion (IQR)	Average	Median
San Joaquin River near Stevinson	426	07/27/2000–09/30/2001	141–1,874	432–1,624	935–1,432	1,142	1,200
Merced River near Stevinson	433	07/24/2000–09/30/2001	45–373	59–301	134–237	180	175
San Joaquin River at Patterson	326	11/01/2000–09/30/2001	408–1,619	608–1,481	1,029–1,265	1,128	1,168
Tuolumne River at Modesto	272	01/01/2001–09/30/2002	49–325	63–267	123–211	166	165
Stanislaus River at Ripon	785	08/01/1999–09/30/2001	52–170	68–145	85–99	102	100

Figure 6-1 Relationship between EC and TDS at 14 MWQI stations

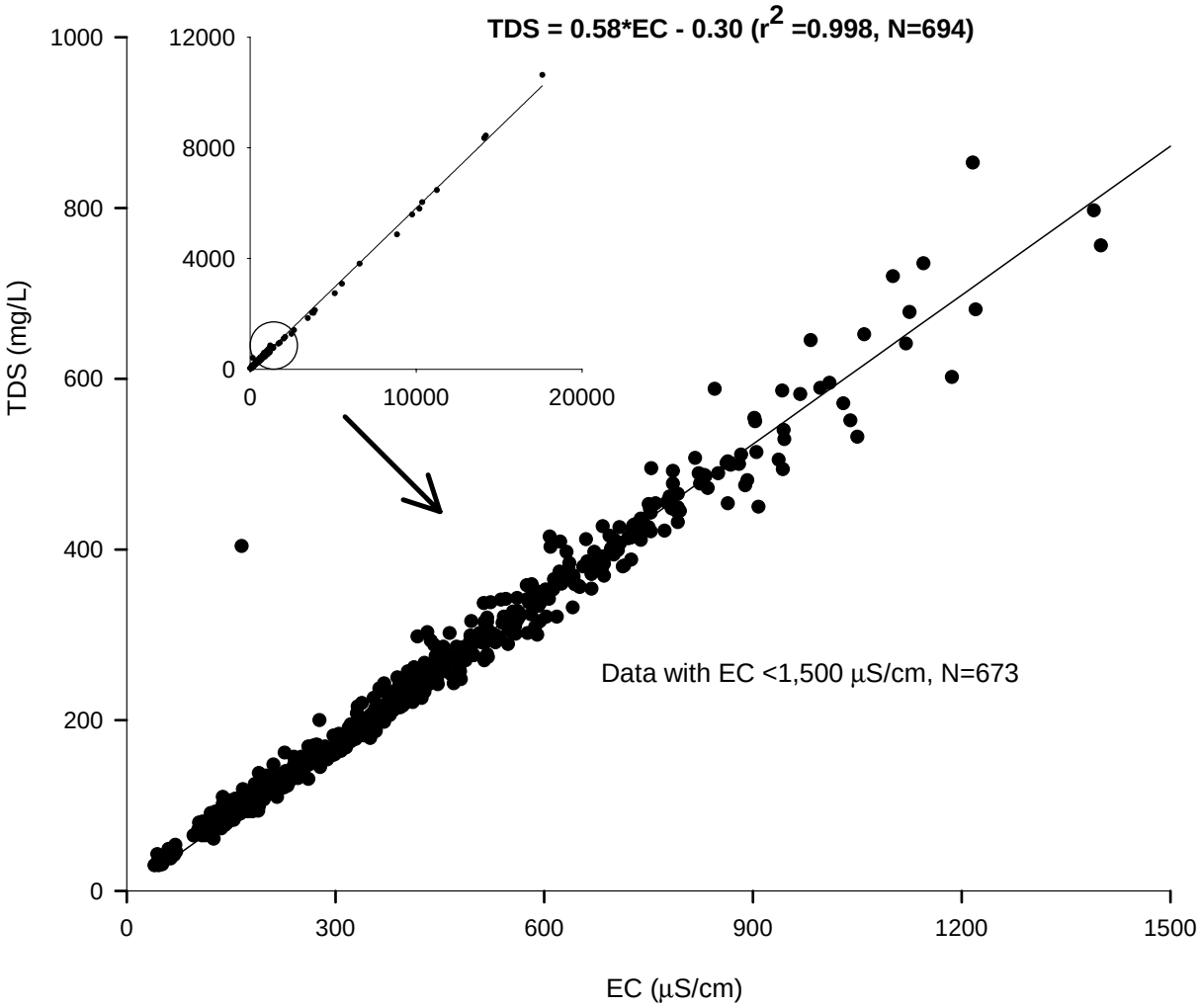


Figure 6-2 Monthly EC and TDS at the American River WTP Intake

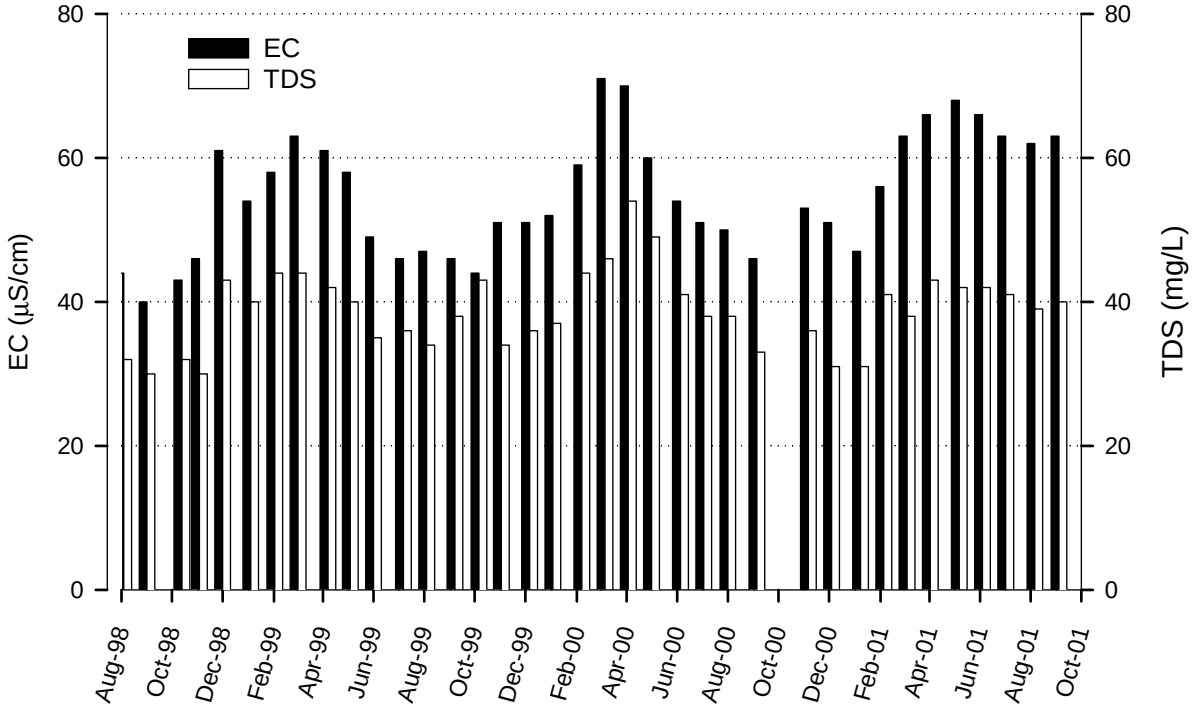


Figure 6-3 Monthly EC and TDS at the West Sacramento WTP Intake

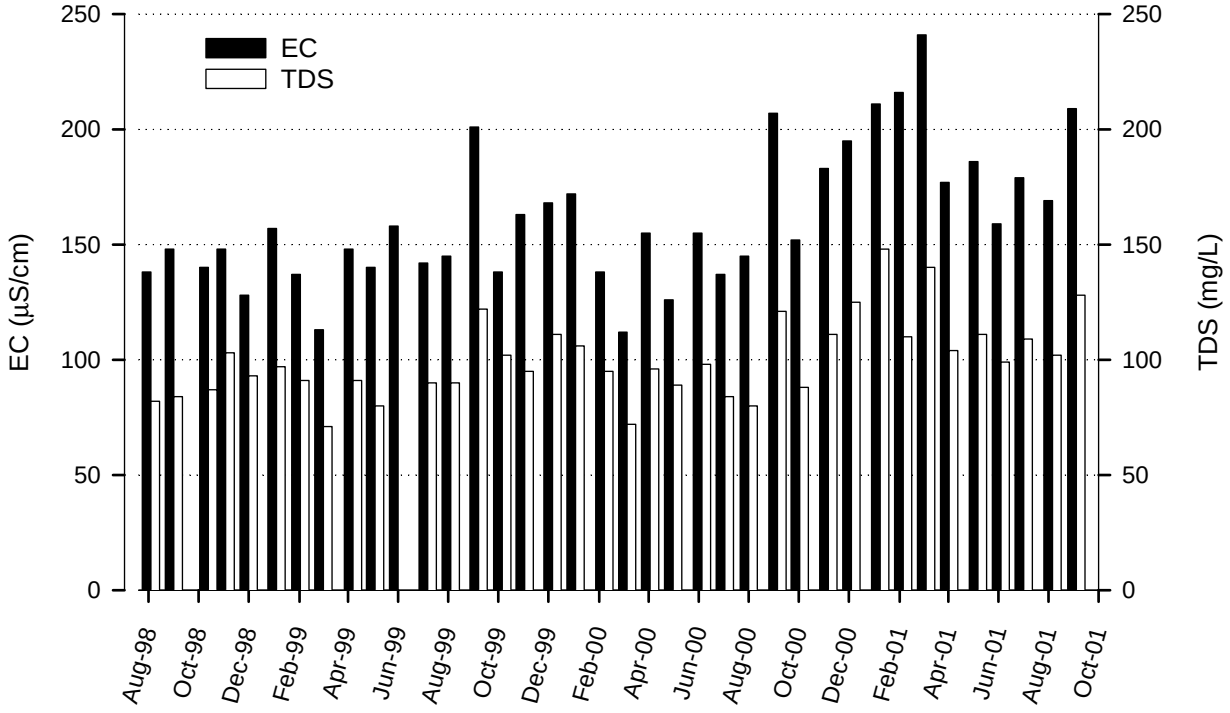


Figure 6-4 Weekly EC and TDS at the Hood station
(Loess smoothing parameter = 0.05)

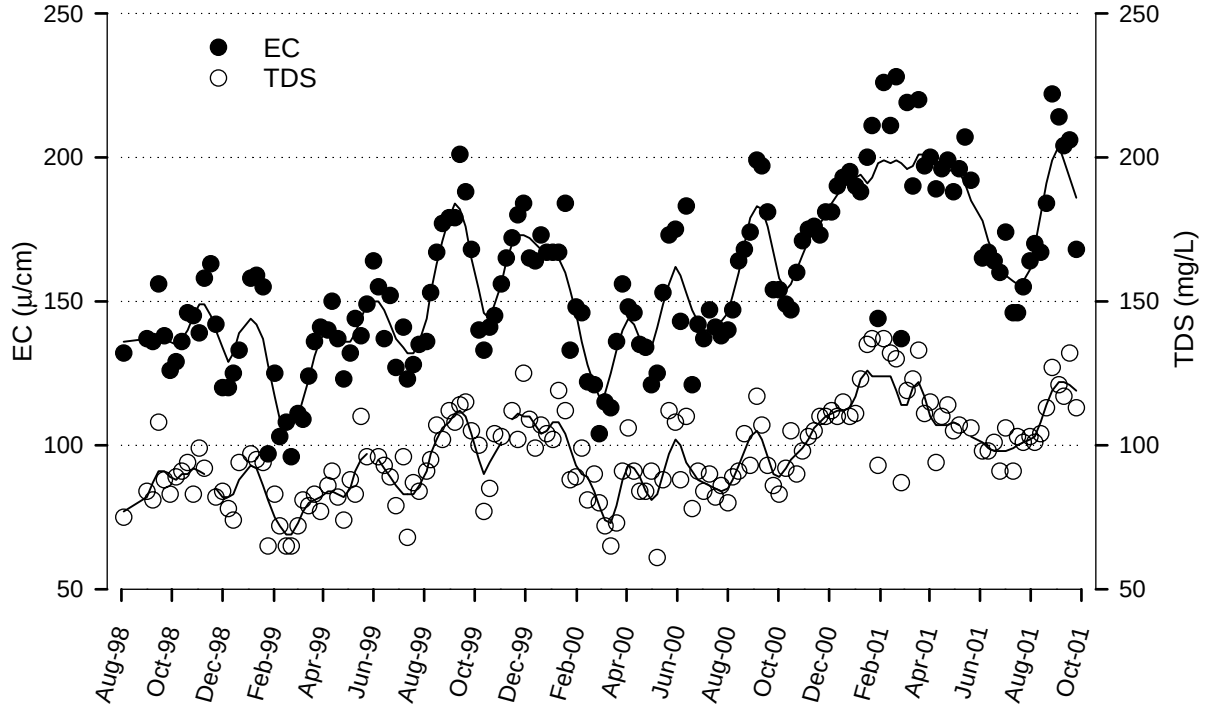


Figure 6-5 Weekly EC and TDS at San Joaquin River near Vernalis
(Loess smoothing parameter = 0.05)

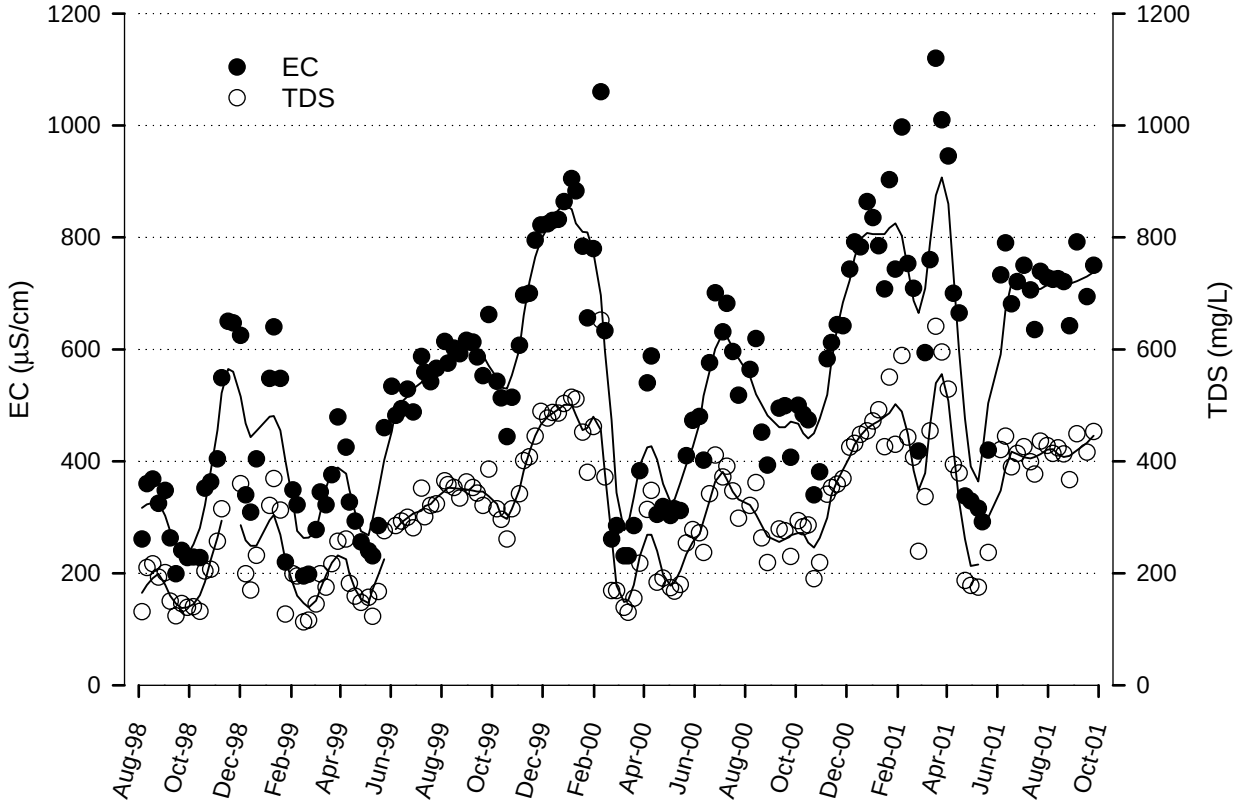


Figure 6-6 Monthly EC and TDS at the San Joaquin River at Highway 4

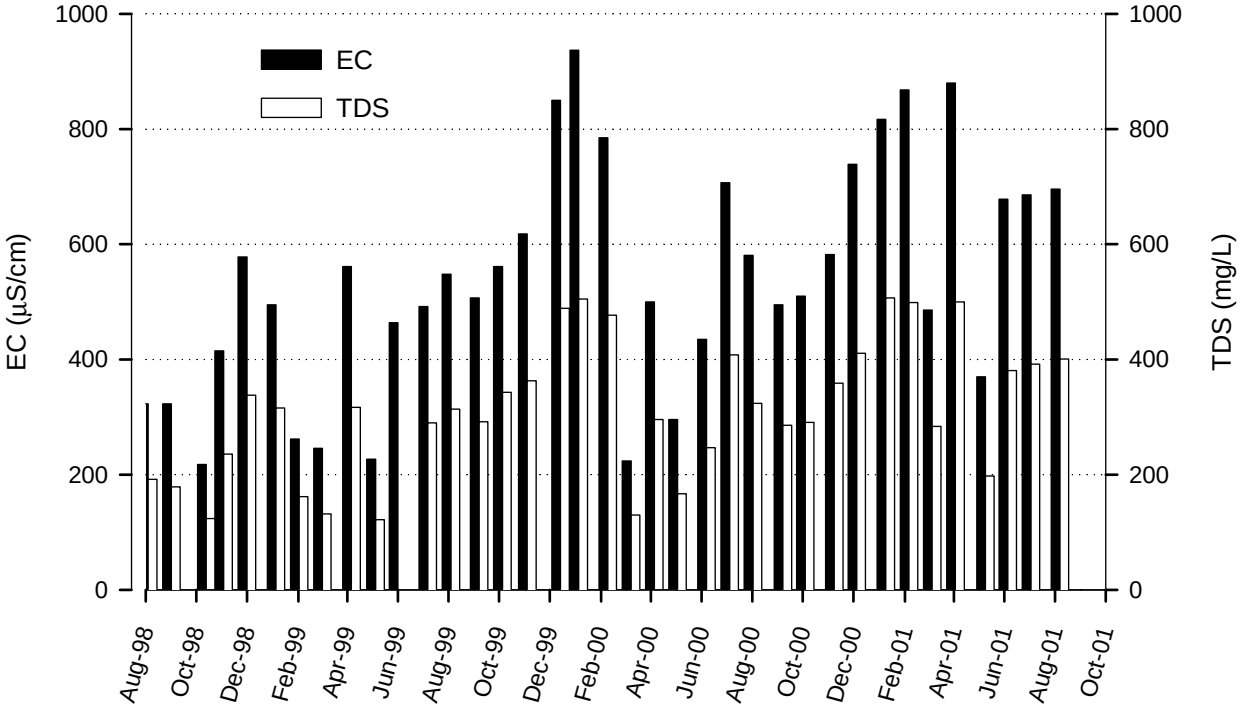


Figure 6-7 Monthly EC and TDS at Old River at Station 9

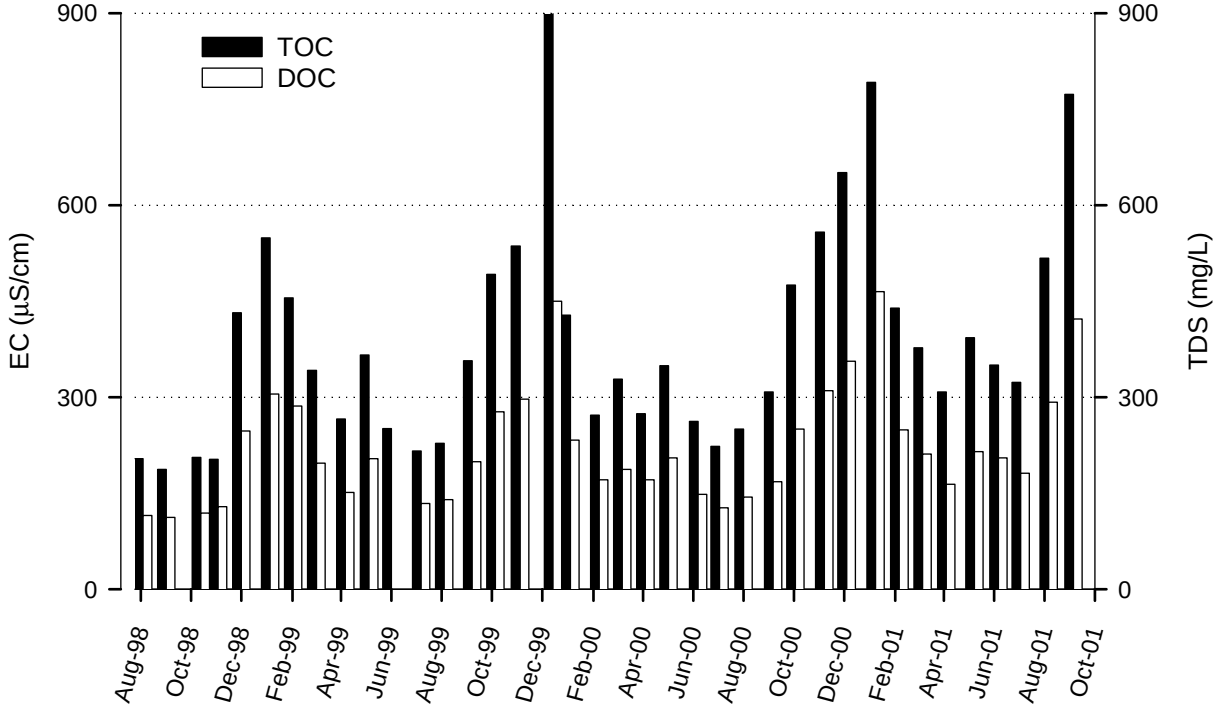


Figure 6-8 Monthly EC and TDS at the Bacon Island Station on Old River

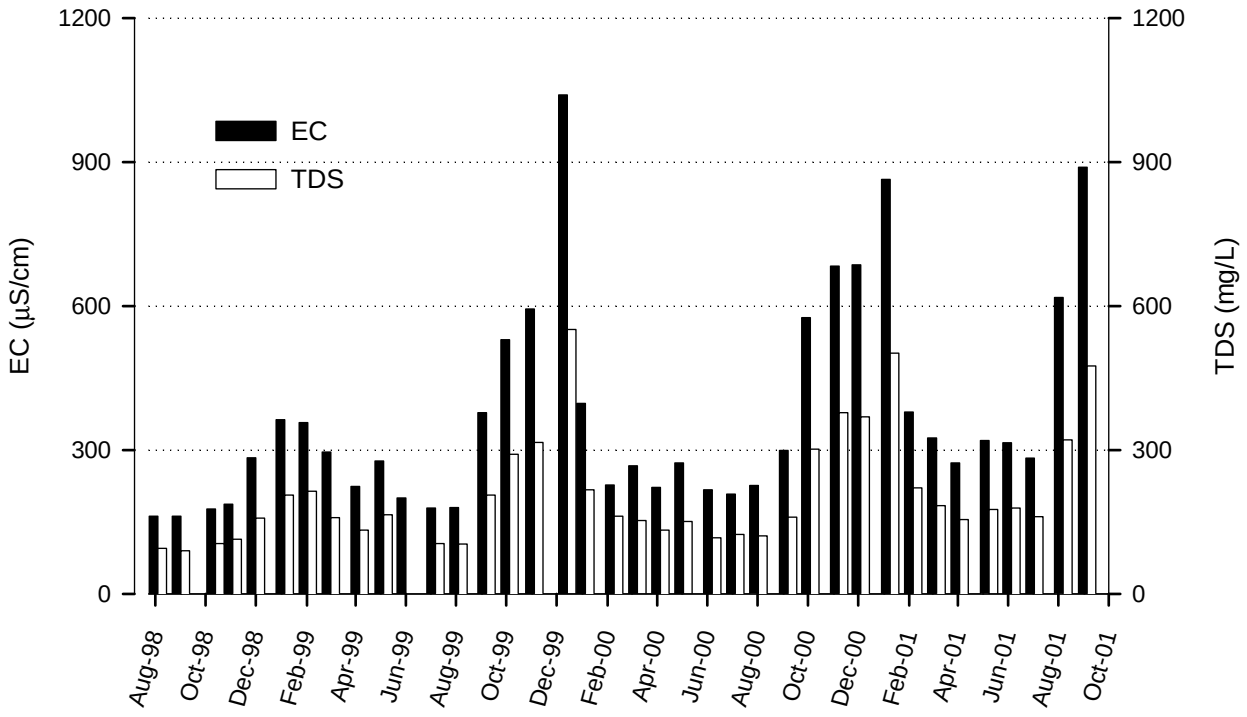


Figure 6-9 Monthly EC and TDS at three Delta diversion stations

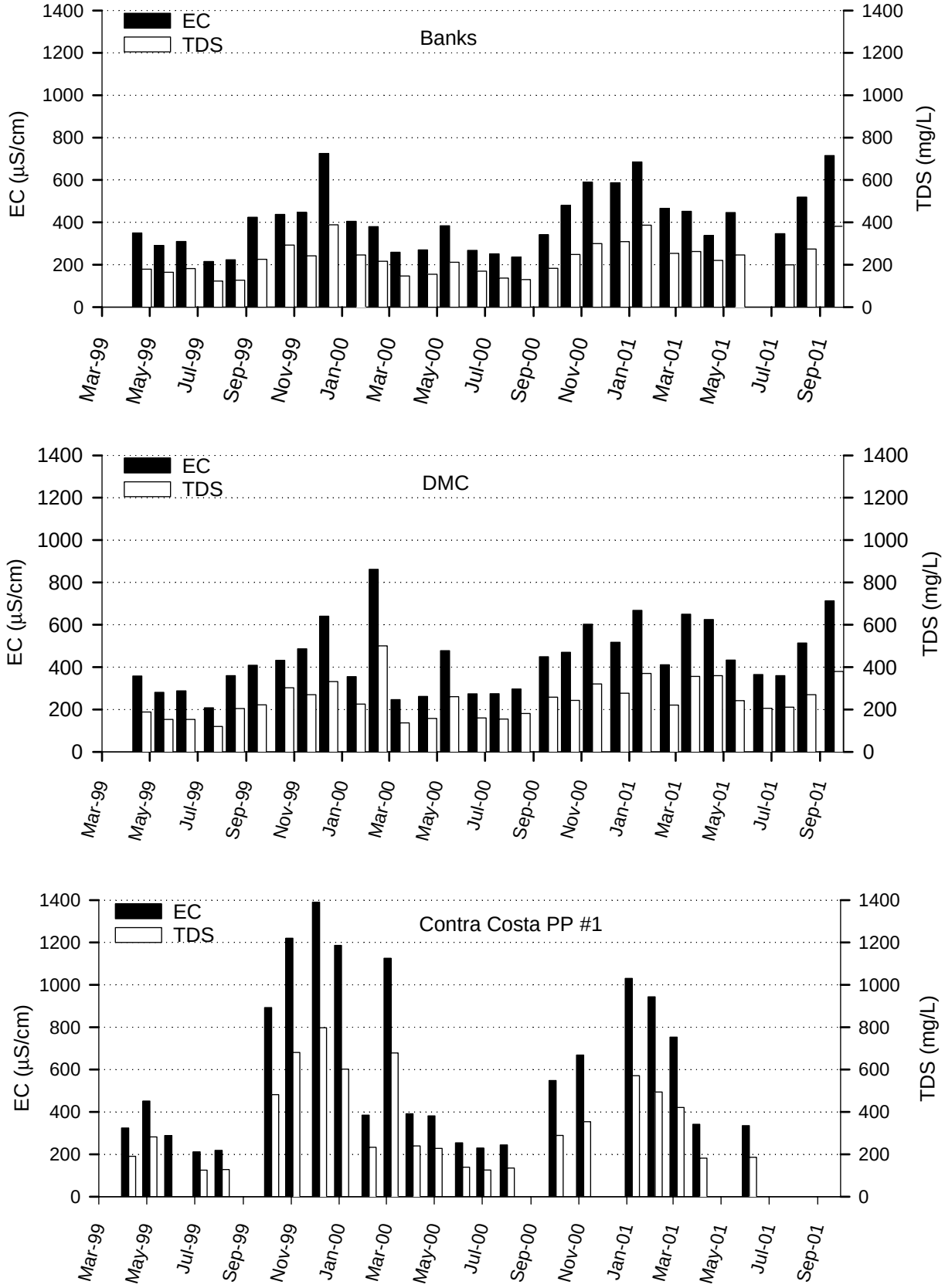


Figure 6-10 EC, chloride, and sulfate relationships

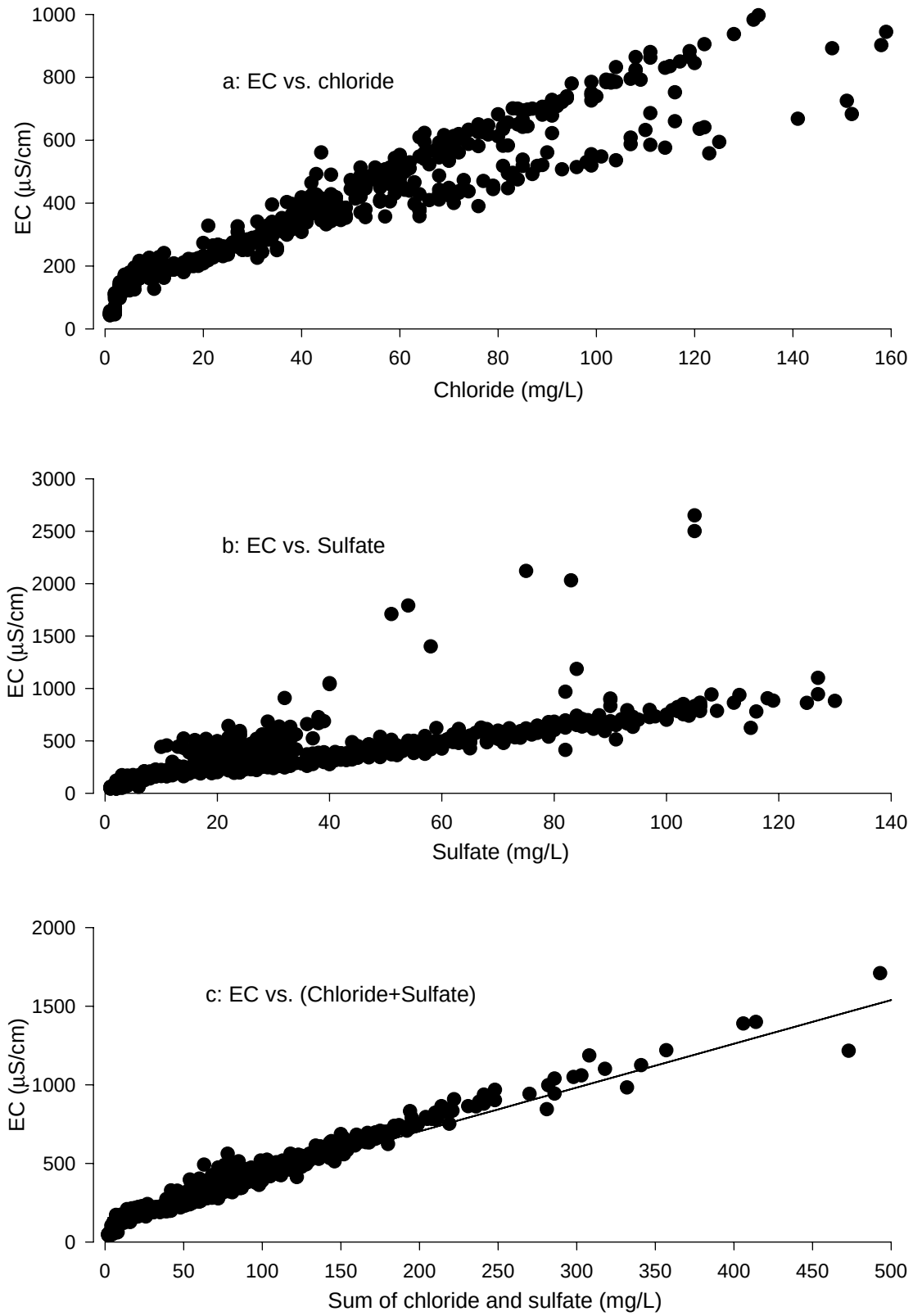
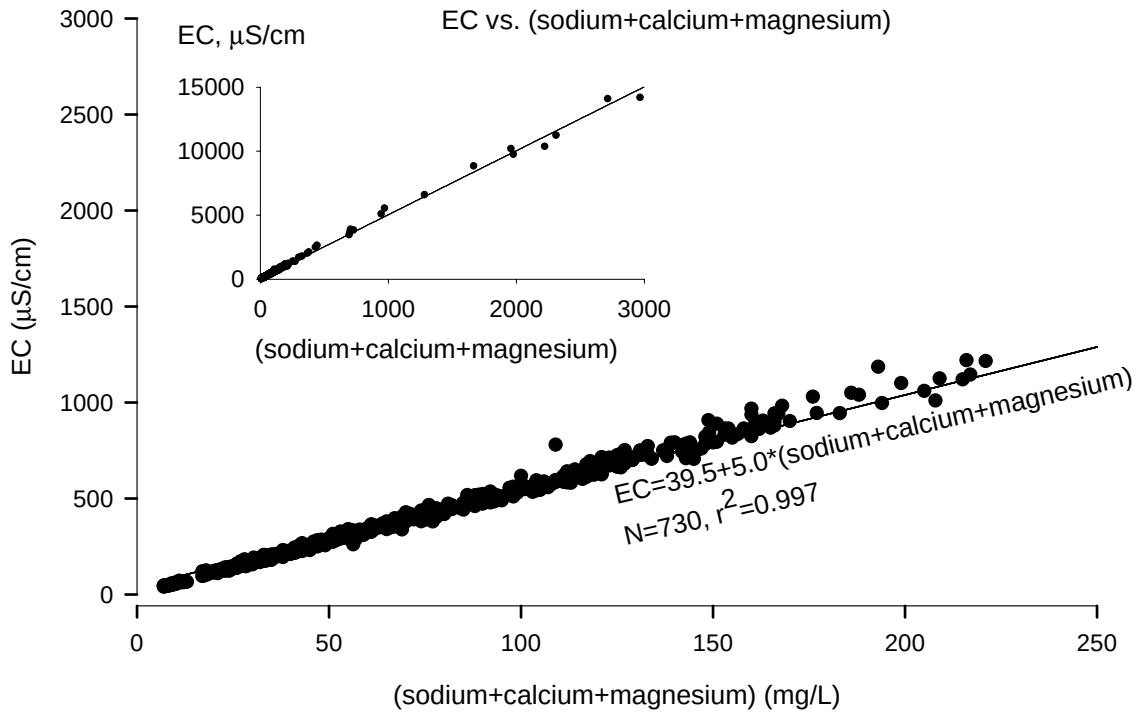


Figure 6-11 Relationships between EC and major cations at 14 MWQI stations



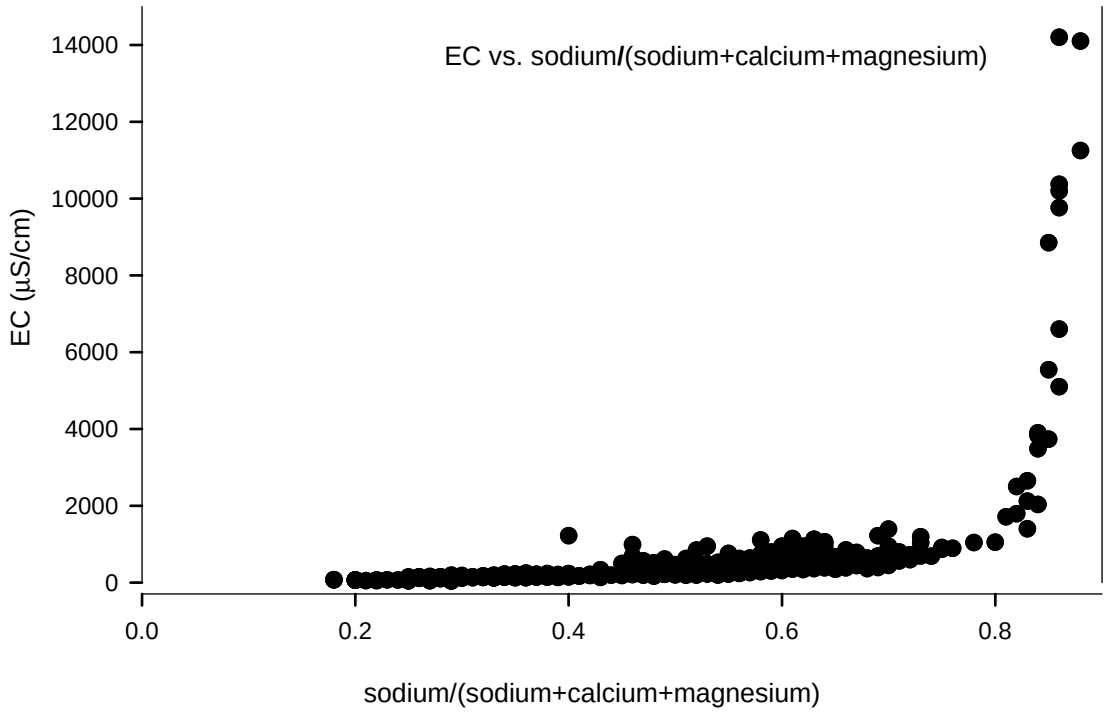
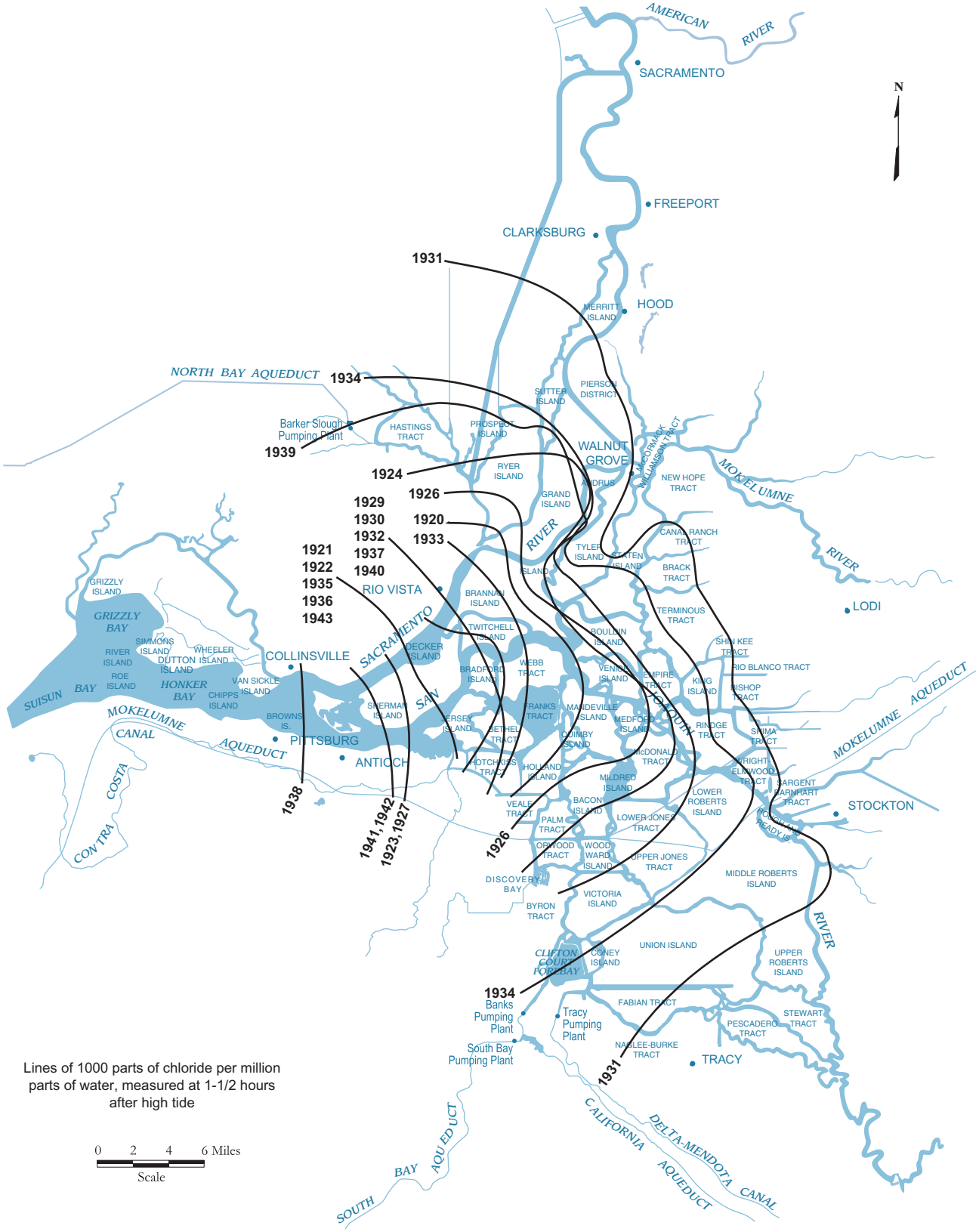


Figure 6-12 Seawater influence in the Delta, 1921-1943



Source: Department of Water Resources, Sacramento - San Joaquin Delta Atlas, 1993. Reprinted from *Sanitary Survey Update 2001*

Figure 6-13 Monthly EC and TDS at the Mallard Island station

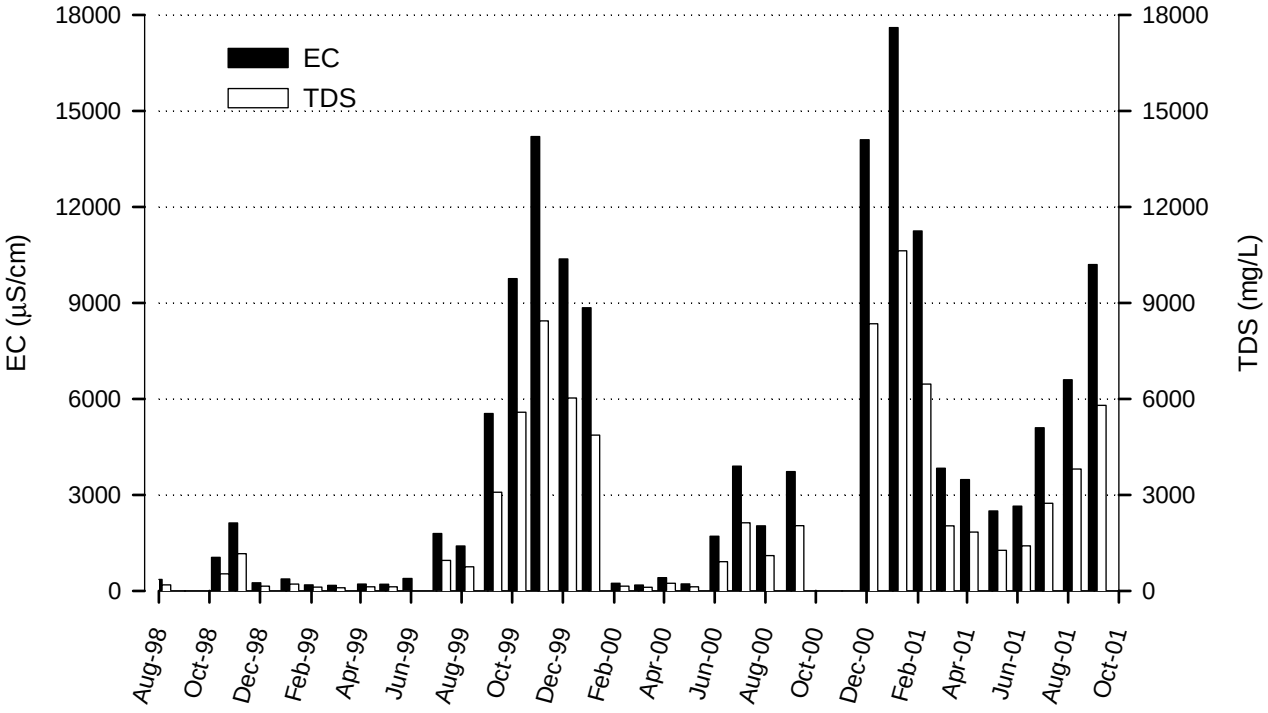


Figure 6-14 Monthly EC and TDS at the agricultural pumping plants at Bacon and Twitchell islands

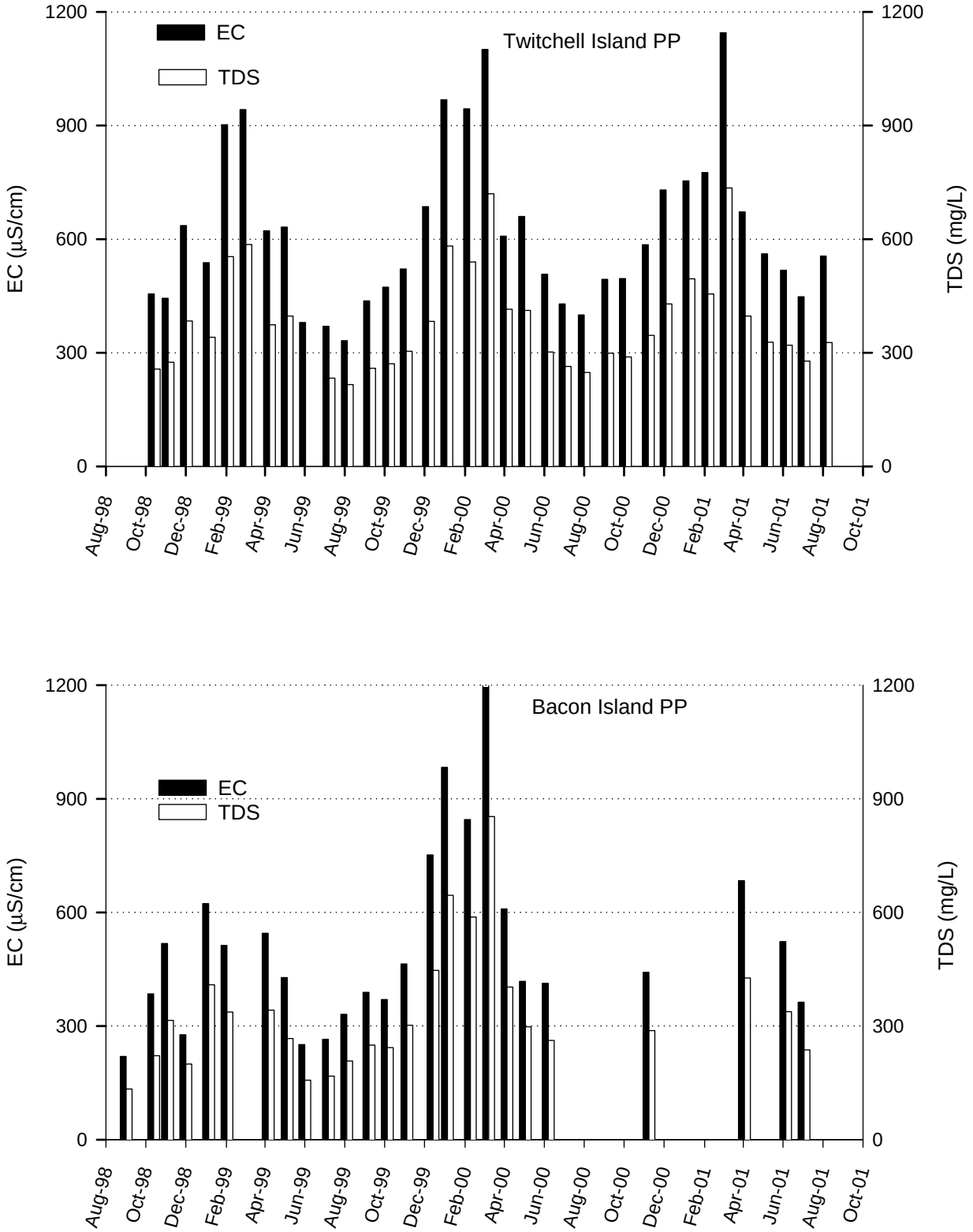
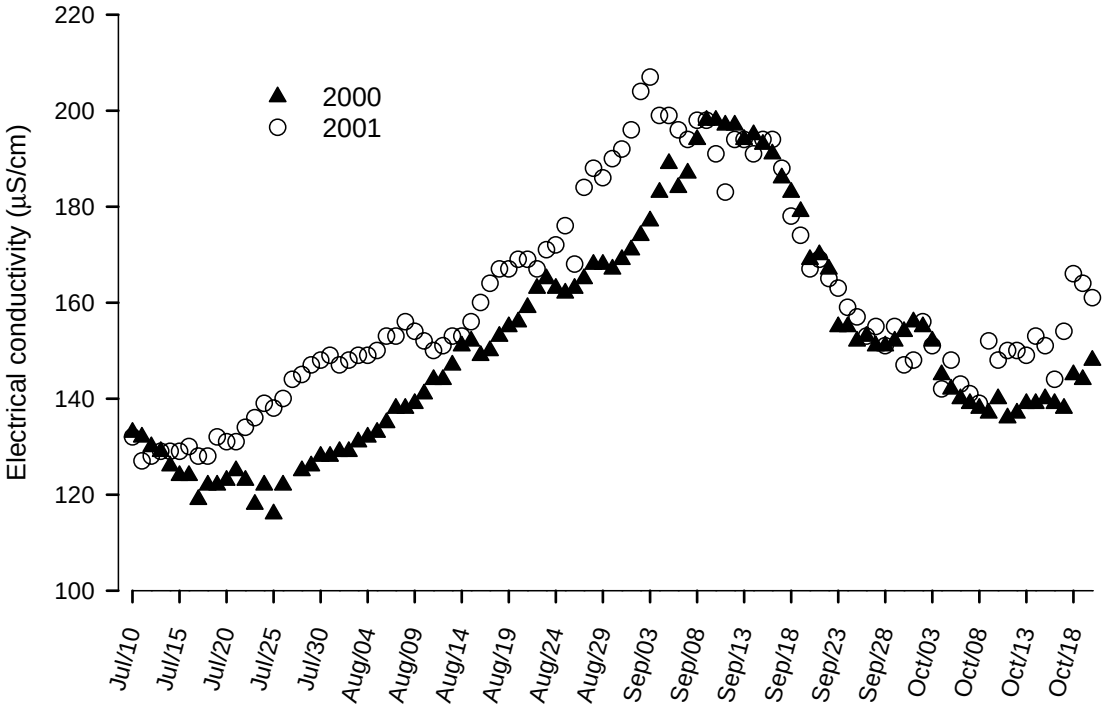


Figure 6-15 Effects of rice drainage on EC at Greenes Landing



Note: Data from CDEC, accessed August 13, 2002. The EC recorder is maintained by the U.S. Bureau of Reclamation. EC was daily average.

Figure 6-16 Stations in the San Joaquin River watershed from Delta-Mendota Canal to Vernalis

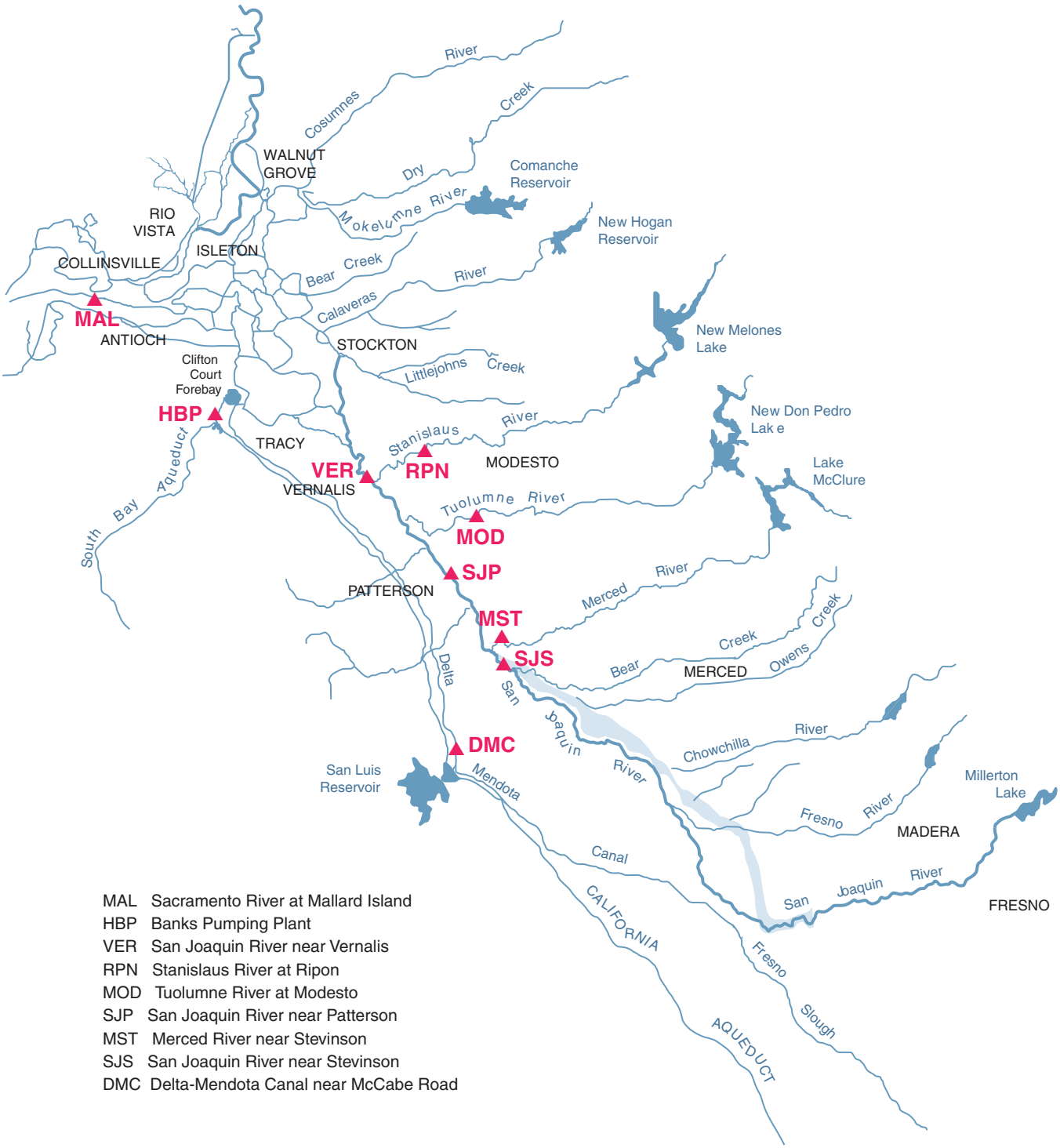
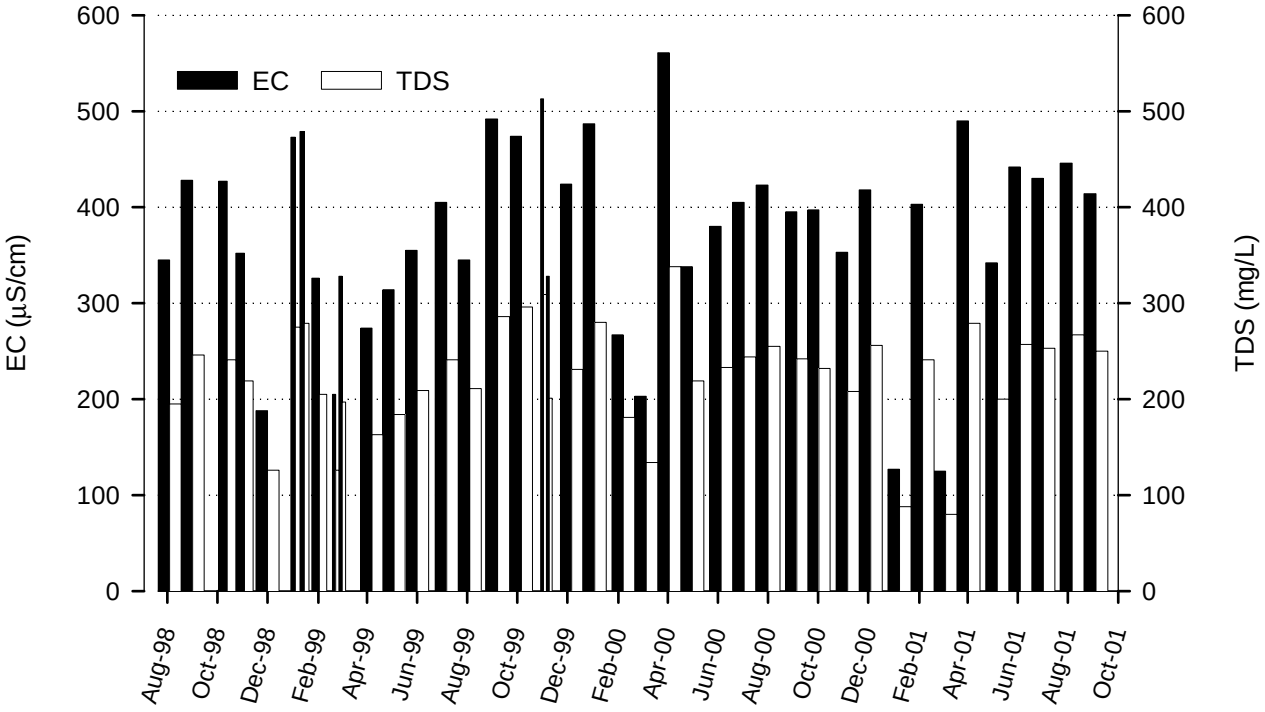



Figure 6-17 EC and TDS at the Natomas East Main Drainage Canal station