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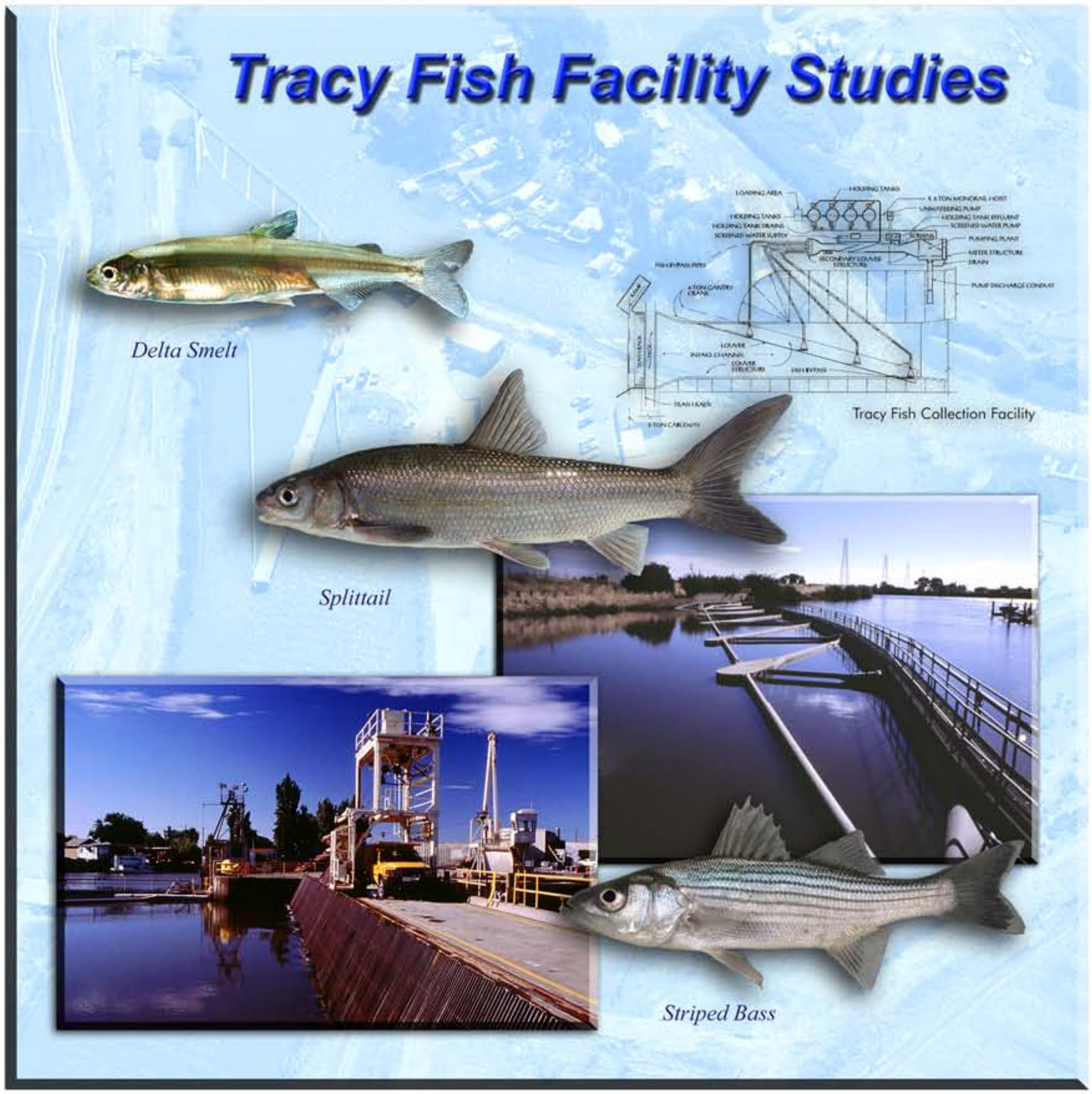

Semicontinuous Water Quality Measurements at the Tracy Fish Collection Facility, Tracy, California, April 2002 to March 2003

Volume 26

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Bureau of Reclamation, Technical Service Center
Fisheries Applications Research Group, D-8290
PO Box 25007
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Water quality variables including temperature, pH, dissolved oxygen, electrical conductivity, oxidation-reduction potential, and turbidity were measured at 30-minute intervals using a calibrated Hydrolab Datasonde 4a multi-probe in the Old River at the Bureau of Reclamation's Tracy Fish Collection Facility, located in the south Sacramento-San Joaquin River Delta, California. This report summarizes the third year of baseline water quality data collection covering the period from April 1, 2002, through March 31, 2003. The water quality data were compared to local meteorology, hydrology, tides, export pumping at State and Federal pumping plants, fish salvage at the TFCF, and temporary barrier installation and removal schedule data. Third-year water quality data showed responses to increased runoff in the Sacramento River and continued drought in the southern Central Valley. Annual ranges (with median values in parentheses) were 8.2 to 26.9 °C. (17.7 °C) for temperature, 195 to 1,020 :S/cm (400 :S/cm) for conductivity, 4.04 to 12.5 mg/L (7.94 mg/L) for dissolved oxygen, 279 to 773 mV (581 mV) for redox potential, 4.60 to 8.67 (7.52) for pH, and $<$ 5 to $>$150 NTU (17.6 NTU) for turbidity. As with the previous 2-years' data, the most significant influence on water quality appears to be tides, the status of nearby temporary channel barriers, and the operation of the Delta Cross Channel gates near Walnut Grove, California. When barriers are installed and the Cross Channel gates are open, from April through October, daily variations and maximum EC are much lower than when higher conductivity water from the San Joaquin River flows relatively unimpeded to the TFCF.

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by

Doug Craft[1], Ron Housewright[2], and John Fields[2]

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1 Bureau of Reclamation - Technical Service Center
Fisheries Applications Research Group, D-8290
PO Box 25007
Denver CO 80225

2 Bureau of Reclamation - Mid-Pacific Regional Office
Environmental Monitoring Branch, MP-150
2800 Cottage Way
Sacramento CA 95825

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Series Editor

Doug Craft
U.S. Department of the Interior – Bureau of Reclamation
Technical Service Center
Fisheries Applications Research Group, D-8290
PO Box 25007
Denver CO 80225-0007

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EXECUTIVE SUMMARY

This report presents semicontinuous data for several water quality variables measured using a Hydrolab Datasonde 4a multi probe (Hydrolab, Inc.) installed at the Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF), Tracy, California. The TFCF is the fish salvage facility at the head of the intake canal for the Tracy Pumping Plant (TPP). It removes entrained fish from Old River water before it is pumped into Reclamation's Delta Mendota Canal by the TPP. These facilities are located in the southern region of the Sacramento-San Joaquin River Delta (South Delta), which flows into San Francisco Bay in northern California.

The purpose of this study is to provide reliable baseline water quality data from the TFCF intake channel to aid fishery scientists and engineers performing on-site experimental work to improve fish salvage. This program is a sub project of the Tracy Fish Facility Improvement Program (TFFIP), administered by the Reclamation Mid-Pacific Region, Sacramento, California, as required by the Central Valley Project Improvement Act of 1992 (CVPIA) .

This is the third year that a calibration and maintenance program has been in place for the Datasonde probe and the third report providing validated baseline water quality data for the TFCF. The variables measured in the Old River at the TFCF intake included temperature (T, in degrees Celsius, °C), pH (in standard units, SU), dissolved oxygen (DO in milligrams per liter, mg/L), electrical conductivity (EC, in microsiemens per centimeter, : S/cm), oxidation-reduction (or redox) potential (Eh, in millivolts, mV), and turbidity (in Nephelometric turbidity units, NTU). The multi probe was cleaned and calibrated on a weekly schedule, and data were downloaded at monthly intervals from April 2002 through March 2003. Conterminous data sets for meteorology, tides, hydrology and water export pumping, fish salvage, and schedules for temporary barrier installation and removal were also compared to the water quality data. The water quality and supplemental data have been validated, peer-reviewed, collated and archived in a Microsoft® Access database, and are available on request.

Table 1 provides a summary of minimum, maximum, and median values for each of the measured water quality variables. During the third year of this study, total precipitation at the TFCF was similar to the previous 2-year record; however, discharge in the San Joaquin River was down 13.6 percent, continuing the downward trend observed to date. This decrease in southern Central Valley runoff is thought to be the cause for the highest maximum EC, 1,040 : S/cm, observed during the 3-year period of record at the TFCF. Notably, the

TABLE 1.—Summary water quality values observed in the intake channel of the Tracy Fish Collection Facility from April 1, 2002, through March 31, 2003

Water Quality Variable	Minimum Value	Maximum Value	Median Value
Temperature, in degrees Celsius, °C.	8.2	26.9	17.7
Electrical conductivity, in microsiemens per centimeter, :S/cm	195	1020	400
Dissolved oxygen, in milligrams per liter, mg/L	4.04	12.5	7.94
Oxidation-reduction potential, in millivolts (adjusted), mV	279	773	581
pH, in standard units, su	4.6	8.67	7.52
Turbidity, in Nephelometric turbidity units, NTU	1-5 (detection limit)	>150 (upper calibration limit)	17.6

Sacramento River showed a 25.7 percent increase for third-year annual discharge. This increase in northern Central Valley runoff is thought to have caused the lowest minimum EC (195 :S/cm) and median EC (400 :S/cm) yet observed at the TFCF during this study.

Median percent DO saturation was 84.1 percent. DO saturation percentage was below 50 percent 0.10 percent of the time (around 8 hours during the year), and below 75 percent 10 percent of the time. pH less than 7.00 was observed 5.0 percent of the time and pH greater than 8.00 was observed 5.0 percent of the time. While turbidity >200 NTU was often observed, values above 150 NTU are beyond the calibration range of the probe and represent short duration transient readings. These transient high turbidity readings were observed more frequently than during the previous 2 years. Ten percent of turbidity data exceeded 50 NTU, and 5.0 percent were greater than 100 NTU.

Other than basin-wide factors (climate, hydrology, and tides), the most significant influences on water quality at the TFCF appear to be the installation and removal of temporary channel barriers and operation of the Delta Cross Channel near Walnut Grove, California. When barriers are installed and the Cross Channel gates are open, from April through October, daily variation and maximum EC are much lower than when higher conductivity water from the San Joaquin River (SJR) flows relatively unimpeded to the TFCF. The much lower, third-year minimum and median EC data also suggest that discharge in the Sacramento River basin strongly influences the water quality at the TFCF.

Another factor that may affect local water quality at the TFCF is the operation of the gates at Clifton Court Forebay during high tides. When temporary barriers are installed, the gate operations may sometimes be seen in the probe depth data; however, the effect on water quality is more complex and deserves further study.

INTRODUCTION

This report is the fourth in a series from the subproject, *Chemical Monitoring and Assessment at the Tracy Fish Collection Facility*, which is part of the Tracy Fish Facility Improvement Program (TFFIP). The TFFIP is an interdisciplinary research and evaluation program started in 1989 and required by the Central Valley Project Improvement Act of 1992 (CVPIA) to investigate design and operational improvements for the Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF) (Liston, et al., 1993). The TFCF, located at the head of the intake channel for the Tracy Pumping Plant (TPP), was designed to collect (salvage) fish to prevent them from being pumped through the TPP into the Delta Mendota Canal (DMC). The TFCF represented state-of-the-art technology when originally installed in the 1950s; however, changing fishery and regulatory conditions have mandated updating of fish screening technology and improvements. TFFIP fish salvage technology research and development benefits the design and assessment of planned Tracy Demonstration Fish Facility (TDFF), a research facility to be located across the channel from the TFCF. Knowledge gained from these research efforts and facilities may also be applied to the design and construction of future fish salvage facilities in the South Delta.

The purpose of this TFFIP subproject is to develop a reference or "baseline" water quality data set that combines historical water chemistry data, agricultural chemical application data, data from semicontinuous Hydrolab probe monitoring of general water quality variables, and chemical analysis data from future water samples collected at the TFCF. A baseline water quality data set is important to the TFFIP because water quality influences the composition and health of the local fish populations. During 1999, personnel from the Reclamation Mid-Pacific (MP) Regional Office, Sacramento, California, began a Hydrolab multi probe calibration and maintenance program. This report summarizes the third full year of successfully validated multi probe water quality measurements at the TFCF, and is the follow-up to volumes 17 and 22 of the Tracy Series reports (Craft, et al., 2002; Craft, et al., 2003).

The water quality variables reported here are all important to the health of fish. The variables measured in this study included temperature (T, in degrees Celsius, °C), pH (in standard units, SU), dissolved oxygen (DO, in milligrams per liter, mg/L), electrical conductivity (EC, in microSiemens per centimeter, : S/cm), redox (or oxidation-reduction) potential (Eh, in millivolts, mV), and turbidity (in Nephelometric turbidity units, NTU). EC is a measure of the ionic (charged) compounds in water and can be thought of as how much salt is dissolved in the water. pH measures the acidity of water, with values around 7 being neutral (good), below 7 being acidic, and above 7 alkaline. pH above 9 and below 6 can be toxic to fish. DO is important because fish need dissolved oxygen to breathe, and DO below 5.0 mg/L can cause weak fish to die. Turbidity measures light scattering of small particles in water and is an indication of how much suspended particulate matter (sediments, algae, etc.) is in the water. High turbidity water for fish can be thought of as smoky air for people. Eh indicates whether the water is oxidizing (good, positive readings) or reducing (bad, zero or negative readings) and is related to the availability of free electrons and dissolved oxygen. Temperature can affect all of the other variables in the water, and strongly affects dissolved oxygen.

Project Background

Both the TFCF and the TPP were built in the early 1950s as part of the Reclamation's Central Valley Project (CVP), a large water diversion infrastructure project that enabled agricultural expansion throughout most of the Central Valley of California. The Tracy facilities are located approximately 8 km northwest of Tracy, California. (See map in figure 1.) The TPP pumps water for irrigation, municipal, and industrial uses from the Old River into the DMC. The water then flows southeast from the fish salvage and pumping facilities. The California Aqueduct and the Harvey O. Banks Pumping Plant are similar nearby water diversion facilities operated by the State of California (the State facility) at Clifton Court Forebay, located 2 km north of the TFCF. Before the CVP and similar State diversion systems were implemented, the lower San Joaquin River (SJR) water flowed unimpeded north into San Francisco Bay. Much of the SJR is now diverted south in the DMC, the Friant-Kern Canal, and other State and Federal canals where it is reused as it flows by gravity southward down the San Joaquin Valley.

General Factors Affecting Water Quality at the TFCF

The chemistry of TFCF intake water from the Old River, a South Delta distributary of the SJR, is the result of many variables interacting in a complex manner. Regional influences include basin-wide interactions between agricultural land use and runoff with the marine sedimentary geology of the Central Valley of California and the extensive re-use of water. The regional influences can change from year to year because of hydrologic cycle variability and other trends, such as drought, increasing urban populations, and land use changes. Local influences include large-scale South Delta mixing of SJR and Sacramento River freshwater sources converging on San Francisco Bay, daily tidal fluctuations, artificial pumping from the TPP and entrainment of high tides at the State facility at Clifton Court Forebay, local irrigation return flows and chemical applications

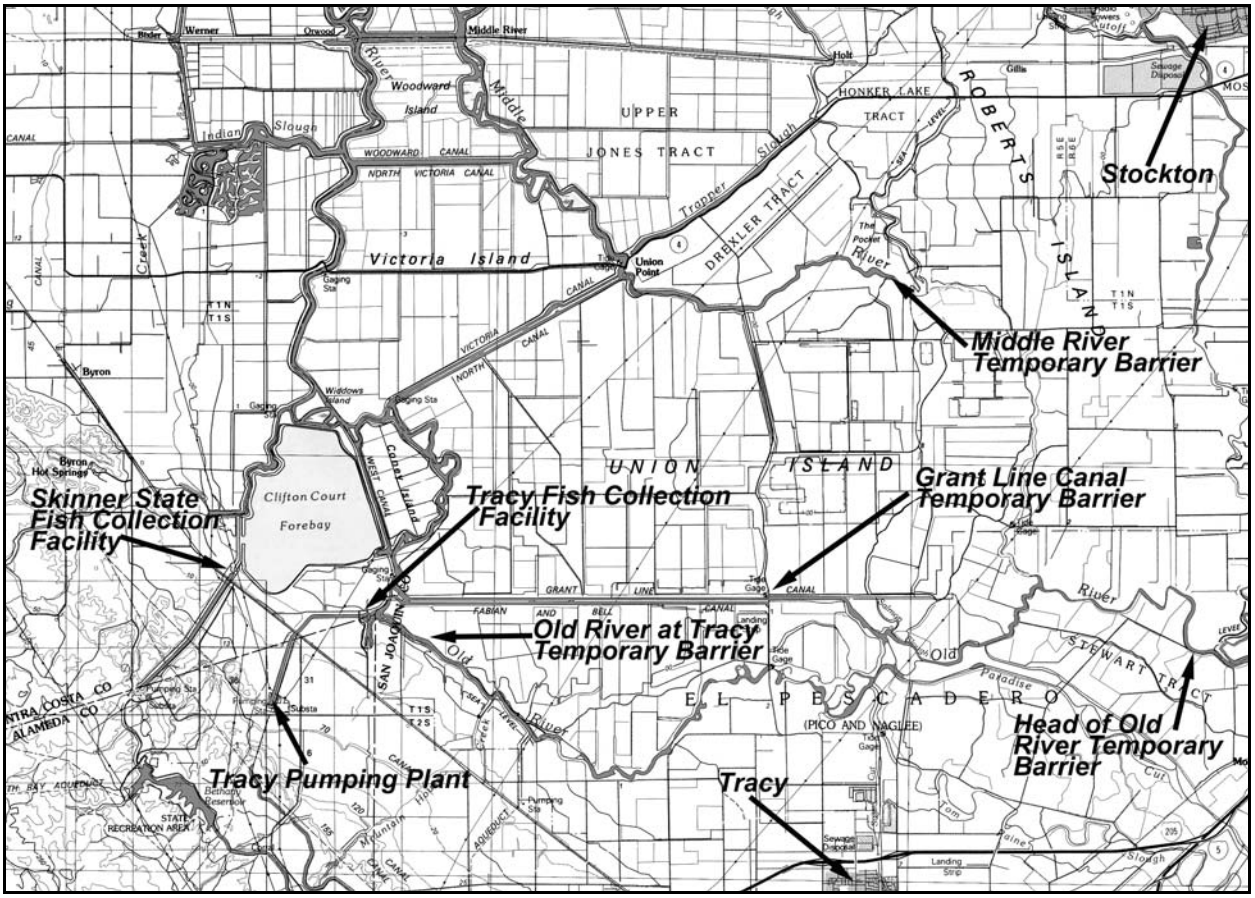

FIGURE 1.—Map showing the location of the Tracy Fish Collection Facility.

on crops, intermittent channel dredging, and the seasonal installation (usually in April and May) and removal (usually in September through November) of temporary channel barriers in the South Delta (Craft, et al., 2003). The temporary barriers are embankments of rocks piled across the flow channels that retard inflow of higher conductivity water from the SJR. The complex interactions that produce the water quality observed at the TFCF underscore the need for accurate measurements that are location and temporally representative.

Although the closest source water at the TFCF is the nearby SJR, tides and the operation of diversion structures, such as local temporary barriers and the Cross Channel Canal near Walnut Grove, California, also allow for southerly transport and mixing of lower concentration Sacramento River water (median EC = 150 :S/cm) into the South Delta near Tracy (State of California, 1999; Craft, et al., 2000; Craft, et al., 2003). Old River water at the TFCF intake contains total dissolved solids (TDS) ranging from 300 to 1,100 mg/L, with median EC of 479 :S/cm (Craft, et al., 2000), and contains sodium and chloride as the principal inorganic constituents. Daily tidal EC fluctuations of 100 to 300 :S/cm commonly observed at the TFCF are thought to be caused by up-gradient transport and mixing of lower concentration waters from the Sacramento River and Mokelumne River by the rising tidal salt wedge (State of California, 1999). These tidal flows impede inflow of higher conductivity water from the SJR. When local inflows from the SJR are further impeded by temporary channel barriers and opening of the Delta Cross-Channel Canal, increased influence from lower concentration water from the northern Central Valley watersheds may help produce better water quality (lower maximum EC) and lower daily variation in EC at the TFCF.

Agricultural activity and associated chemical applications occur in the immediate vicinity of the TFCF (Craft, et al., 2000). Irrigation return-flows may contain nitrogen and phosphorus from fertilizer applications; dissolved and suspended organic carbon from vegetation decay; and herbicide, pesticide, and fungicide chemicals and their formulation additives (usually surfactants, adjuvants, and sticking agents). Storm runoff may also mobilize suspended matter, which increases turbidity and organic carbon in local waters. These chemical inputs enter local canals, sloughs, and rivers, and represent an unpredictable contribution to the gross water quality variables measured at the TFCF.

METHODOLOGY

Hydrolab Datasonde

Temperature, pH, DO, EC, Eh, probe depth (m), and turbidity were measured at 30-minute intervals using a Hydrolab Datasonde multi probe that was installed in a perforated pipe behind the trash rack and intake structures of the TFCF (Craft, et al., 2002). The Datasonde probe assembly included a stirrer that was activated during programmed probe measurements. Personnel from the Reclamation MP Region performed routine calibration and maintenance of the Datasonde on a weekly schedule. Reference photographs and the standard operating procedure followed for calibration and maintenance activities may be found in Craft, et al. (2002). After the probe assembly was cleaned, EC was calibrated using a certified standard reference solution, pH using a 2-buffer (VWR Scientific) calibration, and Eh using Zobell's solution. DO was calibrated using air saturated with water at the measured local barometric pressure, and turbidity was calibrated using a certified 40-mg/L micro bead standard. Calibration for the Datasonde probe was verified before reinstallation in the PVC pipe, and calibration checks and notes were recorded on field sheets and in the field logbook. Turbidity measurements were also checked independently using a separately calibrated turbidity meter.

Computer and Database Methods

Datasonde readings were stored on internal probe memory and downloaded monthly to a PC using HyperTerminal software via the Surveyor 4a data logger. These data were then transmitted as ASCII text e-mail attachments that were imported into Microsoft® Excel spreadsheets. Data were then reviewed, plotted, and shared with the field crew for any required corrective actions. Anomalous data, such as negative values, elevated turbidity readings (>150 NTU), or values measured when the probe was not in the water, were recoded or discarded.

Monthly water quality data files were combined in Excel to create the entire period of record file that was imported into Microsoft® Access as an 18,984-record table. Queried water quality data were exported to Excel® files and plotted to identify any additional anomalous values that were subsequently removed. Statistical analyses were performed using SPSS® (Statistical Package for the Social Sciences, Windows® version 11.5). Processed and altered SPSS® files were also returned to Access as new tables, imported via conversion to an Excel spreadsheet, or appended using cut and paste operations.

A problem with Eh electrode calibration and function produced a consistent shift in Eh after September 3, 2002, so the Eh after this point was adjusted. Before this event, average Eh was 576 mV and after, average Eh was 299 mV. Post-September 3 data were recoded to reflect this difference by adding 277 mV to the originally recorded data. The corrected data are presented here for information purposes; however, they were coded into a separate variable in the database (called *eh_fix*) to indicate this correction. With precautions, Eh may also be estimated from DO, pH, and T data using the following equations (Parkhurst, 2003; Sato, 1960):

(1) $pe = -log(K) + log_{10}[O_2] - 4(pH)$
where $[O_2]$ is DO in mg/L, and log(K) varies with T in degrees Kelvin (/K):

(2) $log(K) = 38.0229 + 0.00799407(T) - 14.506*log(T) + 199838.45(T)^2$

(3) $Eh = pe * 2.3026 * R * T/F$

where Eh is expressed in volts and:
R = 0.0083147 kJ/deg-mol (kilojoules per degree-mole)
F = 96.4935 kJ/V-eq (kilojoules per volt-equivalent)

It should be noted that the above equations assume chemical equilibrium conditions. Calculations produced using equations (1-3) can produce Eh values up to 300 mV higher than those measured by the Datasonde Eh electrode. Natural surface waters are not at chemical equilibrium (Brezonik, 1994), so the thermodynamic interpretation of redox conditions derived from measured Eh is questionable at best (Morel and Hering, 1993; Parkhurst, 2003). Besides thermodynamic assumption violations, mixed potentials arising from several simultaneous redox reactions (and biofouling) on the surface of the platinum Eh electrode strongly suggest that DO is a better indicator of redox conditions in oxygenated surface waters (Lindsay, 1979; Stumm and Morgan, 1996). However, because negative Eh readings (never observed at the TFCF) are corroborative of complete oxygen depletion (Langmuir, 1997; Drever, 1988), their continued measurement may help confirm extremely low DO readings.

Precipitation, air temperature, and sunrise and sunset times were obtained from the National Oceanic and Atmospheric Administration’s National Climate Data Center web site, <http://www.ncdc.noaa.gov> for weather station 049001 – Tracy Pumping Plant. Daily average flow discharge data in cubic feet per second (cfs) for the SJR and Sacramento Rivers were downloaded from the U.S. Geological Survey (USGS) web site, <http://water.wr.usgs.gov> for gage stations 11303500 – San Joaquin River Near Vernalis, California, and station 11447650 – Sacramento River at Freeport, California.

Daily total pumping at the TPP and Cross Channel operations data were obtained from the Reclamation Central Valley Operations Office, Sacramento, California. Operational schedules for the South Delta temporary barriers was obtained from the California Department of Water Resources, Office of State Water Project Planning web site, <http://sdelta.water.ca.gov/web_pg/tempmesr.html>.

Temporary barrier (T.B.) and Delta Cross Channel gate status data were coded as follows:

TABLE 2.—Coding used to describe operations of temporary barriers and other events affecting the chemistry at the Tracy Fish Collection Facility. These codes were altered or rescaled in some figures to enhance presentation with other data.

Event	Installation	Installed	Removal	Not Installed
Old River at TFCF T.B.	5	1	5	0
Grant Line Canal T.B.	6	2	6	0
Head of Old River T.B.	7	3	7	0
Middle River T.B.	8	4	8	0
Delta Cross Channel Gates	NA	1.5 (open)	NA	0 (closed)
Channel Dredging	NA	6.5 (yes)	NA	0 (no)
Calibration Events	NA	0.5 (yes)	NA	0 (no)
Multi Probe Power Failures	NA	2.5 (yes)	NA	0 (no)

Opening and closing schedules for the radial gates at the entrance of Clifton Court Forebay were obtained from the California Department of Water Resources (CDWR, 2003). Although these data are not presented here, they are included in the third-year data base.

Theoretical tidal, sunrise, sunset, and moon phase data were generated using *Tides and Currents for Windows,* version 3.0, (Nobeltec Nautical Software, Beaverton, Oregon). Tidal data were calculated for the tide gage station located at the Grant Line Canal Bridge, approximately 11 km from the TFCF, and provide a reference set of data to compare with Datasonde probe depth. Note that the actual tide stage at the Grant Line canal is significantly influenced by local runoff and water management operations, while calculated values do not include these influences. Local tidal stage measurements from the CDWR at station ORB, Old River at Byron, 37.8900° N by 121.5700° W, were obtained from: <http://cdec.water.ca.gov/riv_flows.html>.

Fish salvage data for the TFCF and the Skinner Fish Collection Facility were obtained from the California Department of Fish and Game (CDFG) web site: <http://www.delta.dfg.ca.gov/> and the CDFG Central Valley Bay-Delta Branch fish salvage FTP site: <ftp://ftp.delta.dfg.ca.gov/salvage>.

All downloaded data files were processed to insert dates or times for missing records before combining with TFCF Hydrolab data.

RESULTS AND DISCUSSION

Table 3 summarizes parametric and rank statistics calculated for data collected from April 2002 through March 2003. Monthly percentiles are found in appendix 1, table A1-1. The data covered in this report are also available online from the Tracy Fish Facility Research website: <http://www.usbr.gov/pmts/tech_services/tracy_research>.

As with previous years' data, the appendix figure A1-1 histograms for each of the water quality variables suggest that some of the data distributions are complex, with only pH and DO approximating a normal distribution for the period of record. T, EC, and unadjusted Eh (more normally-distributed adjusted values are shown in figure A1-1) all exhibit multi-modal distributions. The multiple modes in the T distribution are probably associated with seasonal changes, while EC bimodality is probably related to the installation and removal of temporary channel barriers. The bimodal distribution for unadjusted Eh reflects uncorrected data and the bias from calibration problems mentioned in the Methodology section. The turbidity histogram suggests a log-normal distribution.

Examination of the monthly histograms suggested that distributional properties for all the multi probe variables change throughout the year. Given the lack of normality in the data, the median and rank-based percentiles were used as less biased indicators of central tendency and extreme values.

A factor to consider regarding the simple daily and weekly summaries presented here is the phase relationship of daily tides and the 2-week spring and neap tide cycle. The 24.8-hour tidal cycle will introduce time-series biases for estimates based on calendar days and weeks and may also render statistical comparisons of diel effects inaccurate. These biases may be minimized by applying tidal filters to data sets before calculating daily and weekly estimates; however, tidal filters were not applied here.

Table A1-1 shows monthly summaries that include more detailed percentiles in the tails of the data distributions where extreme values are observed. Because data were consistently collected at 30-minute intervals, the percentiles may be used to estimate the length of time extreme values were observed. For example, table 3 shows that the 0.1 percentile value for T is 8.4 °C. We can infer that temperatures equal to or below this value were observed only 0.1 percent of the year, or for around 8 to 9 hours. This approach provides more meaningful data when extreme values approach or exceed regulated water quality standards.

Annual median T was 17.7 °C. and ranged from 8.2 °C. to 26.9 °C. Minimum EC was 195 :S/cm, with a maximum of 1,020 :S/cm and a median of 400 :S/cm. Daily variation for EC was greatest from February through March, when temporary barriers were removed, though the variability was not as consistently great as seen in previous years' data. Median DO was 7.94 mg/L and ranged from 4.04 mg/L to 12.5 mg/L. Median percent DO saturation was 84.1 percent. DO saturation percentage was below 50 percent 0.2 percent of the time (around 17 hours out of a year), and below 75 percent 20 percent of the time. Median pH was 7.52 and varied from 4.04 (probably related to probe malfunction or biofouling) up to 8.67. pH less than 7 was observed 5 percent of the time, and pH greater than 8.0 was abserved 5 percent of the time. Turbidity was often observed over 200 NTU; however, these values are well beyond the calibration range of the probe and represent transient readings. Median turbidity was 17.6 NTU, with 10 percent of turbidity data exceeding 54.8 NTU and 3.0 percent exceeding the 150 NTU upper limit of calibration. There were greater numbers of high turbidity transient readings than in previous years.

Figures 2a through 2e provide plots of minimum, median, and maximum values summarized by day, week, and month for the third year of data.

TABLE 3.—A more detailed summary of third-year water quality data collected with the multi probe at the Tracy Fish Collection Facility

		Temperature, °C	Conductivity, :S/cm	Percent DO Saturation	Dissolved Oxygen, mg/L	pH, su	Adjusted Redox Potential, mV	Turbidity, NTU
Number of Valid Observations		16220	14913	16220	16220	16109	16220	16054
Number of Missing Observations		1300	2607	1300	1300	1411	1300	1466
Mean		17.5	405	83	7.98	7.51	576	28.7
Median		17.7	400	84.1	7.94	7.52	581	17.6
Minimum		8.2	195	42.5	4.04	4.60	279	<1.0
Maximum		26.9	1020	139	12.5	8.67	773	>150
Percentiles	.1	8.4	199	49.7	4.73	6.32	335	<1.0
	.2	8.5	200	51.8	4.99	6.38	359	<1.0
	.3	8.7	201	53.6	5.16	6.41	367	<1.0
	.4	8.8	202	54.7	5.26	6.43	372	1.1
	.5	9.0	203	55.6	5.31	6.47	376	1.2
	1	9.2	205	58.9	5.60	6.61	393	1.9
	2	9.4	208	62.5	5.89	6.76	411	3.0
	3	9.5	212	64.9	6.08	6.92	431	3.9
	4	9.7	216	66.4	6.24	6.98	456	4.5
	5	9.8	220	67.5	6.34	7.00	469	4.9
	10	10.5	237	70.6	6.66	7.16	492	6.6
	20	11.8	269	76.2	7.10	7.28	520	8.6
	25	12.7	289	78.0	7.27	7.32	532	10.1
	30	13.8	322	79.3	7.43	7.37	544	11.5
	40	15.9	362	82.0	7.70	7.46	566	14.4
	50	17.7	400	84.1	7.94	7.52	581	17.6
	60	19.2	441	85.9	8.24	7.56	595	21.3
	70	22.1	476	87.7	8.54	7.63	608	25.8
	75	22.6	490	88.6	8.70	7.68	618	29.1
	80	23.1	507	89.6	8.89	7.76	629	33.4
	90	24.0	553	92.5	9.33	7.91	666	54.8
	95	24.7	611	95.5	9.59	8.02	685	106
	96	24.9	637	96.5	9.68	8.05	689	132
	97	25.1	686	97.7	9.81	8.10	693	>150
	98	25.4	764	99.4	9.97	8.19	698	>150
	99	25.8	845	103	10.2	8.28	707	>150
	99.5	26.1	873	110	10.6	8.36	712	>150
	99.6	26.2	875	113	10.7	8.40	716	>150
	99.7	26.3	896	118	11.0	8.43	734	>150
	99.8	26.4	930	128	11.7	8.47	749	>150
	99.9	26.5	1010	132	12.1	8.57	757	>150

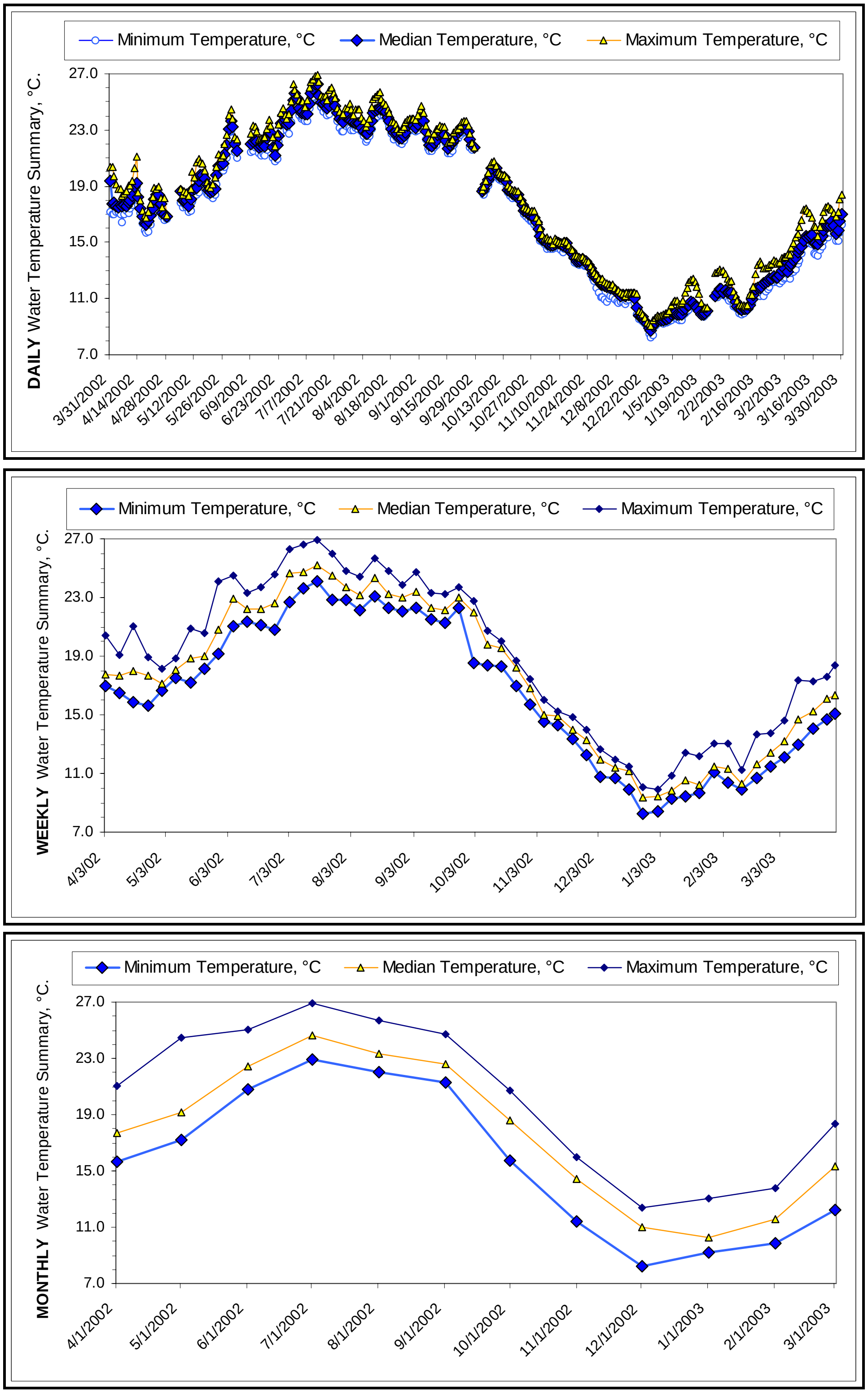

FIGURE 2a.—Third-year minimum, median, and maximum water temperature in degrees Celsius (T, °C) by day, week, and month for the intake channel at the Tracy Fish Collection Facility.

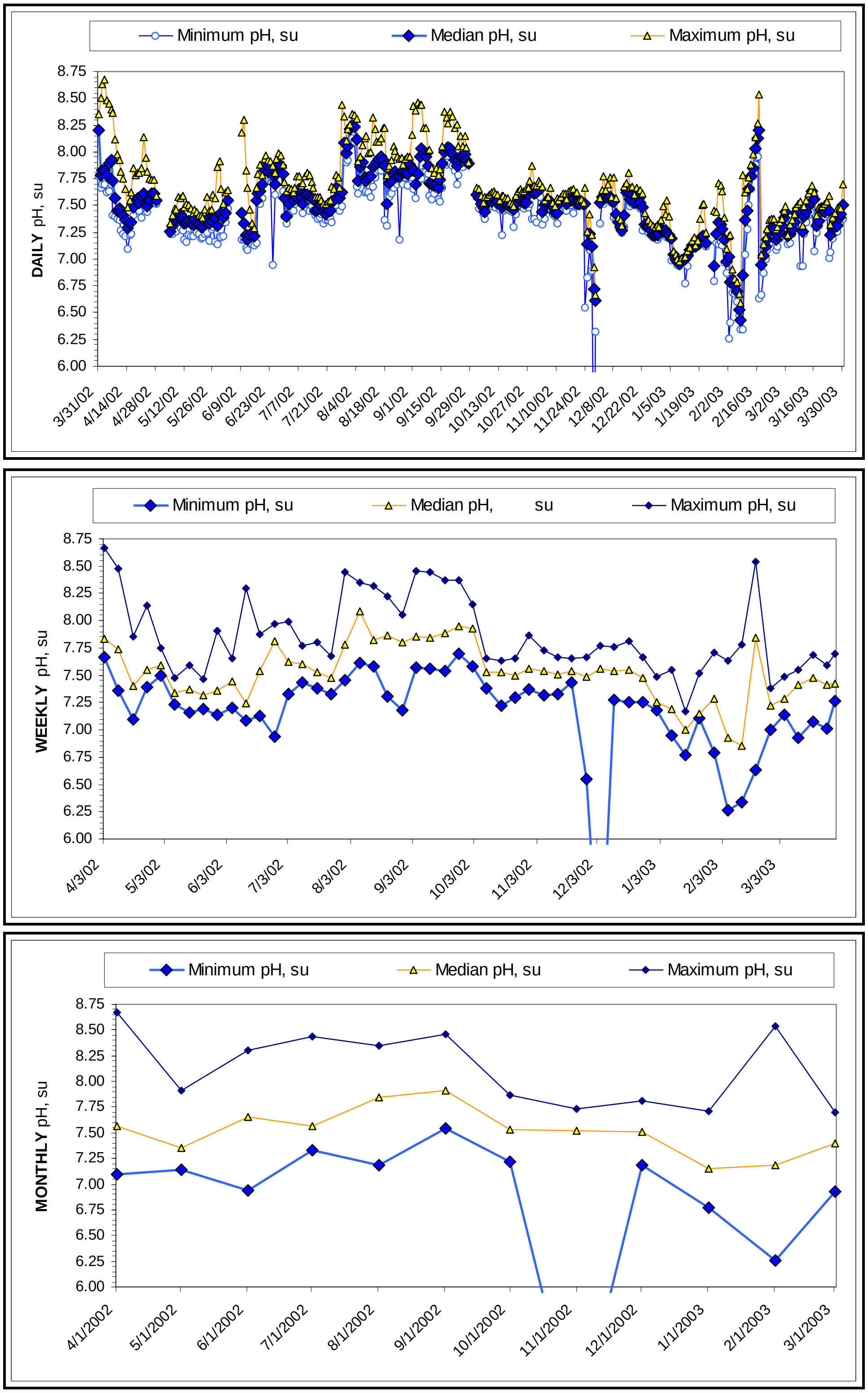

FIGURE 2b.—Third-year minimum, median, and maximum pH in standard units (pH, SU), by day, week, and month for the intake channel at the Tracy Fish Collection Facility.

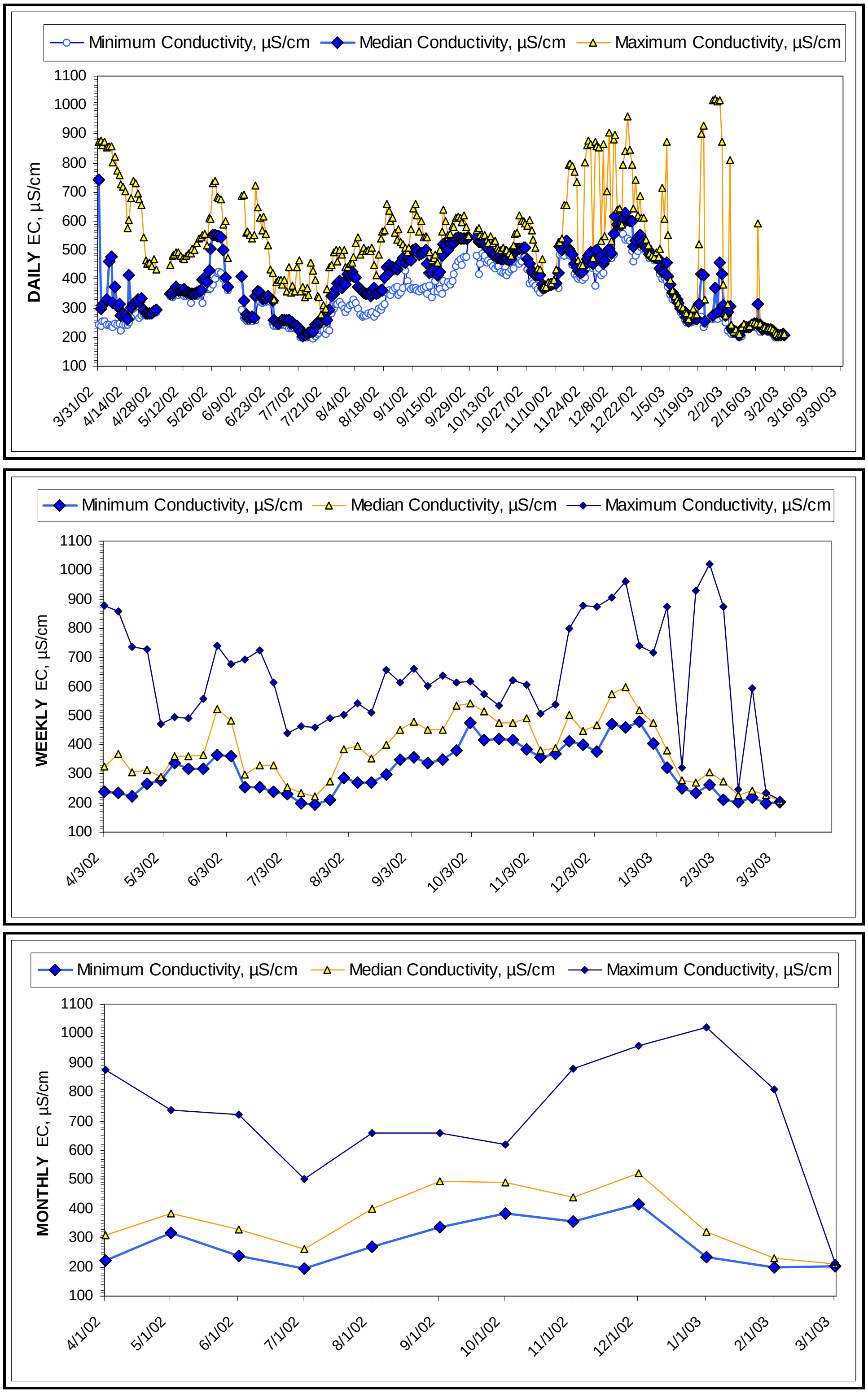

FIGURE 2c.—Third-year minimum, median, and maximum for conductivity in microsiemens per centimeter (EC, : S/cm) by day, week, and month for the intake channel at the Tracy Fish Collection Facility.

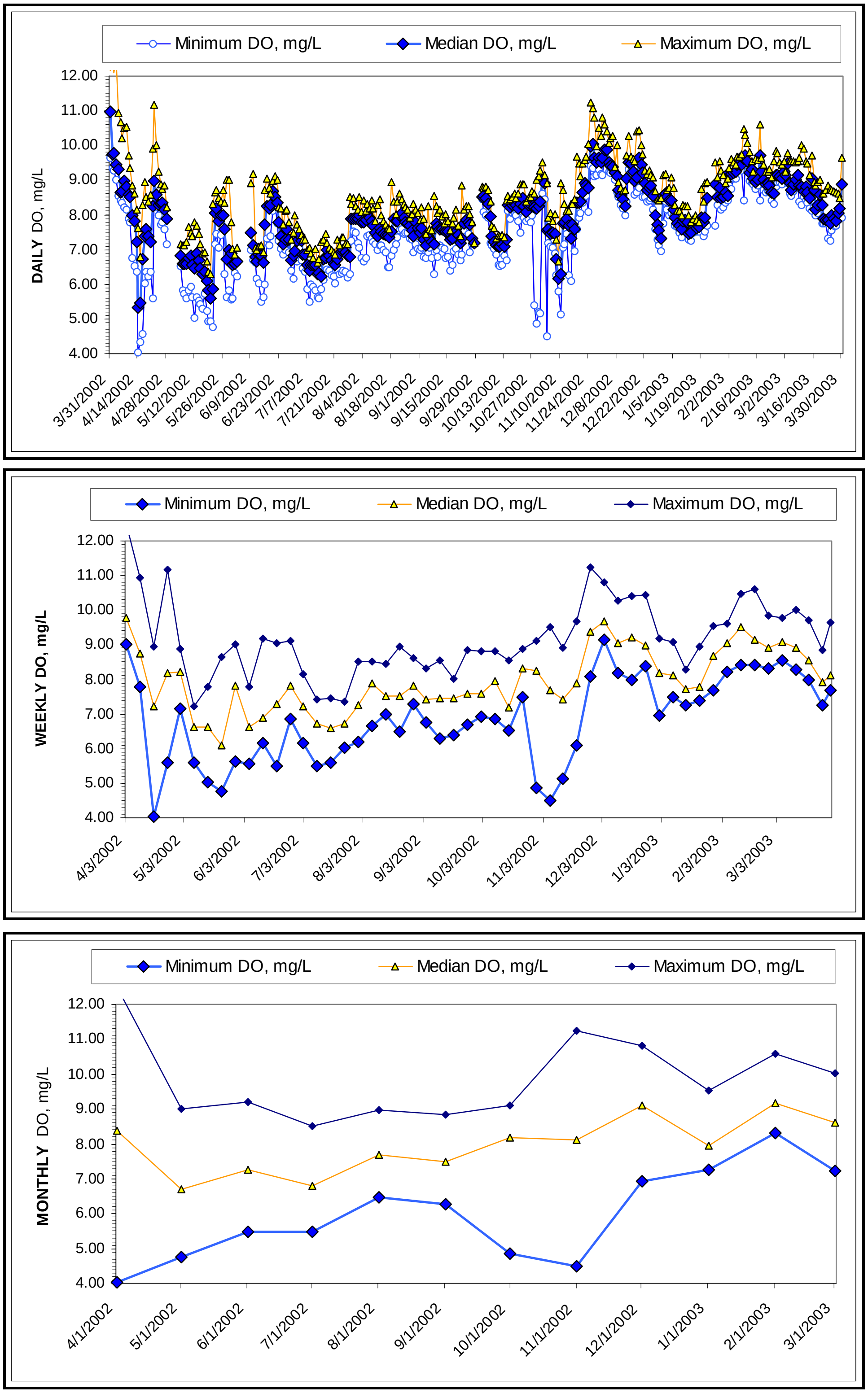

FIGURE 2d.—Third-year minimum, median, and maximum for dissolved oxygen in milligrams per liter (DO, mg/L) by day, week, and month for the intake channel at the Tracy Fish Collection Facility.

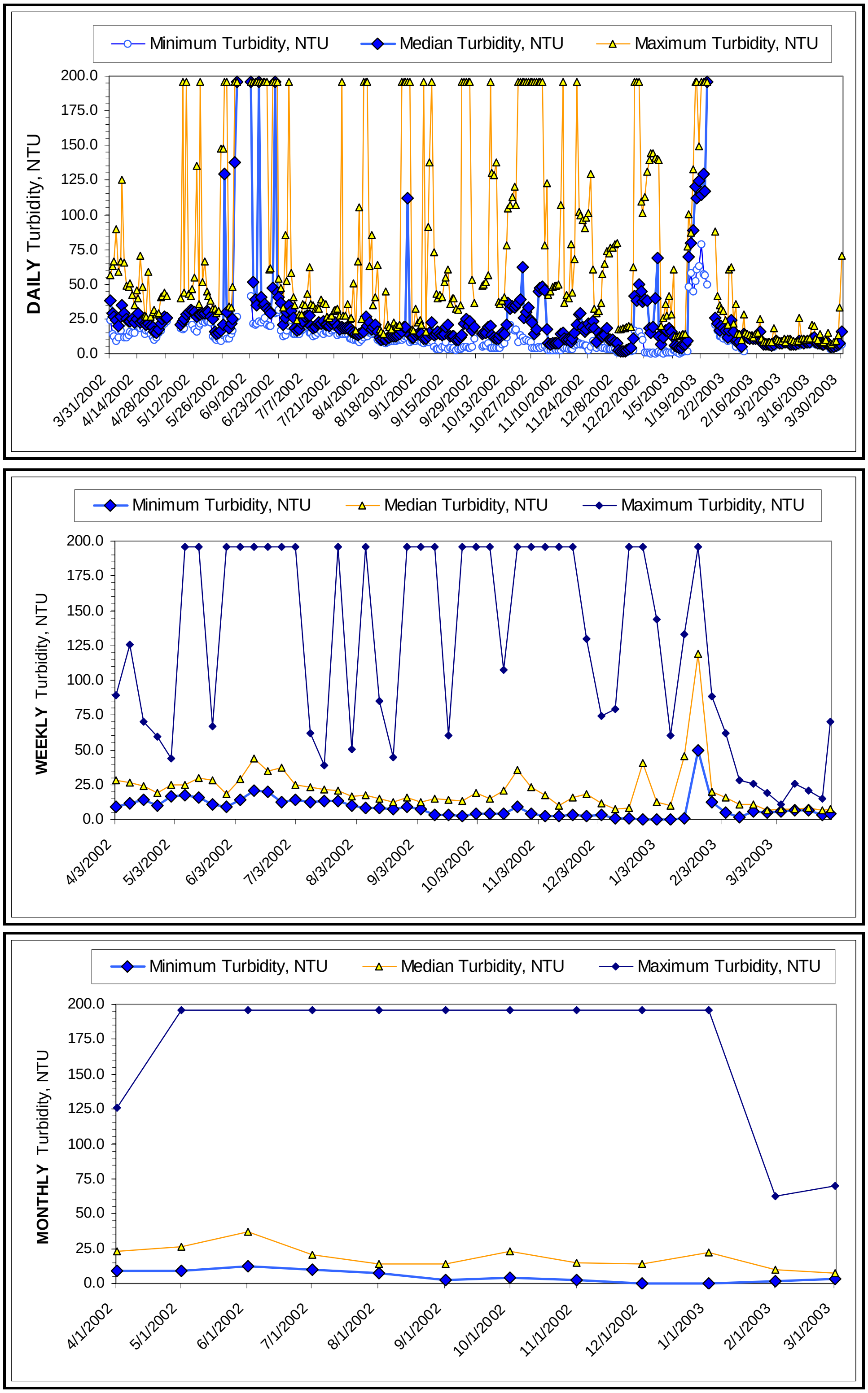

FIGURE 2e.—Third-year minimum, median, and maximum for turbidity in Nephelometric turbidity units (NTU) by day, week, and month for the intake channel at the Tracy Fish Collection Facility. Note that values greater then 150 NTU were coded as 195.99 in the data base.

Background Data and Water Quality Effects

Table 4 provides a three-year summary of annual rainfall near the TFCF; annual streamflow discharge from the SJR at Vernalis, California, and the Sacramento River at Freeport, California; TPP export pumping; and a summary of EC data from the TFCF.

TABLE 4.—Comparison of meteorology and hydrology data with electrical conductivity (EC, in :S/cm) for all three years of water quality data collected at the TFCF.

Study year	Total Annual Precip., inches	Number of Precip. Days	San Joaquin River at Vernalis, CA, acre-ft	Sacramento River at Freeport, CA, acre-ft	Total TPP Pumping, acre-ft	Minimum EC, µS/cm	Median EC, µS/cm	Maximum EC, µS/cm
1: Apr-00 to Mar 01	11.1	64	2,142,483	13,096,324	2,398,586	295	424	762
2: Apr-01 to Mar-02	11.8	72	1,512,571	12,092,125	2,493,873	304	455	824
3: Apr-02 to Mar-03	11.6	43	1,306,641	15,205,393	2,557,565	195	400	1,020

Total annual precipitation near the TFCF has been similar for the past 3 years; however, the third year saw significantly fewer days with measured rain (40.3 percent less than year two). There was no measurable rainfall at the TPP weather station from early June through October.

River discharges during the first 2 years of this study are consistent with the continuing and widespread drought in the western United States. All EC summary values show an increase from year one to year two that is consistent with the decreasing runoff observed in both San Joaquin and Sacramento Rivers watersheds. A continuing decrease of 13.6 percent in discharge in the SJR from year two to year three suggests a continuation of drought in the southern Central Valley watershed. Maximum third-year EC of 1,020 :S/cm suggests that SJR water was more saline as a result of continued (and increasing) pumped diversion volumes and less runoff and dilution from snowmelt.

Third year discharge in the Sacramento River, however, increased by 25.7 percent compared to year two (after showing a 7.70 percent decrease from year one to year two) to the highest discharge volume observed in this period of record. Notably, year three also shows the lowest minimum and median EC values. These results suggest that the water quality at the TFCF is greatly influenced by runoff in the northern watersheds of the Central Valley. The reason for this pronounced influence is likely the operation of the Cross Channel Canal near Walnut Grove, California, and the installation of local temporary barriers. Background data and events are summarized in figures 3a through 3c. Figure 3a shows the status of local temporary barriers and the Cross Channel Canal along with Datasonde probe calibration and power interruption events. Figure 3b shows daily discharge in the SJR and the Sacramento River and export pumping at the TPP and the State's Harvey O. Banks pumping plant. This graph shows the significant winter and early spring runoff discharge in the Sacramento River that probably contributed to the >15,000,000 acre-ft third-year runoff. Precipitation data from the TPP weather station are summarized in figure 3c. The complete lack of precipitation events at the TFCF from early June through October is notable.

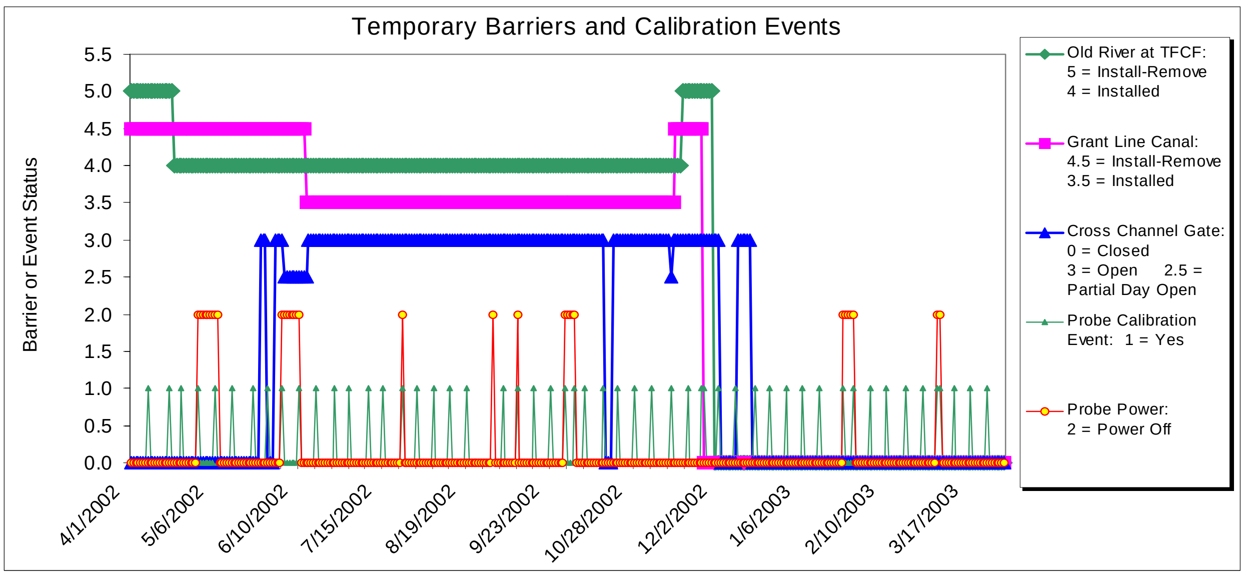

FIGURE 3a.—Nearby temporary barrier and Delta Cross-Channel Canal operational events affecting the Tracy Fish Collection Facility. Datasonde calibration events and power outages are also shown.

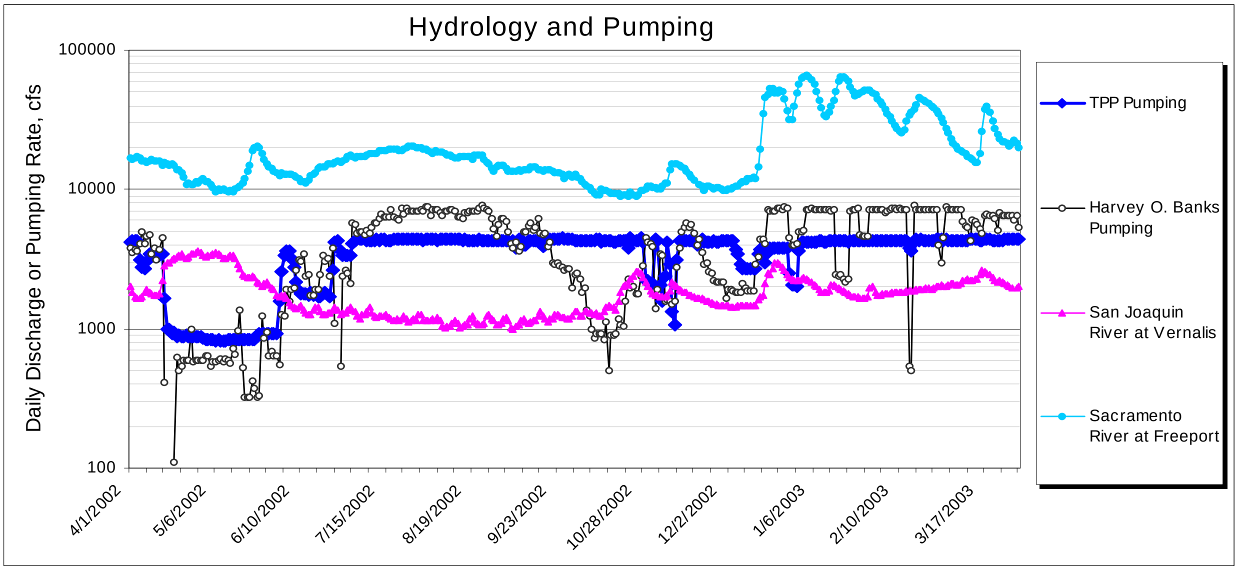

FIGURE 3b.—Daily average flow discharge in cubic feet per second (cfs), for local rivers combined with daily average pumping (cfs) at the State of California's Harvey O. Banks Pumping Facility and the Tracy Pumping Plant. The data are plotted on a logarithmic scale.

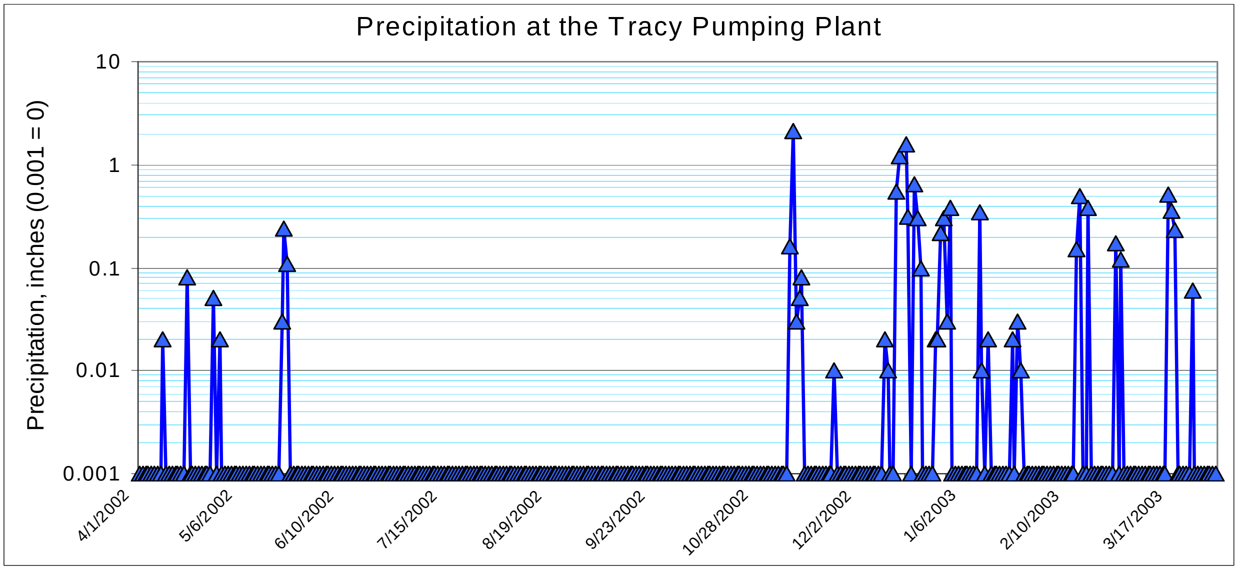

FIGURE 3c.—Precipitation events measured at the TPP weather station from April 1, 2002 through March 31, 2003. Precipitation recorded as zero is coded in this figure as 0.001 inch for plotting on the logarithmic scale.

Despite the complex variable interactions at the TFCF, figures 4a–4c show some interesting associations between some local events and responses in water quality (expressed as minimum and maximum daily values for EC and turbidity) and fish salvage. Figure 4a shows the entire 3-year record of minimum and maximum daily EC along with temporary barrier status. These data corroborate earlier observations (Craft, et al., 2002; Craft, et al., 2003) that temporary barrier installation and Cross Channel gate openings inhibit inflows of higher EC water from the SJR and produce lower median EC water quality. Daily EC variability increases when barriers are removed and higher salinity SJR water flows into the TFCF from the Old River. Low EC variability is also associated with opening of the Delta Cross Channel gates that encourage greater flows to the South Delta of low EC water from the Sacramento River. EC shows a response in daily range to temporary barriers similar to that observed in last year's data, but lacking the consistently high daily EC range of the first 2 years' data. Note that once barriers are installed, minimum EC increases throughout the agricultural season of water re-use, and then minimum EC drops again when the barriers are removed.

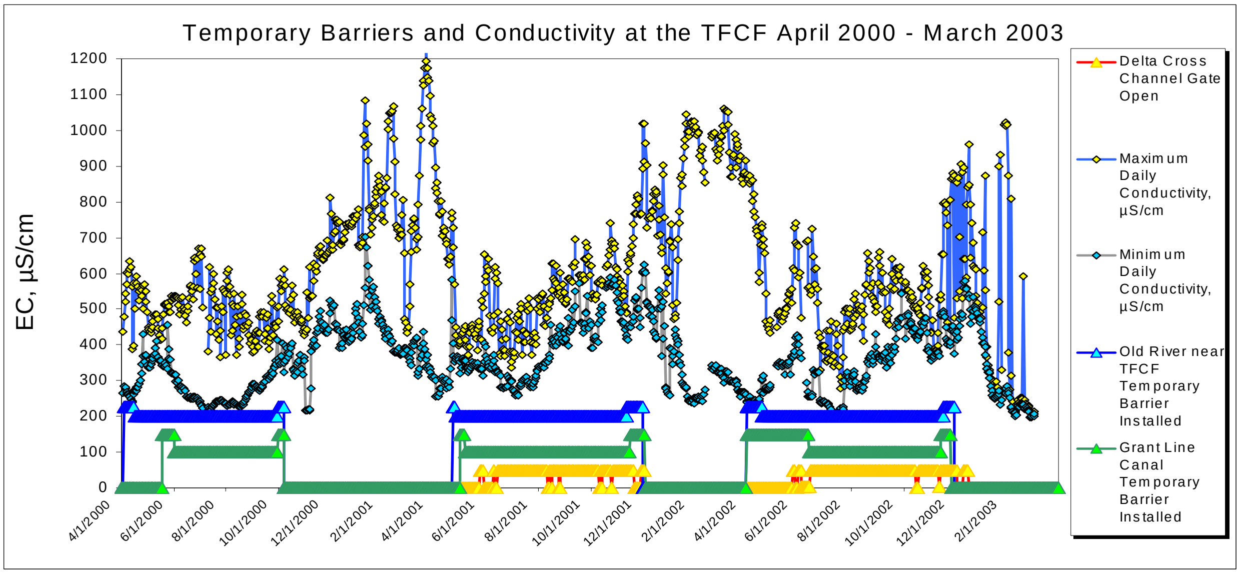

FIGURE 4a.—Local temporary barrier schedules along with minimum and maximum daily conductivity in microsiemens per centimeter (EC, : S/cm). These data cover the three-year period of record for this study.

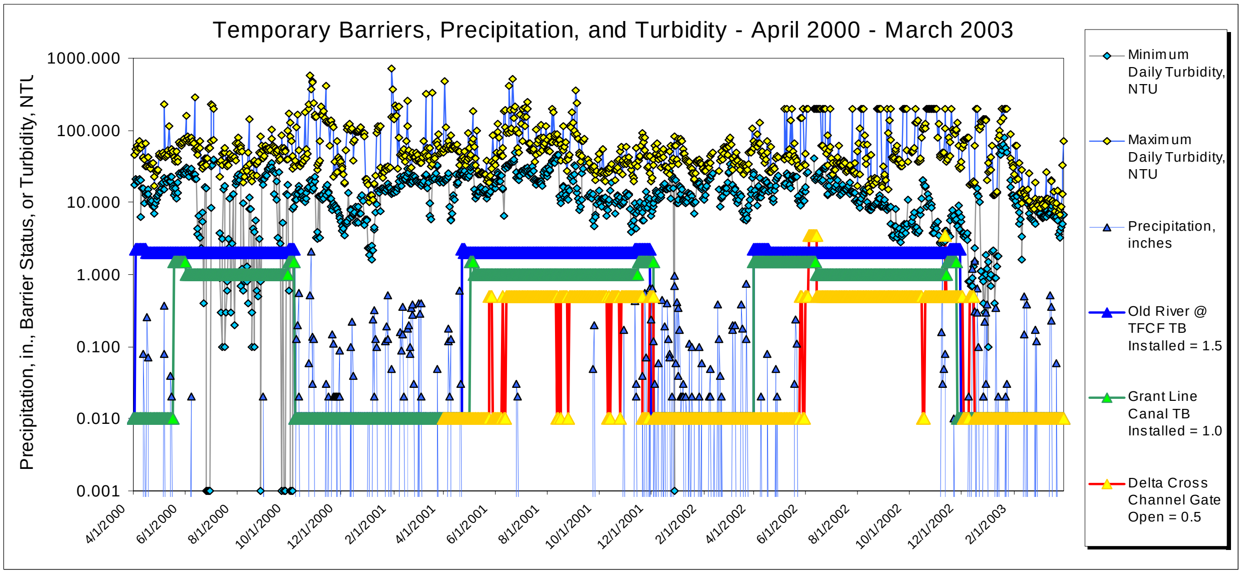

FIGURE 4b.—Minimum and maximum turbidity in NTU along with temporary barrier schedules and precipitation events. These data cover the three-year period of record for this study.

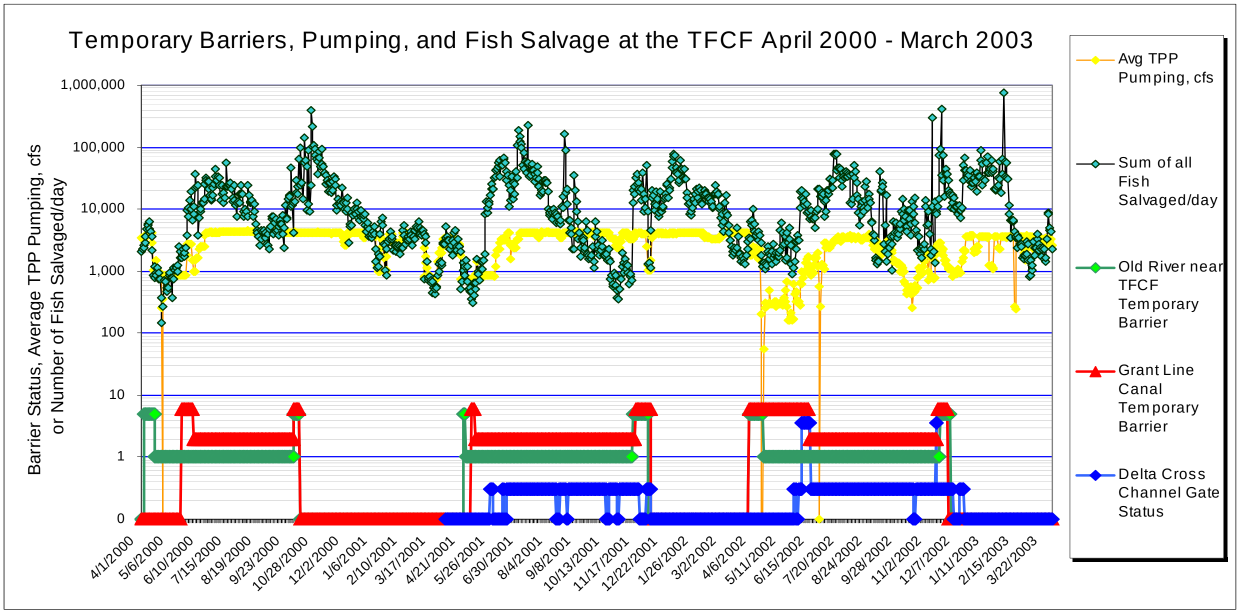

FIGURE 4c.—Total fish salvage at the Tracy Fish Collection Facility with temporary barrier schedules and TPP pumping. These data cover the first 3 years of data collected in this study.

Figure 4b shows minimum and maximum turbidity along with local barrier status and precipitation events for the 3-year period of record. While there are some suggestions of high turbidity transient readings corresponding to precipitation events > 0.5 inch/d in the first year's record, there does not appear to be a consistent response to local rain. For the third-year data, the greatest number of high turbidity transients occurred when temporary barriers were installed. These data suggest that the transients are, perhaps, related to enhanced algal productivity associated with the agricultural season and higher water temperatures. Another possibility is that the lack of consistent response to rain events or dredging may be an artifact of the position of the Hydrolab probe—on the north side of the inflow channel—and the potential for incompletely mixed sediment plumes traversing the center of the channel.

Figure 4c shows 3 years of total fish salvage data (sum of all species per day) reported by the TFCF, average daily TPP pumping in cfs, along with the installation and removal schedules of nearby temporary barriers. During the first 2 years of data, fish salvage shows an increase as TPP pumping increases. These periods coincide with installation of the temporary barriers. During the first two temporary barrier installation periods, salvage numbers then decrease until the temporary barriers are removed, although pumping is constant well beyond barrier removal. The decline during barrier installation may be caused by an interruption of normal fish migration patterns and potential depletion of local fish numbers in the vicinity of the TFCF. Notably, the fish salvage numbers increase abruptly as soon as the temporary barriers are breached. Third-year data showing less constant pumping during barrier installation suggest a closer relationship between pumping and salvage. Clearly, the relationship between pumping, salvage, and temporary barriers is complex and deserves further study.

Diel factors would be expected to influence chemistry and biological responses in any natural surface water system; however, any diel effect for a water quality variable would have to first account for shifting tidal variation seen throughout the month. While these relationships are important, a more sophisticated and detailed statistical analysis of the data is beyond the scope of this report.

CONCLUSIONS

The third year of reliable water quality data at the TFCF provides an interesting comparison to the first and second year data. Notably, EC showed a response to hydrologic changes in both the northern and southern watersheds of the Central Valley. All three years' EC data show that the South Delta temporary barriers have a significant influence on both minimum and maximum EC observed at the TFCF. This year, the increased discharge in the Sacramento River appears to have lowered both minimum and median EC and highlighted the differences between the two major water sources for the TFCF: the San Joaquin and

Sacramento Rivers. The third year's data also continues to suggest that installation and removal of temporary barriers temporarily reduces TFCF fish salvage numbers, though a TPP flow-weighted comparison will be needed before more definitive conclusions may be reached. DO during the third year was below the EPA recommended water quality criteria of 5.0 mg/L (Environmental Protection Agency, 1976) 0.2 percent of the time (compared to 2.9 percent during year one and 0.05 percent during year two). Turbidity spikes were not clearly associated with rainfall events; however, highest turbidity was observed when barriers were in place, and this year saw many more transient high turbidity readings.

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Appendix 1

Basic Statistical Summaries for Third-Year Water Quality Data at the Tracy Fish Collection Facility

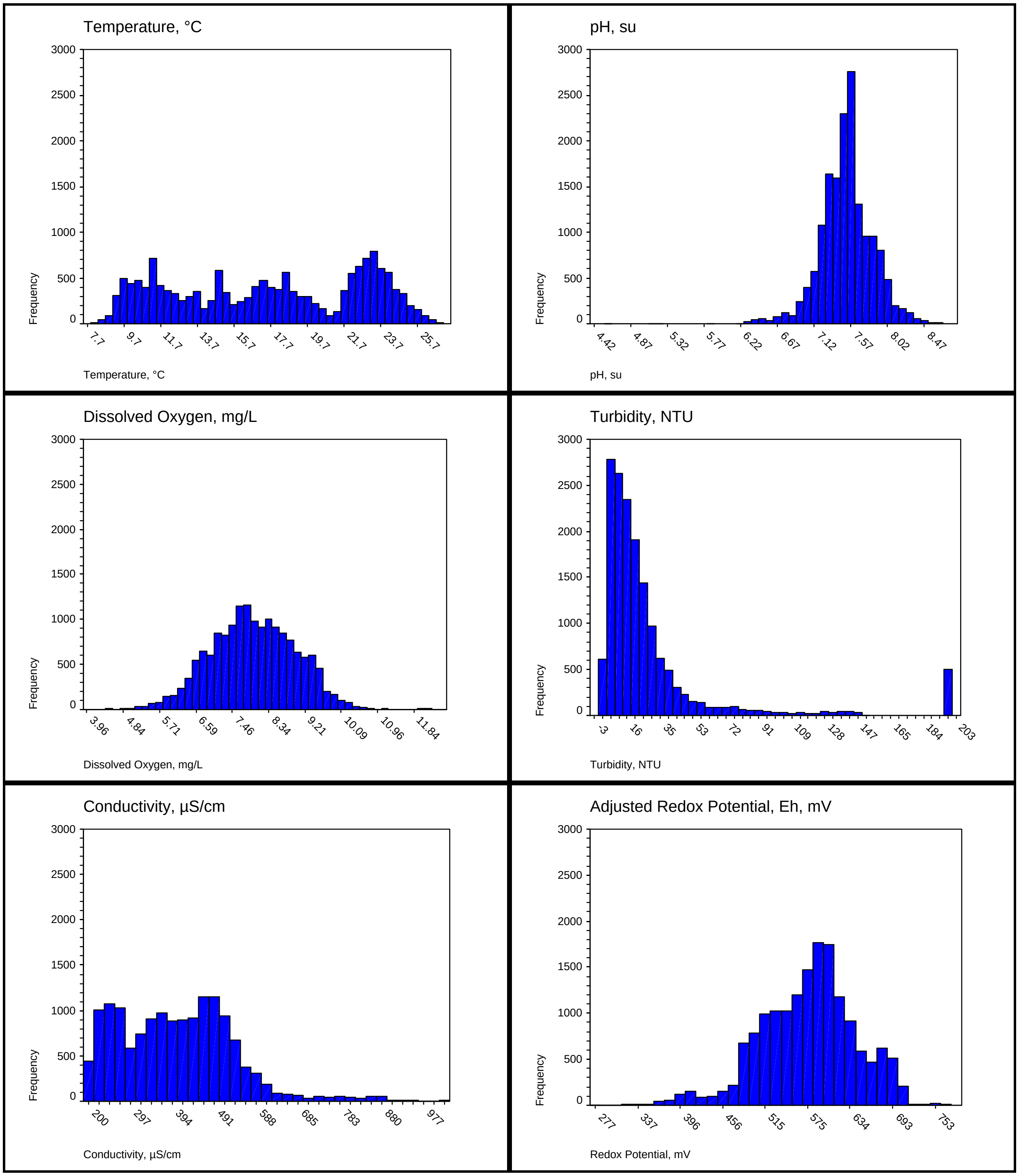

FIGURE A1-1.—Histograms for the third year of water quality data from the Hydrolab Datasonde at the Tracy Fish Collection Facility.

TABLE A1-1.—Summary of monthly statistics and frequencies for the third year of Hydrolab Datasonde data from the Tracy Fish Collection Facility. Eh values have been adjusted to account for calibration bias after September 3, 2002.

		T, ⁄C	***EC, :S/cm***	***Pct DO Saturation***	***DO, mg/L***	***pH, su***	***Adjusted Eh, mV***	***Turbidity, NTU***
Apr 2002	***Valid***	1323	1323	1323	1323	1323	1323	1323
	Missing	117	117	117	117	117	117	117
	Mean	17.7	398	87.3	8.29	7.65	512	25.7
	Median	17.7	310	87.9	8.37	7.57	510	23.4
	Minimum	15.7	224	42.5	4.04	7.10	381	9.2
	Maximum	21.1	877	139	12.5	8.67	624	126
Percentiles	***.1***	15.7	228	42.7	4.06	7.10	382	9.4
	.2	15.7	236	44.7	4.25	7.11	383	9.9
	.3	15.7	240	45.7	4.34	7.12	384	10.3
	.4	15.7	240	47.3	4.49	7.12	385	10.5
	.5	15.7	241	47.8	4.51	7.13	386	10.8
	1	15.8	243	49.6	4.68	7.14	387	11.5
	5	16.3	249	59.2	5.70	7.30	399	13.7
	25	17.1	279	78.6	7.49	7.47	468	19.3
	50	17.7	310	87.9	8.37	7.57	510	23.4
	75	18.3	466	95.3	9.01	7.74	571	29.0
	95	19.3	802	113	10.5	8.33	612	47.2
	99	20.3	868	132	12.1	8.60	619	60.4
	99.5	20.5	871	135	12.3	8.63	621	65.5
	99.6	20.7	872	136	12.3	8.64	621	66.1
	99.7	20.8	874	137	12.4	8.65	623	66.4
	99.8	21.0	874	137	12.4	8.66	623	77.2
	99.9	21.1	876	139	12.5	8.67	624	114
May 2002	***Valid***	1211	1211	1211	1211	1211	1211	1211
	Missing	277	277	277	277	277	277	277
	Mean	19.6	424	74.8	6.84	7.36	539	32.0
	Median	19.2	384	73.1	6.71	7.35	538	26.5
	Minimum	17.2	317	51.1	4.77	7.14	474	9.2
	Maximum	24.5	740	107	9.02	7.91	603	>150
Percentiles	***.1***	17.2	317	51.2	4.78	7.14	475	9.3
	.2	17.2	320	51.4	4.80	7.16	478	9.7
	.3	17.3	333	52.1	4.87	7.17	479	10.2
	.4	17.3	339	52.7	4.92	7.17	480	10.5
	.5	17.3	340	53.1	4.94	7.17	480	10.6
	1	17.3	343	55.0	5.15	7.19	485	10.9
	5	17.7	347	59.7	5.56	7.24	493	13.4
	25	18.5	356	66.9	6.22	7.30	517	20.4
	50	19.2	384	73.1	6.71	7.35	538	26.5
	75	20.4	480	83.7	7.51	7.40	562	31.5
	95	23.2	580	91.9	8.30	7.51	581	128.0
	99	24.1	680	98.4	8.65	7.73	594	148.4
	99.5	24.4	692	103	8.71	7.85	600	>150
	99.6	24.4	694	105	8.83	7.85	600	>150
	99.7	24.4	698	105	8.92	7.86	601	>150
	99.8	24.4	717	105	9.02	7.87	602	>150
	99.9	24.5	737	107	9.02	7.90	603	>150

Table A1-I Continued		T, ⁄C	EC, :S/cm	Pct DO Saturation	DO, mg/L	pH, su	Adjusted Eh, mV	Turbidity, NTU
Jun 2002	***Valid***	1104	1104	1104	1104	1104	1104	1104
	Missing	336	336	336	336	336	336	336
	Mean	22.6	345	85.7	7.40	7.59	601	65.5
	Median	22.4	329	85.2	7.25	7.65	599	36.7
	Minimum	20.8	237	62.7	5.48	6.94	511	12.7
	Maximum	25.1	724	108	9.19	8.30	652	>150
Percentiles	***.1***	20.8	237	62.8	5.49	6.94	511	12.7
	.2	20.9	238	63.6	5.55	6.97	512	13.0
	.3	21.0	239	64.2	5.60	6.98	513	13.4
	.4	21.0	239	64.5	5.62	7.00	514	13.7
	.5	21.0	239	64.9	5.65	7.02	516	13.9
	1	21.0	241	68.4	5.98	7.12	521	14.6
	5	21.2	245	73.1	6.36	7.17	563	20.2
	25	21.9	265	77.9	6.76	7.32	588	28.6
	50	22.4	329	85.2	7.25	7.65	599	36.7
	75	23.3	380	93.1	8.06	7.82	620	55.7
	95	24.2	569	99.9	8.72	7.91	636	>150
	99	24.9	664	103	8.97	8.06	646	>150
	99.5	24.9	688	104	9.03	8.14	648	>150
	99.6	25.0	690	104	9.08	8.17	648	>150
	99.7	25.0	696	104	9.11	8.23	649	>150
	99.8	25.1	705	107	9.15	8.25	651	>150
	99.9	25.1	722	108	9.19	8.29	652	>150
Jul 2002	***Valid***	1469	1469	1469	1469	1469	1469	1469
	Missing	19	19	19	19	19	19	19
	Mean	24.7	284	82.4	6.85	7.59	617	21.6
	Median	24.7	260	81.9	6.80	7.56	622	20.5
	Minimum	22.9	195	66.4	5.49	7.33	521	10.0
	Maximum	26.9	502	101	8.51	8.44	672	>150
Percentiles	***.1***	22.9	196	66.7	5.52	7.33	531	10.1
	.2	22.9	197	69.3	5.59	7.33	544	10.3
	.3	22.9	199	69.5	5.61	7.34	544	10.6
	.4	22.9	199	69.7	5.73	7.34	545	10.8
	.5	22.9	199	69.7	5.77	7.34	546	10.8
	1	23.0	200	71.9	5.87	7.36	551	12.1
	5	23.3	205	74.8	6.15	7.40	560	14.4
	25	24.0	231	79.0	6.57	7.49	593	17.4
	50	24.7	260	81.9	6.80	7.56	622	20.5
	75	25.3	335	85.0	7.06	7.62	642	23.7
	95	26.2	425	93.0	7.86	8.04	658	30.9
	99	26.5	456	98.2	8.30	8.31	668	37.6
	99.5	26.7	475	99.0	8.39	8.35	670	48.1
	99.6	26.8	487	99.3	8.40	8.35	670	78.0
	99.7	26.8	491	99.8	8.44	8.38	671	>150
	99.8	26.8	501	100	8.44	8.40	672	>150
	99.9	26.9	501	101	8.50	8.44	672	>150

Table A1-I Continued		T, ⁄C	EC, :S/cm	Pct DO Saturation	DO, mg/L	pH, su	Adjusted Eh, mV	Turbidity, NTU
Aug 2002	Valid	1480	1480	1480	1480	1480	1480	1480
	Missing	8	8	8	8	8	8	8
	Mean	23.4	405	89.9	7.70	7.86	601	29.5
	Median	23.4	401	89.9	7.70	7.84	600	14.3
	Minimum	22.0	271	77.1	6.48	7.18	487	7.8
	Maximum	25.7	658	104	8.96	8.35	653	>150
Percentiles	.1	22.1	271	77.2	6.48	7.24	508	7.8
	.2	22.1	274	77.5	6.51	7.31	549	7.9
	.3	22.1	275	77.9	6.56	7.32	552	8.1
	.4	22.1	277	78.6	6.64	7.33	555	8.3
	.5	22.1	277	79.0	6.75	7.34	556	8.3
	1	22.2	286	80.0	6.90	7.40	560	8.6
	5	22.4	314	83.4	7.13	7.63	572	9.4
	25	22.9	358	87.3	7.47	7.76	588	11.7
	50	23.4	401	89.9	7.70	7.84	600	14.3
	75	24.0	448	92.8	7.96	7.93	613	18.3
	95	24.7	502	96.4	8.22	8.23	636	>150
	99	25.0	569	99.0	8.45	8.28	646	>150
	99.5	25.3	608	100	8.57	8.31	650	>150
	99.6	25.4	619	100	8.62	8.32	650	>150
	99.7	25.5	629	101	8.67	8.32	652	>150
	99.8	25.6	650	101	8.71	8.33	653	>150
	99.9	25.6	654	103	8.85	8.35	653	>150
Sep 2002	Valid	1329	1329	1329	1329	1329	1329	1329
	Missing	111	111	111	111	111	111	111
	Mean	22.6	485	86.1	7.47	7.89	509	21.6
	Median	22.6	495	86.4	7.48	7.91	529	13.9
	Minimum	21.3	337	71.8	6.28	7.54	290	2.8
	Maximum	24.7	661	103	8.85	8.46	630	>150
Percentiles	.1	21.3	341	72.0	6.31	7.54	292	2.9
	.2	21.3	349	72.7	6.39	7.55	300	3.3
	.3	21.3	352	73.2	6.47	7.56	317	3.4
	.4	21.4	353	73.7	6.48	7.56	322	3.5
	.5	21.4	356	74.0	6.52	7.56	326	3.6
	1	21.5	363	75.0	6.57	7.58	345	3.8
	5	21.7	382	79.3	6.86	7.64	376	5.1
	25	22.2	440	83.3	7.24	7.77	461	10.4
	50	22.6	495	86.4	7.48	7.91	529	13.9
	75	23.1	533	89.0	7.72	7.99	563	21.2
	95	23.7	565	92.5	8.01	8.09	602	50.6
	99	24.2	608	96.1	8.25	8.34	624	>150
	99.5	24.3	627	97.4	8.43	8.41	628	>150
	99.6	24.4	639	98.0	8.50	8.44	629	>150
	99.7	24.5	642	98.8	8.54	8.44	629	>150
	99.8	24.5	649	99.1	8.56	8.44	629	>150
	99.9	24.7	660	101	8.76	8.46	630	>150

Table A1-I Continued		T, ⁄C	EC, :S/cm	Pct DO Saturation	DO, mg/L	pH, su	Adjusted Eh, mV	Turbidity, NTU
Oct 2002	Valid	1343	1343	1343	1343	1343	1343	1343
	Missing	145	145	145	145	145	145	145
	Mean	18.5	490	84.1	7.90	7.54	548	36.7
	Median	18.6	489	86.0	8.17	7.53	554	22.9
	Minimum	15.7	385	49.8	4.87	7.22	279	3.8
	Maximum	20.7	621	93.7	9.11	7.87	627	>150
Percentiles	.1	15.7	385	50.7	4.98	7.25	281	3.8
	.2	15.8	390	53.3	5.22	7.33	287	3.8
	.3	15.8	393	55.6	5.40	7.37	311	3.9
	.4	15.8	394	57.0	5.58	7.37	319	3.9
	.5	15.8	394	57.2	5.60	7.38	334	3.9
	1	15.9	401	59.8	5.83	7.40	378	4.5
	5	16.4	428	73.2	6.80	7.44	455	6.9
	25	17.3	468	80.0	7.26	7.50	518	13.4
	50	18.6	489	86.0	8.17	7.53	554	22.9
	75	19.6	516	88.7	8.37	7.57	584	39.9
	95	20.3	544	90.9	8.63	7.65	613	127.1
	99	20.6	585	92.4	8.80	7.69	623	>150
	99.5	20.7	593	92.7	8.88	7.70	625	>150
	99.6	20.7	597	92.9	8.89	7.71	626	>150
	99.7	20.7	601	93.2	8.99	7.72	626	>150
	99.8	20.7	608	93.4	9.03	7.73	627	>150
	99.9	20.7	618	93.7	9.10	7.82	627	>150
Nov 2002	Valid	1426	1426	1426	1426	1391	1426	1426
	Missing	14	14	14	14	49	14	14
	Mean	14.2	469	80.2	8.22	7.44	591	24.9
	Median	14.5	440	80.1	8.11	7.52	597	15.1
	Minimum	11.4	356	44.5	4.50	4.60	357	2.4
	Maximum	16.0	879	108	11.3	7.73	773	>150
Percentiles	.1	11.4	356	45.9	4.65	4.83	362	2.4
	.2	11.5	360	50.2	5.10	5.24	399	2.7
	.3	11.5	362	50.9	5.15	5.94	408	2.7
	.4	11.5	363	51.4	5.16	6.34	417	2.8
	.5	11.6	364	51.7	5.26	6.43	434	2.8
	1	11.8	365	54.0	5.47	6.52	478	3.0
	5	12.4	373	62.2	6.26	6.79	503	4.0
	25	13.5	389	74.1	7.49	7.46	540	7.7
	50	14.5	440	80.1	8.11	7.52	597	15.1
	75	14.9	499	88.0	8.99	7.56	640	36.7
	95	15.3	761	95.3	10.0	7.66	679	83.3
	99	15.6	867	100	10.5	7.68	687	124.4
	99.5	15.8	871	102	10.8	7.69	695	>150
	99.6	15.9	874	103	10.8	7.69	708	>150
	99.7	15.9	876	103	10.8	7.71	738	>150
	99.8	16.0	878	104	11.0	7.71	752	>150
	99.9	16.0	879	106	11.2	7.73	766	>150

Table A1-I Continued		T, ⁄C	EC, :S/cm	Pct DO Saturation	DO, mg/L	pH, su	Adjusted Eh, mV	Turbidity, NTU
Dec 2002	Valid	1477	1477	1477	1477	1401	1477	1387
	Missing	11	11	11	11	87	11	101
	Mean	10.6	548	81.8	9.00	7.45	662	27.7
	Median	11.0	520	82.5	9.09	7.51	679	13.9
	Minimum	8.2	414	61.4	6.94	7.18	460	<1.0
	Maximum	12.4	960	101	10.8	7.81	773	>150
Percentiles	.1	8.2	418	61.4	6.94	7.18	466	<1.0
	.2	8.3	423	61.8	6.98	7.19	477	<1.0
	.3	8.3	427	62.1	7.01	7.19	480	<1.0
	.4	8.3	432	62.4	7.02	7.19	481	<1.0
	.5	8.3	435	62.8	7.05	7.19	484	<1.0
	1	8.4	440	63.7	7.17	7.20	493	<1.0
	5	8.9	452	67.8	7.65	7.22	536	1.2
	25	9.6	480	77.0	8.60	7.30	652	5.3
	50	11.0	520	82.5	9.09	7.51	679	13.9
	75	11.4	587	87.1	9.46	7.58	694	38.5
	95	12.0	742	91.9	10.1	7.66	712	93.5
	99	12.2	896	95.6	10.3	7.75	756	141.2
	99.5	12.2	922	97.2	10.5	7.76	769	143.5
	99.6	12.2	951	97.4	10.5	7.77	769	143.8
	99.7	12.2	955	98.1	10.6	7.78	770	144.4
	99.8	12.2	959	99.0	10.6	7.79	771	>150
	99.9	12.3	960	100	10.7	7.81	773	>150
Jan 2003	Valid	1290	1290	1290	1290	1290	1290	1214
	Missing	198	198	198	198	198	198	274
	Mean	10.5	365	72.8	8.08	7.16	617	51.2
	Median	10.3	319	71.3	7.96	7.15	626	21.9
	Minimum	9.2	233	65.1	7.25	6.77	469	<1.0
	Maximum	13.0	1020	90.2	9.54	7.71	710	>150
Percentiles	.1	9.2	234	65.1	7.25	6.78	469	<1.0
	.2	9.2	235	65.3	7.26	6.80	470	<1.0
	.3	9.3	239	65.4	7.28	6.81	470	<1.0
	.4	9.3	242	65.4	7.29	6.81	471	<1.0
	.5	9.3	247	65.4	7.30	6.82	471	<1.0
	1	9.4	247	65.8	7.32	6.86	476	1.2
	5	9.5	255	67.1	7.47	6.96	495	3.1
	25	9.9	272	69.1	7.70	7.02	572	10.2
	50	10.3	319	71.3	7.96	7.15	626	21.9
	75	10.9	411	76.3	8.47	7.25	674	85.0
	95	12.3	701	81.2	8.86	7.43	694	>150
	99	12.9	1010	86.3	9.23	7.64	706	>150
	99.5	13.0	1020	87.6	9.43	7.67	708	>150
	99.6	13.0	1020	87.9	9.44	7.68	708	>150
	99.7	13.0	1020	88.4	9.48	7.68	708	>150
	99.8	13.0	1020	89.1	9.50	7.69	709	>150
	99.9	13.0	1020	90.0	9.53	7.71	710	>150

Table A1-I Continued		T, ⁄C	EC, :S/cm	Pct DO Saturation	DO, mg/L	pH, su	Adjusted Eh, mV	Turbidity, NTU
Feb 2003	**Valid**	1337	1337	1337	1337	1337	1337	1337
	Missing	7	7	7	7	7	7	7
	Mean	11.6	240	84.4	9.18	7.20	534	11.1
	Median	11.6	232	84.2	9.17	7.18	526	10.2
	Minimum	9.9	198	75.0	8.30	6.26	458	1.6
	Maximum	13.7	810	101	10.6	8.54	719	62.2
Percentiles	**.1**	9.9	198	75.6	8.30	6.27	458	1.8
	.2	9.9	198	76.8	8.31	6.29	460	2.3
	.3	9.9	199	77.0	8.34	6.30	462	2.5
	.4	9.9	199	77.1	8.34	6.30	462	2.6
	.5	9.9	199	77.3	8.35	6.30	464	2.7
	1	10.0	200	77.6	8.39	6.34	471	3.4
	5	10.2	205	79.6	8.55	6.45	481	5.5
	25	10.7	218	82.6	8.93	6.86	495	7.4
	50	11.6	232	84.2	9.17	7.18	526	10.2
	75	12.4	241	85.9	9.45	7.38	573	12.6
	95	13.3	311	90.0	9.79	8.10	598	21.4
	99	13.5	403	94.2	10.3	8.35	608	37.4
	99.5	13.6	554	95.7	10.4	8.40	609	44.8
	99.6	13.7	589	96.2	10.4	8.41	610	46.0
	99.7	13.7	604	97.9	10.5	8.45	610	52.1
	99.8	13.7	737	99.0	10.5	8.46	610	57.3
	99.9	13.7	786	100	10.6	8.52	682	61.6
Mar 2003	**Valid**	1431	124	1431	1431	1431	1431	1431
	Missing	57	1364	57	57	57	57	57
	Mean	15.2	209	85.5	8.58	7.38	564	8.1
	Median	15.4	209	85.5	8.62	7.40	566	7.4
	Minimum	12.3	202	73.3	7.24	6.93	482	3.2
	Maximum	18.4	213	99.8	10.0	7.70	642	70.3
Percentiles	**.1**	12.3	202	73.4	7.25	6.93	482	3.2
	.2	12.3	202	73.6	7.26	6.93	483	3.4
	.3	12.3	202	73.6	7.28	6.93	483	3.5
	.4	12.4	202	73.8	7.29	6.93	483	3.6
	.5	12.4	202	74.3	7.32	6.93	483	3.6
	1	12.5	202	75.7	7.46	6.94	484	3.9
	5	12.9	204	78.4	7.76	7.14	492	4.8
	25	14.2	208	82.4	8.15	7.30	529	6.6
	50	15.4	209	85.5	8.62	7.40	566	7.4
	75	16.2	210	88.5	8.99	7.47	599	8.5
	95	17.2	212	93.6	9.47	7.59	627	12.6
	99	17.7	212	96.4	9.70	7.66	636	20.5
	99.5	18.1	213	97.6	9.78	7.67	640	30.5
	99.6	18.1	213	97.7	9.81	7.68	640	32.3
	99.7	18.1	213	97.9	9.83	7.68	641	33.8
	99.8	18.2	213	98.1	9.88	7.69	641	41.4
	99.9	18.4	213	99.1	9.97	7.70	642	67.6