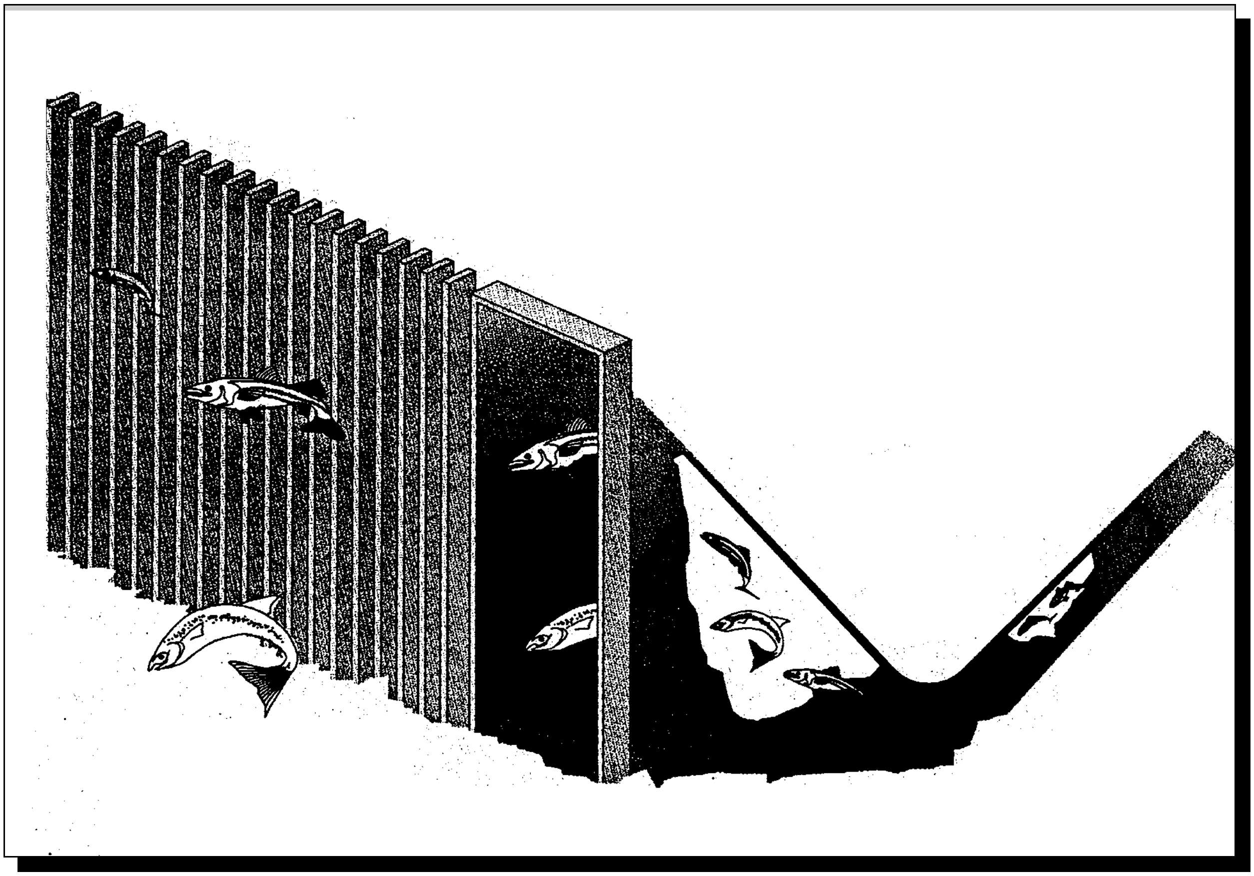
TRACY FISH COLLECTION FACILITY STUDIES CALIFORNIA

Volume 17



Semi-Continuous Water Quality Measurements at the Tracy Fish Collection Facility, Tracy, California, April 2000 to March 2001

January 2002

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13. ABSTRACT ***(Maximum 200 words)***
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VOLUME 17

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By

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Mission Statements

The Mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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EXECUTIVE SUMMARY

This report presents semi-continuous data for several water quality variables measured using a Hydrolab Datasonde 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 canal for the Tracy Pumping Plant (TPP), and removes fish from Old River water before it is pumped into Reclamation's Delta Mendota Canal (DMC) by the TPP. These facilities are located in the southern region of the San Francisco Bay Delta area (South Delta) in northern California. The variables measured in the Old River at the TFCF intake included temperature (T), pH, dissolved oxygen (DO), conductivity (EC), oxidation-reduction potential (Eh), and turbidity. The multi probe was cleaned and calibrated on a weekly schedule, and data downloaded at monthy intervals from April 2000 through March 2001. Also included with the water quality data are weather, tide, and stream flow data from nearby measurement stations. The Hydrolab data have been validated, peer-reviewed, collated and archived in a Microsoft® Access database and are available on request.

Annual average T was 16.9˚ C and ranged from 7.3˚ C to 27.3˚ C. Daily T variation ranged from 0.1˚ to 4.4˚ C. EC averaged 429 µS/cm with a minimum of 201 µS/cm and a maximum of 1,080 µS/cm. DO averaged 8.52 mg/L and percent DO saturation averaged 87.3 percent, varying from 39 to 147 percent. Percent DO saturation was below 49 percent only 0.5 percent of the time, and below 75 percent only 8 percent of the time. Eh was always positive with only 10 percent of data having values less than 293 mV; however, the Eh data are not linearly correlated with DO ($R^2 = 0.012$). pH averaged 7.67 and varied from 6.28 to 8.65. pH below 7 was observed only 2 percent of time and pH above 8 was observed only 10 percent of the time. Turbidity showed values up to 712 NTU; however, these extreme values are well beyond the calibration range of the probe, and represent short duration spikes. Average turbidity was 27.1 NTU. Only 10 percent of data exceeded 48.9 NTU and only 1 percent exceeded 131 NTU.

There was no clear response observed for T, pH, DO, or Eh associated with South Delta temporary barrier installation or removal. EC appears to show a response to installation of the local temporary channel barriers from April through October, with lower overall EC values and less daily fluctuation observed during this period. No response in turbidity was observed for installation of either the barrier in the Old River, or the Grant Line Canal barrier; however, spikes of higher turbidity appeared to coincide with the October barrier removal and higher turbidity values were observed during channel dredging that occurred from mid September through mid-December, 2000. These turbidity maxima are around 100 NTU, and are low relative to the local storm runoff response associated with a heavy October precipitation event (2 in. within 24 hours). Elevated turbidity was also observed during July 2000.

T, EC, DO, and pH show seasonal trends. Maximum average T was observed in August, while minimum average T was seen in January. EC and DO show opposite trends compared to temperature for monthly average plots. Minimum average EC is seen in July and minimum DO in August, and maximum EC is seen in January and maximum DO during February. DO was below the EPA recommended water quality criteria of 5.0 mg/L (Environmental Protection Agency, 1976) only 2.9 percent of the time, during August and a brief episode in January (that may well represent anomalous readings). Monthly average pH shows general maxima during the spring and summer, perhaps caused by increased productivity and higher temperatures in local waters. Eh and turbidity did not show clear seasonal patterns.

Daily extreme data ranges also appear to have a seasonal component for several variables. T and EC both show the greatest daily variability during late winter through early summer. pH, DO and turbidity, on the other hand, do not show any clear seasonal trend in daily variability. The extreme range spikes seen with these variables seem to be more episodic, perhaps more related to short duration local flow conditions or shifts caused by probe maintenance and calibration.

INTRODUCTION

This report is the second in a series from the project, *Chemical Monitoring and Assessment at the Tracy Fish Screen*, which is part of the Tracy Fish Facility Improvement Program (TFFIP). The TFFIP is an interdisciplinary research and evaluation program started in 1989 and funded to investigate design and operational improvements for the Tracy Fish Collection Facility (TFCF). 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 1950's; however, changing fishery and regulatory conditions have mandated updating of fish screening technology and salvage improvements. New fish technologies and improvements also benefit planning, design and assessment of the Tracy Experimental Fish Facility (TEFF), currently under development at the TFCF. Research on new screen and fish entrainment technologies at the TEFF will assist in the design and construction of future fish salvage facilities in the South Delta.

The purpose of this TFFIP project is to develop a reference or "baseline" water quality data set that may combine historical water chemistry data, agricultural chemical application data, data from semi continuous Hydrolab probe monitoring of general water quality variables, along with chemical analysis data from future water samples collected at the TFCF. A baseline water quality data set is important to the TFFIP because because water quality clearly affects the health of the local fish populations. During 1999, personnel from the Bureau of Reclamation (Reclamation) Mid-Pacific (MP) Regional Office, Sacramento, California, began a Hydrolab multi probe calibration and maintenance program. This report summarizes the first full year of successfully validated water quality measurements at the TFCF.

Project Background

Both the TFCF and the TPP were built in the early 1950's as part of the Reclamation's Central Valley Project (CVP), a large irrigation 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, which flows southeast from the screen and pumping facilities. The California Aqueduct is a similar nearby water development facility operated by the State of California (the State facility) at Clifton Court Forebay, located north of the TFCF. Before the CVP and similar State irrigation systems were implemented, the San Joaquin River (SJR) water flowed north unimpeded into San Francisco Bay. Much of the SJR is now diverted south in the DMC, the Friant-Kern Canal, and other State and Federal irrigation canals. Water from the South Delta is conveyed by a series of pumping stations on the DMC to the Mendota Pool to replace water diverted to the Friant-Kern Canal. DMC water flows by gravity southward down the San Joaquin Valley in a network of canals and then returns by way of the SJR.

South Delta water quality and fishery health have been affected by the irrigation infrastructure, expanding water reuse over time, and modern agricultural practices. For example, fish collected at the TFCF during summer months often show symptoms of environmental stress such as skin lesions, damaged gills, poor equilibrium, and mortality during screen operation and temporary holding prior to transport. Implementation of the Endangered Species Act has also raised concerns, as several species of threatened fish are showing population declines in the Delta.

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 within the marine sedimentary geology of the Central Valley of California. The regional influences can change year to year from hydrologic cycle variability and other trends, such as increasing urban populations and changing land use. 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

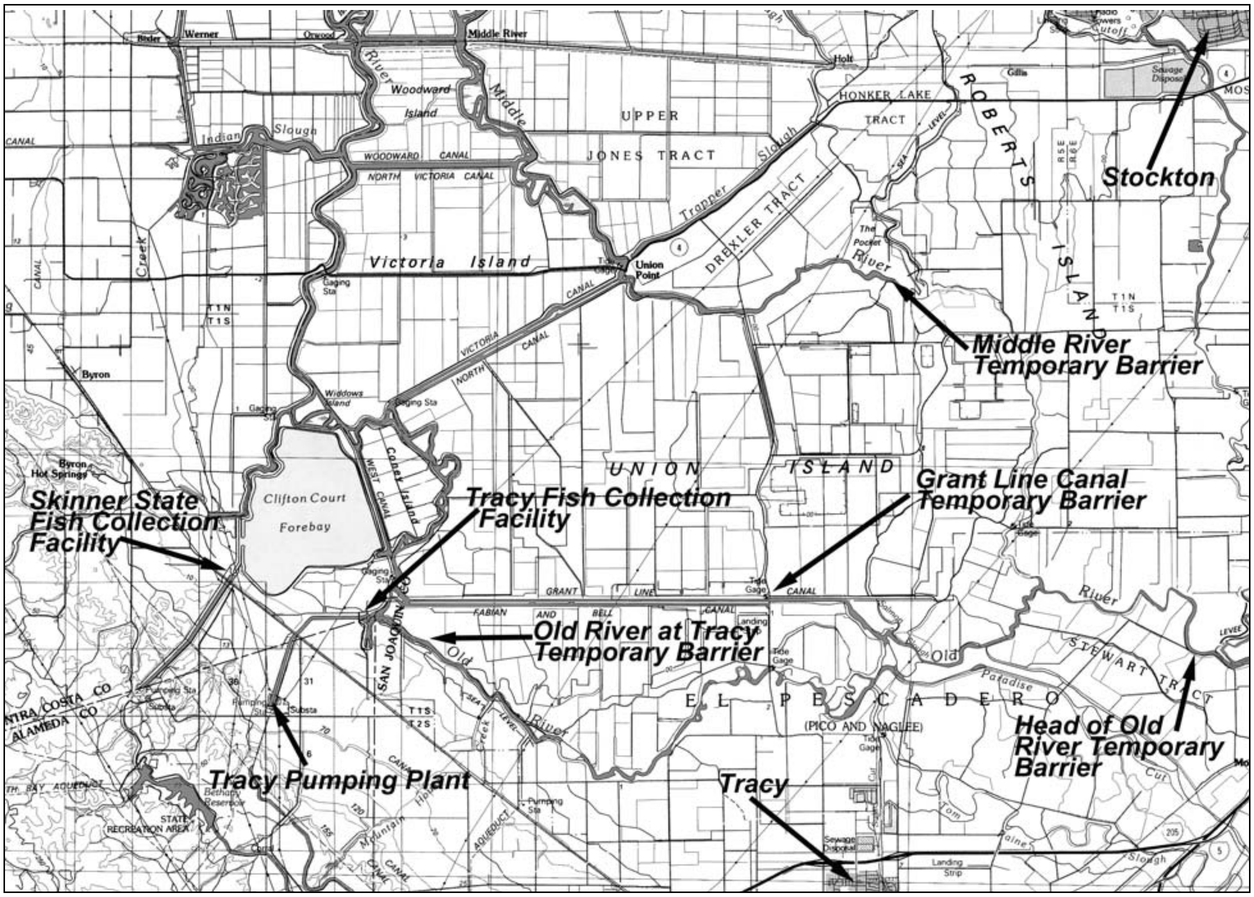

Figure 1.—Map showing the location of the Tracy Fish Collection Facility.

and entrainment of high tides at the State facility at Clifton Court Forebay, local irrigation return flows and chemical applications 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. The temporary barriers are embankments of piled rocks across the flow channels that retard return flow of high tide inflows and appear to influence the quality of water pumped through the TFCF. The complex interactions that produce the water quality observed at the TFCF underscore the need for accurate measurements that are location and temporally representative.

Old River water at the TFCF intake (figures 2a and 2b) contains total dissolved solids (TDS) ranging from 300 to 1100 mg/L and median EC = 479 µS/cm (Craft, et. al. 2000), and contains sodium and chloride as the principal inorganic constituents. The dominant source water at the TFCF is the SJR; however, operation of diversion structures, such as the Cross Channel Canal near Hood, California, also allow for southerly transport and mixing of lower concentration Sacramento River water (median EC = 150 µS/cm) into the South Delta near Tracy (State of California, 1999; Craft, et. al. 2000). Daily tidal conductivity (EC) fluctuations of 100 to 300 µS/cm are commonly observed at the TFCF, thought to be caused by up-gradient transport and mixing of lower concentration waters from the Mokelumne River and Sacramento River by the rising tidal salt wedge (State of California, 1999). When local inflows from the SJR are further impeded by temporary barriers in the river and canal channels, reduced influence from the SJR may help produce better water quality (lower EC) and lower daily variation in EC at the TFCF.

Figure 2a.—Looking eastward at the Old River from the TFCF intake. The debris and trash boom is located at the inlet of the TFCF.

Figure 2b.—The trash rack at the intake of the TFCF. This structure is cleaned regularly by TFCF crews. The Datasonde was installed behind this structure.

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 the Grant Line and Fabian and Bell Canals, the Victoria and North Canals, the Tom Paine Slough and the Paradise Cut, along with the Old and Middle Rivers, and represent an unpredictable contribution to the gross water quality variables measured at the TFCF.

METHODOLOGY

Hydrolab Datasonde

Temperature (T, in ˚C), pH, dissolved oxygen (DO, in mg/L), EC, redox potential (Eh in mV), probe depth (in m), and turbidity (in NTU) were measured at 30-minute intervals using a Hydrolab Datasonde multi probe, installed in a perforated pipe located behind the trash rack and intake structures of the TFCF (figures 2a and 2b). The Datasonde probe assembly included a stirrer which was activated during programmed probe measurements. Personnel from the Reclamation MP Region performed routine calibration and maintenance of the Datasonde (figures 3a and 3b) on a weekly schedule. Appendix 1 provides the standard operating procedure followed for calibration and maintenance activities. 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 a measured barometric pressure, and turbidity was calibrated using a certified 50-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.

Figure 3a.—Calibration shed behind the intake screen at the TFCF. The Datasonde was installed in the pipe located adjacent to the shed platform.

Figure 3b.—Ron Housewright performing routine Datasonde calibration and maintenance in the calibration shed.

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 email 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 or values measured when the probe was not in the water, were 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 which were subsequently removed. Statistical analyses were performed using SPSS® (Statistical Package for the Social Sciences, Windows® version 8.0). Queries exported from Access as Excel files were then converted to SPSS® file format using DBMSCopy (version 6.06, SPSS, Inc.). 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 PC operations.

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 Station 049001 - Tracy Pumping Plant. Weather data for December 2000 were obtained for Station 048999 - Tracy Carbona. The substitution of weather station data are documented in the table field definition in the Access data base. Flow discharge in the San Joaquin River at Vernalis, California, was downloaded from the U.S. Geological Survey (USGS) web site, http://water.wr.usgs.gov/index.html, for Station 11303500 - San Joaquin River Near Vernalis, California. Daily total pumping at the TPP was obtained from the Reclamation Mid-Pacific Region. Tidal and moon phase data were generated using *Tides and Currents for Windows,* version 3.0, (Nobeltec Nautical Software, Beaverton, Oregon). Tidal data were generated for the tide gage station located at the Grant Line Canal Bridge, approximately 11 km from the TFCF.

RESULTS AND DISCUSSION

A summary of the 12-month raw data is provided in table 1, which provides summary parametric and rank statistics for the period of April 2000 through March 2001. Calculated daily data ranges are also summarized in table 1, providing general information on how these variables change during the day. The table 1 maximum DO value may be an anomaly caused by probe malfunction or calibration error, and the reported turbidity minimum is likely below the estimated detection level of 3-5 NTU. More detailed information is available in Appendix 2, which provides histograms for each variable (figure A2-1) and table A2-1 that includes summary statistics for night (data measured after sunset and before sunrise) and day (data measured after sunrise and before sunset) for each month of the study period. Temperature data have a bimodal distribution associated with winter and summer extremes. DO, pH, and turbidity data approximate normal data distributions, while EC and Eh have more skewed distributions.

Annual average T was 16.9˚ C. and ranged from 7.30˚ C. to 27.3˚ C. Daily T ranges varied from 0.1˚ C. to 4.4˚ C. EC averaged 429 µS/cm with a minimum of 201 µS/cm and a maximum of 1,080 µS/cm. Daily variation for EC was greatest from February through March. DO averaged 8.52 mg/L and percent DO saturation averaged 87.3 percent, varying from 39 to 147 percent (the upper value likely being an anomalous calibration artifact). Percent DO saturation was below 49 percent 0.5 percent of the time, and below 75 percent 8 percent of the time. Eh was always positive with 10 percent of data observed less than 293 mV; however, the Eh data are not linearly correlated with DO ($R^2 = 0.012$). Because of mixed potentials on the surface of the platinum Eh electrode, DO is a better indicator of redox conditions in oxygenated surface waters (Lindsay, 1979; Stumm and Morgan, 1996). pH averaged 7.67 and varied from 6.28 to 8.65. pH less than 7 was observed 2 percent of time and pH greater than 8 only 10 percent of the time. Turbidity ranged up to 712 NTU; however, these extreme values are well beyond the calibration range of the probe, and represent very short duration spikes. Average turbidity was 27.1 NTU. Ten percent of turbidity data exceeded 48.9 NTU and only 1 percent exceeded 131 NTU.

Table 1.—All-data summary of water quality variables measured by the Hydrolab Datasonde

Summary		***Water Temp, ℃***	***EC, µS/cm***	***DO, mg/L***	***DO saturation Percent***	***pH, su***	***Redox Potential mV***	***Turbidity NTU***
n		15657	15974	15968	14326	15664	15973	15349
Mean		16.9	429	8.52	87.28	7.67	367	29.9
s		5.80	150	1.44	12.65	0.294	67.0	27.1
Range		20.1	882	9.75	108	2.37	448	711
Minimum		7.30	201	3.38	38.50	6.28	57.0	0.100**
Maximum		27.4	1080	13.1	147	8.65	505	712
Percentiles	***10***	9.06	251	6.82	76.20	7.35	293	10.6
	20	10.2	289	7.39	79.60	7.48	321	15.1
	30	11.6	334	7.73	81.90	7.54	339	18.4
	40	14.7	373	8.15	84.10	7.60	356	21.3
	50	18.0	410	8.65	86.40	7.66	367	24.2
	60	19.3	448	9.01	88.70	7.71	379	27.6
	70	21.6	484	9.44	91.40	7.78	394	31.6
	80	22.9	538	9.78	94.20	7.87	424	37.3
	90	24.2	640	10.2	99.60	8.06	464	48.9
maximum daily range		4.44	874	8.59	88.9	1.45		454
minimum daily range		0.140	4.65	0.130	1.45	0.0300		1.45
average daily range		1.12	251	1.21	13.4	0.266		46.9
median daily range		1.06	223	0.960	11.2	0.210		28.5

Hydrology, Precipitation, Tidal, and Event Data

Background hydrologic data and events are summarized in figures 4a through 4e. Hourly average probe depth measured by the Datasonde in figure 4a may be compared to tidal fluctuations seen in figure 4b. Daily average stream flow in the San Joaquin River (in acre-ft/day) at the USGS gage station at Vernalis, California, is plotted along with daily average pumping (in acre-ft/day) at the TPP in figure 4c. The Vernalis gage data show that the highest sustained runoff flows in the Central Valley watershed occur in the spring and are associated with snowmelt runoff. The SJR also responds to the winter rainy season storms with stream flow peaks, notably those peaks seen in late February and early March. During mid-June through December, TPP pumping is approximately twice the discharge from the SJR at Vernalis. The precipitation plot in figure 4d, measured at the TPP weather station, shows that rainfall episodes are generally infrequent with most of the precipitation events occurring October through April. Occasional heavy rain events are seen, as on October 26-28, 2001, but the semiarid climate is evident in the almost total lack of precipitation seen during the summer months. Figure 4e plots calibration events, internal Datasonde power interruptions, and the installation and removal of two nearby South Delta temporary barriers, installed during spring and removed in the fall.

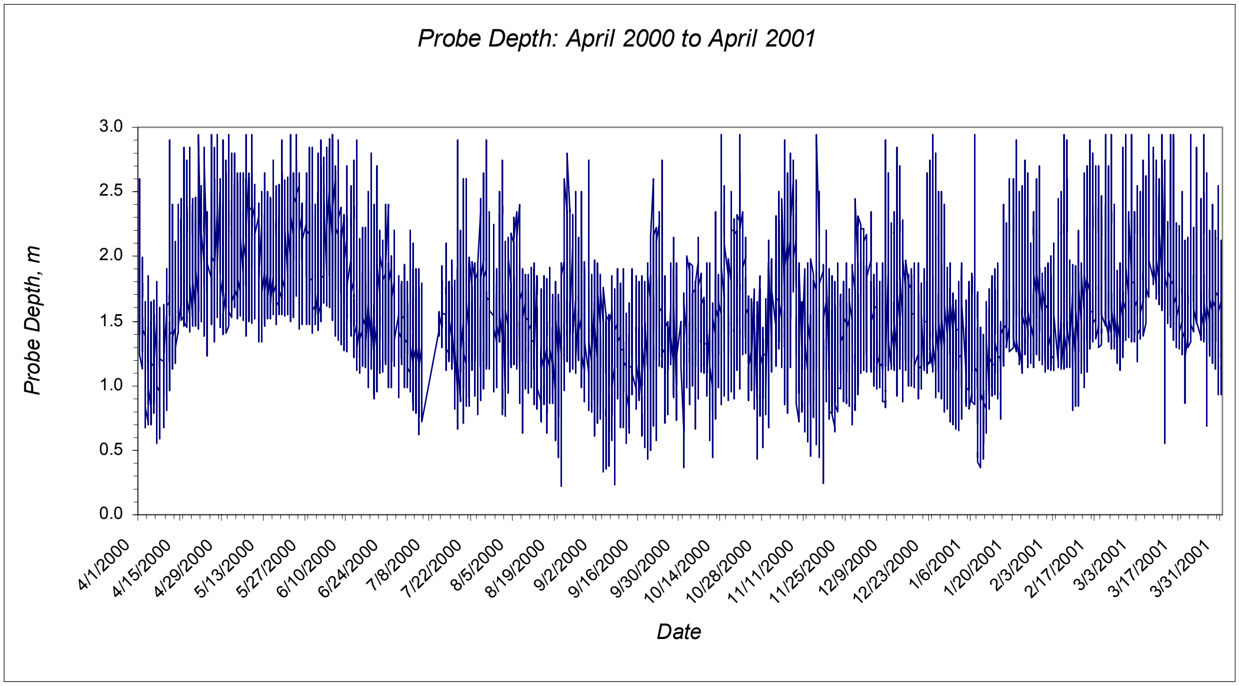

Figure 4a.—Tidal variables: probe depth measured on the Hydrolab probe. Compare with calculated tidal stage at Grant Line Bridge in figure 4b.

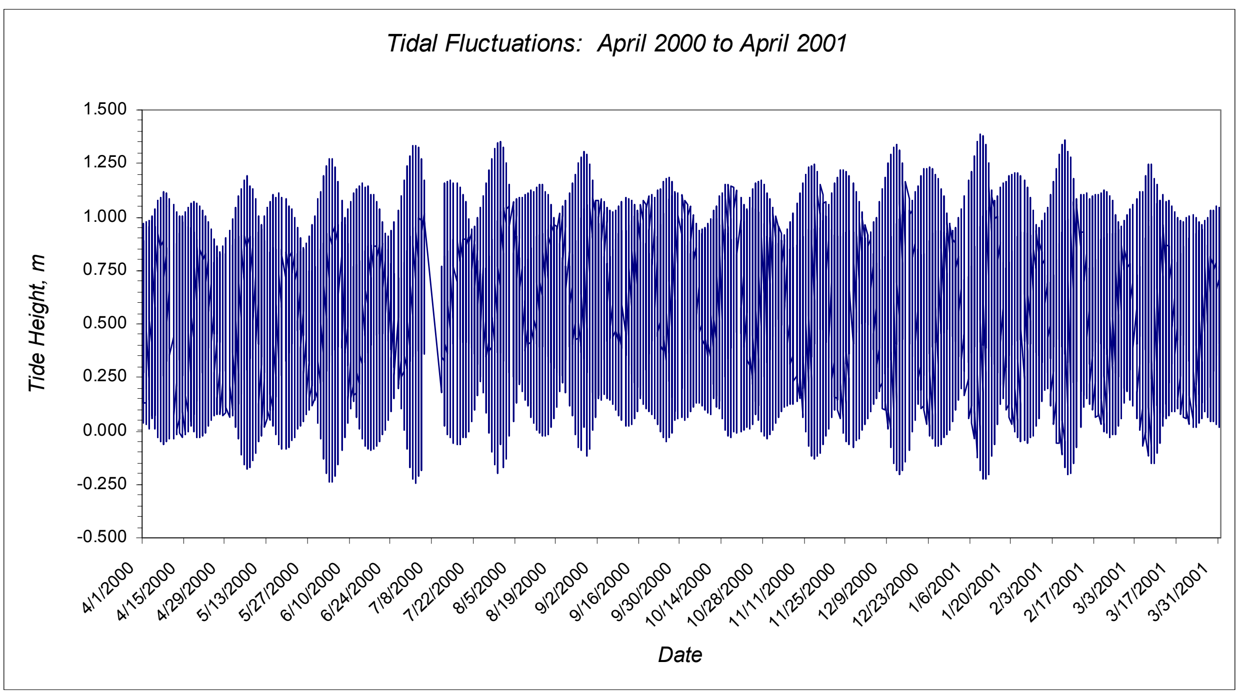

Figure 4b.—Calculated tidal stage at the Grant Line Bridge.

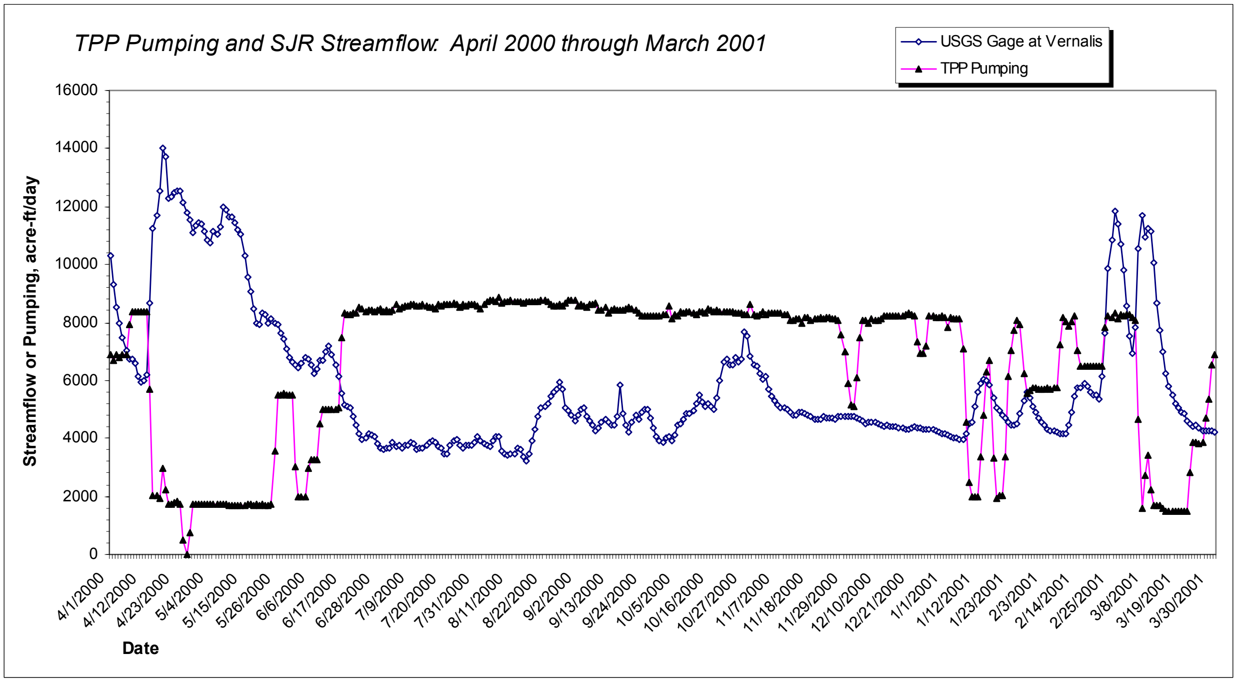

Figure 4c.—Streamflow discharge measured at the USGS Gage Station at Vernalis presented with daily pumping volumes at the TPP. Both plots are in acre-ft/day.

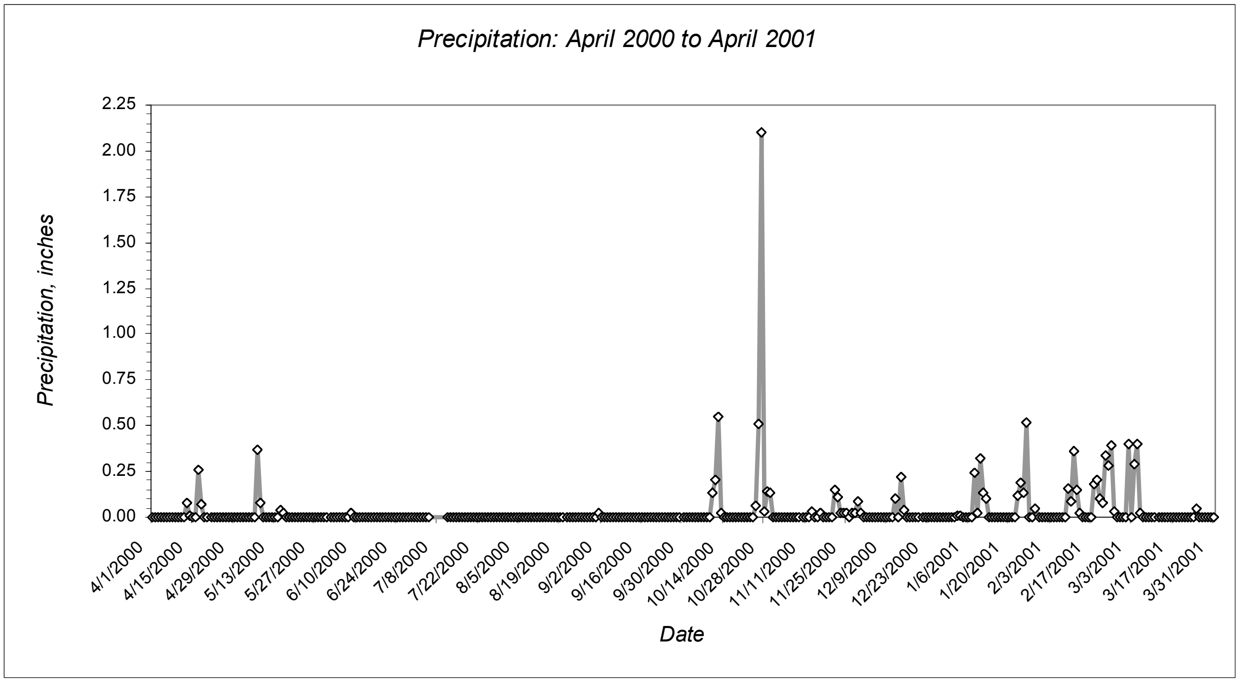

Figure 4d.—Precipitation events measured at the TPP, containing data from the Tracy Carbona weather station for December 2000.

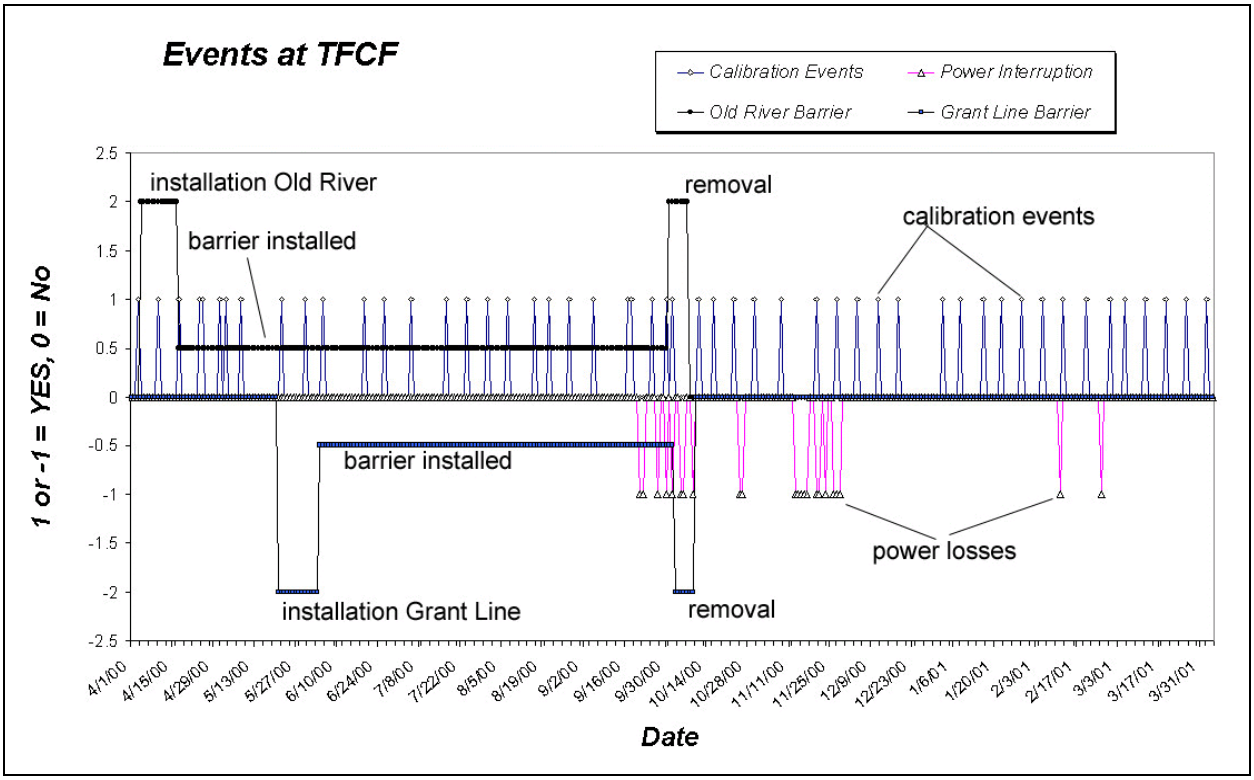

Figure 4e.—Calibration and special events affecting Datasonde measurements.

Water Quality Data

The validated Datasonde data are plotted in figures 5 through 7. Monthly average values are plotted in figure 5, hourly average data are plotted in figures 6a through 6f, and daily range data are plotted in figure 7. The trends observed in the figure 5 monthly averages may be seen in more detail in the hourly average data plots found in figure 6a through 6f.

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Figure 5.—Monthly average values at the TFCF measured by the Hydrolab Datasonde.

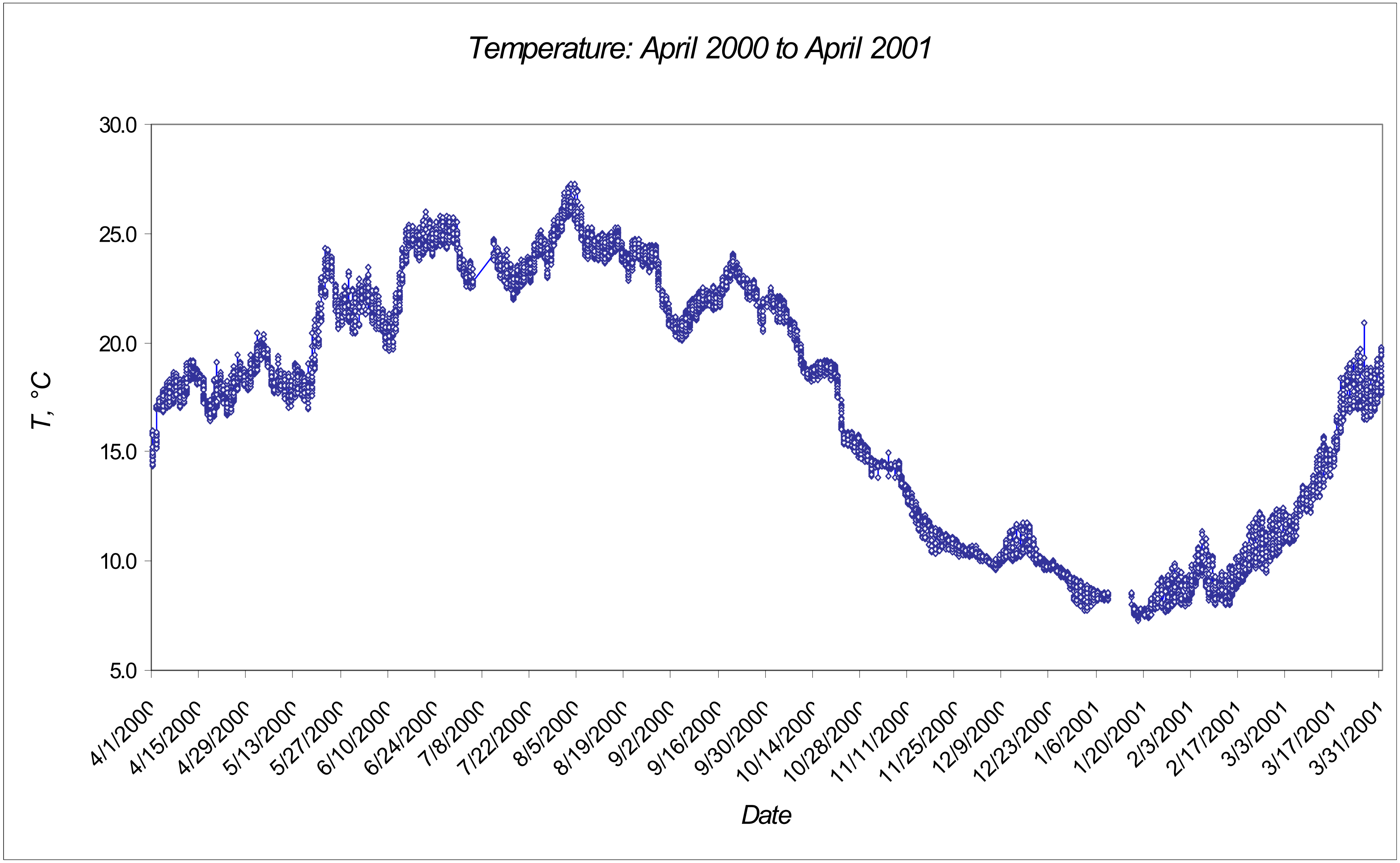

Figure 6a.—Hourly average temperature measured by the Hydrolab Datasonde

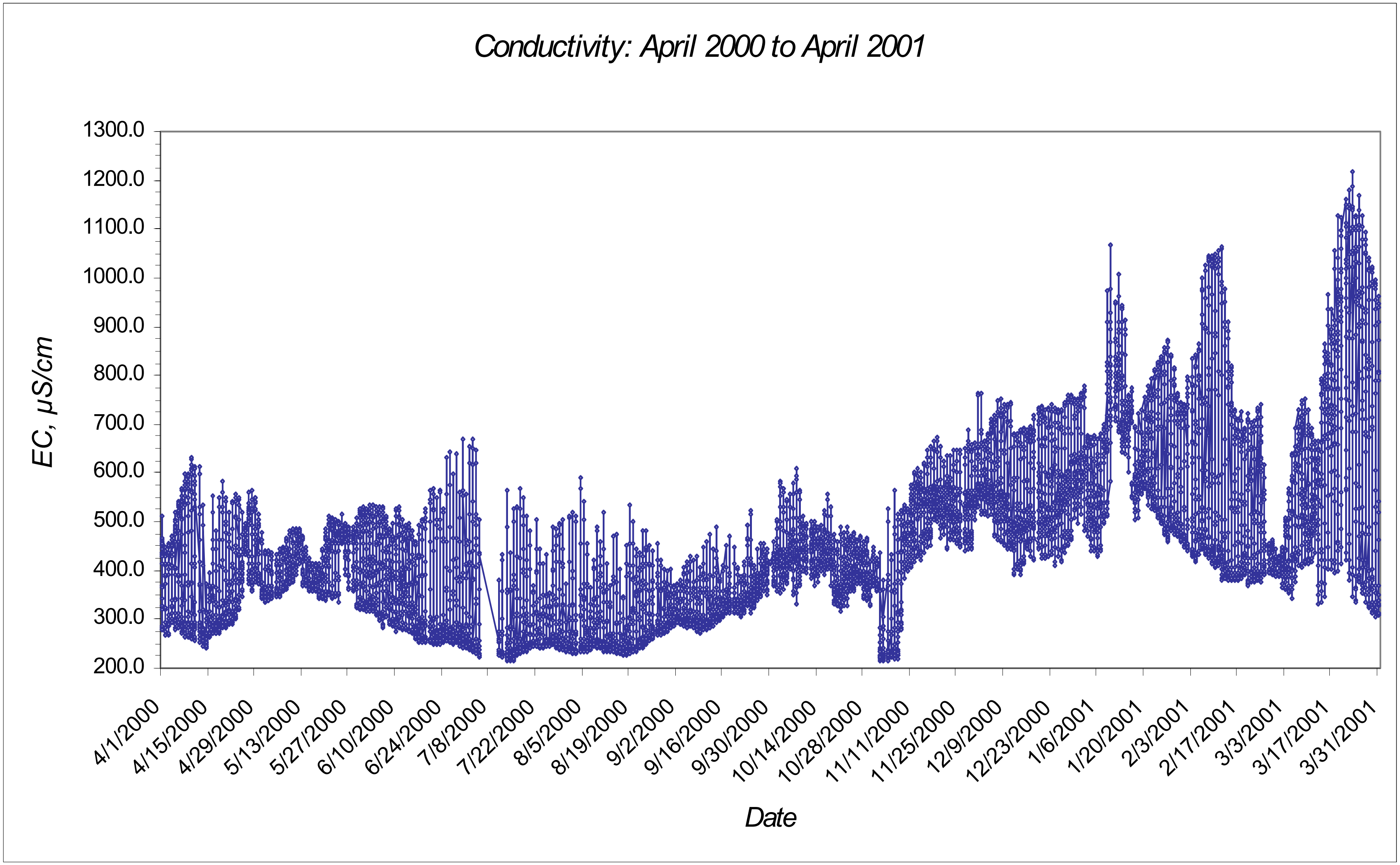

Figure 6b.—Hourly average conductivity measured by the Hydrolab Datasonde.

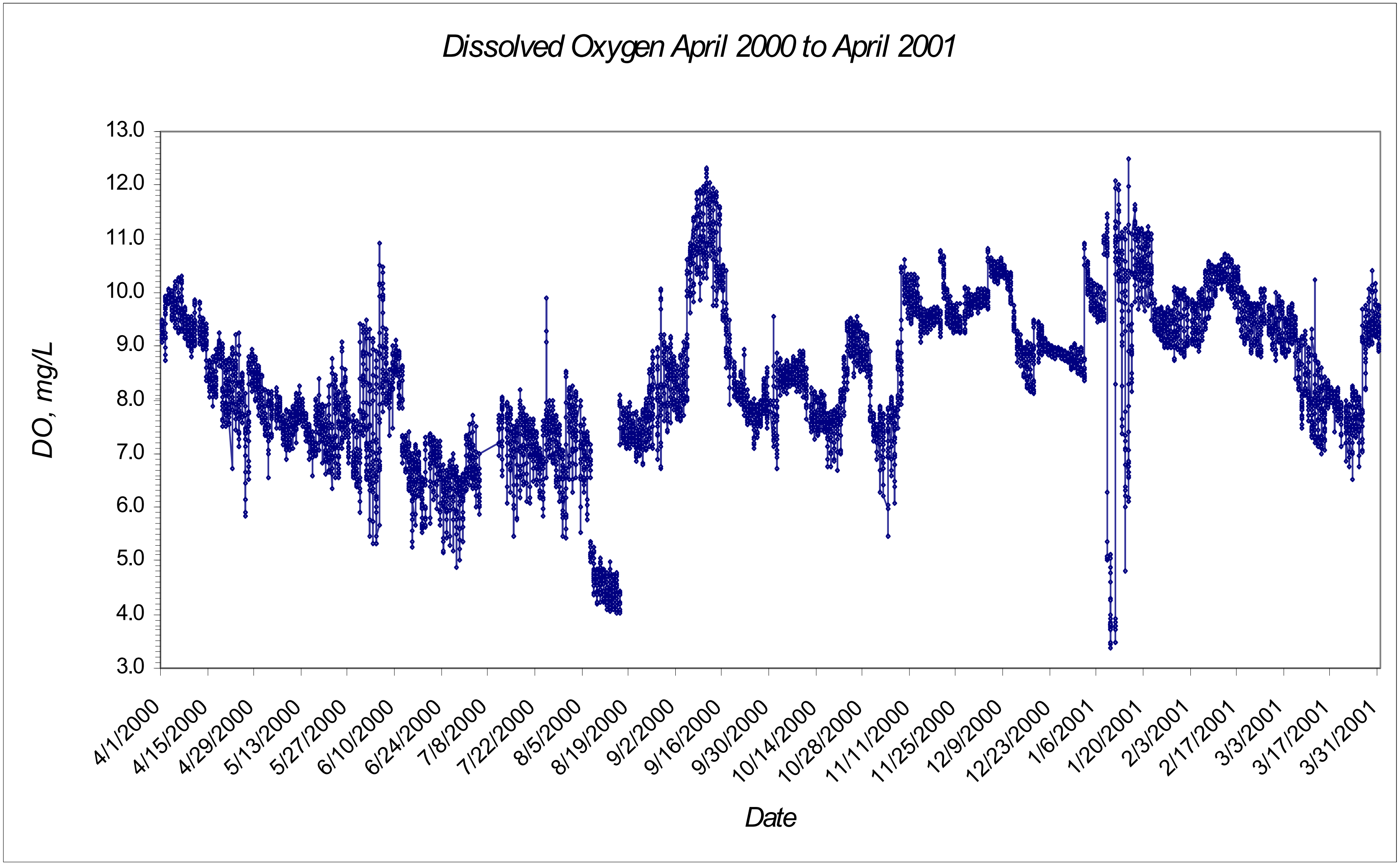

Figure 6c.—Hourly average dissolved oxygen at the TFCF measured by the Hydrolab Datasonde.

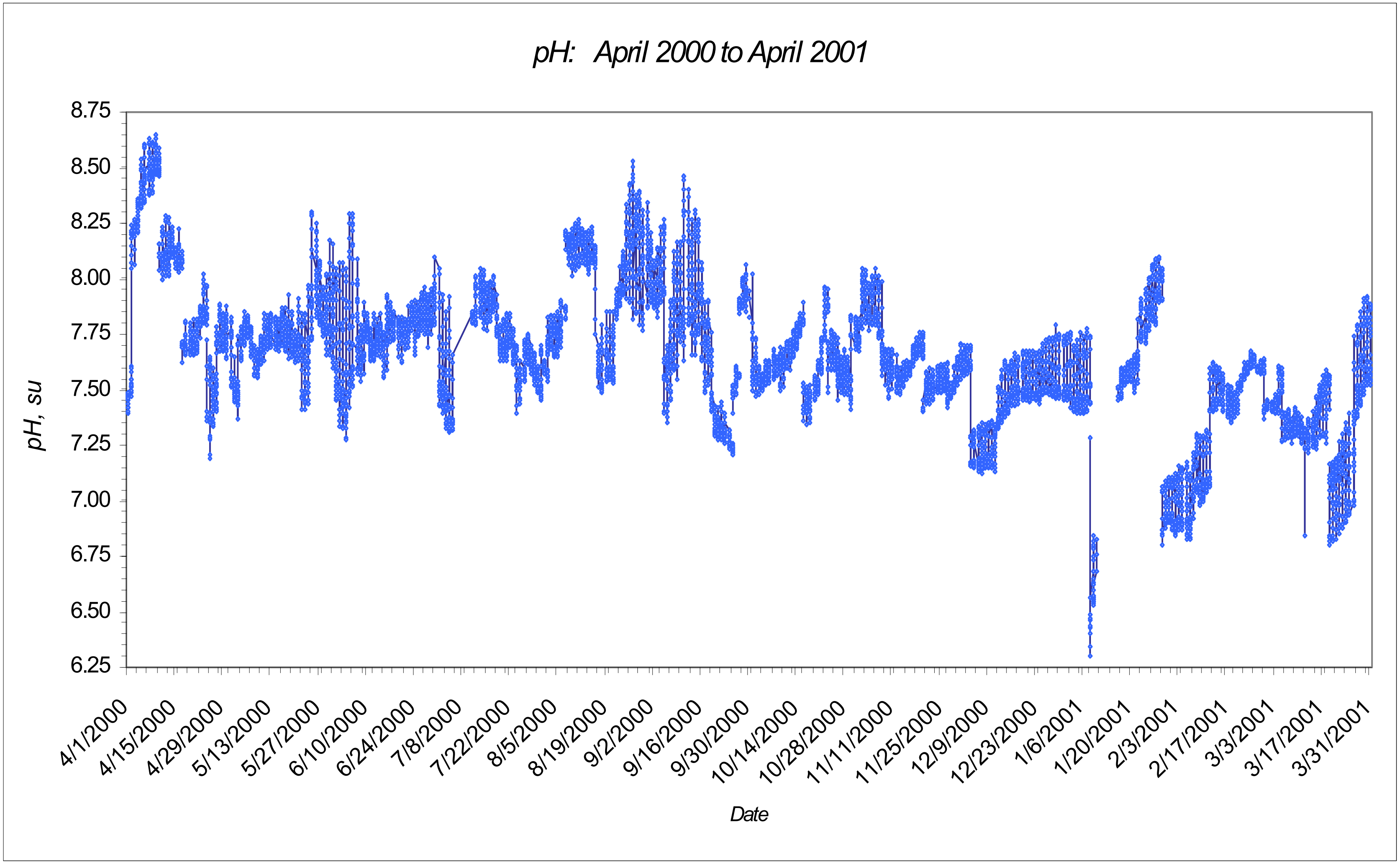

Figure 6d.—Hourly average pH at the TFCF measured with the Hydrolab Datasonde.

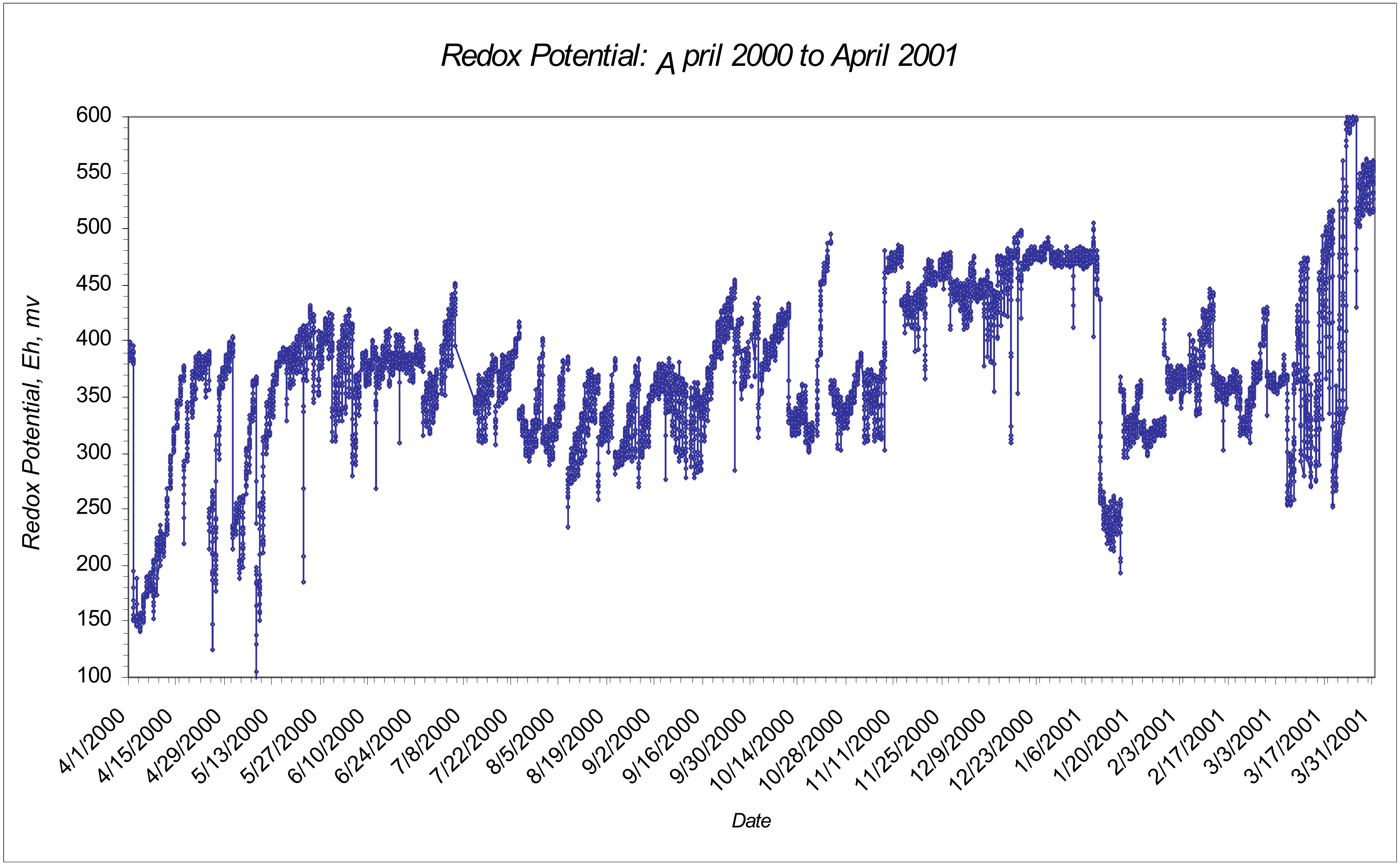

Figure 6e.—Hourly average redox potential (Eh) at the TFCF measured with the Hydrolab Datasonde.

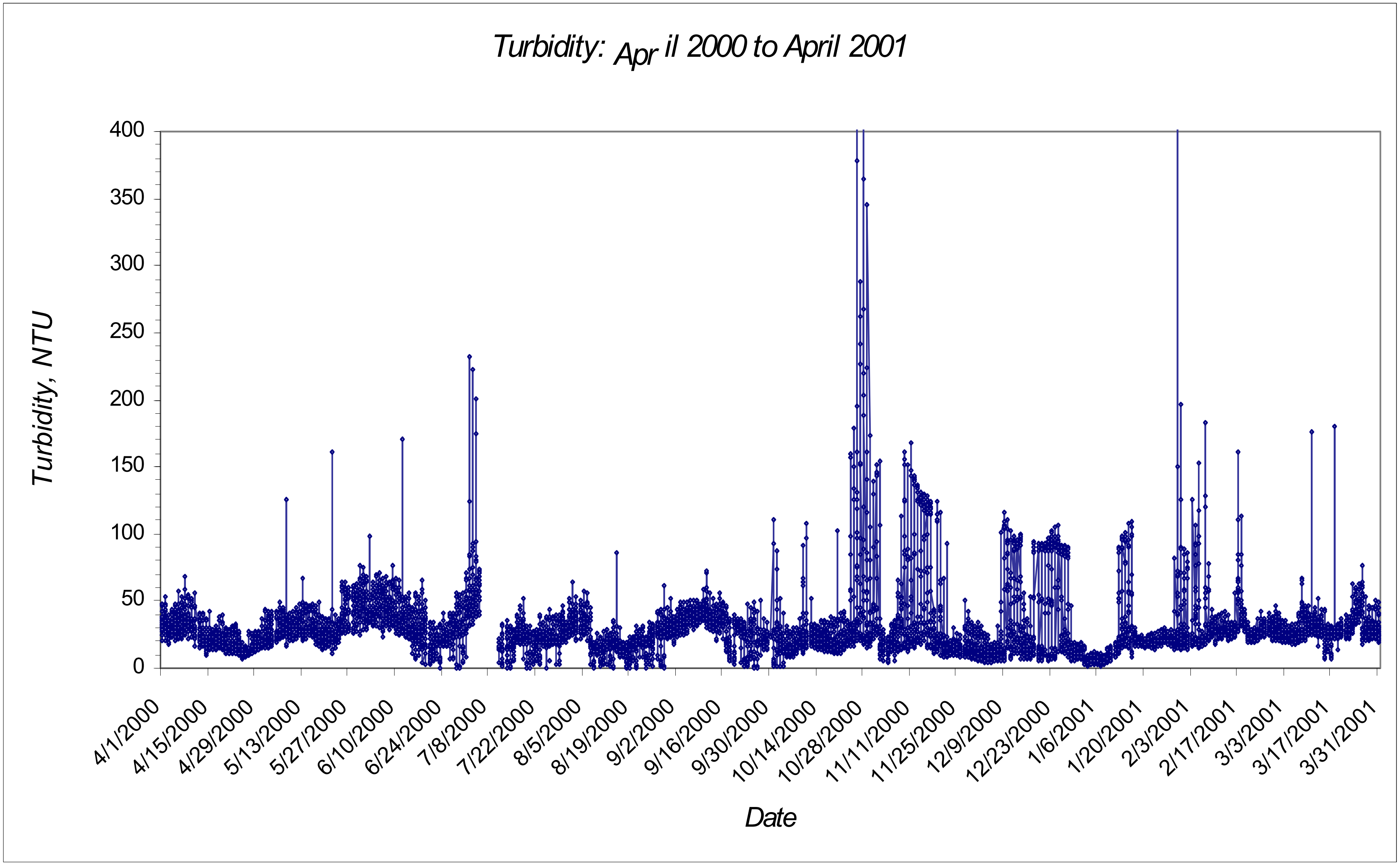

Figure 6f.—Hourly average redox potential (EH) at the TFCF measured with the Hydrolab Datasonde.

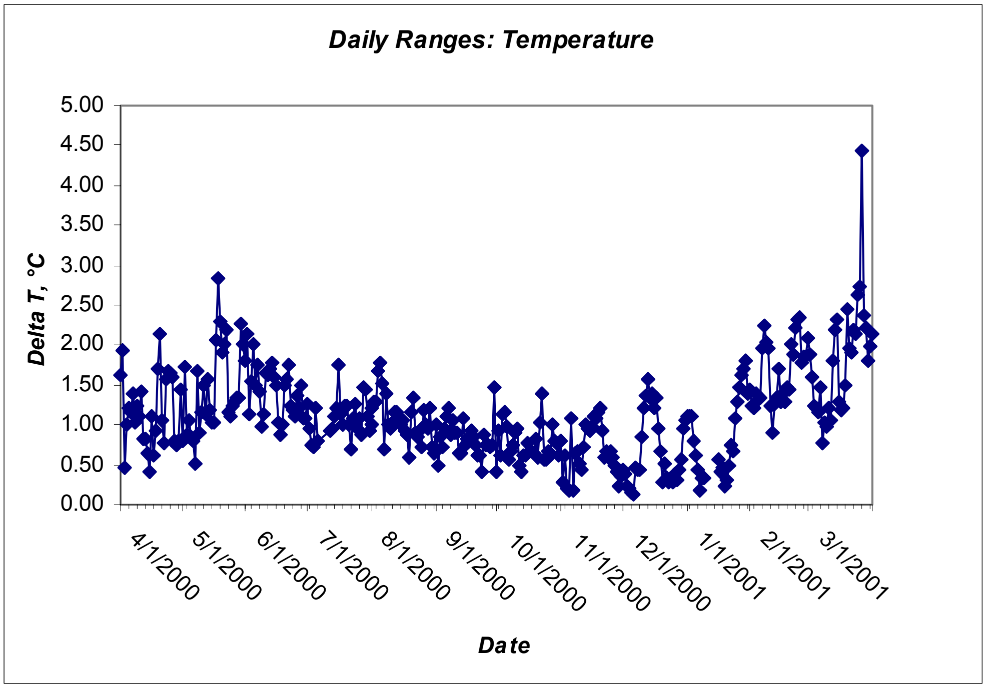

Figure 7a.—Daily range plot for temperature.

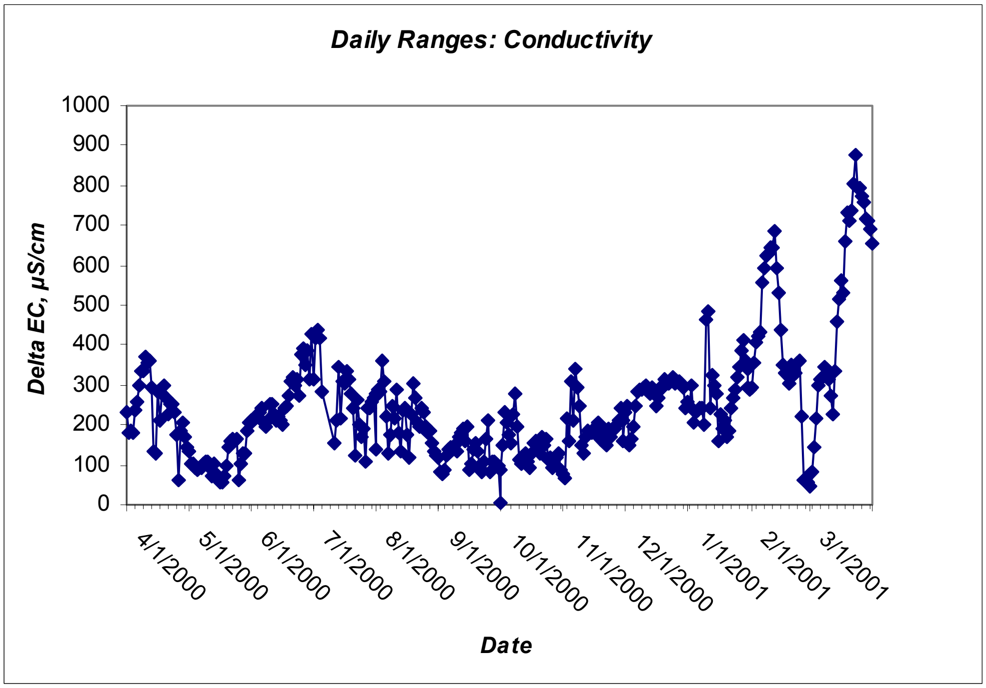

Figure 7b.—Daily range plot for conductivity.

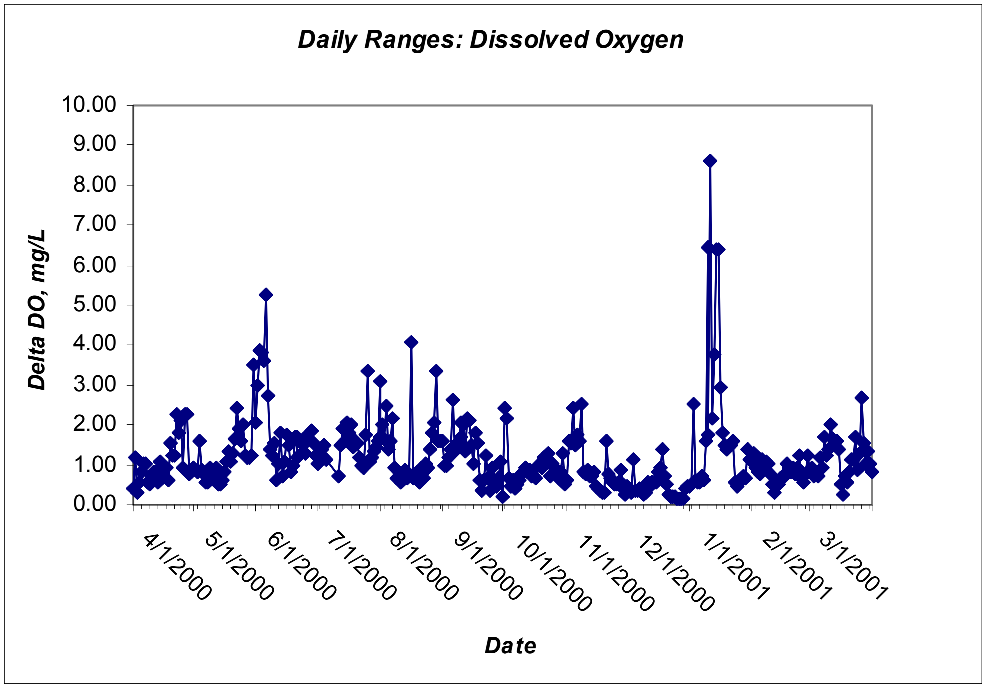

Figure 7c.—Daily range plot for dissolved oxygen.

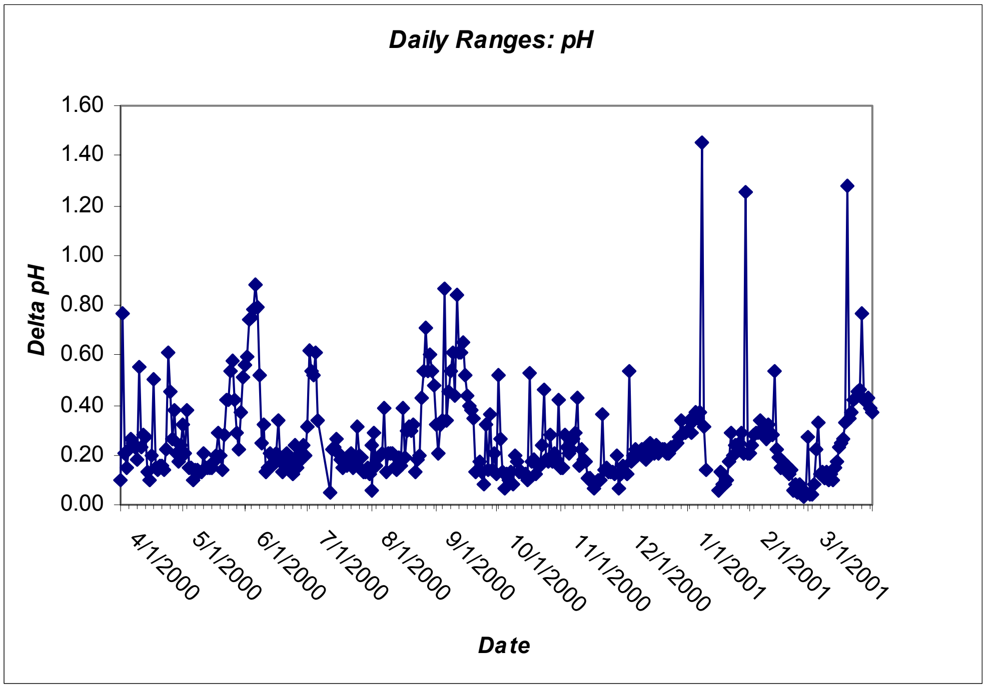

Figure 7d.—Daily range plot for pH.

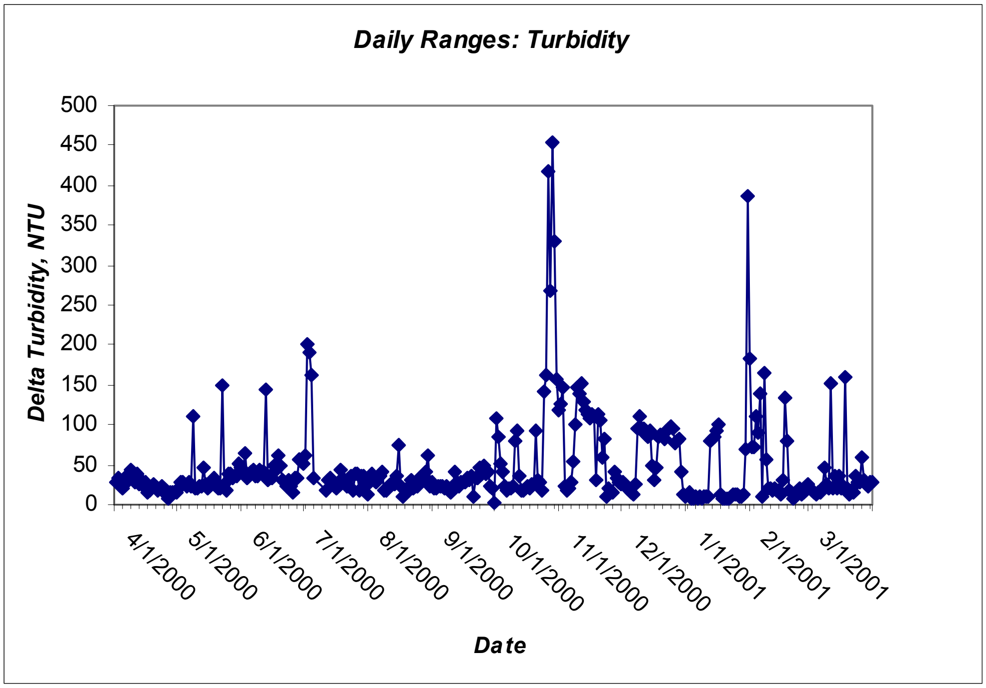

Figure 7e.—Daily range plot for turbidity.

Monthly Average Trends

T, EC, DO, and pH show seasonal trends for monthly averages. Maximum average T was observed in August, while minimum average T was seen in January. EC and DO show opposite trends to temperature for monthly average plots. Minimum average EC is seen in July and maximum EC is seen in January. The observed EC trend is notable because the expected seasonal effect for a watershed that experiences a snowmelt cycle and irrigation would be lowest EC during maximum spring runoff with increasing EC through the summer. Minimum DO was observed during August, consistent with highest temperatures, agricultural nutrient loading, and algal productivity in local waters. Maximum DO was observed in February. Monthly average pH shows general maxima during the spring and summer, probably caused by increased productivity and higher temperatures in local waters, and lower average pH was observed during winter months. Eh and turbidity do not show clear seasonal patterns.

The EC data in figure 6b and monthly average trends seen in figure 7 suggest that temporary barrier installations and diversion structures such as the Cross Channel Canal may be enhancing the contribution from better quality Sacramento River water. The barrier in the Old River is approximately 2 km from the TFCF and was installed April 4-16, 2000. The Grant Line Canal barrier is located around 11 km from the TFCF near the tidal gage at Grant Line Bridge, and was installed May 19 through June 1, 2000. Both temporary barriers were removed October 1-7, 2000. No clear response associated with barrier installation or removal was observed for T, pH, DO, or Eh. No response in turbidity was observed for installation of either barrier; however, spikes of higher turbidity appear to coincide with the October barrier removal. These turbidity maxima are in the range of 100 NTU, and are low relative to the local storm runoff response associated with the large October precipitation event seen in figure 4d. Elevated turbidity spikes (maxima around 100 NTU) were also observed during local channel dredging performed from September 15 through December 15, 2000.

Daily Variability

Highly variable daily readings appear to have a seasonal component for several variables. T and EC both show the greatest daily variability during late winter through early summer. The hourly EC data in figure 6b clearly shows greater variability during these months. pH, DO and turbidity, on the other hand, do not show any clear seasonal trend in daily variability. The extreme range spikes seen with these variables seems to be more episodic, perhaps more related to short duration local flow conditions or shifts after probe cleaning and calibration. The large turbidity spike seen in figure 6f associated with a large precipitation event in late October 2000 is also seen in the range plot in figure 7e, suggesting that the daily tidal inflows do interrupt prevailing local flow patterns.

Diel factors would be expected to influence chemistry and biological responses in any natural surface water system; however, a comparison of night and day averages using analysis of variance, revealed no significant statistical differences. This result was expected given the complexity of variable interactions at the TFCF. For example, 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

T, DO, and pH follow seasonal patterns that are consistent with snowmelt runoff and Central Valley watershed processes. The EC data suggests that the South Delta temporary barriers have a beneficial influence on water quality at the TFCF. Because of higher temperatures and lower DO, the summer months are probably the most stressful for fish at the TFCF; however, DO is below the EPA recommended water quality criteria of 5.0 mg/L (Environmental Protection Agency, 1976) only 2.9 percent of the time. These low DO periods occurred during August and a brief episode in January 2001 (that may be anomalous readings). Turbidity spikes appear to be related to events near the TFCF such as heavy rainstorms and removal of the temporary barriers. Given the short time periods where DO percent saturation is low and turbidity is high, the first full year of high quality data suggest that the general water quality at the TFCF is good.

The preliminary summary presented in this report suggests that more detailed data analysis may reveal additional relationships between hydraulic, weather, and water quality variables. For example, confirmation of enhanced Sacramento River influence on water quality at the TFCF could be evaluated by graphically comparing multi probe data with conterminous major ions analyses (for sodium, potassium, calcium, magnesium, carbonate, bicarbonate, sulfate, and chloride) of source waters (the SJR and Sacramento River) and the TFCF intake during tidal cycles. A more involved pre-processing and transformation of water quality variables could establish whether diel effects are significant.

The correlations between water quality variables and fishery health could also be further investigated. What is the relationship between gross channel debris quantity and turbidity? How does DO change with turbidity and debris loading? What about local agricultural activities such as planting, harvesting, spraying? How do these additional variables relate to fish salvage and mortality? Fish salvage, mortality, and quantitative debris removal data from routine TFCF operations (as well as similar data from the nearby State facility) would be meaningful variables to compare with the data presented here. Additional systematic documentation of events, such as mitten crab counts, fish kills, presence of lesions or other health data on salvaged fish, and species percentages would be helpful data to compare with water quality.

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Glossary

Measurement Units

acre	English unit for land area, (1 acre = 2.471 ha).
acre-ft	acre-foot. English unit for water volume. One acre covered with water to a depth of 1 foot, (1 acre-ft = 1.233 X 10^3 m^3 = 1.233 X 10^6 L)
cfs	cubic feet per second, English and engineering unit for flow discharge (1 cfs = 2.447 X 10^6 L/day, 1 cfs = 1.983 acre-ft/day).
g	gram, SI mass unit.
ha	hectare, SI area unit (1 Ha = 1.00 X 10^4 m^2).
kg	kilogram, SI mass unit (1 kg = 1000 g).
L	liter, SI volume unit.
M	molarity, moles per liter.
m	meter, SI length unit.
mg	milligram, SI mass unit, (1 mg = 10^{-3} g).
mg/L	milligrams per liter, SI concentration unit.
mi^2	square mile (1 mi^2 = 640.0 acres = 2.590 X 10^6 m^2 = 259.0 ha).
mL	milliliter, SI volume unit, (1000 mL = 1.000 L).
mm	millimeter (10^{-3} m), SI length unit.
mV	millivolt, (10^{-3} volts) SI voltage unit.
µS/cm	microsiemens per centimeter, SI unit for electrical conductivity. Also µmhos/cm.
NTU	nephelometric turbidity units.
SI	Système Internationale d'Unités, the international standard system for metric measurement units.
su or s.u.	standard units, usually applied to pH.
V	volt, SI voltage unit.

Water Quality Variables Measured at the TFCF

DO	dissolved oxygen, mg/L
EC	electrical conductivity, µS/cm
Eh	redox potential, mV
pH	negative logarithm of the hydrogen ion activity, a measure of acidity or alkalinity.
T	temperature, ˚C
TDS	total dissolved solids, mg/L, also called "filterable residue"
TSS	total suspended solids, mg/L, also called "non-filterable residue"

Quality Control and Statistics Terms

accuracy	a measurement of closeness to the true or actual value.
calibration verification	a known concentration certified standard, different from the standards used to calibrate an instrument, that is analyzed after calibration and during the period the instrument is analyzing samples. Used to independently verify initial (ICV) and continuing calibration (CCV).
check sample	a sample analyzed during an instrument run having known concentrations, not necessarily certified or traceable.
certified	as applied to a standard, having documentation attesting to the precision, accuracy, and traceability of a reported concentration.
distribution	the overall shape of the data set with respect to data values and frequency of occurrence.
mean	arithmetic average, denoted as x-bar, or $\bar{X}$.
median	the middle value in a set of data that has been sorted from lowest value to highest value
n	number of data points.
precision	a measure of the variability of repeated measurements.
QA	quality assurance, overall efforts, audits, and tests performed to make sure that sample collectors and the analysis lab are following the QC requirements. These could include lab and field sampling audits, or submission of known concentration samples as blind check samples.

QC	quality control, efforts and tests undertaken *in the lab* to check or document analysis data quality.
qualitative	detected, but not at a high level of precision and/or accuracy.
quantitative	detected with a higher degree of precision and accuracy.
Recovery	observed concentration divided by theoretical or true concentration, usually expressed as a percentage.
residual	the difference between the statistically predicted value and the actual value, for a mean, $\bar{x} - x_i$.
R-squared, R^2	adjusted correlation coefficient, a measure of linear correlation.
s	sample standard deviation.
SRM	standard reference material, a known-concentration standard, usually manufactured and tested by a national standards organization (such as NIST.)
standard deviation	a statistical estimate of variability about a mean.
validated, validation	the process of checking and documenting the quality of analysis data.
variable	a measured property that varies.
$\bar{x}$, x-bar	arithmetic average or mean.

Agency, Organizational, and Location Abbreviations

CALFED	CALifornia-FEDeral - a state and federal interagency coordination group formed to address fishery and water quality issues in California
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
DFG	California Department of Fish and Game
EPA	U.S. Environmental Protection Agency
IEP	Interagency Ecological Program - a technical consortium of state and federal agencies involved with research in the Sacramento-San Joaquin Delta region.
MP	Mid-Pacific Region, Bureau of Reclamation
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration.
SJR	San Joaquin River
SPSS	Statistical Package for the Social Sciences, SPSS, Inc.
TEFF	Bureau of Reclamation, Tracy Experimental Fish Facility
TFCF	Bureau of Reclamation, Tracy Fish Collection Facility
TFFIP	Bureau of Reclamation, Tracy Fish Facility Improvement Program
TPO	Bureau of Reclamation, Tracy Project Office
TPP	Bureau of Reclamation, Tracy Pumping Plant
TSC	Bureau of Reclamation, Technical Service Center, Denver, Colorado.
TTAT	Tracy Technical Advisory Team
USBR	U.S. Department of the Interior, Bureau of Reclamation.
USGS	U.S. Department of the Interior, Geological Survey.

APPENDIX 1

Standard Operating Procedure for Calibration and Maintenance of the Hydrolab Datasonde

STANDARD OPERATING PROCEDURE
FOR
WATER QUALITY PARAMETERS
AT THE
TRACY FISH COLLECTING FACILITY

Environmental Monitoring Branch
MP-157

Reviewed and Approved by D. Craft, Technical Program Manager
June 12, 2001

Bureau of Reclamation
Mid-Pacific Region
Sacramento, California

January 24, 2001

INTRODUCTION

This procedure is an amendment to the Environmental Monitoring Branch Standard 0perating Procedures (SOP) for Field Monitoring. This SOP describes calibration, record keeping, and measurement of water quality variables at the Tracy Fish Collection Facility (TFCF) in the Old River Channel using a Hydrolab Datasonde multi probe.

BACKGROUND

This program was implemented to measure temperature (T), pH, dissolved oxygen (DO, in mg/L), conductivity (EC, in µS/cm), redox potential (Eh, in mV), and turbidity (in NTU) on a semi-continuous schedule at Reclamation's TFCF. The purpose for these measurements is to provide baseline water quality data to fishery researchers performing studies for new screen designs, and as reference data for environmental impact assessment for planned construction of a research facility near the TFCF. The TFCF is located on the Old River at the intake for the Tracy Pumping Plant, and the Datasonde probe is located down stream of the debris screen and the intake screen.

OPERATION AND CALIBRATION OF HYDROLAB DATASONDE

The operating procedures of the Hydrolab Datasonde multi probe and Surveyor 4a data logger are provided in the operating manuals. An abbreviated procedure is given below.

1. Remove the submerged Datasonde from the steel pipe, which is attached to the expanded metal platform on the north side of the Old River Channel just downstream of the debris screen.

2. After removing the Datasonde from the pipe, hang it upright on the hook above the wooden shelf in the aluminum sampling shed before disconnecting the cable.

3. Disconnect the support and signal cables from the sonde. When removing the signal connector, gently pull straight out to avoid bending the pins. After disconnecting the support cables, screw the supporting links back together and leave them on the Datasonde support handle.

4. Connect the Surveyor 4a and the Datasonde using the download cable. (Make sure that the raised dot on the cable plug is lined up with the large pin on the Datasonde connecter.) Turn on the Surveyor 4a.

5. Unscrew and remove the weighted probe frame assembly from the bottom of the Datasonde and replace it with the probe storage cup filled with tap or canal water.

6. To clean the probe assembly, remove the cup and rinse the Datasonde probe assembly three times (3X) with deionized (DI) water. Rinse probes with a soapy water solution from a squeeze bottle then rinse 3X with DI water. Then rinse the sensing electrodes with isopropyl alcohol, followed by another 3X DI water rinse. Re-attach the probe storage cup containing tap or canal water and allow to sit upright one hour to rehydrate the sensors.

7. Before all measurements and recalibration, rinse the sensors with DI water three times. Between calibration measurements, keep the probes hydrated by re-attaching the Datasonde cup containing water.

8. Download the data stored in the Datasonde memory to the Surveyor 4a before recalibrating and/or reprogramming the Datasonde. The following procedure is used to download the data from Datasonde to the Surveyor 4a.

    8.1 Make sure that the Surveyor 4a and Datasonde are correctly connected and turn on the Surveyor 4a. Allow 5 minutes for Surveyor 4a warm up.

    8.2 Push *files* button and select *sonde.*

    8.3 Select *download.*

    8.4 Choose the file you want to download by scrolling through the file list and push the *select* button when the file is highlighted.

8.5 Data downloading will now start. This takes several minutes and the display will show a message when the download is complete.

8.6 To verify that the file has been successfully downloaded, disconnect the Surveyor 4a from the Datasonde and select *files.* Select *review*, then highlight the file just downloaded, press the *select* button, and then select *beginning.*

8.7 Scroll to the last readings in the data file and enter the variable values into the Tracy log book. These readings serve as pre-calibration values and include pH, water temperature (°C) , EC (µS/cm.), dissolved oxygen (mg/L), redox (oxidation-reduction) potential Eh (mV), and turbidity (NTU).

9. The datasonde is calibrated for the following parameters: pH using pH = 4.00 and pH = 7.00 buffer solutions, EC using air as the "zero" and a 550 µS/cm standard, DO using air saturated with water vapor and the current barometric pressure, turbidity using a 50-NTU standard, and Eh using a 428 mV standard. The portable turbidity meter is used to standardize the canal water which then is used as a secondary standard to calibrate the Datasonde turbidity sensor. Use the following calibration solutions:

9.1 The pH buffers, EC, and turbidity standards are available from Electronic Data Solutions in Jerome Idaho at the address below.

9.1.1 Electronic Data Solutions
P.O. Box 31
Jerome, Idaho 83338
Phone (208) 324-8006

9.1.2 Given below is the ordering information for the standards from Electronic Data Solutions.

Standard Name	Stock Number
pH 4.00	2-0400R-8
pH 7.00	2-0700Y-8
pH 10.0	2-1000B-8
EC 550 µS/cm	3-0550-4 (custom made)
Turbidity 40 NTU	4-0500-4 (custom made)

9.2 Zobell's Redox Solution is available from Hydrotech ZS Consulting in Hutto,Texas. Below is given Hydrotech address and Zobell’s solution ordering information.

Caution: Avoid contact with Zobell's solution. If spilled on skin wash off with soap and water. For eye contract wash with water for at least 15 minutes and get immediate medical attention. If accidently taken internally induce vomiting immediately after giving two glasses of water. For this solution the manufacturer’s MSDS does not recommend use of any personal protective equipment.

9.2.1 Hydrotech ordering address

Hydrotech ZS Consulting
324 Axis Deer Trail
Hutto, TX 78634

9.2.2 Ordering information for Zobell's Redox Solution

Product name	Product Code
Zobell’s Redox Solution	ZSC002

9.2.3 Zobell's Redox Solution formulation as shown on Certificate of Analysis.

Chemical amount	Amount	Unit
Deionized water Type II	40.0	L
Potassium Chloride	298.0	g
Potassium Ferricyanide	43.9004	g
Potassium Ferrocyanide	56.3201	g

9.3 The turbidity solution used to calibrate the portable meter is a 40 NTU micro bead standard requiring no dilution.

9.3.1 40 NTU Standard Solution No. 66115-024
100 NTU Standard No. 66115-026

9.3.2 Available from VWR Scientific, Inc.
1-800-932-5000
http://www.vwrsp.com

9.4 pH, EC, turbidity and ORP standards must be verified at least once a year bu submitting standards to an external laboratory for analysis . This is used to confirm that calibration standards are accurate. Any maintenance needed on the sondes is done according to Hydrolab manual or phone instructions from Hydrolab.

10. A calibration sheet is completed with the date, time, project, standard values, name and Datasonde serial number. Enter standard values, initial readouts and adjusted values on the calibration sheet and in the logbook.

11. The Datasonde is calibrated in the following manner :

11.1 Rinse the electrodes three times with DI water between each calibration.

11.2 Rinse the electrodes with the calibration standard three times.

11.3 Fill the cup up to the mark with the standard and screw on the bottom of sonde.

11.4 Push *setup/calibrate* button. Push *calibrate*, select *sonde,* and scroll to desired parameter with the arrow keys. Press *select,* enter the parameter value and press *done*. The display then should read "*calibration successful*".

11.5 The pH, and EC calibrations use two standards to for better accuracy. pH is calibrated at 4.00 and 7.00, and the EC at 0 and 550 µS/cm. The 0 standard for EC is air after the sensor has been rinsed 3X with DI water and then dried.

11.6 Calibration for EC, pH, and redox is achieved by pouring the calibration standard into the datasonde cup. Follow instructions given in A through D above. Enter parameter values of initial and final readings on calibration sheet and log book.

11.7 Calibrate turbidity as follows:

11.7.1 Place Datasonde into a gallon plastic jar containing canal water for which the turbidity has been measured using a different calibrated turbidity instrument. Follow steps 11.1 through 11.4 above. Enter the initial and final reading onto calibration sheet and logbook (The turbidity of the canal water is measured by a portable meter, standardized using a 40 NTU standard as stated in step 9 above.)

11.7.2 DI water is used for the low turbidity standard. Follow instructions as in 11.7.1.

11.8 Calibrate DO as follows:

11.8.1 Measure the barometric pressure directly using a barometer. Because the elevation of Tracy facility is very near sea level, corrected weather service barometric pressure may be obtained from the Tracy Flight Service (209-831-4335). Measure the air temperature using a thermometer.

11.8.2 Pour approximately 1/8 in. water in the bottom of the Datasonde cup, screw on Datasonde cup and shake to saturate the air with water. Allow 5 minutes for temperature equilibration.

11.8.3 Obtain the correct DO reading for the observed barometric pressure using the DO table in the black sampling manual under the Tracy heading (kept in the van). Find the correct value for the DO calibration using the measured at temperature and the barometric pressure.

11.8.4 Use the table DO value to calibrate the Datasonde as instructed in 11.1 through 11.4 above.

11.8.5 Enter temperature, barometric pressure, standard value for DO, initial reading, and final reading on the calibration sheet and in the logbook.

11.9 Depth is calibrated only if it is not reading zero in air. Depth is calibrated as per step 11.4.

12. Zero point for oxygen is checked every two or three months using a sodium sulfite solution. This is accomplished by inserting the oxygen sensor directly into the plastic bag containing the sodium sulfite solution. Allow reading to stabilize and enter on calibration sheet and in the logbook. The zero oxygen reading is not adjustable.

13. Renew the DO membrane and electrolyte, and the pH electrode electrolyte at the beginning of each month.

14. Internal Datasonde batteries are replaced monthly or when the voltage drops below 8.0 VDC.

15. The Datasonde is removed from the shed. The Datasonde is attached to the supporting steel cable and then it is put into the steel pipe. Tighten the chain link with wrench. Leave the download cable attached to the Datasonde.

16. Confirm that all the information entered on the calibration sheet is identical to the logbook entries.

17. Record pH, temperature, turbidity, EC, DO, and ORP readings that appear on the Surveyor screen after allowing time for stabilization. Enter into the Tracy Logbook, as reading after recalibration, and record the time. Pull Datasonde from pipe and remove the download cable. Put protective cap over pins and put Datasonde back into steel pipe.

18. The data is transferred from the Surveyor 4a to a PC with Windows 98 or NT using the HyperTerminal software by the following procedure.

18.1 Connect the Surveyor to the PC's serial port using the Hydrolab download cable. (Part No. 013150)

18.2 Turn on Surveyor power and allow 2 minutes for warmup, and then press *files* button.

18.3 Scroll to *transmit*, and press the *select* button. Scroll to the file name to download with arrow keys and press *select*.

18.4 Scroll to *SS-Importable* and press *select*. Then press any key to start download when computer is ready.

18.5 To set up the PC follow these procedures below:

18.5.1 Load HyperTerminal program.

18.5.2 Click on *transfer,* then *receive file*. This will bring up the window with the receiving file folder name in the upper box and driver name, *X-modem*, in the lower box.

18.5.3 Click on *receive* and enter the data file name in the next window. Then choose *OK* and this will open the data receiving window.

18.5.4 The PC is now ready to receive data. Press any button on the Surveyor to start the down loading process.

19. Creating a New Datasonde 4a Program

19.1 Connect the Datasonde 4a to the Surveyor 4 with same cable used to down load the files.

19.2 Turn on surveyor, allow time to come on and select *files.*

19.3 From small window select *create.*

19.4 Select *time-triggered* as file type.

19.5 Press *select* to bring up the file naming screen. Name file. Time triggered files names normally have the form (TT+date).

19.6 Press *done* to go to starting date screen. Enter starting date.

19.7 Press *done* to go to starting time screen. Enter starting time.

19.8 Press *done* to go to the stopping date screen. Enter the stopping date. (Enter a date at least a week beyond next expected visit to the Datasonde if for some reason your schedule needs to be changed.)

19.9 Press *done* to bring up the stopping time screen. Enter the stopping time. (This may be any time of the day since you allowing extra days. You can even leave time all zeros [midnight].)

19.10 Press *done* to bring up the sampling interval screen. Set the sampling interval to 30 minutes.

19.11 Press *done* to bring up the warmup time screen. Leave the warmup time at 2 minutes.

19.12 Press *done* to bring up the parameter screen. Pick the parameter sensors you want to use with add or remove parameters you do not want with remove.

19.13 Press *done* and screen will read file created at the bottom. The Datasonde now will automatically gather selected data.

20. Changing Datasonde 4a batteries.

20.1 Eight (8) C-size batteries are used to power the Datasonde and they are changed the first Monday of every month or as close as your schedule will allow. (The batteries will last 2 months but they are changed monthly as a precaution.)

20.2 To change batteries loosen the curled knob on top of the sonde, take off the battery compartment top (with the O-rings) and remove the old batteries. Install in new batteries, observing proper polarity, and replace battery holder after applying a small amount of silicone grease to the O-rings and tighten the curled bolt to secure the battery compartment top. Caution: wipe water from around the top of the Datasonde before removing battery compartment cap, and wipe water from the inside of the top of the battery compartment.

APPENDIX 2

Statistical Summary Tables for Hydrolab Probe Data
April 2000 through March 2001
Summary by Month and Night and Day

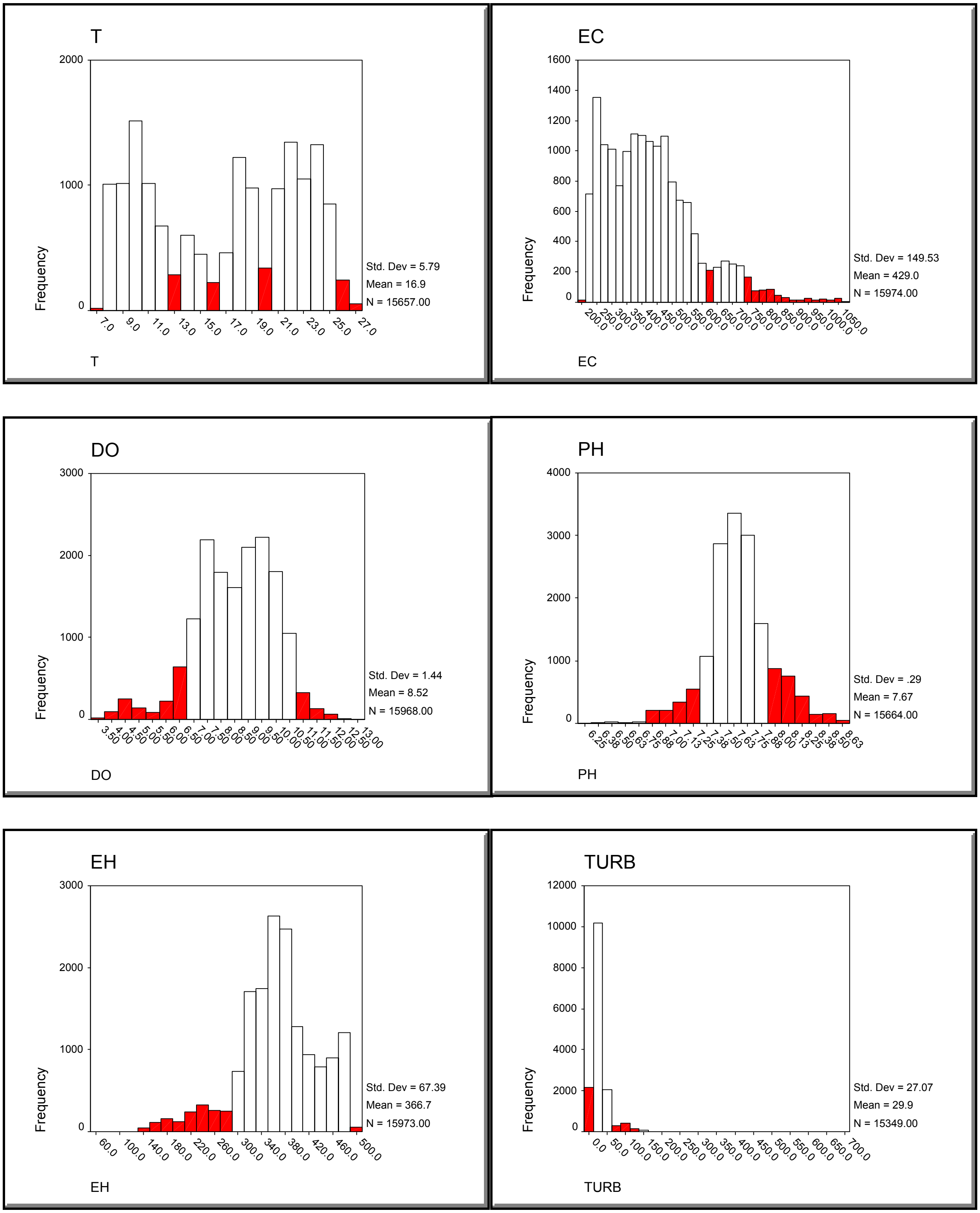

Figure A2-1.—Histograms for each of the Hydrolab measured variables.

Table A2-1.—Summary of Tracy Hydrolab data by month and night vs. day.

Month of Year	Night or Day	Statistic	Channel Temp °C	EC, µS/cm	Dissolved Oxygen, mg/L	Percent DO Saturation	pH, s.u.	Redox Potential, mV	Turbidity, NTU
Jan	day	N	**233**	**299**	**297**	**297**	**233**	**299**	**299**
		Mean	8.27	619	9.63	86.6	7.50	353	19.3
		Median	8.29	595	9.76	83.9	7.54	329	17.9
		Minimum	7.30	440	3.39	38.8	6.30	193	1.90
		Maximum	9.89	909	12.5	141	8.10	505	109
		S	0.497	108	1.42	14.9	0.360	84.5	18.7
		Range	2.59	469	9.11	102	1.80	312	107
	night	N	**337**	**435**	**435**	**435**	**346**	**435**	**435**
		Mean	8.28	661	9.43	84.5	7.55	356	22.0
		Median	8.30	665	9.70	83.0	7.61	328	18.3
		Minimum	7.37	427	3.47	39.2	6.43	213	1.90
		Maximum	9.76	1070	12.1	128	8.10	492	402
		S	0.489	130	1.65	15.2	0.368	84.9	27.9
		Range	2.39	640	8.59	88.9	1.67	279	400
	All Jan	N	**570**	**734**	**732**	**732**	**579**	**734**	**734**
		Mean	8.28	644	9.51	85.4	7.53	355	20.9
		Median	8.30	633	9.71	83.4	7.59	328	18.2
		Minimum	7.30	427	3.39	38.8	6.30	193	1.90
		Maximum	9.89	1070	12.5	141	8.10	505	402
		S	0.492	123	1.56	15.1	0.365	84.7	24.6
		Range	2.59	640	9.11	102	1.80	312	400
Feb	day	N	**296**	**295**	**295**	**295**	**295**	**295**	**295**
		Mean	9.51	507	9.87	86.2	7.32	371	31.6
		Median	9.32	442	9.87	85.8	7.41	365	26.8
		Minimum	7.97	372	8.82	75.9	6.85	318	14.2
		Maximum	12.3	1040	10.7	92.5	7.68	444	161
		S	1.08	160	0.464	3.26	0.266	26.4	18.4
		Range	4.33	668	1.87	16.6	0.83	126	147
	night	N	**374**	**374**	**374**	**374**	**374**	**374**	**374**
		Mean	9.74	596	9.73	85.4	7.34	369	31.6
		Median	9.61	547	9.75	85.5	7.43	366	27.3
		Minimum	8.03	371	8.74	75.6	6.83	303	15.3
		Maximum	12.4	1070	10.7	92.3	7.66	447	183
		S	1.04	185	0.505	3.69	0.253	28.4	17.6
		Range	4.34	694	1.99	16.7	0.84	144	168
	All Feb	N	**670**	**669**	**669**	**669**	**669**	**669**	**669**
		Mean	9.64	557	9.79	85.8	7.33	370	31.6
		Median	9.50	468	9.79	85.7	7.42	366	27.1
		Minimum	7.97	371	8.74	75.6	6.83	303	14.2
		Maximum	12.4	1070	10.7	92.5	7.68	447	183
		S	1.06	180	0.492	3.52	0.259	27.5	18.0
		Range	4.40	694	1.99	16.9	0.85	144	169
Mar	day	N	**377**	**377**	**377**	**377**	**377**	**377**	**377**
		Mean	15.1	598	8.45	83.3	7.34	430	31.7
		Median	15.0	536	8.18	81.4	7.35	404	29.1
		Minimum	10.4		6.76	69.1	6.28	254	6.75
		Maximum	20.9	1170	10.4	111	7.92	651	181
		S	2.69	228	0.812	8.38	0.212	104	14.8
		Range	10.5	1170	3.64	42.3	1.64	398	174
	night	N	**366**	**366**	**366**	**366**	**366**	**366**	**366**
		Mean	15.1	677	8.39	82.7	7.37	424	29.5
		Median	14.9	643	8.15	81.3	7.38	398	28.2
		Minimum	10.9	321	6.52	68.8	6.85	253	7.30
		Maximum	19.8	1220	10.1	108	7.89	645	64.7
		S	2.56	237	0.791	8.20	0.201	106	8.10
		Range	8.85	897	3.61	39.5	1.04	392	57.4
	All Mar	N	**743**	**743**	**743**	**743**	**743**	**743**	**743**
		Mean	15.1	637	8.42	83.0	7.36	427	30.6
		Median	15.0	588	8.16	81.3	7.37	399	28.5
		Minimum	10.4		6.52	68.8	6.28	253	6.75
		Maximum	20.9	1220	10.4	111	7.92	651	181
		S	2.62	236	0.802	8.29	0.207	105	12.0
		Range	10.5	1220	3.88	42.7	1.64	399	174

Table A2-1.—Summary of Tracy Hydrolab data by month and night vs. day.

Month of Year	Night or Day	Statistic	Channel Temp C	EC, µS/cm	Dissolved Oxygen, mg/L	Percent DO Saturation	pH, s.u.	Redox Potential, mV	Turbidity, NTU
Apr	day	N	383	383	383	383	383	383	383
		Mean	17.8	370	8.79	92.4	7.98	288	23.6
		Median	17.9	338	8.92	92.8	7.98	316	21.8
		Minimum	14.4	240	5.85	62.4	7.19	125	7.25
		Maximum	19.4	630	10.3	110	8.65	399	67.9
		S	0.874	101	0.794	8.37	0.345	85.8	11.0
		Range	5.08	390	4.46	47.8	1.46	274	60.6
	night	N	330	330	330	330	330	330	330
		Mean	17.6	400	8.83	92.5	7.96	289	25.1
		Median	17.7	391	8.82	92.1	7.94	303	23.7
		Minimum	14.6	246	6.53	69.5	7.29	144	11.0
		Maximum	19.5	614	9.99	106	8.60	399	57.7
		S	0.822	101	0.755	7.79	0.345	87.0	9.40
		Range	4.84	368	3.46	36.7	1.31	256	46.7
	All Apr	N	713	713	713	713	713	713	713
		Mean	17.7	384	8.81	92.4	7.97	289	24.3
		Median	17.8	370	8.88	92.5	7.98	313	23.1
		Minimum	14.4	240	5.85	62.4	7.19	125	7.25
		Maximum	19.5	630	10.3	110	8.65	399	67.9
		S	0.853	102	0.776	8.10	0.345	86.3	10.3
		Range	5.11	390	4.46	47.8	1.46	274	60.6
May	day	N	447	445	445	445	445	445	445
		Mean	20.0	406	7.52	82.6	7.75	342	31.7
		Median	19.5	393	7.55	82.1	7.75	368	28.3
		Minimum	17.1	320	5.91	67.1	7.37	72.0	11.2
		Maximum	24.3	529	9.33	104	8.31	432	161
		S	1.89	52.7	0.493	5.71	0.141	68.5	14.3
		Range	7.23	209	3.43	37.2	0.93	360	150
	night	N	291	291	291	291	291	291	291
		Mean	19.7	418	7.57	82.7	7.74	346	33.4
		Median	19.1	413	7.60	81.8	7.73	375	31.1
		Minimum	16.9	334	6.34	72.1	7.44	158	14.4
		Maximum	23.5	525	9.43	106	8.29	426	65.5
		S	1.85	53.0	0.453	6.09	0.139	67.0	11.2
		Range	6.58	191	3.09	33.4	0.85	269	51.2
	All May	N	738	736	736	736	736	736	736
		Mean	19.9	411	7.54	82.6	7.74	344	32.4
		Median	19.3	402	7.56	82.0	7.74	371	29.1
		Minimum	16.9	320	5.91	67.1	7.37	72.0	11.2
		Maximum	24.3	529	9.43	106	8.31	432	161
		S	1.88	53.1	0.478	5.86	0.140	67.9	13.2
		Range	7.34	209	3.52	38.4	0.93	360	150
Jun	day	N	444	444	444	444	444	444	438
		Mean	23.3	371	7.03	82.1	7.75	373	35.2
		Median	24.1	337	6.73	80.1	7.76	379	34.3
		Minimum	19.6	243	4.87	59.7	7.28	268	0.30
		Maximum	26.0	670	10.9	123	8.30	429	171
		S	1.76	99.3	1.12	11.0	0.153	25.6	16.1
		Range	6.38	428	6.04	63.3	1.02	161	170
	night	N	270	270	270	270	270	270	265
		Mean	23.2	331	7.25	84.6	7.77	375	31.7
		Median	24.1	292	7.02	82.8	7.80	379	31.7
		Minimum	20.1	243	5.32	61.3	7.36	299	0.20
		Maximum	25.5	555	10.2	113	8.25	417	69.1
		S	1.64	82.3	0.961	9.09	0.134	18.6	14.8
		Range	5.43	312	4.86	52.2	0.89	118	68.9
	All Jun	N	714	714	714	714	714	714	703
		Mean	23.3	355	7.11	83.1	7.76	374	33.9
		Median	24.1	323	6.82	81.2	7.77	379	32.6
		Minimum	19.6	243	4.87	59.7	7.28	268	0.20
		Maximum	26.0	670	10.9	123	8.30	429	171
		S	1.72	95.2	1.07	10.4	0.147	23.2	15.7
		Range	6.38	428	6.04	63.3	1.02	161	171

Table A2-1.—Summary of Tracy Hydrolab data by month and night vs. day.

Month of Year	Night or Day	Statistic	Channel Temp C	EC, µS/cm	Dissolved Oxygen, mg/L	Percent DO Saturation	pH, s.u.	Redox Potential, mV	Turbidity, NTU
Jul	**day**	**N**	**352**	**352**	**352**	**352**	**352**	**352**	**325**
		Mean	23.7	302	7.01	82.9	7.69	359	29.6
		Median	23.6	251	7.01	82.6	7.69	364	24.7
		Minimum	22.1	217	5.42	64.8	7.31	293	0.30
		Maximum	26.2	671	9.90	118	8.05	450	201
		S	0.837	97.4	0.602	7.33	0.175	36.2	21.2
		Range	4.02	454	4.48	53.2	0.74	158	201
	night	**N**	**236**	**236**	**236**	**236**	**236**	**236**	**215**
		Mean	23.6	269	7.18	84.7	7.70	367	29.5
		Median	23.5	247	7.32	85.9	7.68	370	24.1
		Minimum	22.0	221	5.88	68.1	7.36	305	0.50
		Maximum	26.1	569	8.20	95.3	8.05	451	232
		S	0.820	57.4	0.507	5.87	0.166	31.7	25.1
		Range	4.09	348	2.32	27.2	0.69	146	232
	All Jul	**N**	**588**	**588**	**588**	**588**	**588**	**588**	**540**
		Mean	23.7	289	7.08	83.6	7.70	362	29.6
		Median	23.6	249	7.11	84.0	7.69	366	24.4
		Minimum	22.0	217	5.42	64.8	7.31	293	0.30
		Maximum	26.2	671	9.90	118	8.05	451	232
		S	0.830	85.2	0.571	6.83	0.171	34.6	22.8
		Range	4.16	454	4.48	53.2	0.74	159	232
Aug	**day**	**N**	**406**	**406**	**406**	**406**	**406**	**406**	**401**
		Mean	24.5	298	6.68	80.2	7.96	317	22.4
		Median	24.4	271	7.22	86.6	7.98	314	21.4
		Minimum	21.4	228	4.02	48.2	7.49	234	0.60
		Maximum	27.3	591	10.1	120	8.53	385	57.6
		S	1.14	72.8	1.53	18.0	0.246	26.7	11.2
		Range	5.85	363	6.04	72.0	1.04	151	57.0
	night	**N**	**328**	**328**	**328**	**328**	**328**	**328**	**306**
		Mean	24.3	272	6.82	81.5	7.95	334	22.2
		Median	24.2	254	7.34	87.8	8.02	331	20.3
		Minimum	21.5	228	4.05	48.8	7.51	281	0.10
		Maximum	26.6	483	9.86	118	8.40	386	85.8
		S	1.03	49.9	1.49	17.4	0.235	26	12.1
		Range	5.15	255	5.81	68.9	0.88	105	85.7
	All Aug	**N**	**734**	**734**	**734**	**734**	**734**	**734**	**707**
		Mean	24.4	287	6.75	80.8	7.95	325	22.3
		Median	24.3	261	7.28	87.3	8.01	324	21.2
		Minimum	21.4	228	4.02	48.2	7.49	234	0.10
		Maximum	27.3	591	10.1	120	8.53	386	85.8
		S	1.09	64.9	1.51	17.8	0.241	27.6	11.6
		Range	5.85	363	6.04	72.0	1.04	152	85.7
Sep	**day**	**N**	**369**	**369**	**369**	**369**	**369**	**369**	**360**
		Mean	22.0	337	9.24	106	7.75	359	31.5
		Median	22.0	329	8.61	98.8	7.79	360	33.0
		Minimum	20.2	273	7.09	81.9	7.21	277	0.90
		Maximum	24.1	524	12.3	142	8.47	447	72.3
		S	0.866	46.1	1.50	16.9	0.297	36.2	11.5
		Range	3.88	251	5.22	60.1	1.26	170	71.4
	night	**N**	**327**	**327**	**327**	**327**	**327**	**327**	**315**
		Mean	21.9	339	9.18	105	7.74	376	30.3
		Median	22.0	331	8.62	98.4	7.81	369	32.5
		Minimum	20.1	277	7.50	84.4	7.23	291	0.20
		Maximum	23.8	493	12.2	140	8.40	455	70.7
		S	0.868	45.7	1.35	15.2	0.288	35.5	12.1
		Range	3.70	216	4.64	55.5	1.18	164	70.5
	All Sep	**N**	**696**	**696**	**696**	**696**	**696**	**696**	**675**
		Mean	22.0	338	9.21	105	7.74	367	30.9
		Median	22.0	330	8.61	98.7	7.80	363	32.9
		Minimum	20.1	273	7.09	81.9	7.21	277	0.20
		Maximum	24.1	524	12.3	142	8.47	455	72.3
		S	0.867	45.9	1.43	16.1	0.293	36.8	11.8
		Range	3.93	251	5.22	60.1	1.26	179	72.1

Table A2-1.—Summary of Tracy Hydrolab data by month and night vs. day.

Month of Year	Night or Day	Statistic	Channel Temp C	EC, µS/cm	Dissolved Oxygen, mg/L	Percent DO Saturation	pH, s.u.	Redox Potential, mV	Turbidity, NTU
Oct	**day**	**N**	**328**	**328**	**328**	**316**	**328**	**328**	**321**
		Mean	18.3	423	8.22	87.9	7.62	370	27.4
		Median	18.8	414	8.30	87.3	7.62	359	22.4
		Minimum	13.9	327	6.70	71.2	7.36	303	1.00
		Maximum	22.4	609	9.55	109	8.02	495	226
		S	2.38	54.3	0.602	6.28	0.111	42.9	23.6
		Range	8.44	282	2.86	38.3	0.66	193	225
	night	**N**	**400**	**400**	**400**	**381**	**400**	**400**	**397**
		Mean	18.4	420	8.25	88.3	7.62	374	39.6
		Median	18.7	421	8.31	87.9	7.61	361	22.0
		Minimum	14.2	318	6.75	72.0	7.34	301	1.60
		Maximum	22.5	583	9.51	102	7.96	490	472
		S	2.37	46.7	0.607	6.14	0.113	47.3	58.2
		Range	8.28	264	2.76	29.5	0.62	189	471
	All Oct	**N**	**728**	**728**	**728**	**697**	**728**	**728**	**718**
		Mean	18.4	421	8.23	88.1	7.62	372	34.1
		Median	18.7	418	8.30	87.8	7.61	360	22.2
		Minimum	13.9	318	6.70	71.2	7.34	301	1.00
		Maximum	22.5	609	9.55	109	8.02	495	472
		S	2.37	50.3	0.604	6.20	0.112	45.4	46.4
		Range	8.58	291	2.86	38.3	0.68	194	471
Nov	**day**	**N**	**300**	**299**	**299**		**299**	**299**	**299**
		Mean	12.2	445	9.06		7.65	423	29.5
		Median	11.8	467	9.44		7.61	441	19.6
		Minimum	10.2	217	6.41		7.44	303	3.75
		Maximum	14.9	673	10.5		8.05	484	168
		S	1.60	127	0.915		0.159	49.1	29.2
		Range	4.71	456	4.04		0.61	181	164
	night	**N**	**408**	**408**	**408**		**408**	**408**	**408**
		Mean	12.3	478	9.22		7.64	428	38.9
		Median	11.8	518	9.59		7.60	442	18.9
		Minimum	10.2	217	5.45		7.40	310	5.25
		Maximum	14.6	687	10.8		8.05	486	156
		S	1.49	112	1.10		0.143	45.3	40.8
		Range	4.32	470	5.32		0.65	176	151
	All Nov	**N**	**708**	**707**	**707**		**707**	**707**	**707**
		Mean	12.3	464	9.15		7.65	426	34.9
		Median	11.8	500	9.53		7.60	442	19.2
		Minimum	10.2	217	5.45		7.40	303	3.75
		Maximum	14.9	687	10.8		8.05	486	168
		S	1.54	119	1.03		0.150	47.0	36.6
		Range	4.71	471	5.32		0.65	183	164
Dec	**day**	**N**	**277**	**277**	**277**	**241**	**277**	**277**	**277**
		Mean	9.96	545	9.34	82.0	7.45	454	34.2
		Median	10.0	542	9.02	79.6	7.48	465	15.2
		Minimum	8.60	392	8.17	73.3	7.14	309	3.55
		Maximum	11.7	747	10.7	94.3	7.75	499	107
		S	0.533	82.4	0.66	6.16	0.154	30.5	33.5
		Range	3.13	355	2.47	21.0	0.62	191	103
	night	**N**	**465**	**465**	**465**	**412**	**465**	**465**	**465**
		Mean	10.0	587	9.38	82.5	7.48	464	35.0
		Median	10.0	564	9.05	80.0	7.50	471	17.3
		Minimum	8.07	404	8.14	73.5	7.13	410	3.90
		Maximum	11.7	764	10.8	96.2	7.80	499	115
		S	0.669	95.6	0.689	6.38	0.165	18.7	33.7
		Range	3.65	359	2.68	22.7	0.67	88.5	112
	All Dec	**N**	**742**	**742**	**742**	**653**	**742**	**742**	**742**
		Mean	10.0	571	9.36	82.3	7.47	460	34.7
		Median	10.0	556	9.04	79.9	7.49	469	16.5
		Minimum	8.07	392	8.14	73.3	7.13	309	3.55
		Maximum	11.7	764	10.8	96.2	7.80	499	115
		S	0.623	93.0	0.677	6.30	0.161	24.2	33.6
		Range	3.65	372	2.68	22.9	0.67	191	112

Table A2-1.—Summary of Tracy Hydrolab data by month and night vs. day.

Month of Year	*Night or Day*	*Statistic*	*Channel Temp C*	*EC, µS/cm*	*Dissolved Oxygen, mg/L*	*Percent DO Saturation*	*pH, s.u.*	*Redox Potential, mV*	*Turbidity, NTU*
All Data	***day***	***N***	**4212**	**4274**	**4272**	**3925**	**4208**	**4274**	**4220**
		Mean	17.9	426	8.28	86.5	7.67	367	29.1
		Median	18.7	402	8.20	85.1	7.67	365	25.4
		Minimum	7.30		3.39	38.8	6.28	72.0	0.30
		Maximum	27.3	1170	12.5	142	8.65	651	226
		S	5.63	153	1.45	13.0	0.306	73.0	19.6
		Range	20.0	1170	9.11	103	2.38	579	226
	night	***N***	**4132**	**4230**	**4230**	**3750**	**4141**	**4230**	**4167**
		Mean	16.3	473	8.57	86.7	7.64	379	31.0
		Median	17.3	446	8.71	85.4	7.63	374	24.7
		Minimum	7.37	217	3.47	39.2	6.43	144	0.10
		Maximum	26.6	1220	12.2	140	8.60	645	472
		S	5.70	182	1.37	12.1	0.297	74.1	29.0
		Range	19.3	1002	8.67	101	2.17	501	472
	All data								
		Mean	17.1	449	8.42	86.6	7.65	373	30.0
		Median	18.1	422	8.45	85.3	7.65	370	25.1
		Minimum	7.30	201	3.39	38.8	6.28	72.0	1.10
		Maximum	27.3	1220	12.5	142	8.65	651	712
		S	5.72	169	1.42	12.5	0.302	73.8	24.7
		Range	20.0	1220	9.11	103	2.38	579	472