Summary of Suspended-Sediment Concentration Data, San Francisco Bay, California, Water Year 2004

By Paul A. Buchanan and Megan A. Lionberger

Prepared in cooperation with the CALFED Bay–Delta Authority and the
U.S. Army Corps of Engineers, San Francisco District

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Conversion Factors, Datum, Abbreviations, and Acronyms

Multiply	By	To obtain
inch (in.)	25.40	millimeter
foot (ft)	.3048	meter
foot per second (ft/s)	.3048	meter per second
quart	9.463×10^{-1}	liter

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88); horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Mean lower low water (MLLW): The average of the lower low water height above the bottom, in feet, of each tidal day observed during the National Tidal Datum Epoch. The National Tidal Datum Epoch is the specific 19-year period (1960–1978 for values given in this report) adopted by the National Ocean Service as the official time segment during which tide observations are taken and reduced to obtain mean values.

Abbreviations and Acronyms

ADAPS	automated data-processing system
DWR	California Department of Water Resources
mV	millivolt
FTS	Forest Technology Systems
NTU	nephelometric turbidity units
PI_{np}	nonparametric prediction interval
PVC	polyvinyl chloride
RMS	root-mean-squared (error)
SSC	suspended-sediment concentration
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
WY	water year (October 1–September 30)

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Abstract

Suspended-sediment concentration data were collected by the U.S. Geological Survey in San Francisco Bay during water year 2004 (October 1, 2003–September 30, 2004). Optical sensors and water samples were used to monitor suspended-sediment concentration at two sites in Suisun Bay, three sites in San Pablo Bay, two sites in Central San Francisco Bay, and three sites in South San Francisco Bay. Sensors were positioned at two depths at most sites. Water samples were collected periodically and analyzed for concentrations of suspended sediment. The results of the analyses were used to calibrate the output of the optical sensors so that a record of suspended-sediment concentrations could be derived. This report presents the data-collection methods used and summarizes, in graphs, the suspended-sediment concentration data collected from October 2003 through September 2004. Calibration curves and plots of the processed data for each sensor also are presented.

Introduction

Sediments are an important component of the San Francisco Bay estuarine system. Bottom sediments provide habitat for benthic organisms and are a reservoir for nutrients that contribute to estuarine productivity (Hammond and others, 1985). Potentially toxic substances, such as metals and pesticides, can adsorb to sediment particles (Kuwabara and others, 1989; Domagalski and Kuivila, 1993; Flegal and others, 1996). Benthic organisms then can ingest these substances and introduce them into the food web (Luoma and others, 1985; Brown and Luoma, 1995; Luoma, 1996). Large tidal-induced current velocities and wind waves in shallow water are capable of resuspending bottom sediments (Powell and others, 1989; Schoellhamer, 1996).

The transport and fate of suspended sediments are important factors in determining the transport and fate of sediment-associated contaminants. In Suisun Bay, the maximum suspended-sediment concentration (SSC) usually marks the position of the turbidity maximum—a crucial ecological zone where suspended sediments, nutrients, phytoplankton, zooplankton, larvae, and juvenile fish accumulate (Peterson and others, 1975; Arthur and Ball, 1979; Kimmerer, 1992; Jassby and Powell, 1994; Schoellhamer and Burau, 1998; Schoellhamer, 2001).

Suspended sediments limit the penetration of light into San Francisco Bay, which affects photosynthesis and primary phytosynthetic carbon production (Cole and Cloern, 1987; Cloern, 1987, 1996). Sediments also deposit in ports and shipping channels, which then require dredging to maintain navigation (U.S. Environmental Protection Agency, 1992). The U.S. Geological Survey (USGS), in cooperation with the CALFED Bay–Delta Program, and the U.S. Army Corps of Engineers, is studying the factors that affect SSC in San Francisco Bay.

Purpose and Scope

This report summarizes SSC data collected by the USGS in San Francisco Bay during water year (WY) 2004 and is the latest in a series of reports based on data collected beginning in WY 1992 (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996; Buchanan and Ruhl, 2000, 2001; and Buchanan and Ganju, 2002, 2003, 2004, 2005). Collection of SSC data in San Francisco Bay required development of monitoring methods and calibration techniques, which are presented in this report. SSC were monitored at two sites in Suisun Bay (a tidal estuary that drains into San Pablo Bay), three sites in San Pablo Bay (a northern extension of San Francisco Bay), two sites in Central San Francisco Bay, and three sites in South San Francisco Bay. SSC data from WY 1992 through WY 2004 were used to help determine the factors that affect SSC in San Francisco Bay (U.S. Geological Survey, 2006, accessed October 30, 2006). SSC data for WY 1992 through 2004 are available from the U.S. Geological Survey at http://sfbay.wr.usgs.gov/access/Fixed_sta/ (accessed October 30, 2006).

Study Area

San Francisco Bay (fig. 1) comprises several major subembayments; Suisun Bay, San Pablo Bay, Central San Francisco Bay (Central Bay), and South San Francisco Bay (South Bay). In San Francisco Bay, tides are semidiurnal (two high and two low tides per day) and have a range of about 5.5 feet (ft) in Suisun Bay, 6.5 ft at the Golden Gate and Central Bay, and about 10 ft in South Bay. The tides also follow a 14-day spring-neap cycle. Typical tidal currents range from 0.6 feet per second (ft/s) in shallow water to more than 3 ft/s in deep channels (Cheng and Gartner, 1984; Smith, 1987). Winds typically are strongest in the summer, during afternoon, onshore sea breezes. Most precipitation occurs from late autumn to early spring, and freshwater discharge into San Francisco Bay is greatest in the spring, as a result of runoff from snowmelt. About 90 percent of the discharge into the Bay is from the Sacramento–San Joaquin River Delta, which drains the Central Valley of California (Smith, 1987).

Typically, discharge from the Delta contains about 60 percent of the fluvial sediments that enter the Bay (McKee and others, 2006), though this percentage varies from year to year. During wet winters, turbid plumes of water from the Delta have extended into South Bay (Carlson and McCulloch, 1974). The bottom sediments in South Bay and in the shallow water areas (about 12 ft or less) of Central, San Pablo, and Suisun Bays are composed mostly of silts and clays. Silts and sands are present in the deeper parts of Central, San Pablo, and Suisun Bays and in Carquinez Strait (Conomos and Peterson, 1977).

Acknowledgments

The authors gratefully acknowledge the U.S. Coast Guard (USCG), the National Park Service, California Department of Transportation, California Department of Water Resources (DWR), EAI International, and the City of Vallejo for their permission and assistance in establishing the monitoring sites used in this study.

The project was done in cooperation with the CALFED Bay–Delta Program, the USGS Priority Ecosystem Science Program, and the U.S. Army Corps of Engineers, as part of the San Francisco Estuary Regional Monitoring Program for Trace Substances.

Methods

Instrument Description and Operation

Three different types of optical sensors were used to monitor SSC during WY 2004. The first type of sensor is manufactured by D & A Instrument Company and is a cylinder approximately 7 inches (in.) long and 1 in. in diameter with an optical window at one end, a cable connection at the other end, and an encased circuit board. A high-intensity infrared-emitting diode produces a beam through the optical window that is scattered, or reflected, by particles that are about 0.2–12 in. in front of the window. A detector (four photodiodes) receives backscatter from a field of 140–165 degrees, which is converted to a voltage output and recorded on a separate data logger. The second type of sensor, manufactured by Forest Technology Systems (FTS), is self-cleaning and differs from the D & A Instrument Company sensor in that it measures the intensity of light scattered at 90 degrees between a laser diode and a high-sensitivity silicon photodiode detector. The output, in nephelometric turbidity units (NTU), is recorded on a separate data logger. The third type of sensor, versions of which are used by both Hydrolab and YSI instruments, measures the intensity of light scattered at 90 degrees between a light-emitting diode and a high-sensitivity photodiode detector, and the output (NTU) is processed by internal software. The Hydrolab and YSI instruments are self-contained, including a power source and data logger.

Optical sensors were positioned in the water column using polyvinyl chloride (PVC) pipe carriages coated with an antifoulant paint to impede biological growth. Carriages were designed to align with the direction of flow and to ride along a stainless steel or Kevlar-reinforced nylon suspension line attached to an anchor weight, which allowed sensors to be easily raised and lowered for servicing (fig. 2). The plane of the optical window maintained a position parallel to the direction of flow as the carriage and sensor aligned itself with the changing direction of flow. Optical sensor depths in the water column are listed in table 1.

Biological growth (fouling) interferes with the collection of accurate optical sensor data. Fouling generally was greatest on the sensor closest to the water surface. However, at shallower sites where the upper sensor was set 10 ft above the lower sensor, fouling was similar on both sensors. Self-cleaning optical sensors were used where conditions allowed. Due to the difficulty in servicing some of the monitoring stations, sensors were cleaned manually every 1–5 (usually 3) weeks. Fouling would begin to affect sensor output from 2 days to several weeks after cleaning, depending on the level of biological activity in the Bay. Generally, biological fouling was greatest during spring and summer.

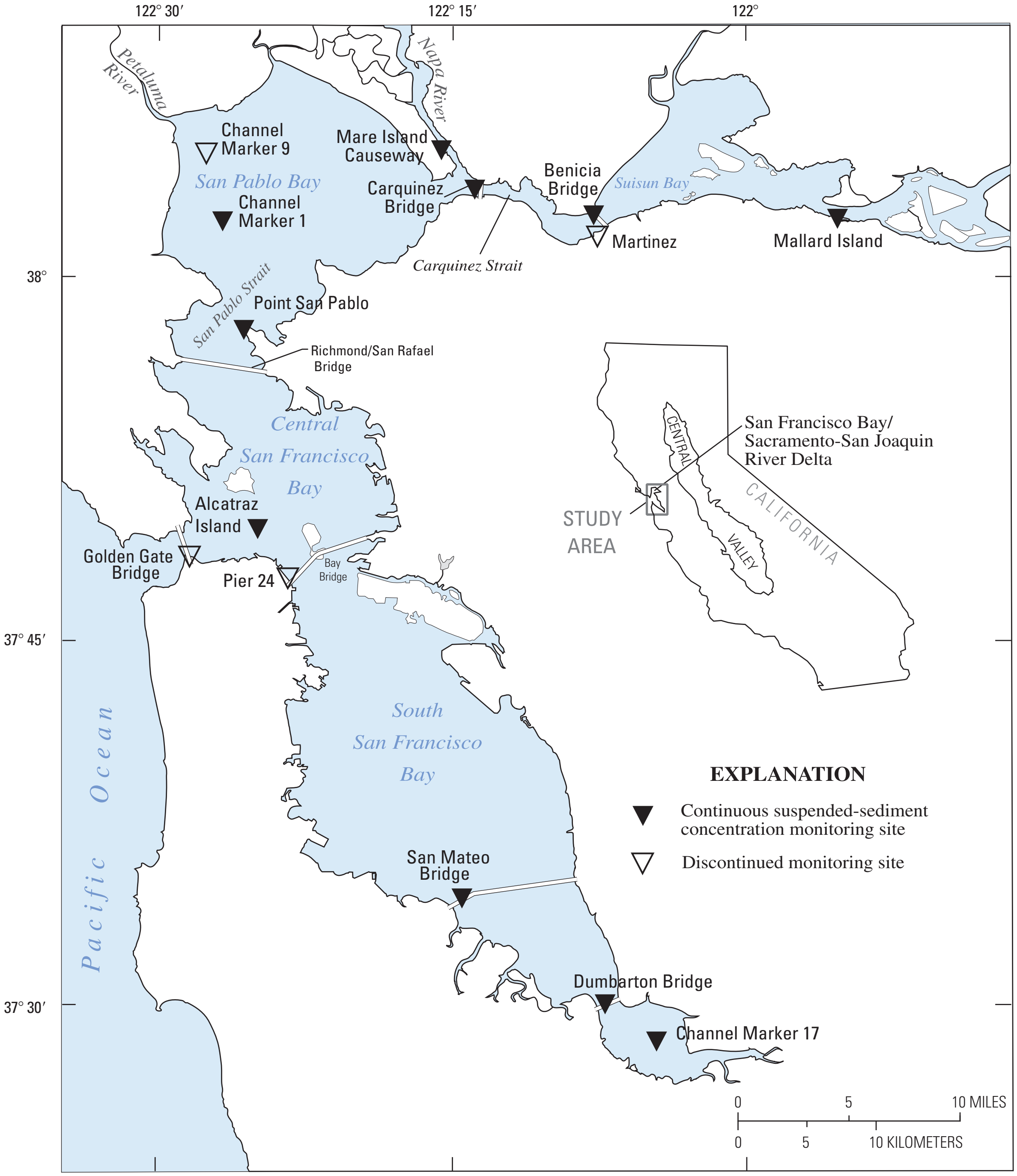

Figure 1. San Francisco Bay study area, California.

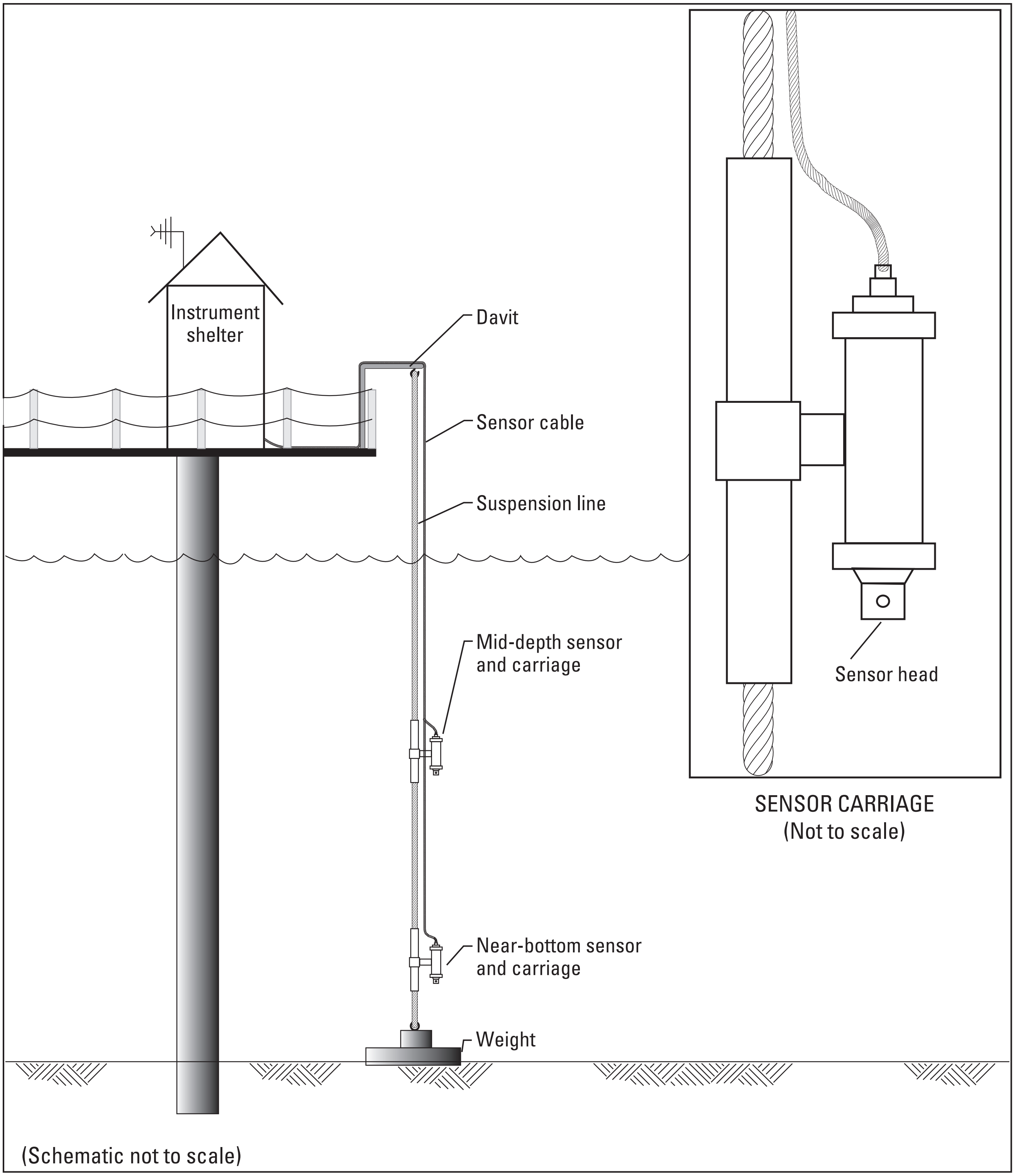

Figure 2. Typical monitoring installation, San Francisco Bay study.

Table 1. Optical sensor depths (in feet) below mean lower low water (MLLW), Suisun Bay, San Pablo Bay, and Central and South San Francisco Bays, California, water year 2004 .

[For definition of MLLW, see Conversion Factors, Datum, Abbreviations and Acronyms entry at front of this report]

Abbreviated station name	Site identification number	Latitude	Longitude	Sensor position	Depth below MLLW[1]	Water depth at MLLW
Mallard Island	11185185	38°02′34″	121°55′09″	Near-surface	3.3	25
				Near-bottom	20	
Benicia Bridge	11455780	38°02′42″	122°07′32″	Near-surface	9	80
				Near-bottom	61	
Carquinez Bridge	11455820	38°03′41″	122°13′53″	Mid-depth	40	88
				Near-bottom	83	
Mare Island Causeway	11458370	38°06′40″	122°16′25″	Mid-depth	3	30
				Near-bottom	25	
Channel Marker 1	380240122255701	38°02′40″	122°25′57″	Mid-depth	2	8
Point San Pablo	11181360	37°57′53″	122°25′42″	Mid-depth	8	26
				Near-bottom	23	
Alcatraz Island	374938122251801	37°49′38″	122°25′18″	Mid-depth	6	16
San Mateo Bridge	11162765	37°35′04″	122°14′59″	Mid-depth	19	48
				Near-bottom	40	
Dumbarton Bridge	373015122071000	37°30′15″	122°07′10″	Mid-depth	20	45
				Near-bottom	41	
Channel Marker 17	372844122043800	37°28′44″	122°04′38″	Mid-depth	11	25
				Near-bottom	21	

[1] Depth below water surface.

On-site checks of sensor accuracy were performed using turbidity solutions prepared from a 4,000-NTU formazin standard. Formazin is an aqueous suspension of an insoluble polymer and is the primary turbidity standard (Greenberg and others, 1992). The turbidity solutions were prepared by diluting a 4,000-NTU stock standard with de-ionized water in a clean, sealable bucket. Prepared solutions ranged from 50 to 200 NTU. Prepared solutions were checked with a Hach Drel 2000 Spectrophotometer for accuracy. At the field site, the cleaned sensors were immersed in the solution and the output was recorded on the station log. Monitoring of sensor performance in a known standard helps to identify output drift or sensor malfunction.

Data acquisition was controlled by electronic data loggers. The logger used with the D & A Instrument Company sensor was programmed to power the optical sensor every 15 minutes, collect data each second for 1 minute, then average and store the output voltage for that 1-minute period. The Hydrolab, YSI and FTS data loggers collect instantaneous values every 15 minutes. Power was supplied by 12-volt batteries.

Establishment of Monitoring Sites

Suisun Bay Installations

SSC data were collected in Suisun Bay at Mallard Island and at Benicia Bridge (fig. 1, table 1). Optical sensors were installed at the DWR Mallard Island Compliance Monitoring Station on February 8, 1994. Optical sensors were positioned to coincide with DWR near-bottom electrical conductance and temperature sensors and the near-surface pump intake. The pump intake is attached to a float and draws water from about 3 ft below the surface. The near-surface optical sensor is attached to a separate float and positioned at the same depth as the pump intake.

Optical sensors were deployed off of Pier 7 on the Benicia Bridge on March 15, 1996. The Benicia Bridge site was shut down August 7, 1998, for seismic retrofitting of the bridge and was reestablished with sondes equipped with optical, conductance, and temperature sensors on May 1, 2001. A monitoring site at the Martinez Marina fishing pier was discontinued in WY 1996 because data from the Benicia Bridge site were considered more representative of SSC in the Carquinez Strait area of Suisun Bay (Buchanan and Schoellhamer, 1998).

San Pablo Bay Installations

SSC data were collected in Carquinez Strait at Carquinez Bridge, Napa River at Mare Island Causeway, and San Pablo Bay at Channel Marker 1 (fig. 1, table 1). Sondes with optical, conductance, and temperature sensors were deployed off of the center pier structure at Carquinez Bridge on April 21, 1998. Optical sensors were deployed off of a catwalk beneath Mare Island Causeway on October 1, 1998. A sonde with optical, conductance, and temperature sensors was deployed off of USCG Channel Marker 1 on October 7, 2003. A monitoring site at USCG Channel Marker 9 was discontinued in WY 2003 because data from the USCG Channel Marker 1 site were considered less affected by the processes that occur at the mouth of the Petaluma River (Ganju and others, 2004).

Central San Francisco Bay Installations

SSC data were collected in San Pablo Strait at Point San Pablo and San Francisco Bay at Alcatraz Island (fig. 1, table 1). Optical sensors were deployed at San Pablo Strait on the northern end of the Richmond Terminal no. 4 pier on the western side of Point San Pablo on December 1, 1992. The station at Point San Pablo was shut down on January 2, 2001, and reestablished on December 11, 2001, off a pier-adjacent structure approximately 25 ft from the previous deployment site. A sonde with optical, conductance, and temperature sensors was deployed off the northeast side of Alcatraz Island on November 6, 2003. A monitoring station at San Francisco Bay at Pier 24 was discontinued on January 3, 2002. The USGS assumed operation of these stations from DWR in October 1989 (collection of conductivity and temperature data was funded cooperatively by DWR and the USGS). A monitoring station at the south tower of the Golden Gate Bridge was operational during water years 1996 and 1997. Conductivity and temperature data collected at Point San Pablo and Pier 24 prior to October 1, 1989, can be obtained from DWR.

South San Francisco Bay Installations

SSC data were collected in South San Francisco Bay at San Mateo Bridge, Dumbarton Bridge, and USCG Channel Marker 17 (fig. 1, table 1). Optical sensors were deployed off of Pier 20 on the San Mateo Bridge, on the east side of the ship channel, on December 23, 1991. In addition to SSC, specific conductance and temperature (cooperatively funded by DWR and the USGS) were monitored at near-bottom and near-surface depths at San Mateo Bridge. The USGS assumed operation of this station from DWR in October 1989. Conductivity and temperature data collected at San Mateo Bridge prior to October 1, 1989, can be obtained from DWR. Optical sensors were deployed off of Pier 23 on the Dumbarton Bridge on the west side of the ship channel on October 21, 1992. Optical sensors were deployed at USCG Channel Marker 17 on February 26, 1992.

Water-Sample Collection

Water samples, used to calibrate the output of the optical sensors to SSC, were collected using a horizontally positioned Van Dorn sampler before and after the sensors were cleaned. The Van Dorn sampler is a plastic tube with rubber stoppers at each end that snap shut when triggered by a small weight dropped down a suspension cable. The Van Dorn sampler was lowered to the depth of the sensor by a reel and crane assembly and triggered while the sensor was collecting data. After collection, the water sample was marked for identification and placed in a clean, 1-liter, plastic bottle for transport. The SSC of water samples collected with a Van Dorn sampler and a P-72 point sampler, used until WY 1994, were virtually identical (Buchanan and others, 1996).

Samples were sent to the USGS Sediment Laboratory in Marina, California, for analysis of SSC. Suspended sediment includes all particles in the sample that do not pass through a 0.45-micrometer membrane filter. The analytical method used to quantify concentrations of suspended solid-phase material was consistent from 1992 through the present study; however, the nomenclature used to describe sediment data was changed (Gray and others, 2000). *Suspended-sediment concentrations* were referred to as *suspended-solids concentrations* in previous reports (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996; Buchanan and Ruhl, 2000, 2001). Water samples collected for this study were analyzed for suspended-sediment concentration by filtering samples through a pre-weighed tared 0.45-micrometer membrane filter. The filtrate was rinsed with de-ionized water to remove salts, and the insoluble material and filter were dried at 103°C and weighed (Fishman and Friedman, 1989).

Data Processing

Data loggers stored the optical sensor output at 15-minute intervals (96 data points per day). Recorded data were downloaded from the data loggers onto either a storage module or laptop computer during site visits. Raw data from the storage modules or laptop computer were loaded into the USGS Automated Data-Processing System (ADAPS).

The time-series data were retrieved from ADAPS and processed to remove invalid data. Invalid data included rapidly increasing sensor outputs and unusually high sensor outputs of short duration. As biological growth accumulated on the optical sensors, the sensor output increased (except for the Hydrolab's optical sensor output, which decreased). An example time-series of raw and processed optical sensor data is presented in figure 3. After sensors were cleaned, sensor output immediately decreased (fig. 3A: May 6, 30, June 17, and July 8). Efforts to correct for biofouling proved to be unsuccessful because the signal often was highly variable. Thus, data affected by biofouling often were unusable and were removed from the record (fig. 3B). Identifying the point at which fouling begins to affect optical sensor data is somewhat subjective. Indicators are used to help define the point at which fouling begins to take place such as an elevated baseline, increasingly variable signal, and comparisons with the other sensor at the site. Spikes in the data, which are anomalously high voltages probably caused by debris temporarily wrapped around the sensor or by large marine organisms (fish, crabs) on or near the sensor, also were removed from the raw data record (fig. 3B). Sometimes, incomplete cleaning of a sensor would cause a small, constant shift in sensor output that could be adjusted by applying a correction derived from water-sample data collected during the period of incomplete cleaning.

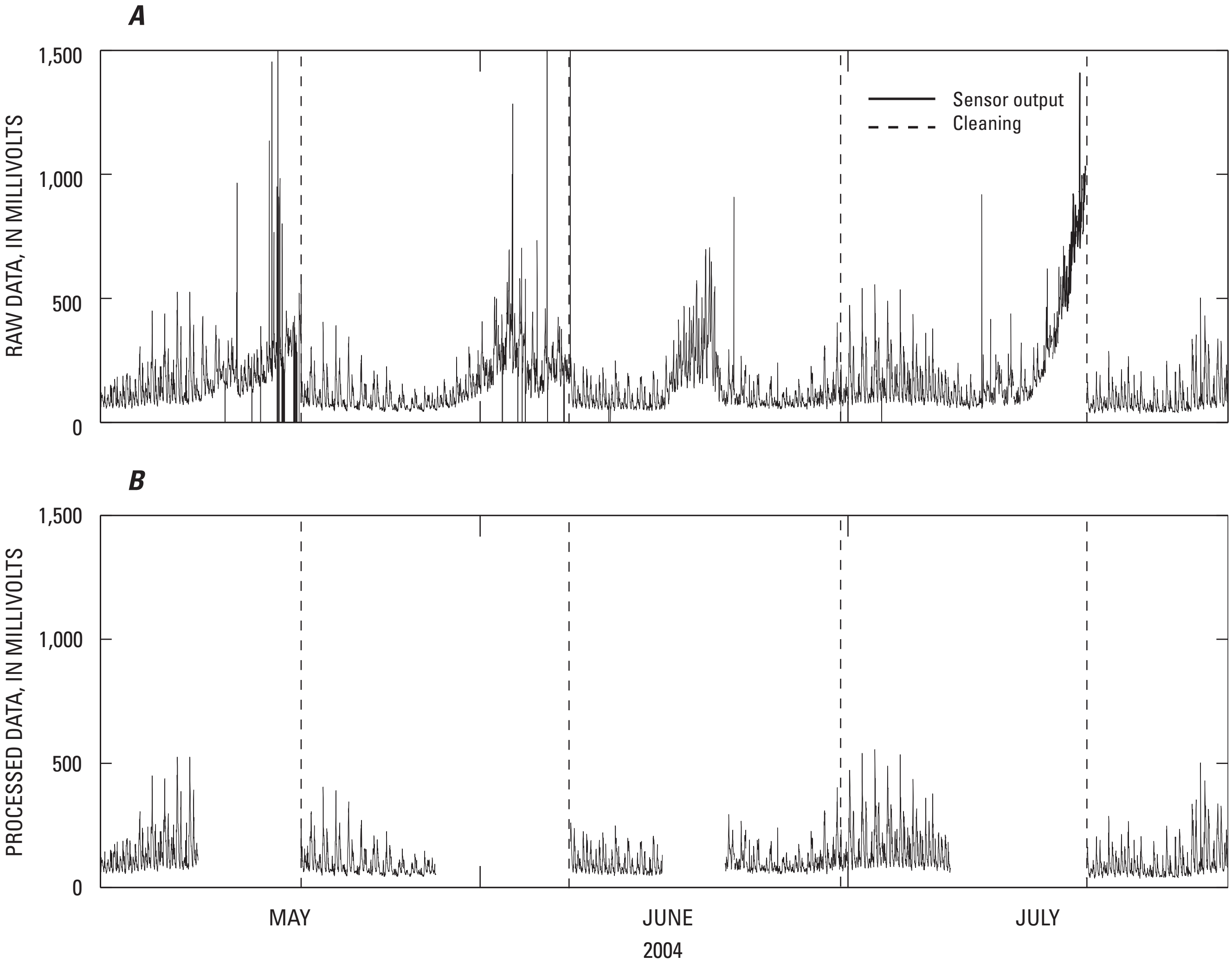

Figure 3. Example of (*A*) raw and (*B*) processed optical backscatterance data, near-bottom sensor, Mare Island Causeway, San Pablo Bay, California, water year 2004.

Sensor Calibration and Suspended-Sediment Concentration Data

The output for the three types of sensors used for this study are proportional to the SSC in the water column at the depth of the sensor. SSC calculated from the output of side-by-side sensors with different instrument designs (BTG and D & A Instrument Company) were virtually identical (Buchanan and Schoellhamer, 1998). Calibration of the sensor output to SSC will vary according to the size and optical properties of the suspended sediment; therefore, the sensors must be calibrated using suspended material from the field (Levesque and Schoellhamer, 1995).

The output from the optical sensors was converted to SSC by linear regression using the robust, nonparametric, repeated median method (Siegel, 1982). In some data sets, the variance of the residuals is not constant, as it increases with voltage. Constant variance of residuals is necessary when using ordinary least-squares to obtain the best linear unbiased estimator of suspended-sediment concentration (Helsel and Hirsch, 1992, p. 225). Therefore, robust regression is more appropriate than ordinary least squares for the calibration curves. In addition, the prediction interval and the 95-percent confidence interval were calculated and presented for each calibration equation. Whenever possible, water-sample data collected in previous water years are included in the calibrations to incorporate the largest range of observed concentrations. Previously collected water-sample data are discarded if a sensor's calibration has drifted.

The repeated median method calculates the slope in a two-part process. First, for each point (X,Y) in a dataset of n values, the median of all possible “point i” to “point j” slopes was calculated

$$\beta_i = median \frac{(Y_j - Y_i)}{(X_j - X_i)} \qquad \text{for all } j \neq i \tag{1}$$

The calibration slope was calculated as the median of β_i

$$\text{slope} = \hat{\beta}_1 = median\left(\beta_i\right) \tag{2}$$

Finally, the calibration intercept was calculated as the median of all possible intercepts using the slope calculated above

$$\text{intercept} = \hat{\beta}_o = median\left(Y_i - \hat{\beta}_1 X_i\right) \tag{3}$$

The final linear calibration equation is

$$Y = \hat{\beta}_1 X + \hat{\beta}_o \tag{4}$$

The nonparametric prediction interval (PI_{np}) (Helsel and Hirsch, 1992, p. 76) is a constant-width error band that contains about 68 percent, or one standard deviation, of the calibration data set. The 68 percent value was selected because essentially it has the same error prediction limits as the root-mean-squared (RMS) error of prediction in ordinary least squared regression; the latter was used in previous data reports (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996) to analyze random sets of normally distributed data. The prediction interval describes the likelihood that a new observation comes from the same distribution as the previously collected data set.

The PI_{np}, unlike the RMS error of prediction, frequently is not symmetrical about the regression line. For example, the PI_{np} may be reported as +10 milligrams per liter (mg/L) and -7 mg/L. This asymmetry about the regression line is a result of the distribution of the data set. The PI_{np} is calculated by computing and sorting, from least to greatest, the residuals for each point. Then, based on the sorted list of residuals:

$$\text{nonparametric prediction interval} = PI_{np} = \hat{Y}_{\left(\frac{\alpha}{2}\right)(n+1)} \text{ to } \hat{Y}_{\left(1-\frac{\alpha}{2}\right)(n+1)} \tag{5}$$

where

$\hat{Y}$ is the residual value,

n is the number of data points, and

α is the confidence level of 0.68.

To calculate the 95-percent confidence interval associated with the estimated calibration slope, all possible point-to-point slopes were sorted in ascending order, and the ranks of the upper and lower bounds were calculated as follows:

$$Ru = \left(\frac{\frac{n(n-1)}{2} + 1.96\left(\sqrt{\frac{n(n-1)(2n+5)}{18}}\right)}{2} \right) \tag{6}$$

and

$$Rl = \frac{\frac{n(n-1)}{2} - 1.96\left(\sqrt{\frac{n(n-1)(2n+5)}{18}}\right)}{2} \tag{7}$$

where

Ru is the rank of the upper bound slope,

Rl is the rank of the lower bound slope, and

n is the number of samples.

To establish the 95-percent confidence interval, the upper and lower ranks calculated above are rounded to the nearest integer and the slope associated with each rank is identified. This is a large-sample approximation and was used for each of the confidence intervals presented in this report. However, in the event that fewer than 10 samples had been collected, a direct calculation could be performed using the methodology presented in Helsel and Hirsch (1992, p. 273–274).

A statistical summary of the SSC, calculated from optical sensor data, is presented in table 2. The usable percentage of a complete year of valid data (96 data points per day × 365 days) for each site also is presented in table 2.

Table 2. Statistical summary of calculated suspended-sediment concentration data and usable percentage of a complete year of valid data (96 data points per day x 365 days) collected using optical sensors, Suisun Bay, San Pablo Bay, and Central and South San Francisco Bays, California, water year 2004.

[All values are in milligrams per liter except percent valid data. Lower quartile is 25th percentile; upper quartile is 75th percentile]

Site	Depth	Mean	Median	Lower quartile	Upper quartile	Percent valid data
Mallard Island	Near-surface	34	31	24	41	88
	Near-bottom	39	36	29	46	80
Benicia Bridge	Near-surface	46	37	25	59	81
	Near-bottom	96	85	53	127	81
Carquinez Bridge	Mid-depth	49	41	28	62	77
	Near-bottom	77	65	42	95	70
Mare Island Causeway	Mid-depth	69	53	33	90	63
	Near-bottom	121	99	64	158	80
Channel Marker 1	Mid-depth	76	55	34	94	62
Point San Pablo	Mid-depth	46	36	23	58	70
	Near-bottom	61	49	33	76	79
Alcatraz Island	Mid-depth	18	17	15	20	58
San Mateo Bridge	Mid-depth	41	37	27	49	47
	Near-bottom	40	33	24	48	47
Dumbarton Bridge	Mid-depth	44	35	26	52	33
	Near-bottom	48	35	25	54	39
Channel Marker 17	Mid-depth	52	30	17	61	45
	Near-bottom	61	35	21	69	50

This section of the report also includes figures showing graphical results of the regression analysis (calibration) relating SSC (in milligrams per liter) to optical sensor output. The calibration figures (for example, fig. 4) include the number of water samples (all water samples used to develop calibration, including those from previous water years), the calculated linear regression equation, the nonparametric prediction interval (shown on the calibration figures as a grey band), and the 95-percent confidence interval for the regression line slope. In addition, the time-series plots of calculated SSC data are shown for each site.

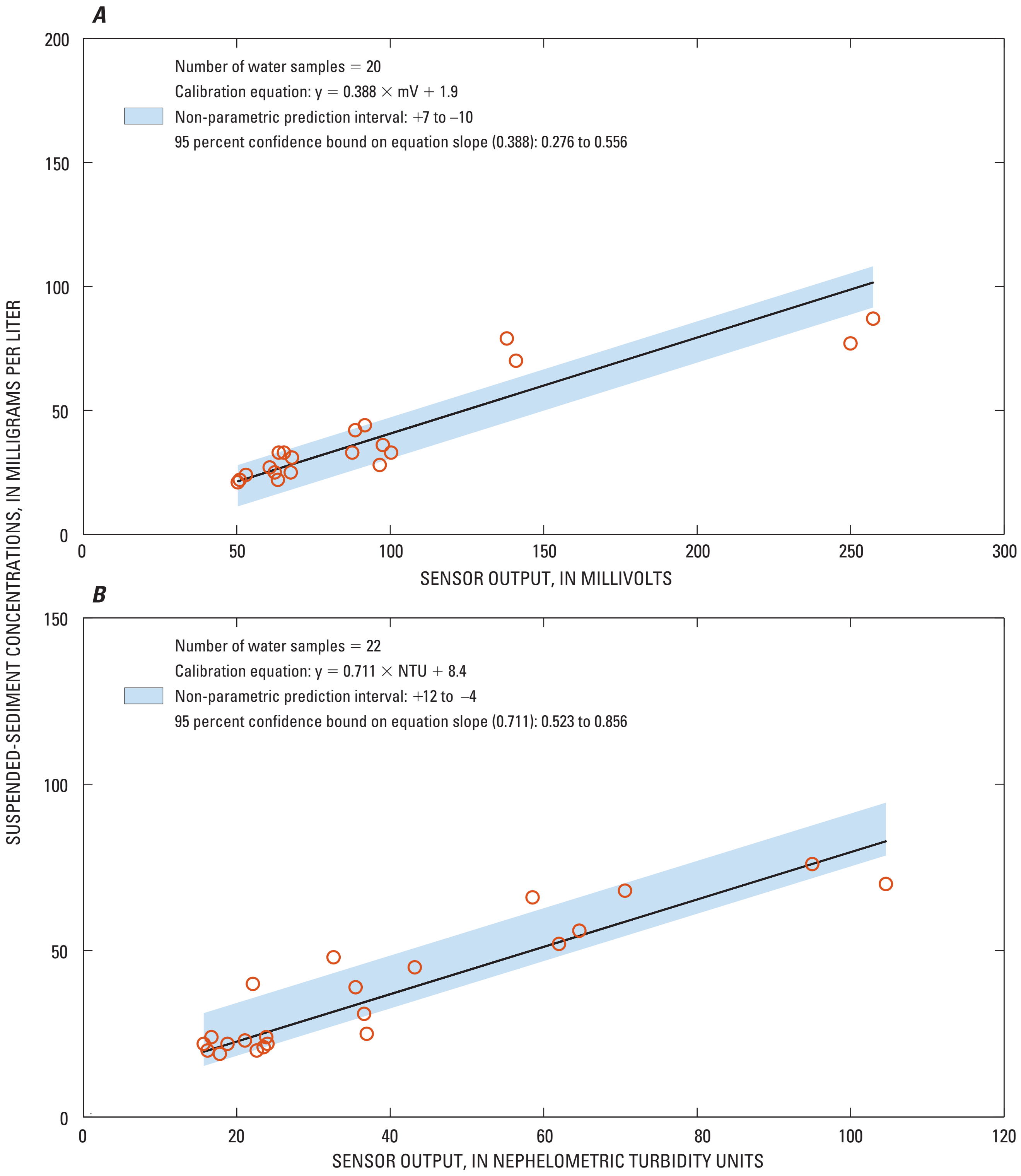

Figure 4. Calibration of near-surface optical backscatterance sensors, (*A*) October 1–December 10 and (*B*) December 10–September 30 at Mallard Island, Suisun Bay, California, water year 2004.

Suisun Bay

Mallard Island

PERIOD OF CALIBRATION.—
NEAR-SURFACE SENSOR (*A*): October 1, 2003, to December 10, 2003 (fig. 4A).
NEAR-SURFACE SENSOR (*B*): December 10, 2003, through September 30, 2004 (fig. 4B).
NEAR-BOTTOM SENSOR: December 10, 2003 through September 30, 2004 (fig. 5).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
NEAR-SURFACE SENSOR(*A*): 20 (3 from WY 2004).
NEAR-SURFACE SENSOR(*B*): 22 (22 from WY 2004).
NEAR-BOTTOM SENSOR: 22 (22 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
NEAR-SURFACE SENSOR(*A*): SSC = 0.388 × millivolt (mV) + 1.9.
NEAR-SURFACE SENSOR(*B*): SSC = 0.711 × mV + 8.4.
NEAR-BOTTOM SENSOR: SSC = 0.769 × mV + 7.2.
NONPARAMETRIC PREDICTION INTERVAL.—
NEAR-SURFACE SENSOR(*A*): +7 to -10 mg/L.
NEAR-SURFACE SENSOR(*B*): +12 to -4 mg/L.
NEAR-BOTTOM SENSOR: +9 to -5 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
NEAR-SURFACE SENSOR (*A*): 0.276 to 0.556.
NEAR-SURFACE SENSOR (*B*): 0.523 to 0.856.
NEAR-BOTTOM SENSOR: 0.643 to 1.108.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensor and (or) recording instruments. Sensors were positioned at near-surface (attached to float assembly) and near-bottom depths to coincide with DWR near-surface pump intake and the near-bottom electrical conductance and temperature sensors. Sensors with wipers (DTS-12's) were deployed December 10, 2003. The wiper on the near-surface sensor malfunctioned and was replaced on June 22, 2004, with another DTS-12. Because the two sensors (DTS-12's) responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), the calibration was developed by combining water samples collected during each sensor deployment. The output from the near-bottom sensor (OBS) was highly irregular from October 1, 2003, through December 10, 2003, and these data were removed from the record. The calculated SSC time-series data for WY 2004 are presented in figure 6.

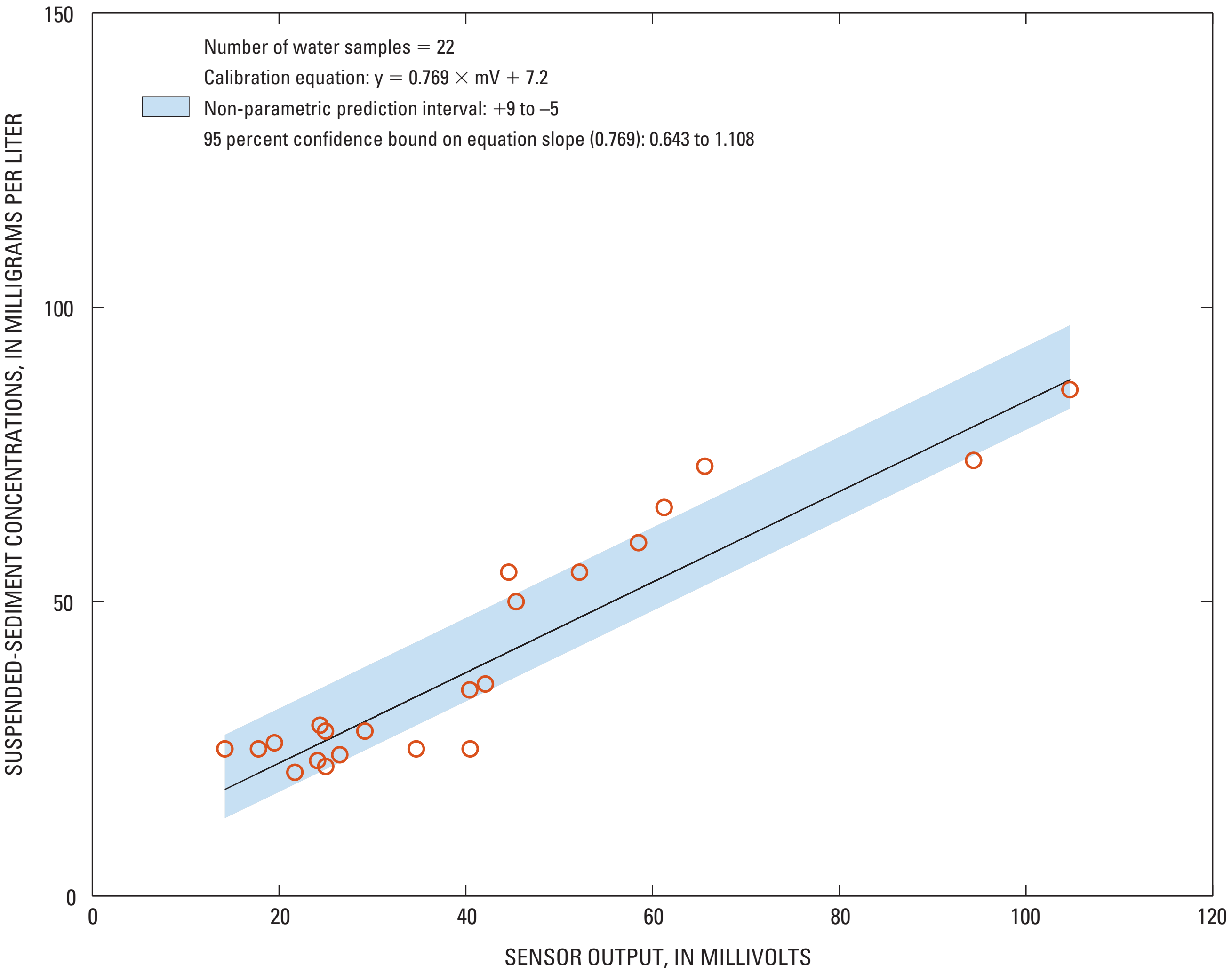

Figure 5. Calibration of near-bottom optical backscatterance sensor at Mallard Island, Suisun Bay, California, water year 2004.

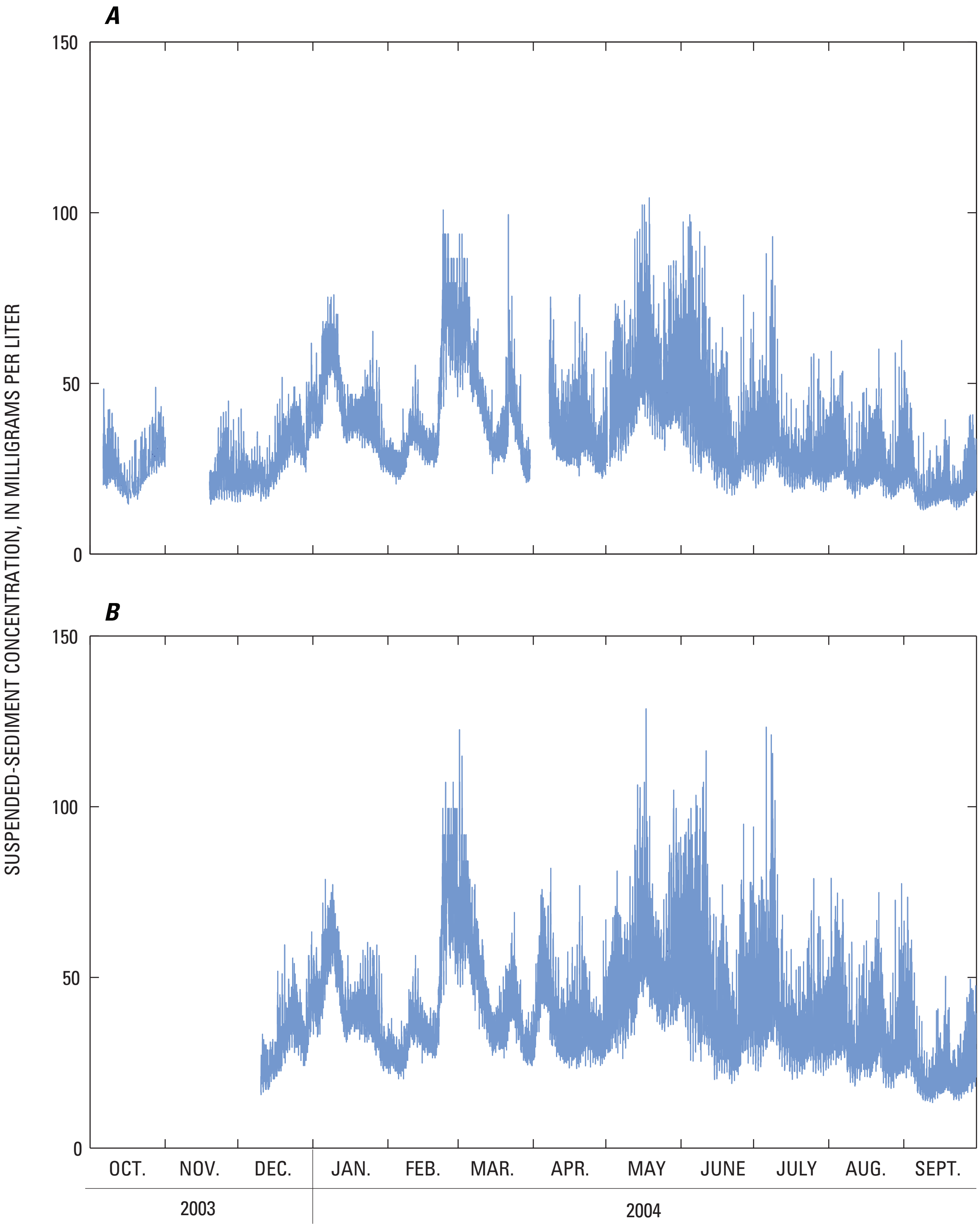

Figure 6. Time series of (*A*) near-surface and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Mallard Island, Suisun Bay, California, water year 2004.

Benicia Bridge

PERIOD OF CALIBRATION.—

NEAR-SURFACE SENSOR: November 17, 2003, through September 30, 2004 (fig. 7).

NEAR-BOTTOM SENSOR (*A*): October 1, 2003, to October 29, 2003, and July 29, 2004, through September 30, 2004 (fig. 8A).

NEAR-BOTTOM SENSOR (*B*): November 17, 2003, to July 29, 2004 (fig. 8B).

NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—

NEAR-SURFACE SENSOR: 18 (18 from WY 2004).

NEAR-BOTTOM SENSOR (*A*): 31 (7 from WY 2004).

NEAR-BOTTOM SENSOR (*B*): 12 (12 from WY 2004).

CALCULATED LINEAR CORRELATION EQUATION.—

NEAR-SURFACE SENSOR: SSC = 1.010 × NTU + 0.4.

NEAR-BOTTOM SENSOR (*A*): SSC = 1.160 × NTU + 8.8.

NEAR-BOTTOM SENSOR (*B*): SSC = 1.123 × NTU + 18.7.

NONPARAMETRIC PREDICTION INTERVAL.—

NEAR-SURFACE SENSOR: +13 to -3 mg/L.

NEAR-BOTTOM SENSOR (*A*): +23 to -10 mg/L.

NEAR-BOTTOM SENSOR (*B*): +15 to -44 mg/L.

95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—

NEAR-SURFACE SENSOR: 0.824 to 1.146.

NEAR-BOTTOM SENSOR (*A*): 1.065 to 1.372.

NEAR-BOTTOM SENSOR (*B*): 0.838 to 1.457.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. MLLW was approximately 80 ft deep at the site but only approximately 60 ft deep immediately adjacent to the site, therefore, the near-bottom sonde was set approximately 25 ft above the bottom so that the data are representative of the surrounding area. The near-surface Hydrolab sensor was replaced with a YSI sensor on October 29, 2003, but because of a faulty calibration reset, usable data were not collected until November 17, 2003. The calibration used for data collected at the near-bottom location from October 1, 2003, to October 29, 2003, and July 29, 2004, to September 30, 2004, was developed from samples collected during the deployment of two Hydrolab sensors. Because the two Hydrolab sensors responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), the calibration was developed by combining water samples collected during each sensor deployment. The near-bottom Hydrolab sensor was replaced by a YSI sensor on October 29, 2003, but because of a faulty calibration reset, usable data were not collected until November 17, 2003. The calculated SSC time-series data collected for WY 2004 are presented in figure 9.

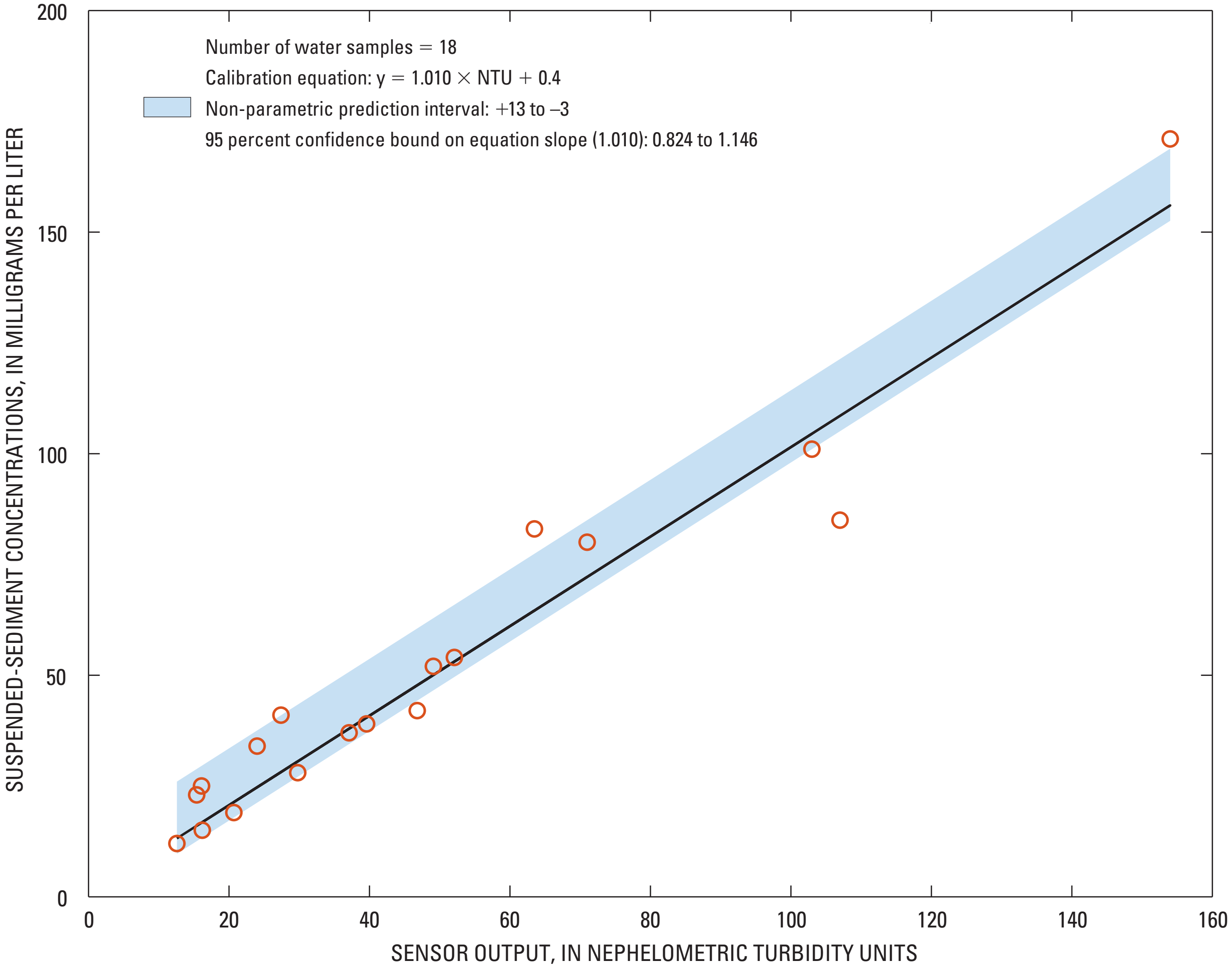

Figure 7. Calibration of near-surface optical backscatterance sensor at Benicia Bridge, Suisun Bay, California, water year 2004.

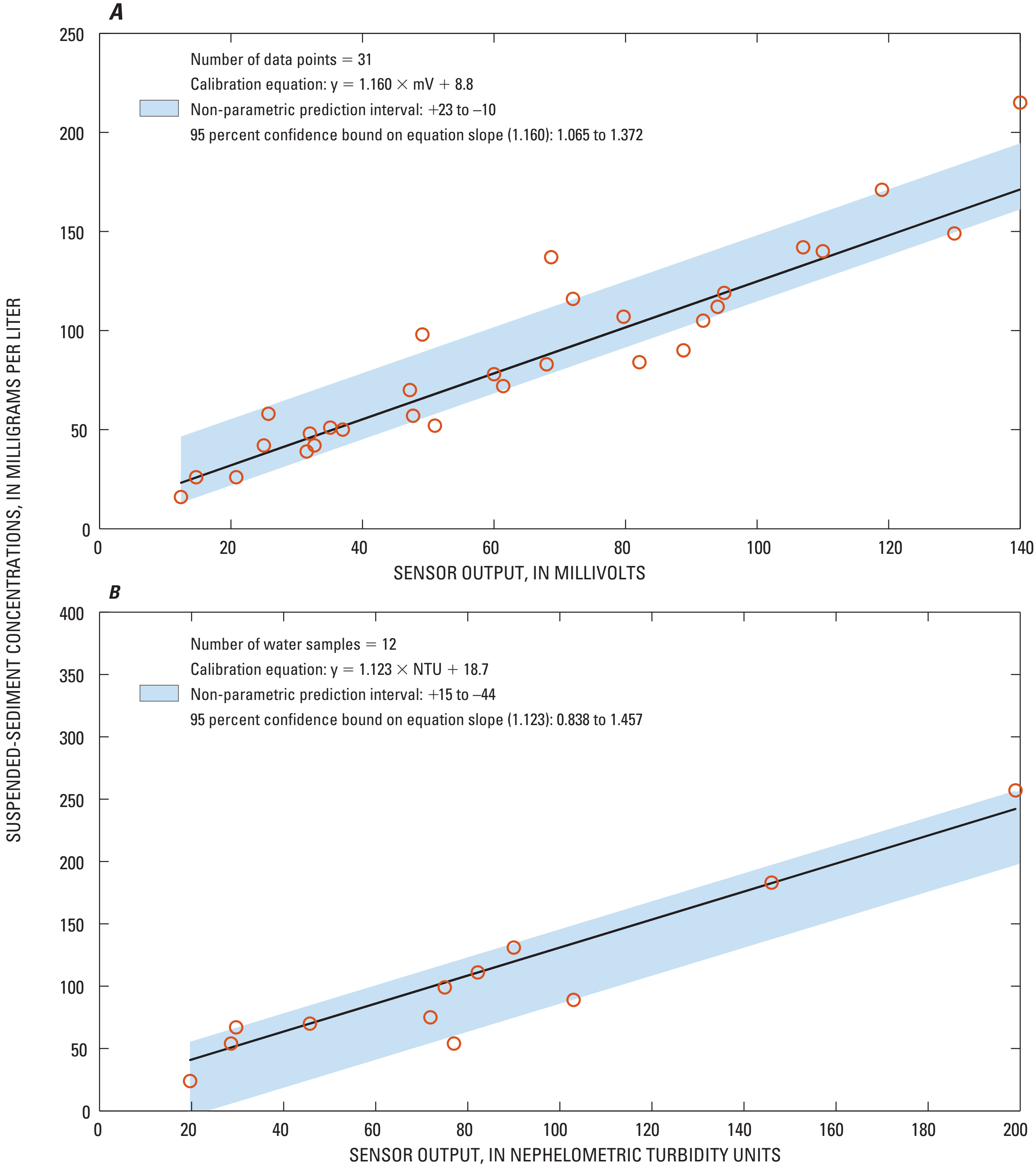

Figure 8. Calibration of near-bottom optical backscatterance sensors, (*A*) October 1–October 29, July 29–September 30 and (*B*) November 17–July 29 at Benicia Bridge, Suisun Bay, California, water year 2004.

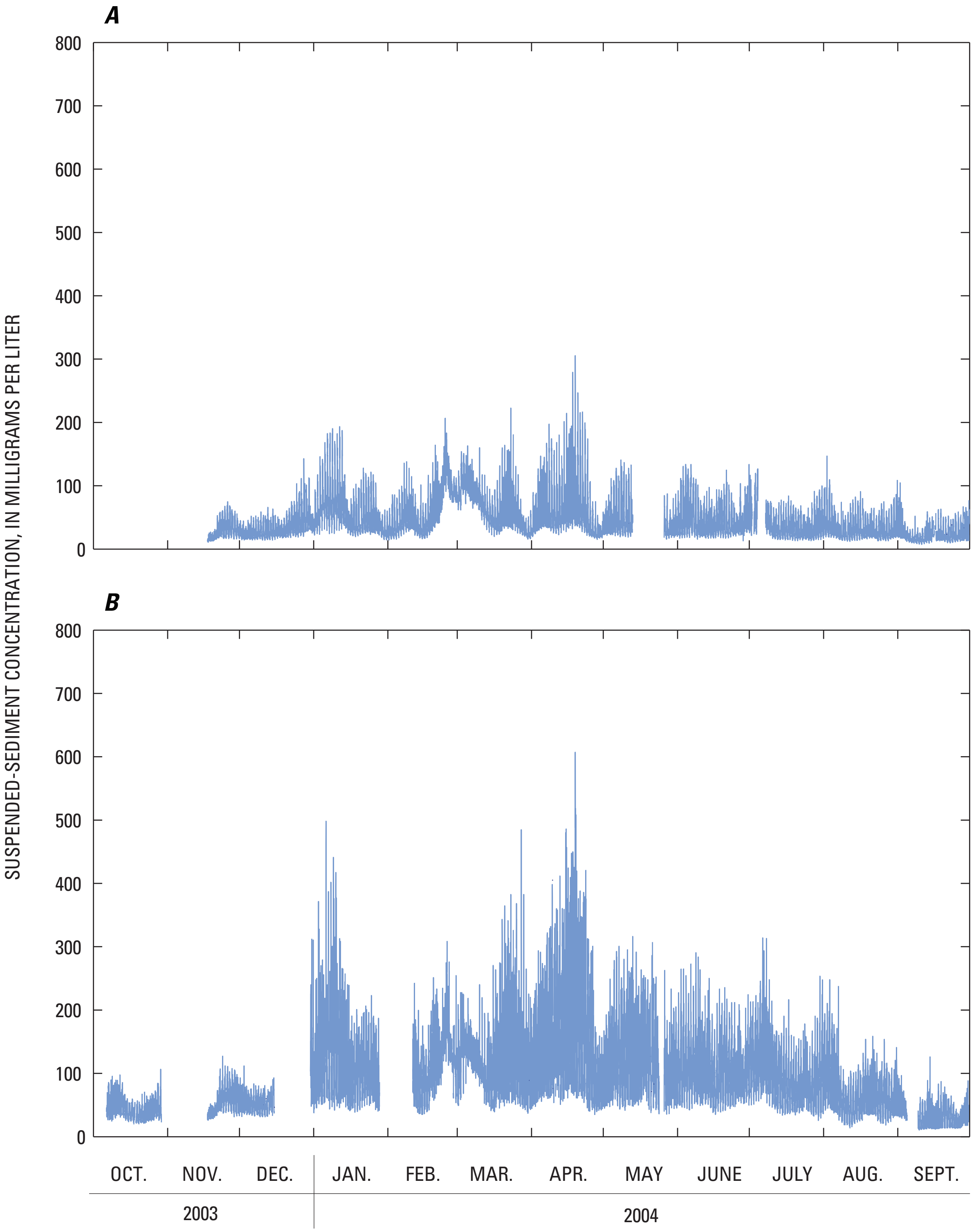

Figure 9. Time series of (*A*) near-surface and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Benicia Bridge, Suisun Bay, California, water year 2004.

San Pablo Bay

Carquinez Bridge

PERIOD OF CALIBRATION.—

MID-DEPTH SENSOR (*A*): October 1, 2003, to October 29, 2003, and December 8, 2003, to March 3, 2004 (fig. 10A).

MID-DEPTH SENSOR (*B*): November 18, 2003, to December 8, 2003, and March 3, 2004, through September 30, 2004 (fig. 10B).

NEAR-BOTTOM SENSOR (*A*): October 1, 2003, to October 29, 2003, and May 13, 2004, to June 14, 2004 (fig.11A).

NEAR-BOTTOM SENSOR (*B*): November 18, 2003, to May 4, 2004, and June 14, 2004, through September 30, 2004 (fig. 11B).

NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—

MID-DEPTH SENSOR (*A*): 17 (6 from WY 2004).

MID-DEPTH SENSOR (*B*): 11 (11 from WY 2004).

NEAR-BOTTOM SENSOR (*A*): 5 (5 from WY 2004).

NEAR-BOTTOM SENSOR (*B*): 14 (14 from WY 2004).

CALCULATED LINEAR CORRELATION EQUATION.—

MID-DEPTH SENSOR (*A*): SSC = 0.762 × NTU + 24.0.

MID-DEPTH SENSOR (*B*): SSC = 0.921 × NTU + 3.8.

NEAR-BOTTOM SENSOR (*A*): SSC = 0.845 × NTU + 15.5.

NEAR-BOTTOM SENSOR (*B*): SSC = 1.116 × NTU +16.5.

NONPARAMETRIC PREDICTION INTERVAL.—

MID-DEPTH SENSOR (*A*): +8 to -16 mg/L.

MID-DEPTH SENSOR (*B*): +11 to -10 mg/L.

NEAR-BOTTOM SENSOR (*A*): undeterminable with five samples.

NEAR-BOTTOM SENSOR (*B*): +17 to -18 mg/L.

95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—

MID-DEPTH SENSOR (*A*): 0.486 to 1.190.

MID-DEPTH SENSOR (*B*): 0.697 to 1.119.

NEAR-BOTTOM SENSOR (*A*): 0.608 to 1.092.

NEAR-BOTTOM SENSOR (*B*): 0.861 to 1.341.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. The instruments were found out of position on October 6, 2003, and the data were deleted during this period. The mid-depth Hydrolab sensor was replaced with a YSI sensor on October 29, 2003, but because of a faulty calibration reset and a datalogger problem, usable data were not collected until December 8, 2003, when a Hydrolab was deployed. The calibration used for data collected at the mid-depth location from October 1, 2003, to October 29, 2003, and December 8, 2003, to March 3, 2004, was developed from samples collected during the deployment of two Hydrolab sensors. Because the two Hydrolab sensors responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), the calibration was developed by combining water samples collected during each sensor deployment. The calibration used for data collected at the mid-depth location from March 3, 2004, through September 30, 2004, was developed from samples collected during the deployment of two YSI sensors. Because the two YSI sensors also responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), the calibration for the second part of the water year was developed by combining water samples collected during each sensor deployment.

The near-bottom Hydrolab sensor was replaced with a YSI sensor on October 29, 2003, but because of a faulty calibration reset, usable data were not collected until December 8, 2003. The YSI malfunctioned and was replaced with a Hydrolab on May 13, 2004. The YSI was repaired and redeployed on June 14, 2004. The calibration used for data collected at the near-bottom location from October 1, 2003, to October 29, 2003, and May 13, 2004, to June 14, 2004, was developed from samples collected during the deployment of two Hydrolab sensors. Because the two Hydrolab sensors responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), the calibration was developed by combining water samples collected during each sensor deployment. The calculated SSC time-series data collected for water year 2004 are presented in figure 12.

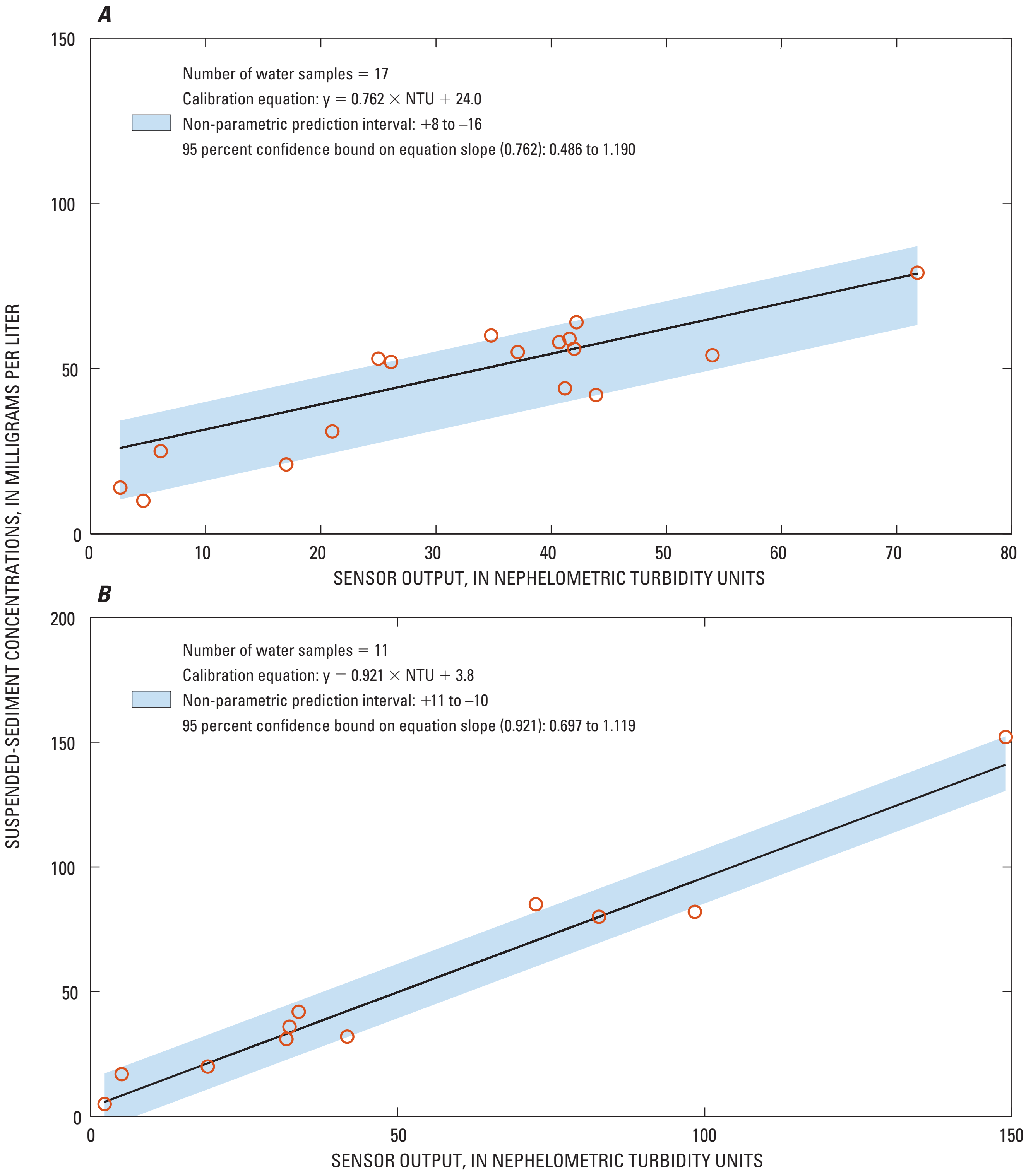

Figure 10. Calibration of mid-depth optical backscatterance sensors, (*A*) October 1–October 29, December 8–March 3 and (*B*) March 3–September 30 at Carquinez Bridge, San Pablo Bay, California, water year 2004.

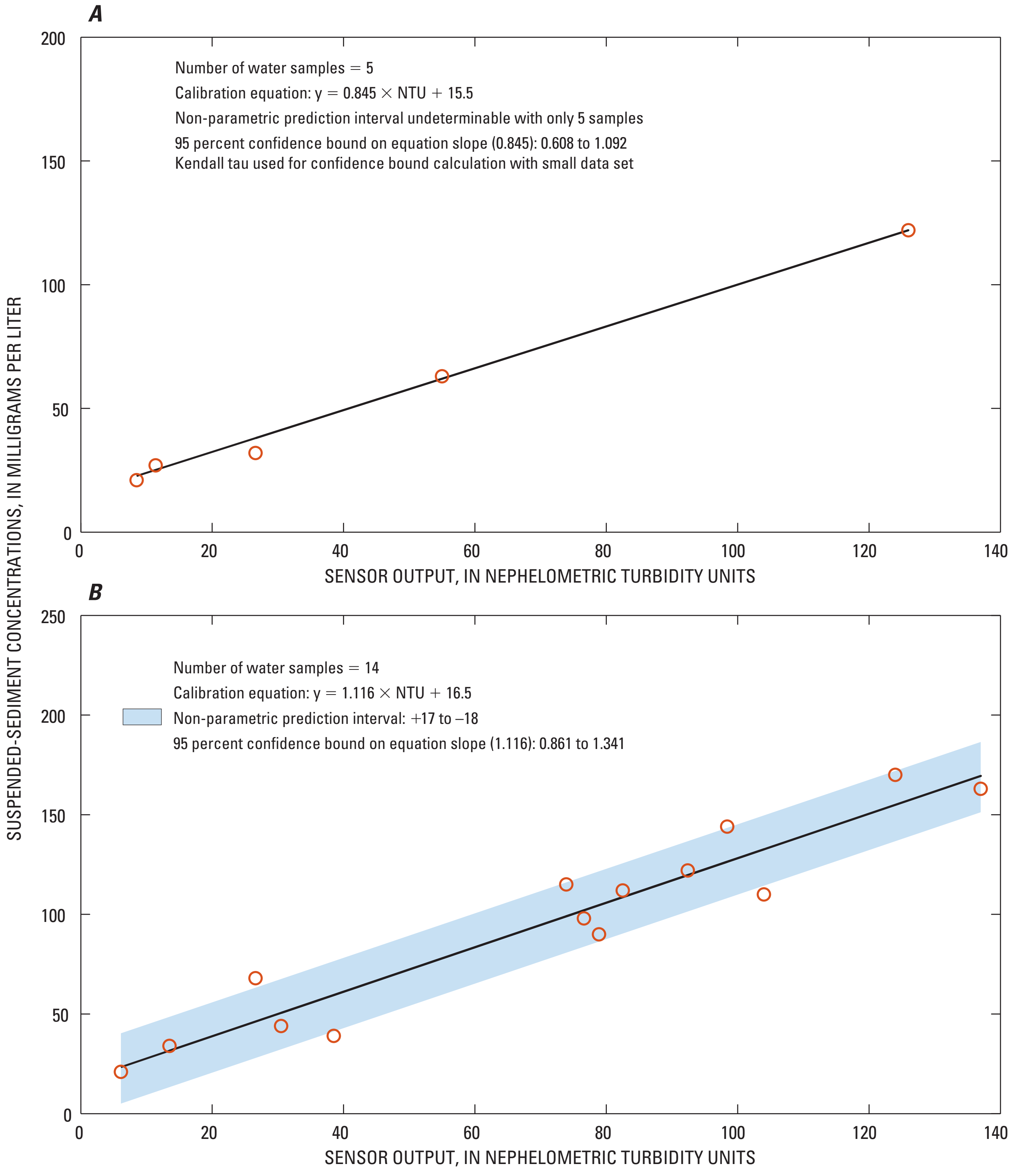

Figure 11. Calibration of near-bottom optical backscatterance sensors, (*A*) October 1–October 29, May 13–June 14 and (*B*) November 18–May 4, June 14–September 30 at Carquinez Bridge, San Pablo Bay, California, water year 2004.

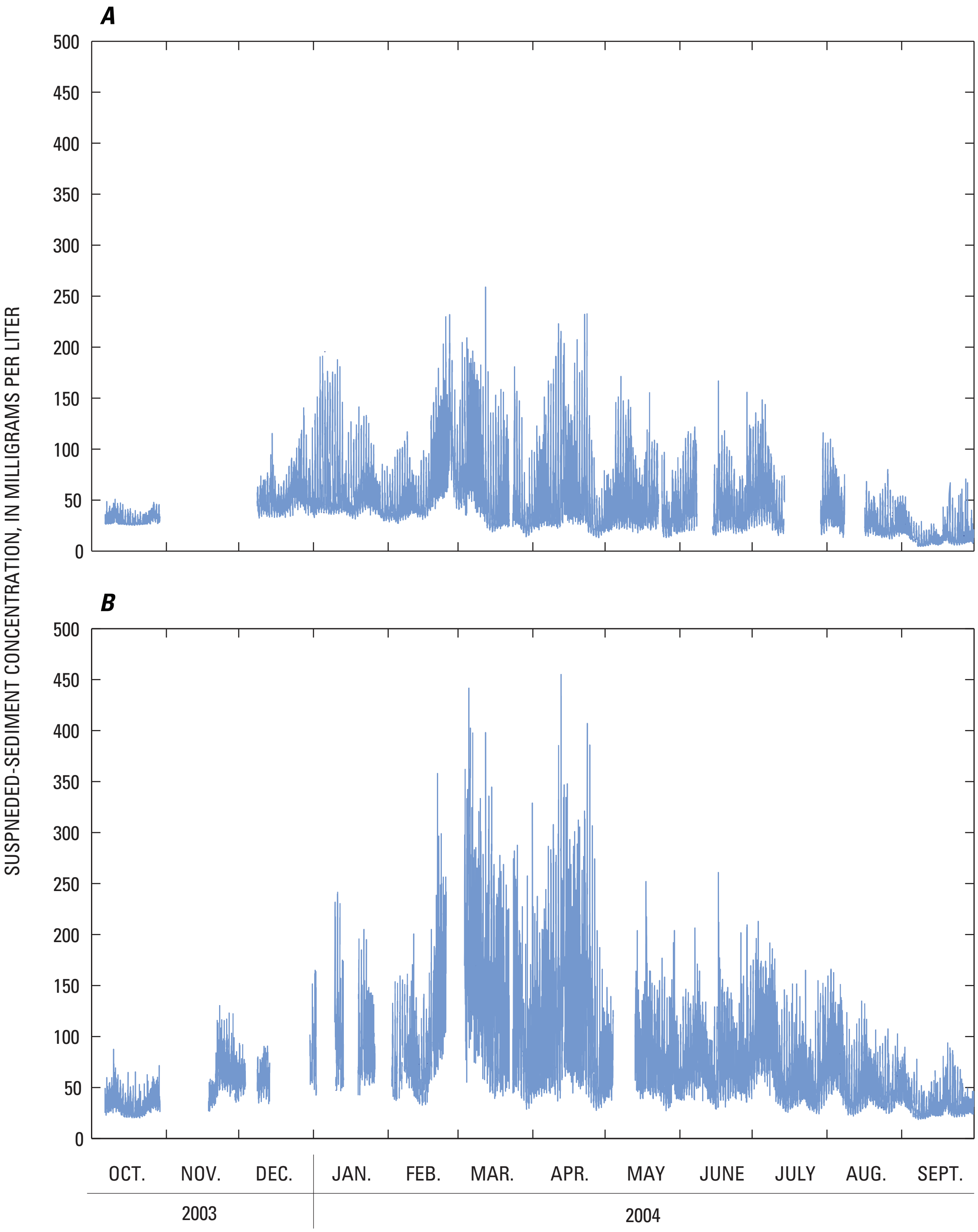

Figure 12. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Carquinez Bridge, San Pablo Bay, California, water year 2004.

Mare Island Causeway

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: November 14, 2003, through September 30, 2004 (fig. 13).
NEAR-BOTTOM SENSOR (*A*): October 1, 2003, to August 12, 2004, (fig. 14A).
NEAR-BOTTOM SENSOR (*B*): August 12, 2003, through September 30, 2004, (*fig.* 14B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 21 (21 from WY 2004).
NEAR-BOTTOM SENSOR (*A*): 27 (20 from WY 2004).
NEAR-BOTTOM SENSOR (*B*): 7 (3 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
MID-DEPTH SENSOR: $SSC = 0.650 \times mV - 10.9$.
NEAR-BOTTOM SENSOR (*A*): $SSC = 0.730 \times mV + 8.2$.
NEAR-BOTTOM SENSOR (*B*): $SSC = 0.919 \times mV - 39.6$.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +12 to -8 mg/L.
NEAR-BOTTOM SENSOR (*A*): +59 to -16 mg/L.
NEAR-BOTTOM SENSOR (*B*): +20 to -24 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 0.583 to 0.701.
NEAR-BOTTOM SENSOR (*A*): 0.631 to 0.879.
NEAR-BOTTOM SENSOR (*B*): 0.811 to 1.657.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. No valid data were collected from the mid-depth sensor prior to November 14, 2003. The mid-depth sensor first was replaced on October 2, 2003, because the output was highly irregular. The mid-depth replacement sensor also was replaced on November 14, 2003, because the sensor was not functioning correctly. The near-bottom sensor was replaced on August 12, 2004, because the instrument was reading one fixed value even when the turbidity was changing. The calibration developed after August 12, 2004, for the near-bottom sensor, included four water samples collected in WY 2005 to help define the calibration. The calculated SSC time-series data collected for WY 2004 are presented in figure 15.

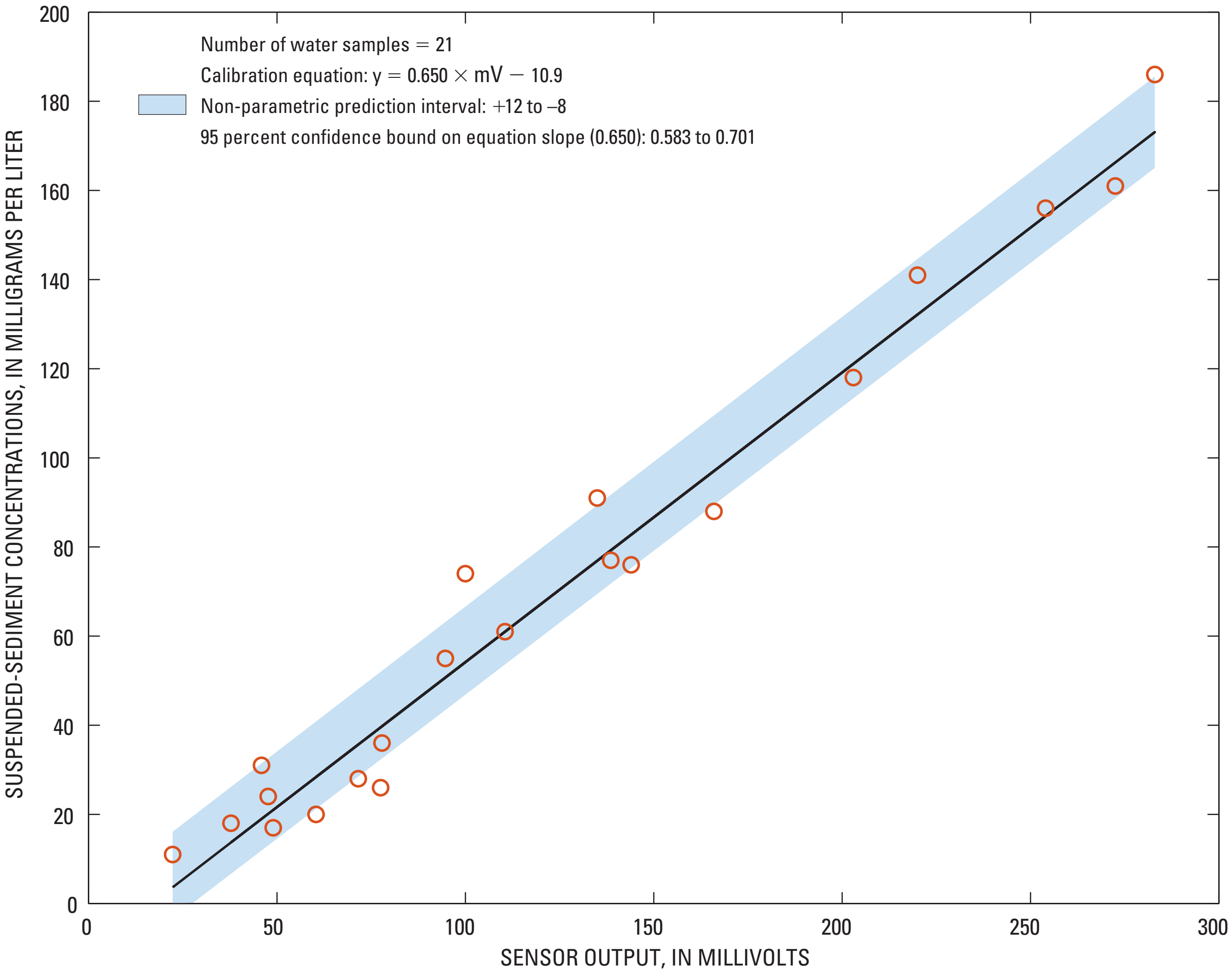

Figure 13. Calibration of mid-depth optical backscatterance sensor at Mare Island Causeway, San Pablo Bay, California, water year 2004.

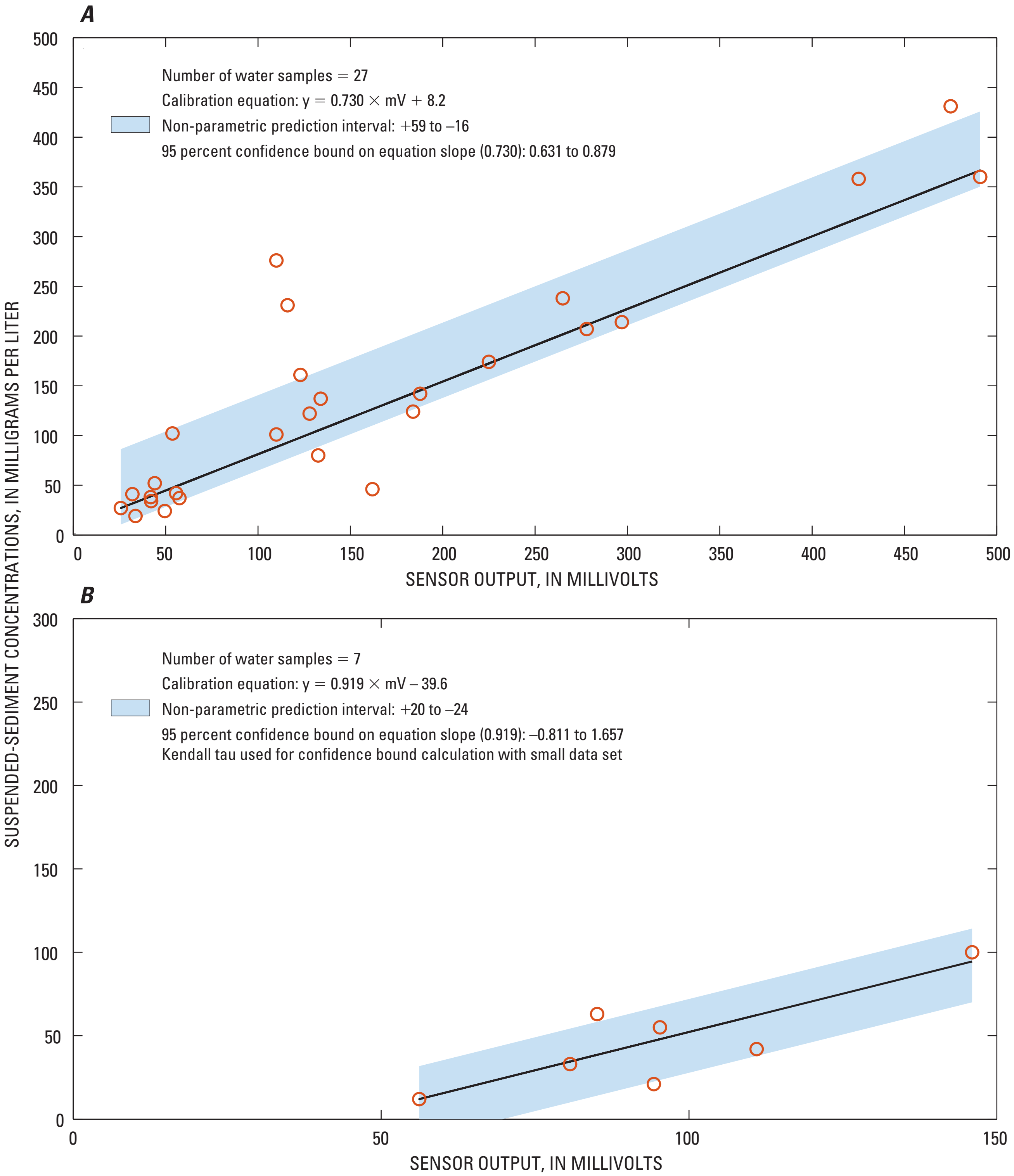

Figure 14. Calibration of near-bottom optical backscatterance sensors, (*A*) October 1–August 12 and (*B*) August 12–September 30 at Mare Island Causeway, San Pablo Bay, California, water year 2004.

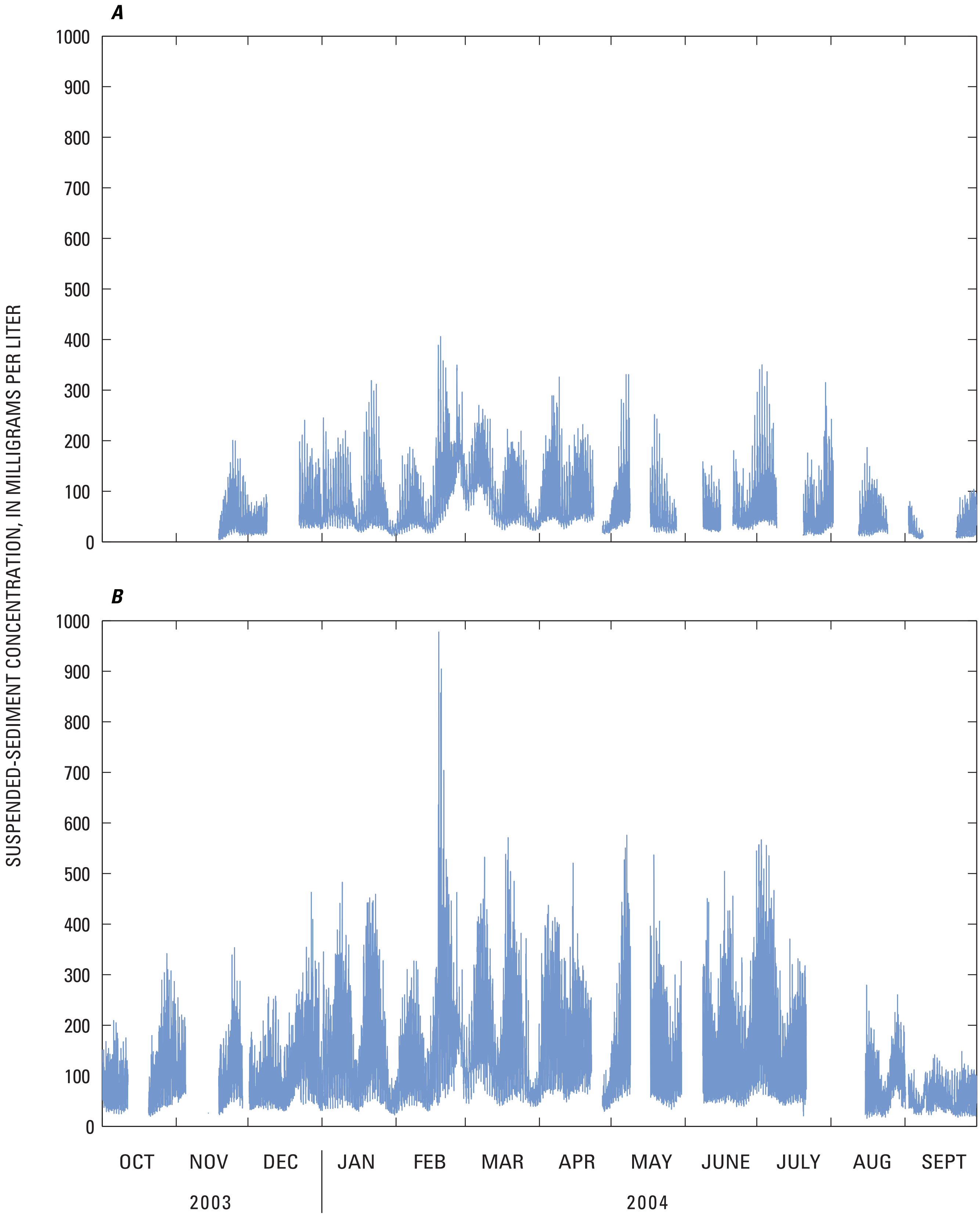

Figure 15. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Mare Island Causeway, San Pablo Bay, California, water year 2004.

Channel Marker 1

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: November 18, 2003, through September 30, 2004, (fig. 16).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 18 (18 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
MID-DEPTH SENSOR: SSC = 1.565 × NTU + 4.7.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +13 to -21 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 0.861 to 1.926.

REMARKS.—Interruptions in record caused by fouling or malfunction of the sensing and (or) recording instruments. The Hydrolab sensor retrieved from the discontinued station at Channel Marker 9 could not be deployed on October 7, 2003, because it had malfunctioned. On October 28, 2003, a YSI sensor was deployed but because of a faulty calibration reset; usable data were not collected until November 18, 2003. During periods of heavy fouling, the sensor wiper was ineffective in keeping the optical ports clean because of biological growth on the wiper itself obscuring the optical ports. The calculated SSC time-series data collected for WY 2004 are presented in figure 17.

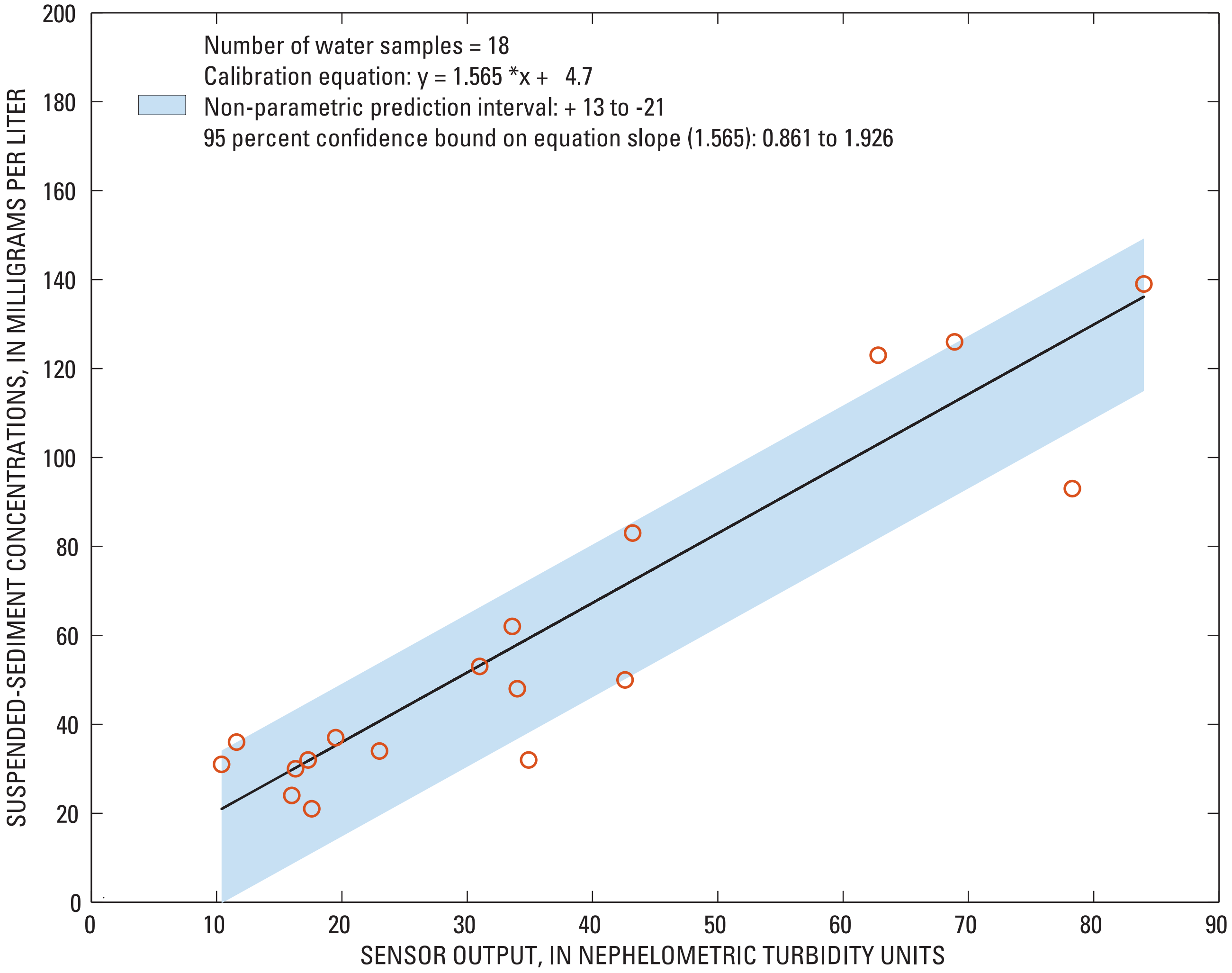

Figure 16. Calibration of near-bottom optical backscatterance sensor at Channel Marker 1 at San Pablo Bay, California, water year 2004.

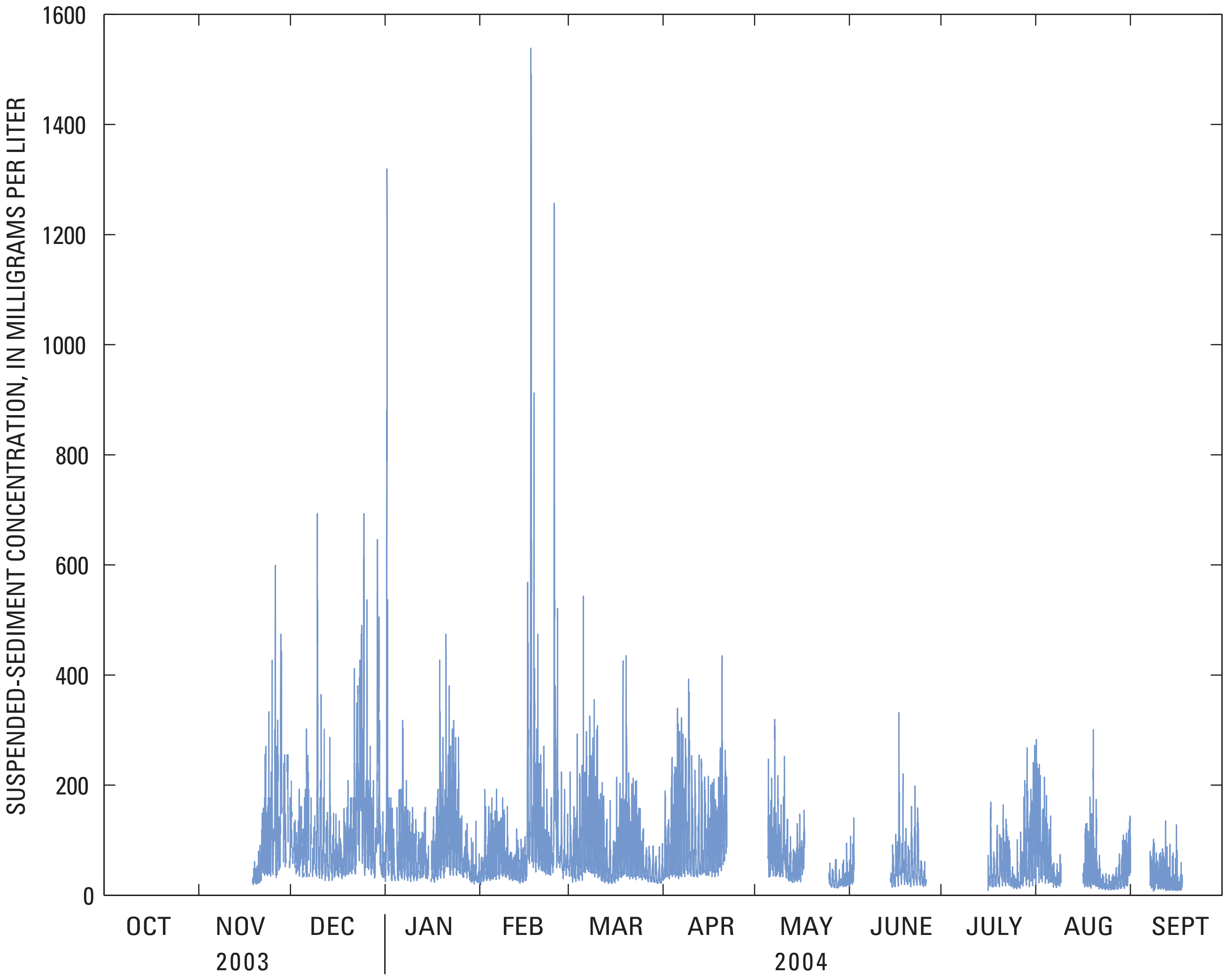

Figure 17. Time series of near-bottom suspended-sediment concentrations calculated from sensor readings at Channel Marker 1, San Pablo Bay, California, water year 2004.

Central San Francisco Bay

Point San Pablo

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR (*A*): October 1, 2003, to October 30, 2003 (fig. 18A).
MID-DEPTH SENSOR (*B*): November 19, 2003, through September 30, 2004 (fig. 18B).
NEAR-BOTTOM SENSOR: November 19, 2003, through September 30, 2004 (fig. 19).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR (*A*): 17 (1 from WY 2004).
MID-DEPTH SENSOR (*B*): 17 (17 from WY 2004).
NEAR-BOTTOM SENSOR: 20 (20 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
MID-DEPTH SENSOR (*A*): SSC = 1.975 × NTU – 1.2.
MID-DEPTH SENSOR (*B*): SSC = 1.746 × NTU – 1.3.
NEAR-BOTTOM SENSOR: SSC = 1.588 × NTU + 7.7.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR (*A*): +17 to -5 mg/L.
MID-DEPTH SENSOR (*B*): +20 to -14 mg/L.
NEAR-BOTTOM SENSOR: +21 to -14 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
MID-DEPTH SENSOR (*A*): 1.270 to 2.727.
MID-DEPTH SENSOR (*B*): 1.095 to 2.538.
NEAR-BOTTOM SENSOR: 1.141 to 2.278.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. The mid-depth calibration used from October 1, 2003, to October 30, 2003, (fig. 18A) was developed from water samples collected during the deployment of two Hydrolab sensors which responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003). The mid-depth Hydrolab sensor was replaced by a YSI sensor on October 30, 2003, but because of a faulty calibration reset, usable data were not collected until November 19, 2003. The near-bottom Hydrolab sensor malfunctioned, and no usable data were collected from October 1, 2003, to October 30, 2003. The near-bottom Hydrolab sensor was replaced by a YSI sensor on October 30, 2003, but because of a faulty calibration reset, usable data were not collected until November 19, 2003. The calculated SSC time-series data collected for WY 2004 are presented in figure 20.

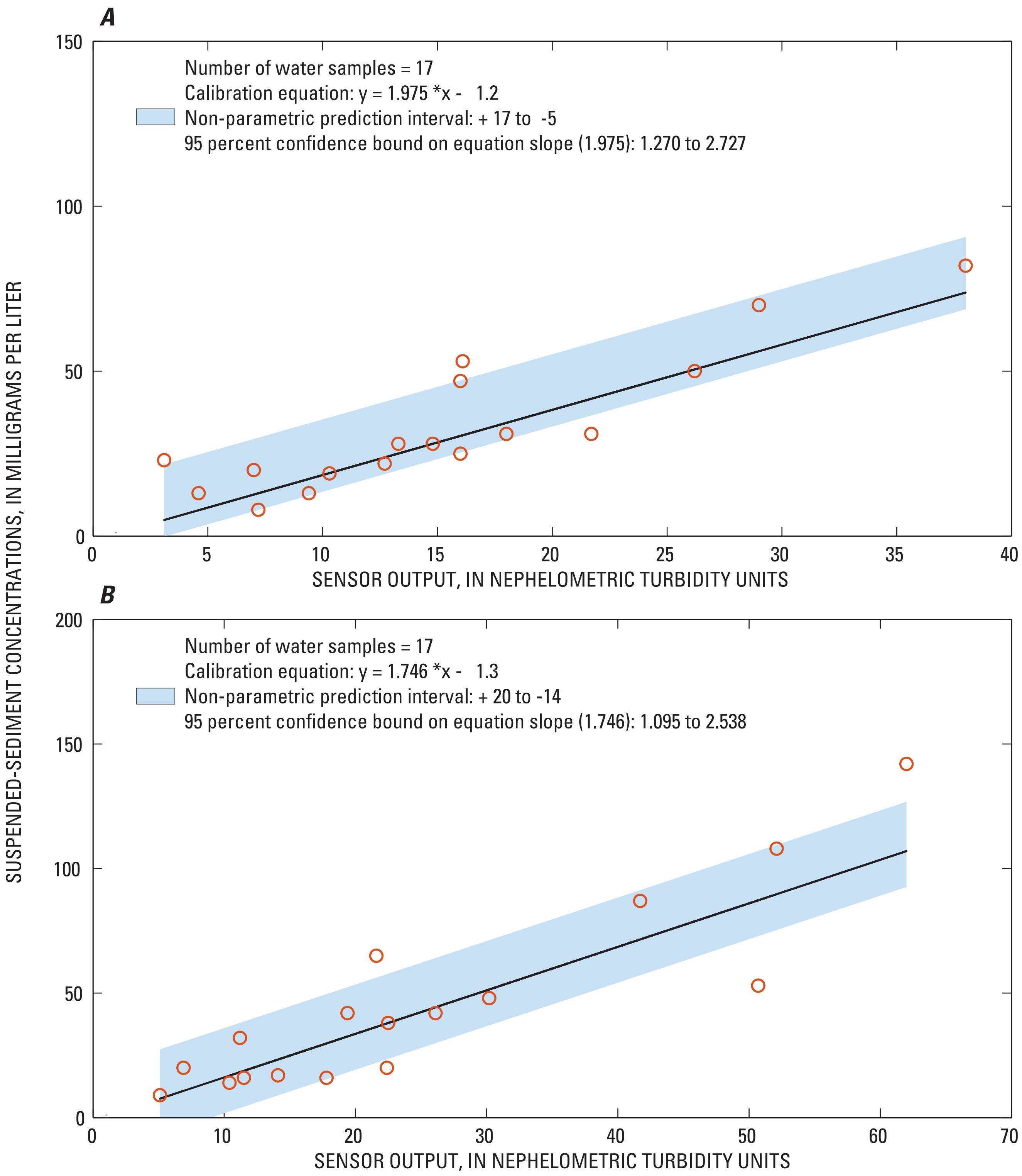

Figure 18. Calibration of mid-depth optical backscatterance sensors, (*A*) October 1–October 30 and (*B*) November 19–September 30 at Point San Pablo, Central San Francisco Bay, California, water year 2004.

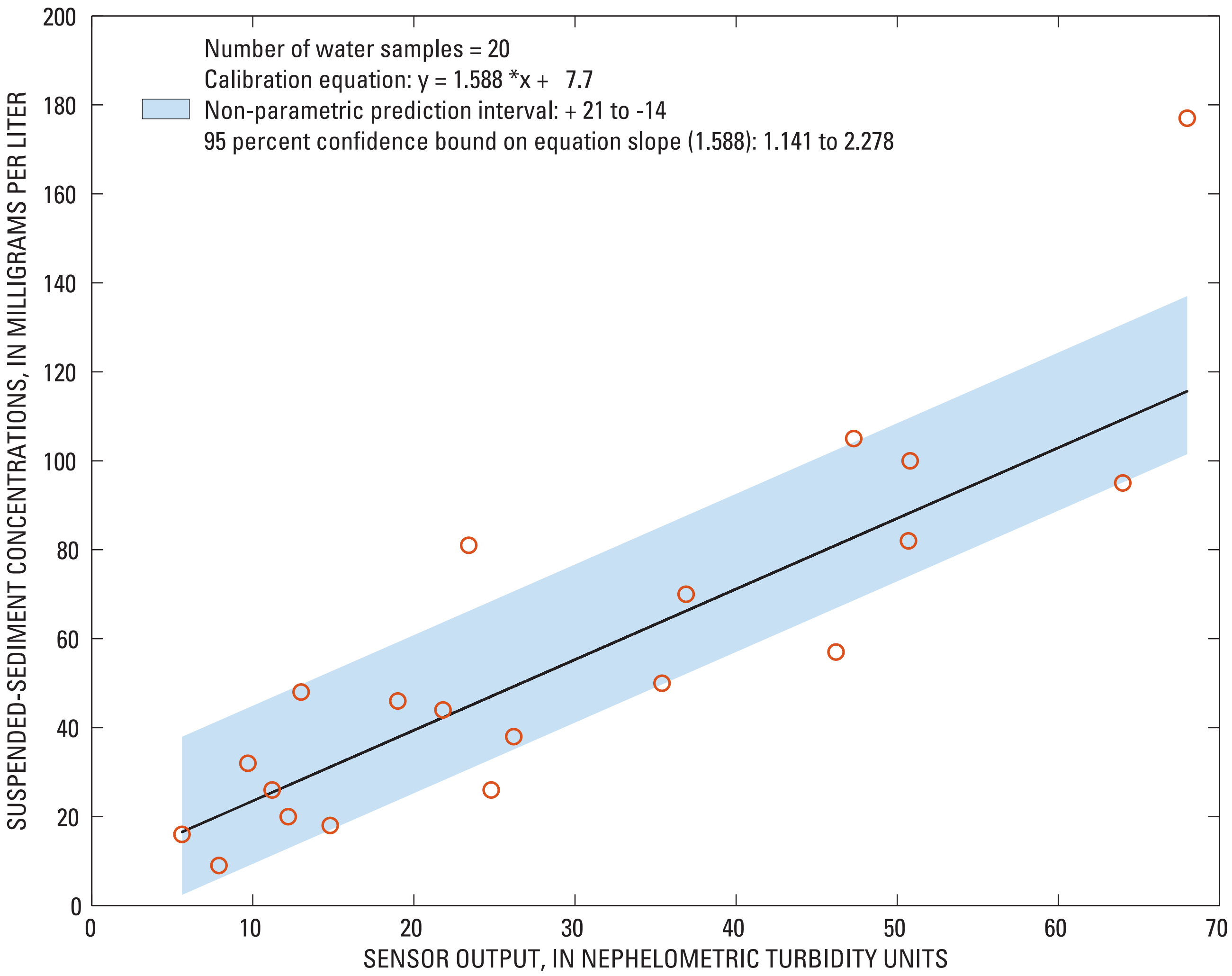

Figure 19. Calibration of near-bottom optical backscatterance sensor at Point San Pablo, Central San Francisco Bay, California, water year 2004.

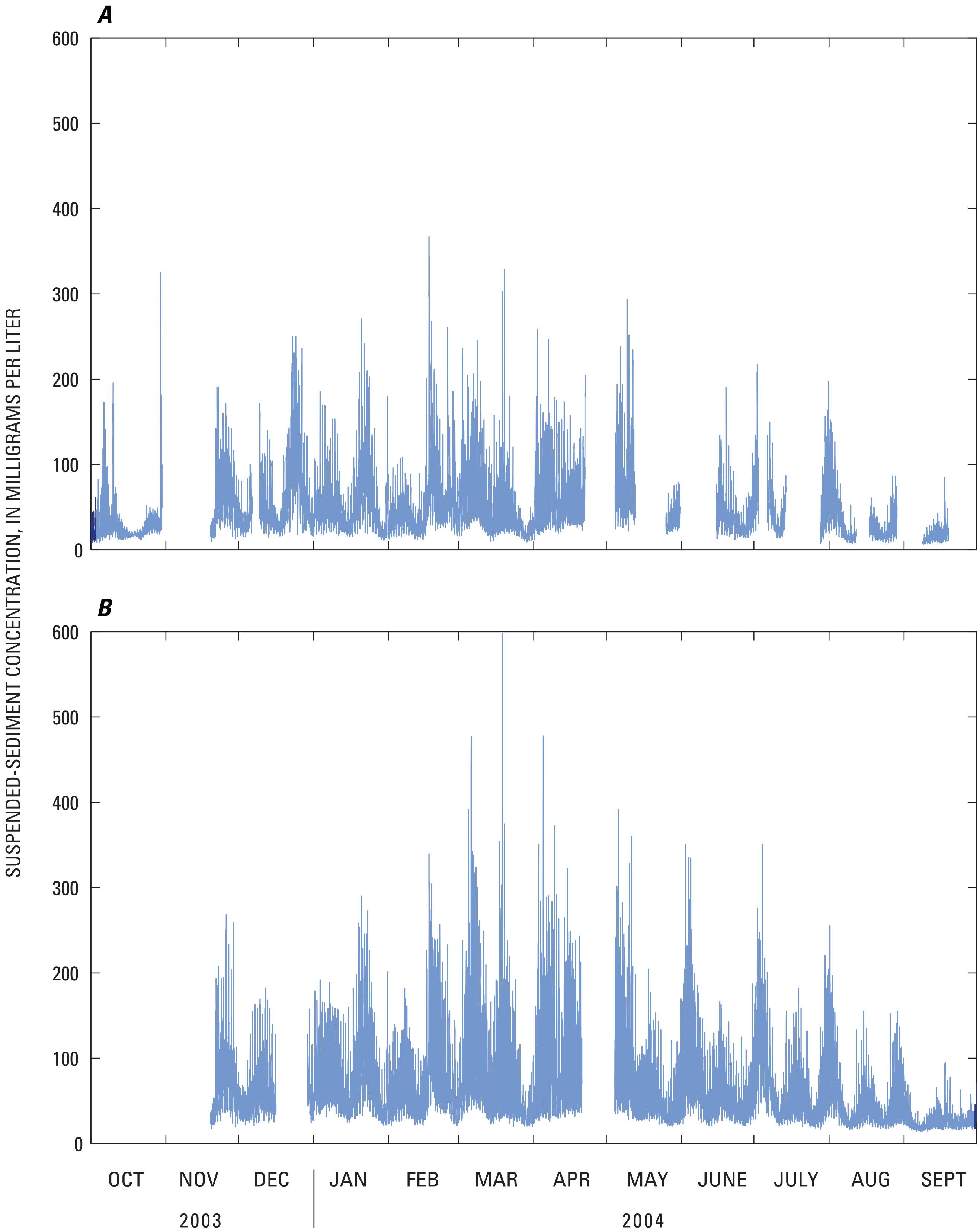

Figure 20. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Point San Pablo, Central San Francisco Bay, California, water year 2004.

Alcatraz Island

PERIOD OF CALIBRATION.—
  MID-DEPTH SENSOR (*A*): November 6, 2003, to August 12, 2004 (fig. 21A).
  MID-DEPTH SENSOR (*B*): September 9, 2004, through September 30, 2004 (fig. 21B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
  MID-DEPTH SENSOR (*A*): 34 (17 from WY 2004).
  MID-DEPTH SENSOR (*B*): 17 (3 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
  MID-DEPTH SENSOR (*A*): SSC = 11.028 × NTU + 9.5.
  MID-DEPTH SENSOR (*B*): SSC = 2.357 × NTU + 8.4.
NONPARAMETRIC PREDICTION INTERVAL.—
  MID-DEPTH SENSOR (*A*): +8 to -5 mg/L.
  MID-DEPTH SENSOR (*B*): +9 to -4 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
  MID-DEPTH SENSOR (*A*): 0.946 to 1.287.
  MID-DEPTH SENSOR (B): 1.538 to 4.286.

REMARKS.—Interruptions in record caused by fouling or malfunction of the sensing and (or) recording instruments. The YSI deployed on November 6, 2003, malfunctioned on August 12, 2004, and was replaced with a Hydrolab on August 18, 2004. The data collected by the Hydrolab were not used because one water sample was collected during the deployment and a calibration could not be developed. The Hydrolab was replaced with a second YSI on September 9, 2004. The calibration used for the YSI deployed from November 6, 2003, to August 12, 2004, (fig. 21A) was developed using 17 additional samples having high SSC collected from Carquinez Strait at Carquinez Bridge during WY 2005 to improve the calibration slope. Samples from both locations could be used to develop the calibration because the YSI responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003). The calibration used for the YSI deployed from September 9, 2004, through the end of WY 2004 (fig. 21B) was developed using 14 additional water samples collected during WY 2005 to improve the calibration. The YSI wipers were ineffective during periods of heavy fouling because of biological growth on the wipers obscuring the optical ports. The calculated SSC time-series data collected for WY 2004 are presented in figure 22.

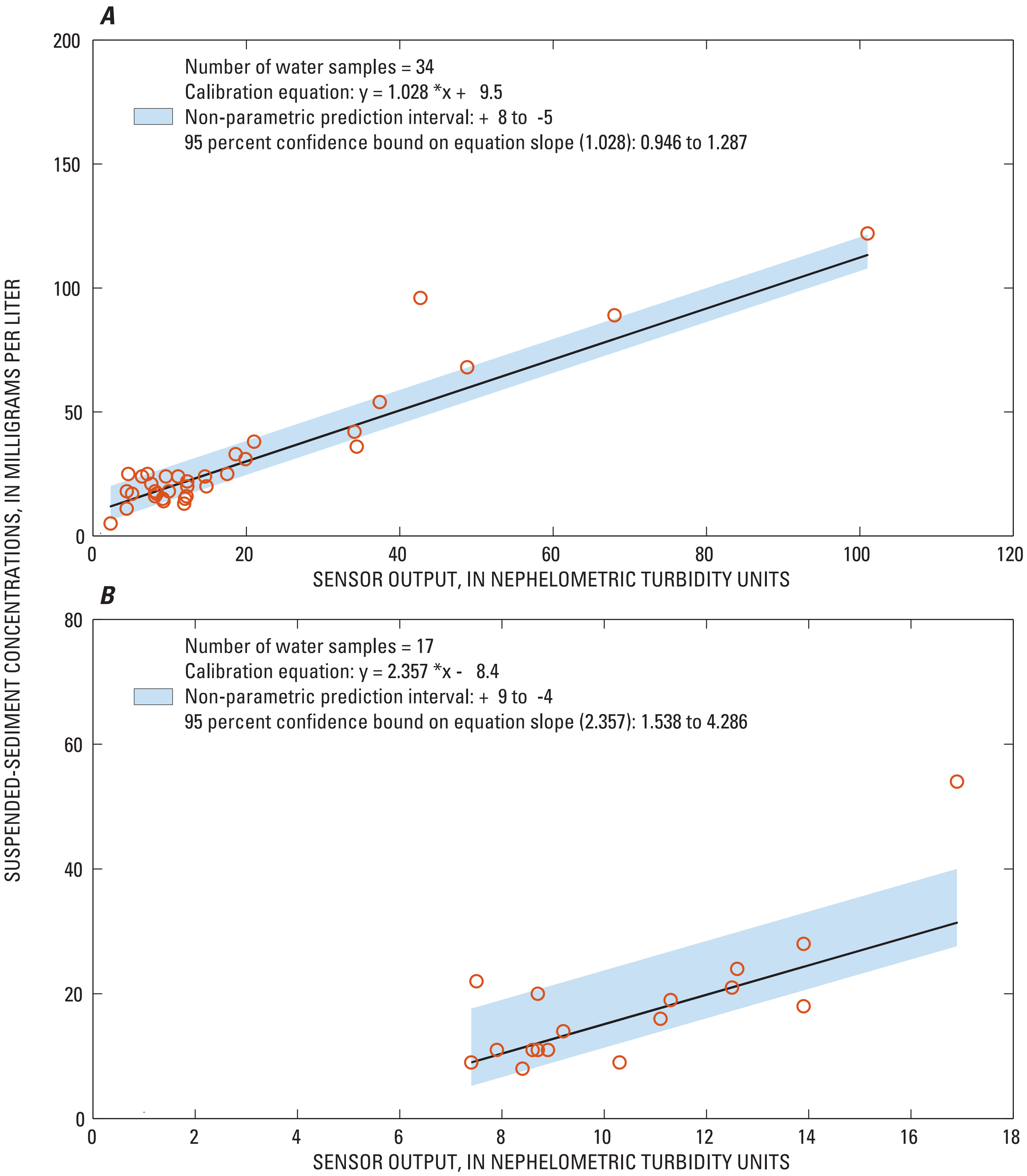

Figure 21. Calibration of mid-depth optical backscatterance sensors, (*A*) November 6–August 12 and (*B*) September 9–30, at Alcatraz Island, Central San Francisco Bay, California, water year 2004.

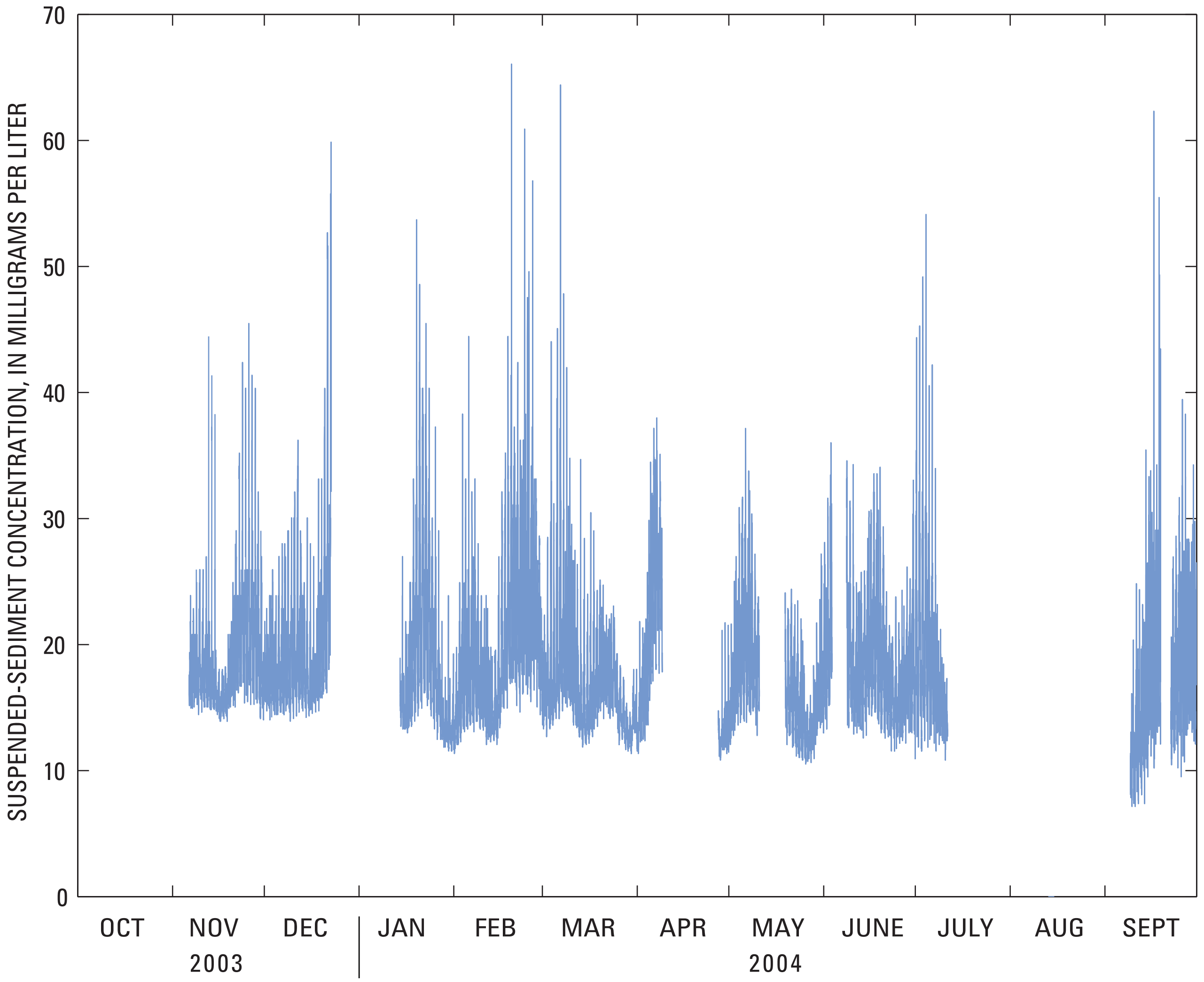

Figure 22. Time series of mid-depth suspended-sediment concentrations calculated from sensor readings at Alcatraz Island, Central San Francisco Bay, California, water year 2004.

South San Francisco Bay

San Mateo Bridge

PERIOD OF CALIBRATION.—
  MID-DEPTH SENSOR: WY 2004 (fig. 23A).
  NEAR-BOTTOM SENSOR: WY 2004 (fig. 23B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
  MID-DEPTH SENSOR: 55 (16 from WY 2004).
  NEAR-BOTTOM SENSOR: 48 (20 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
  MID-DEPTH SENSOR: $SSC = 0.524 \times mV + 2.8$.
  NEAR-BOTTOM SENSOR: $SSC = 0.522 \times mV + 4.5$.
NONPARAMETRIC PREDICTION INTERVAL.—
  MID-DEPTH SENSOR: +8 to -13 mg/L.
  NEAR-BOTTOM SENSOR: +12 to -8 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
  MID-DEPTH SENSOR: 0.452 to 0.674.
  NEAR-BOTTOM SENSOR: 0.439 to 0.667.

REMARKS.—Interruptions in record were caused by fouling. Biological fouling in South San Francisco Bay is extreme, especially during the summer months, resulting in a fragmented data set. The calculated SSC time-series data collected for WY 2004 are presented in figure 24.

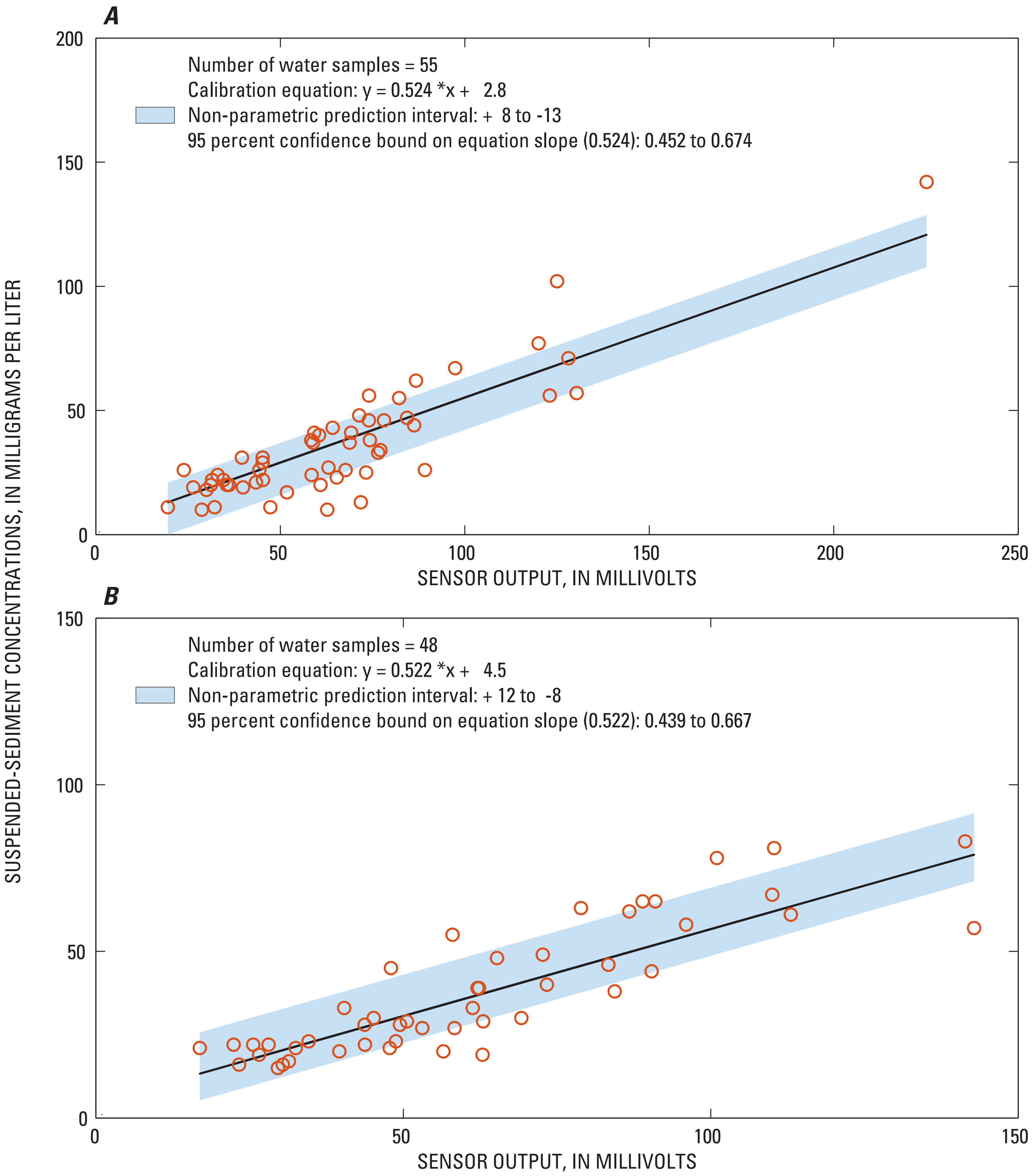

Figure 23. Calibration of (*A*) mid-depth and (*B*) near-bottom optical backscatterance sensors at San Mateo Bridge, South San Francisco Bay, California, water year 2004.

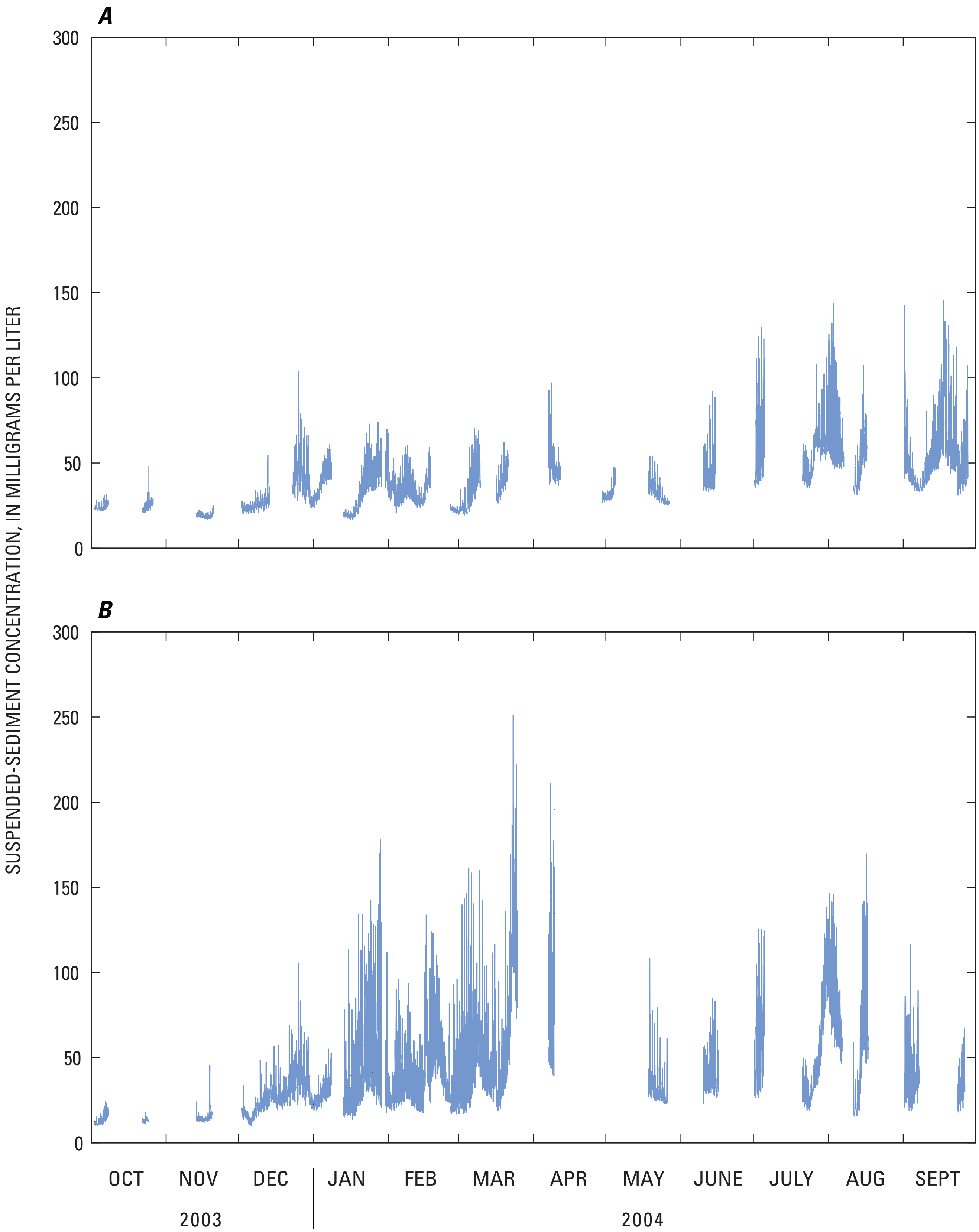

Figure 24. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at San Mateo Bridge, South San Francisco Bay, California, water year 2004.

Dumbarton Bridge

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: WY 2004 (fig. 25).
NEAR-BOTTOM SENSOR (*A*): October 1, 2003, to March 16, 2004 (fig. 26A).
NEAR-BOTTOM SENSOR (*B*): March 17, 2004, through September 30, 2004 (fig. 26B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 41 (18 from WY 2004).
NEAR-BOTTOM SENSOR (*A*): 86 (8 from WY 2004).
NEAR-BOTTOM SENSOR (*B*): 17 (11 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
MID-DEPTH SENSOR: SSC = 0.666 × mV - 3.7.
NEAR-BOTTOM SENSOR (*A*): SSC = 0.606 × mV - 11.6.
NEAR-BOTTOM SENSOR (*B*): SSC = 0.666 × mV - 11.7.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +9 to -10 mg/L.
NEAR-BOTTOM SENSOR (*A*): +12 to -11 mg/L.
NEAR-BOTTOM SENSOR (*B*): +14 to -10 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 0.568 to 0.794.
NEAR-BOTTOM SENSOR (*A*): 0.553 to 0.637.
NEAR-BOTTOM SENSOR (*B*): 0.487 to 0.837.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. The near-bottom sensor was removed on March 16, 2004, because it was inoperable and replaced by a second OBS sensor on March 17, 2004. The calibration developed after March 17, 2004, for the near-bottom sensor, included six water samples collected in WY 2005, to help define the calibration. The calculated SSC time-series data collected for WY 2004 are presented in figure 27.

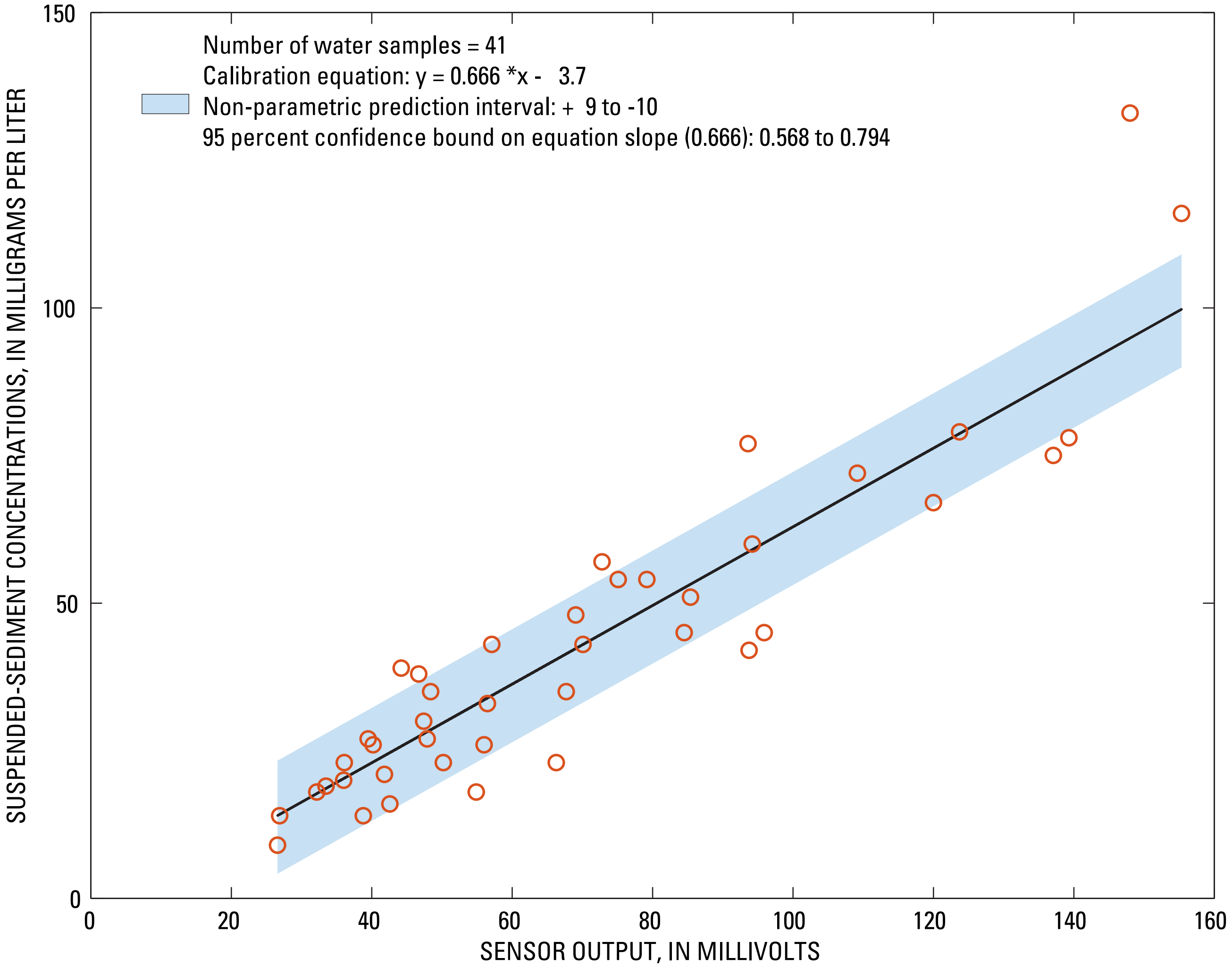

Figure 25. Calibration of mid-depth optical backscatterance sensor at Dumbarton Bridge, South San Francisco Bay, California, water year 2004.

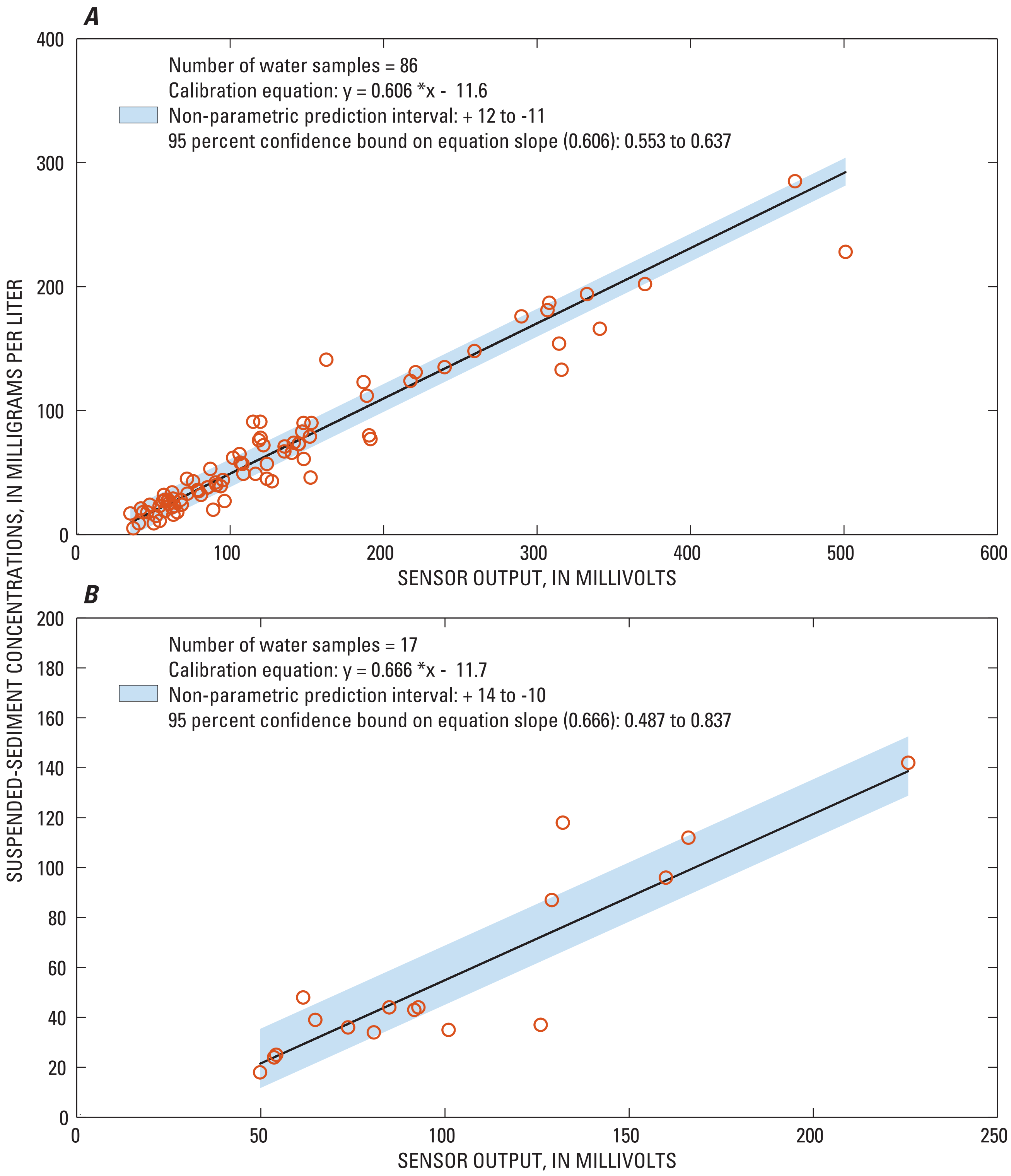

Figure 26. Calibration of near-bottom optical backscatterance sensors, (*A*) October 1–March 16 and (*B*) March 17–September 30 at Dumbarton Bridge, South San Francisco Bay, California, water year 2004.

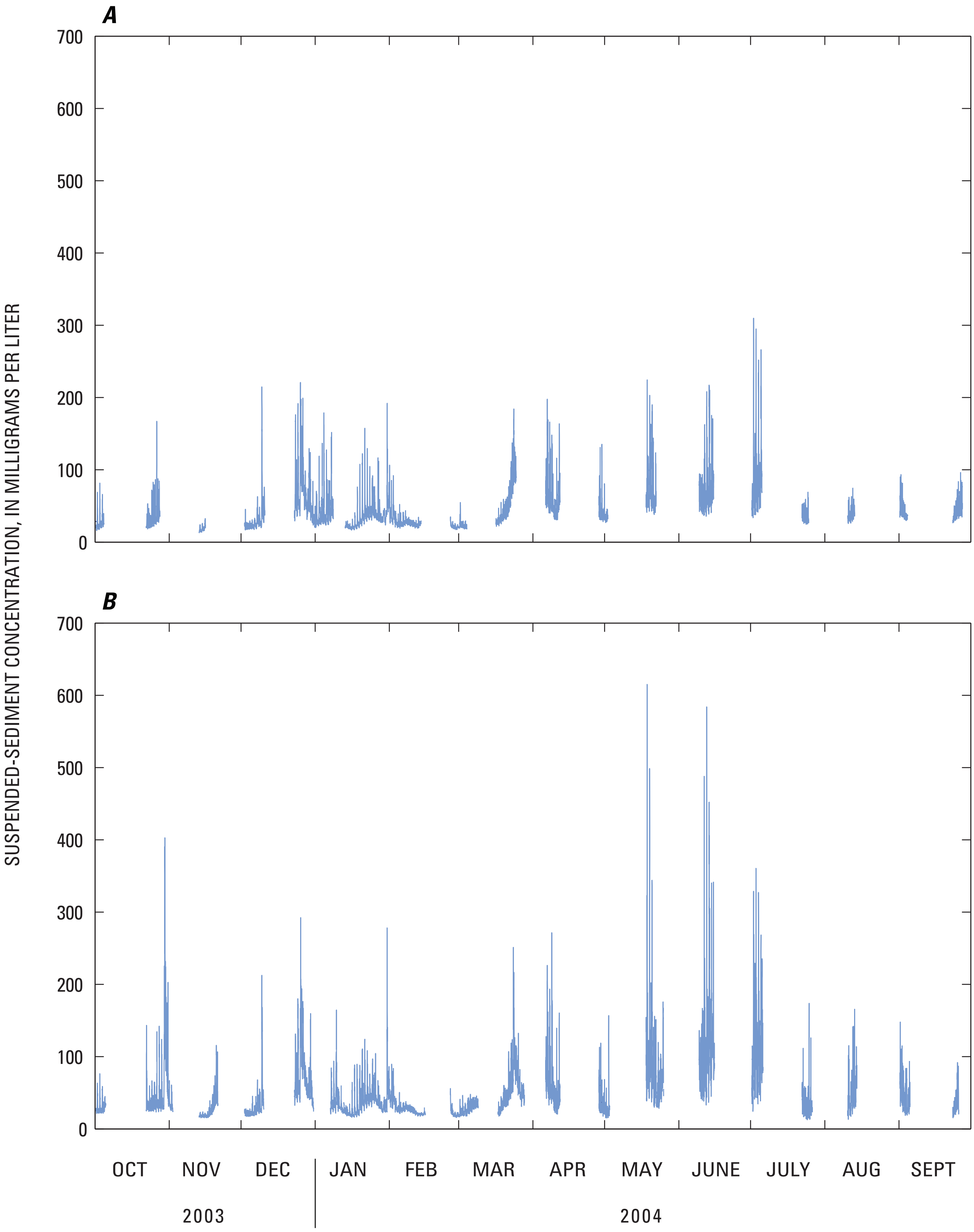

Figure 27. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Dumbarton Bridge, South San Francisco Bay, California, water year 2004.

Channel Marker 17

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR (*A*): October 1, 2003, to June 9, 2004 (fig. 28A).
MID-DEPTH SENSOR (*B*): June 9, 2004, through September 30, 2004 (fig. 28B).
NEAR-BOTTOM SENSOR (*A*): October 1, 2003, to June 9, 2004 (fig. 29A).
NEAR-BOTTOM SENSOR (*B*): July 1, 2004, through September 30, 2004 (fig. 29B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.— MID-DEPTH SENSOR (*A*): 129 (15 from WY 2004).
MID-DEPTH SENSOR (*B*): 5 (5 from WY 2004).
NEAR-BOTTOM SENSOR (*A*): 103 (14 from WY 2004).
NEAR-BOTTOM SENSOR (*B*): 8 (6 from WY 2004).
CALCULATED LINEAR CORRELATION EQUATION.—
MID-DEPTH SENSOR (*A*): SSC = 0.628 × mV - 14.5.
MID-DEPTH SENSOR (*B*): SSC = 1.023 × NTU + 10.8.
NEAR-BOTTOM SENSOR (*A*): SSC = 0.556 × mV - 1.2.
NEAR-BOTTOM SENSOR (*B*): SSC = 1.218 × NTU-NTU - 0.3.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR (*A*): +13 to -12 mg/L.
MID-DEPTH SENSOR (*B*): undeterminable with five samples.
NEAR-BOTTOM SENSOR (*A*): +17 to -11 mg/L.
NEAR-BOTTOM SENSOR (*B*): +18 to -11 mg/L.
95-PERCENT CONFIDENCE BOUND ON SLOPE CALCULATION.—
MID-DEPTH SENSOR (A): 0.609 to 0.654.
MID-DEPTH SENSOR (B): 0.200 to 1.476.
NEAR-BOTTOM SENSOR (*A*): 0.539 to 0.635.
NEAR-BOTTOM SENSOR (*B*): 0.989 to 1.550.

REMARKS.—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. Hydrolab instruments, equipped with turbidity, specific-conductance and temperature sensors, replaced OBS sensors at near-surface and near-bottom depths on June 9, 2004. The sensor at mid-depth was replaced on August 11, 2004, because it was inoperable. Because the two sensors (Hydrolabs) responded similarly to the uniform sediment characteristics found in San Francisco Bay (Schoellhamer and others, 2003), a calibration was developed by combining water samples collected during each sensor deployment. The near-bottom sensor deployed on June 9, 2004, collected no data and was replaced on July 1, 2004. The calculated SSC time-series data collected for WY 2004 are presented in figure 30.

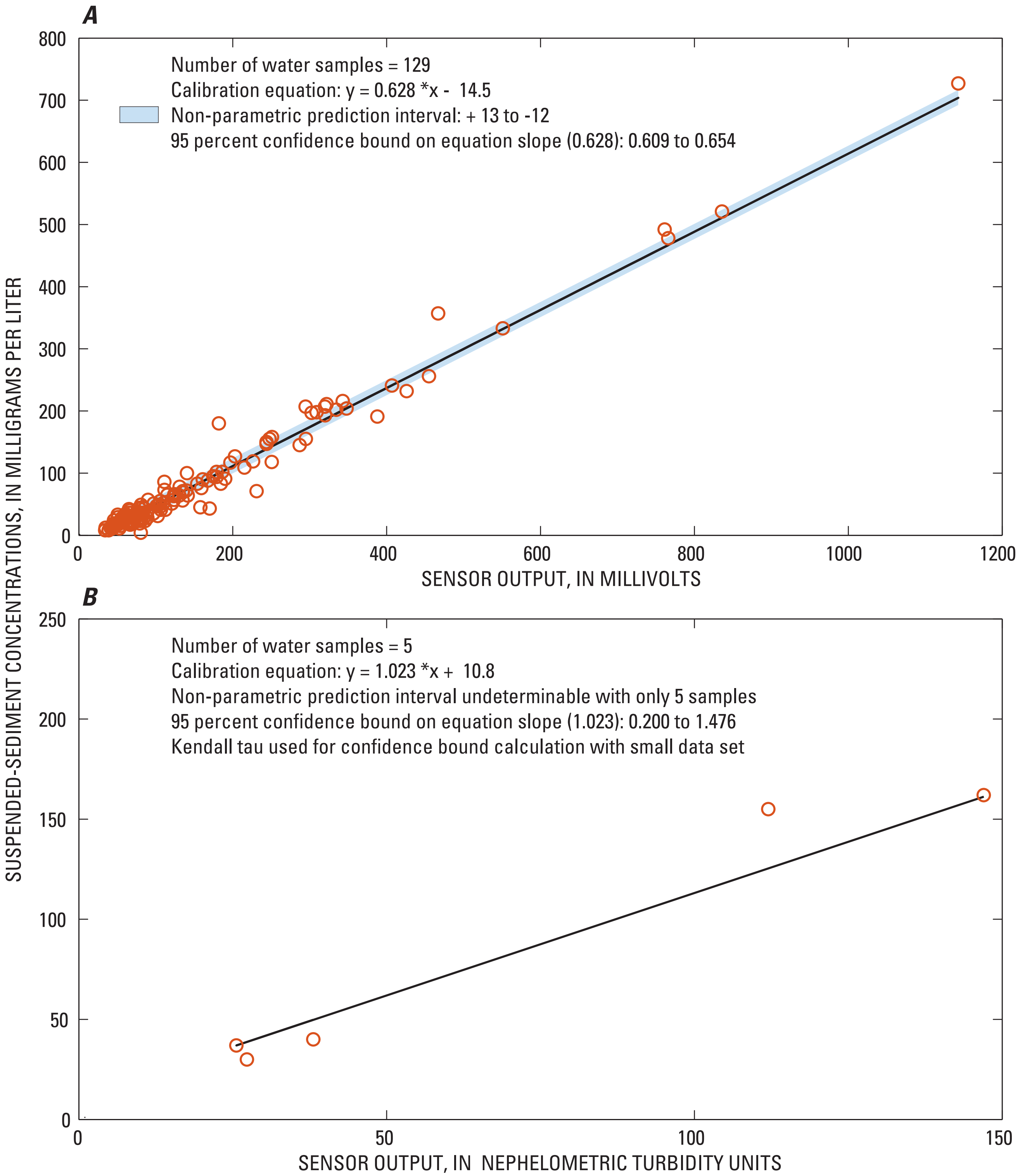

Figure 28. Calibration of mid-depth optical backscatterance sensors, (*A*) October 1–June 9 and (*B*) June 9–September 30 at Channel Marker 17, South San Francisco Bay, California, water year 2004.

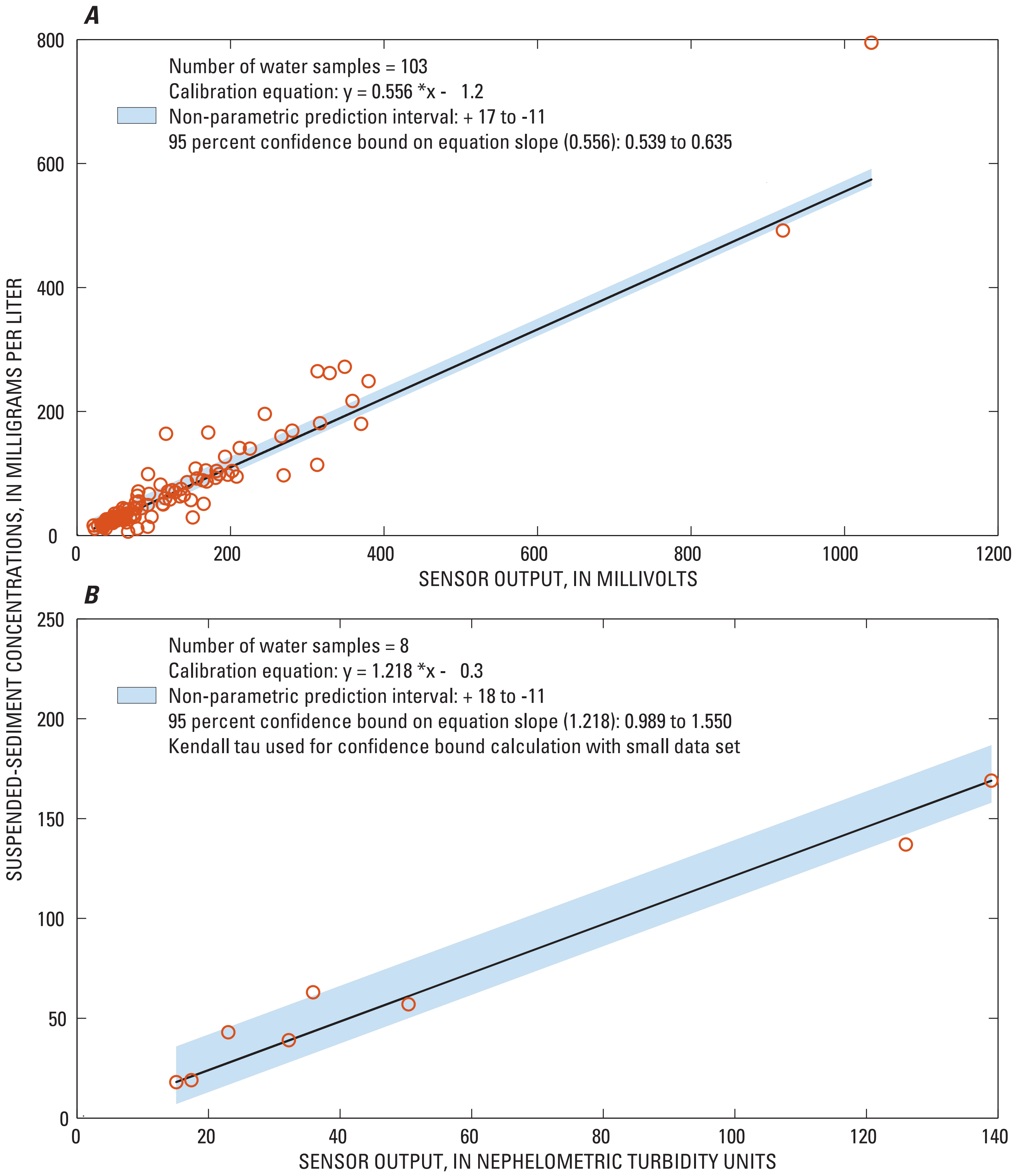

Figure 29. Calibration of near-bottom optical backscatterance sensors, (*A*) October 1–June 9 and (B) July 1–September 30 at Channel Marker 17, South San Francisco Bay, California, water year 2004.

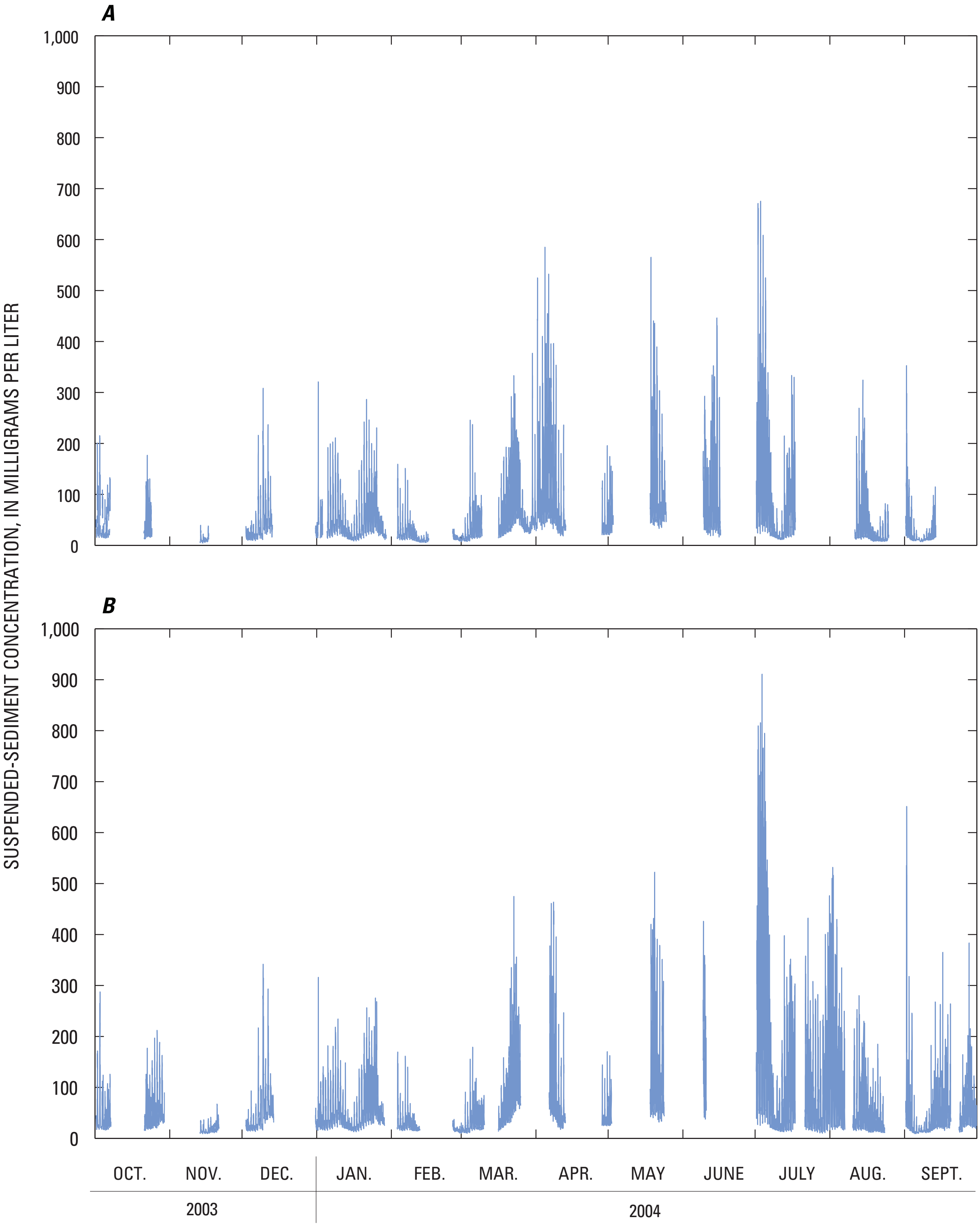

Figure 30. Time series of (*A*) mid-depth and (*B*) near-bottom suspended-sediment concentrations calculated from sensor readings at Channel Marker 17, South San Francisco Bay, California, water year 2004.

Summary

Suspended-sediment concentration (SSC) data were collected by the U.S. Geological Survey (USGS) at two sites in Suisun Bay, three sites in San Pablo Bay, two sites in Central San Francisco Bay, and three sites in South San Francisco Bay during water year 2004. Three types of optical sensors, each controlled by electronic data loggers, were used to monitor suspended sediment. Water samples were collected to calibrate the output of the optical sensors to SSC, and the recorded data were recovered and processed. Water-sample sediment concentration data are available in the USGS sediment database. Time-series data are available in the USGS sediment database and the USGS automated data-processing system database. The calculated SSC data are available from the USGS at http://sfbay.wr.usgs.gov/access/Fixed_sta/ (accessed October 30, 2005).

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