Continuous Water-Quality and Suspended-Sediment Transport Monitoring in the San Francisco Bay, California, Water Years 2018–19

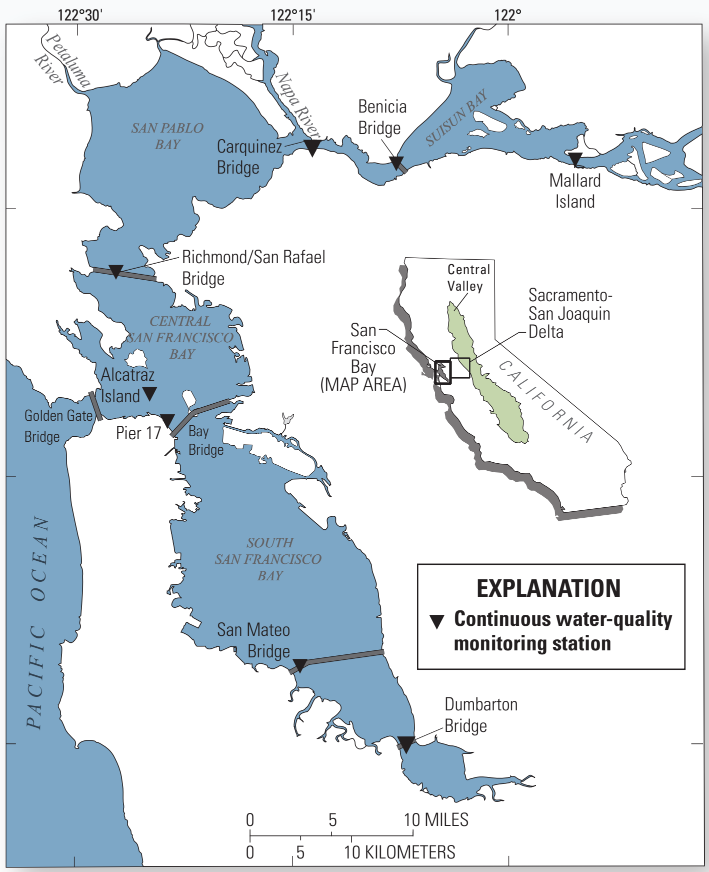
Water-Quality in San Francisco Bay

The U.S. Geological Survey (USGS) monitors water quality and suspended-sediment transport in the San Francisco Bay (Bay) as part of a multi-agency effort to address estuary management, water supply, and ecological concerns. The San Francisco Bay area is home to millions of people, and the Bay teems with marine and terrestrial flora and fauna. Freshwater mixes with saltwater in the Bay and is subject to riverine influences (floods, droughts, managed reservoir releases, and freshwater diversions) and marine influences (tides, waves, and effects of saltwater). To understand this environment, the USGS, along with its cooperators (see “Acknowledgments” section), has been monitoring the Bay’s waters continuously since 1988.

There are several water-quality characteristics that are important to State and Federal resource managers. Salinity, water temperature, and suspended-sediment concentration are some important water-quality properties that are monitored at key locations throughout the Bay. Salinity, which indicates the mixing of fresh and ocean waters in the Bay, is derived from specific conductance measurements. Water temperature, along with salinity, affects the density of water, which controls gravity-driven circulation patterns and stratification in the water column. Turbidity, a measure of light scattered from suspended particles in the water, is used to estimate suspended-sediment concentration.

Suspended sediment affects Bay water quality in multiple ways: it attenuates sunlight in the water column, affecting phytoplankton growth; it can deposit on tidal marsh and intertidal mudflats, which can help restore and sustain these habitats as sea level rises; and it can settle in ports and shipping channels, which can necessitate dredging. In addition, suspended sediment often carries adsorbed contaminants as it is transported in the water column, which affects their distribution and concentration in the environment. Excessive concentrations of sediment-adsorbed contaminants in deposits on the bottom of the Bay can affect ecosystem health.

External factors, such as tidal currents, waves, and wind, also can affect water quality in the Bay. Tidal currents in the Bay change direction four times daily, and wind direction and intensity typically fluctuate on a daily cycle. Consequently, salinity, water temperature, and suspended-sediment concentration vary spatially and temporally throughout the Bay. Therefore, continuous measurements at multiple locations are needed to monitor these changes. Data collected at eight stations are transmitted in near real-time using cellular telemetry. The purposes of this fact sheet are to (1) provide information about the USGS San Francisco Bay water-quality monitoring network; (2) highlight various applications in which these data can be utilized; and (3) provide internet links to access the resulting continuous water-quality data collected by the USGS.



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales;
Albers Equal-Area Conic projection, standard parallels are 29° 30' N. and 45° 30' N.; North American Datum of 1983

Figure 1. San Francisco Bay study area, California (Einhell and others, 2020).

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Program Overview

Continuous water-quality measurements are collected at eight stations in the San Francisco Bay (Bay; table 1; fig. 1). Instruments typically are suspended in the water from stainless-steel cables that are anchored to the bottom of the Bay (figs. 2, 3) and are equipped with sensors that measure specific conductance, temperature, and turbidity. Data are recorded every 15 minutes and are transmitted by cellular telemetry (yielding provisional data available within 1 hour of measurement) or retrieved during periodic station visits (yielding provisional data available within 1 week of the station visit). Table 1 lists the vertical location of the instruments at each station and provides the percentage of valid data collected during water years 2018 and 2019. The percentage of valid data ranged from 62 to 100 percent with an average of 90 percent across all parameters and stations. The variability in the range of values is attributed to sensor failure and biological fouling. Biological growth (fig. 4) affects sensor readings and usually increases with time, which requires the affected data to be corrected or deleted. Every 2–5 weeks, each station is visited for cleaning, inspection of instrument calibration, and retrieval of data as needed. Water samples are collected at the sensor depth to statistically relate turbidity data to suspended-sediment concentration (SSC; fig. 5; Livsey and Downing-Kunz, 2020, p. 24). Periodically, discharge and cross-sectionally averaged SSC are measured concurrently at some stations to estimate the suspended-sediment flux at that location (Rasmussen and others, 2009). These data assist resource managers in quantifying the amount and direction of suspended sediment flowing in the Bay, which is necessary to understand sediment deposition. Discharge is measured using a boat-mounted acoustic Doppler current profiler (Mueller and others, 2013), and water samples are collected at several points across the channel with a depth-integrating suspended-sediment sampler (fig. 6; U.S. Geological Survey, 2006) using the equal-discharge-increment method (Edwards and Glysson, 1999). Suspended-sediment flux, expressed in mass per unit time, is computed as the product of discharge and the channel-average SSC at the indicated cross section.

Table 1. Continuous water-quality monitoring stations in San Francisco Bay, California, for the period October 1, 2017, through September 30, 2019 (U.S. Geological Survey, 2021).

[MLLW, mean lower low water; WY, water year; SSC, suspended-sediment concentration; m, meter; —, parameter not collected at that station]

Water depth in meters from MLLW[2]	Measurement location	Sensor depth in meters from MLLW	Percent valid data[1] by water-quality parameter (WY 2018–19)			Year monitoring began
			Specific conductance	Temperature	Turbidity/SSC	
Suisun Bay at Mallard Island, U.S. Geological Survey station number 11185185						
7.6	Upper	Suspended 1 m below water surface	—	—	94	1994
	Lower	6.1	—	—	97	
Suisun Bay at Benicia Bridge, U.S. Geological Survey station number 11455780						
24.4	Upper	2.4	100	100	90	2001
	Lower	18.6	99	100	90	
Carquinez Strait at Carquinez Bridge, U.S. Geological Survey station number 11455820						
23.8	Upper	9.2	94	100	—	1999
	Lower	22.3	93	93	—	
San Francisco Bay at Richmond/San Rafael Bridge, U.S. Geological Survey station number 375607122264701						
13.7	Upper	4.6	96	97	82	2006
	Lower	12.2	95	96	78	
San Francisco Bay at Alcatraz Island, U.S. Geological Survey station number 374938122251801						
4.9	Mid-depth	1.6	89	95	62	2003
San Francisco Bay at Pier 17, U.S. Geological Survey station number 374811122235001						
4.9	Lower	3.7	88	90	77	2013
San Francisco Bay at San Mateo Bridge near Foster City, U.S. Geological Survey station number 11162765						
14.6	Upper	1.2	94	98	—	1990
	Lower	11.6	98	100	—	
South San Francisco Bay at Dumbarton Bridge, U.S. Geological Survey station number 373015122071000						
13.7	Upper	6.1	84	92	62	2010
	Lower	12.5	83	91	74	

[1]Percentage of valid data represents the number of valid data points for all of water years 2018 and 2019 divided by the maximum possible number of data points for that period (96 data points is the maximum number per day with data collected at 15-minute intervals), multiplied by 100.

[2]Estimated from the National Oceanic and Atmospheric Agency Nautical Chart Catalog during the 1983–2001 National Tidal Datum Epoch (National Oceanic and Atmospheric Administration, 2021).

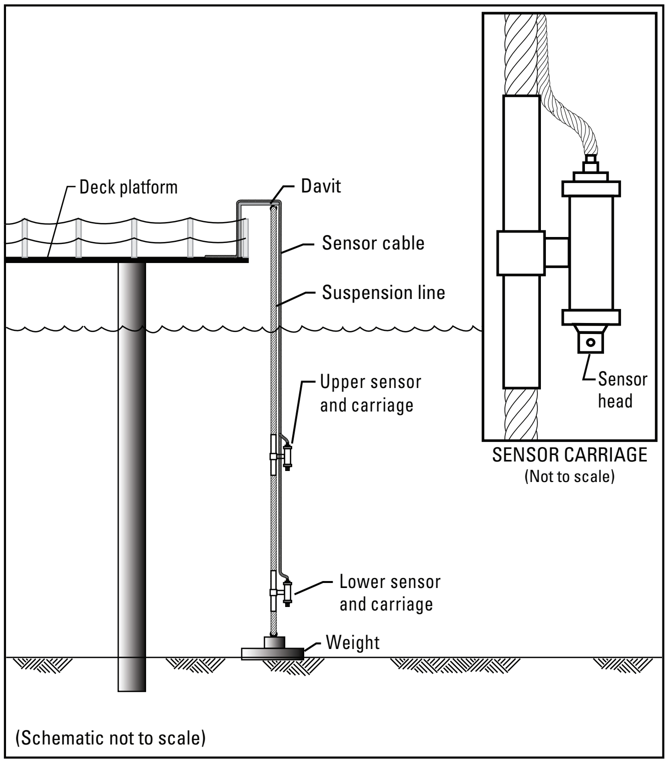

Figure 2. Monitoring installation schematic, San Francisco Bay study.

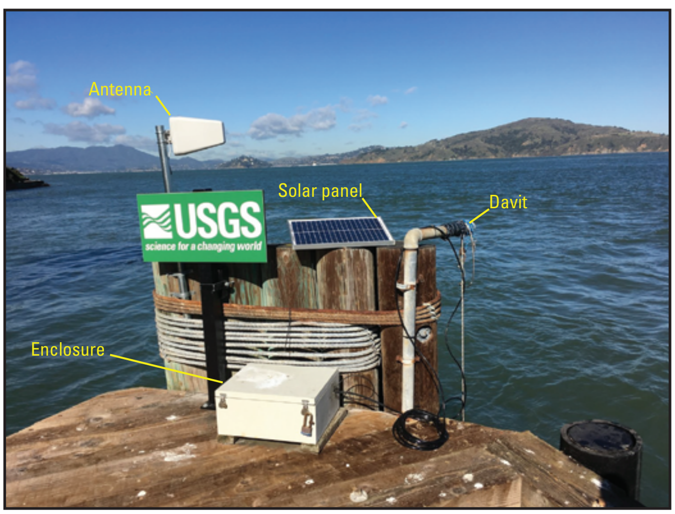

Figure 3. Monitoring installation at Alcatraz Island (station number 374938122251801) with labeled equipment (U.S. Geological Survey, 2021). The solar panel provides power to the real-time equipment inside the enclosure. Data are received from the instruments and then transmitted by cellular telemetry. Photograph by Darin Einhell, U.S. Geological Survey, February 6, 2018.

Figure 4. Example of extreme biological fouling that can occur on water-quality instruments at San Mateo Bridge (station number 11162765; U.S. Geological Survey, 2021). Photograph by Selina Davila Olivera, U.S. Geological Survey, June 8, 2020.

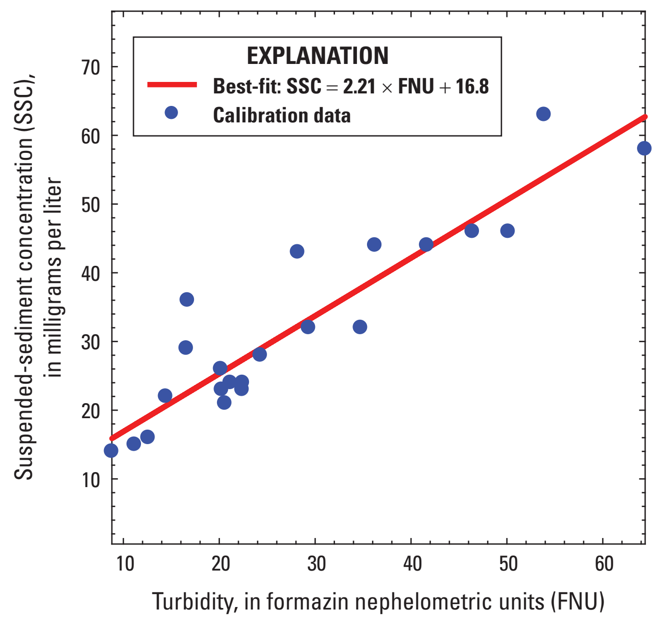

Figure 5. Example rating curve from Pier 17 (station number 374811122235001; U.S. Geological Survey, 2021) during water year 2018 and 2019 that statistically relates suspended-sediment concentration (SSC) in discrete water samples to optical turbidity sensor output. Turbidity is measured continuously to provide a surrogate model to estimate SSC.

Specific conductance, water temperature, and turbidity data are collected at two depths in the water column at deep stations to help characterize the vertical variability. The different depths help resolve differences in water quality between the top and bottom of the water column at these locations. For stations in shallow water, such as Pier 17 (table 1; USGS station number 374811122235001) and Alcatraz Island (table 1; USGS station number 374938122251801), data are collected only at one depth (U.S. Geological Survey, 2021). Specific conductance (reported in microsiemens per centimeter at 25 degrees Celsius) and water temperature (reported in degrees Celsius) are measured using the YSI, Inc. (https://www.ysi.com/), model 6560 conductivity and temperature sensor. Two types of optical sensors are used to measure turbidity (reported in formazin nephelometric units, FNU): the DTS-12, manufactured by Forest Technology Systems (https://ftsinc.com/) and sensor model 6136, manufactured by YSI, Inc.

Figure 6. Depth-integrating sampler used to collect a suspended-sediment concentration sample at Sacramento-San Joaquin Delta. Photograph by Darin Einhell, U.S. Geological Survey, March 6, 2018.

Records undergo a thorough evaluation process before final approval. Data are analyzed, approved, and audited to ensure integrity. Data corrections (necessary because of biological fouling, sedimentation of the sensor, or instrument electronic drift) are applied to the affected periods of record following USGS guidelines (Wagner and others, 2006). Further details about these methods are available at https://ca.water.usgs.gov/projects/baydelta (access the “Methods” section).

Data obtained from this network have several applications, including calibrating numerical models (Bever and MacWilliams, 2013) and understanding the response of Bay water quality to extreme events such as prolonged drought (Work and others, 2017). Collected continuous water-quality and suspended-sediment transport data, including water years 2018 and 2019 (October 1, 2017, through September 30, 2019), are archived in the USGS National Water Information System (U.S. Geological Survey, 2021) and are available to the public.

Acknowledgments

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For additional information:

https://ca.water.usgs.gov/projects/baydelta/
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Banner photograph: View near Alcatraz Island. Photograph taken by Darin C. Einhell, U.S. Geological Survey.

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