Record-High Specific Conductance and Water Temperature in San Francisco Bay during Water Year 2015

The San Francisco estuary is commonly defined to include San Francisco Bay (bay) and the adjacent Sacramento–San Joaquin River Delta (delta). The U.S. Geological Survey (USGS) has operated a high-frequency (15-minute sampling interval) water-quality monitoring network in San Francisco Bay since the late 1980s (Buchanan and others, 2014). This network includes 19 stations at which sustained measurements have been made in the bay; currently, 8 stations are in operation (fig. 1). All eight stations are equipped with specific conductance (which can be related to salinity) and water-temperature sensors. Water quality in the bay constantly changes as ocean tides force seawater in and out of the bay, and river inflows—the most significant coming from the delta—vary on time scales ranging from those associated with storms to multiyear droughts. This monitoring network was designed to observe and characterize some of these changes in the bay across space and over time. The data demonstrate a high degree of variability in both specific conductance and temperature at time scales from tidal to annual and also reveal longer-term changes that are likely to influence overall environmental health in the bay.

In water year (WY) 2015 (October 1, 2014, through September 30, 2015), as in the preceding water year (Downing-Kunz and others, 2015), the high-frequency measurements revealed record-high values of specific conductance and water temperature at several stations during a period of reduced freshwater inflow from the delta and other tributaries because of persistent, severe drought conditions in California. This report briefly summarizes observations for WY 2015 and compares them to previous years that had different levels of freshwater inflow.

Instrumentation and Data Collection

At each monitoring station, YSI Inc. Model 6920 V2 water-quality sondes are deployed on a taut cable mount at a constant elevation above the bottom of the bay; thus, the water depth above the sensors varies as tides rise and fall. At some stations, sensors are located at two different elevations above the bottom to reveal vertical variations (fig. 2). Data from monitoring stations are telemetered using a cellular modem and uploaded daily to USGS database servers. Telemetry facilitates rapid and remote evaluation of sensor performance and scheduling of field maintenance to minimize data gaps. Sensor output is affected by biological growth, which usually increases with time and requires the affected data to be edited or deleted; other periods of missing data are caused by instrument failures or construction projects near monitoring stations (Wagner and others, 2006). The scope of the dataset is shown in table 1; all data are archived as provisional in near-real time in the USGS National Water Information System (http://waterdata.usgs.gov/nwis) and undergo review before final approval. Further details on methods are available at http://ca.water.usgs.gov/projects/baydelta/.

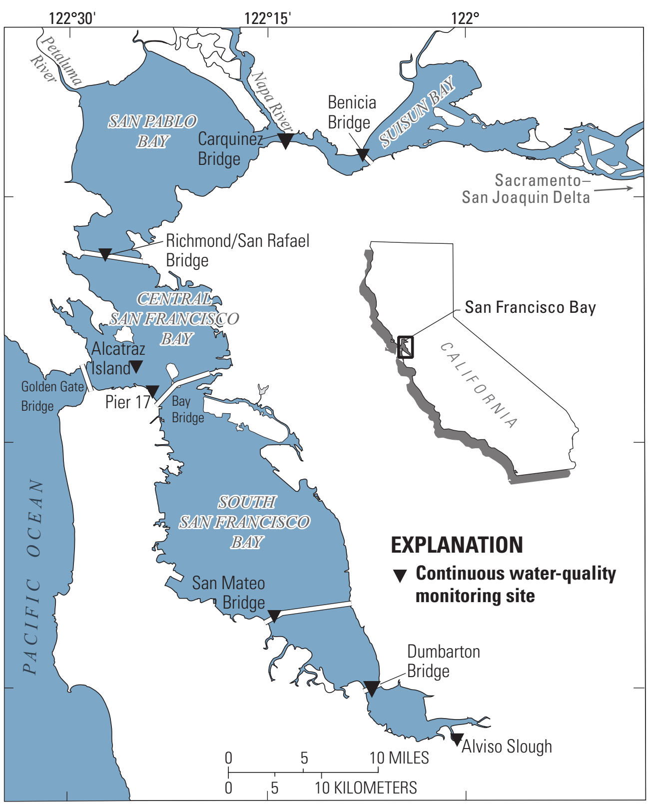


Figure 1. Locations of fixed water-quality monitoring stations in San Francisco Bay, California, for the 2015 water year (October 1, 2014, to September 30, 2015).

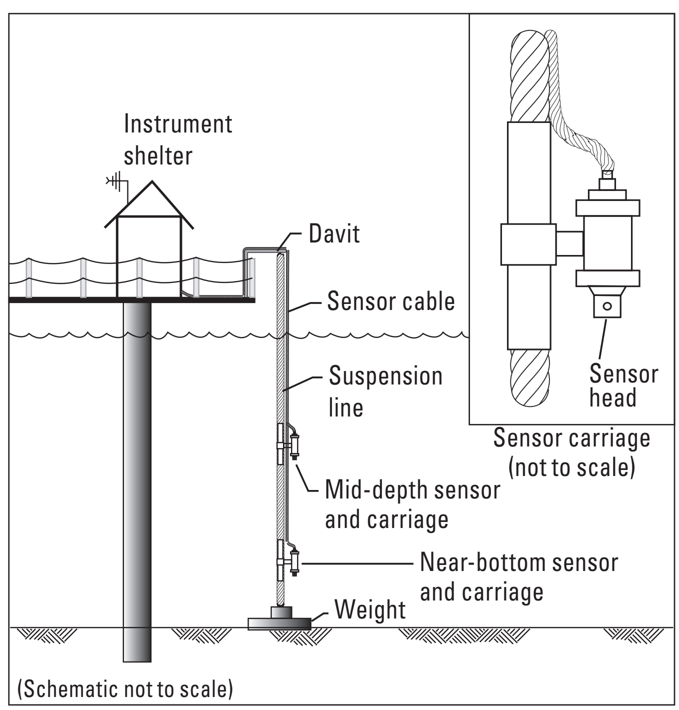


Figure 2. Typical monitoring-station installation.

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20171022
Open-File Report 2017–1022

The high-frequency monitoring network produced instantaneous measurements at 15-minute intervals, measuring water temperature and specific conductance 96 times per day, or 35,040 times per year. Annual maximum values and annual mean values for specific conductance and water temperature were computed for each station and compared to results from previous years. To ensure that annual mean values were representative despite periods of missing data, the following thresholds were applied: if more than 33 percent of the data for a given water year were missing or if the duration of any one gap was longer than 45 consecutive days, the mean value for that water year at that site was not computed. Annual mean values were also excluded for stations that had periods of record of less than 5 years (Dumbarton Bridge and Pier 17, table 1). Salinity was computed according to the Practical Salinity Scale 1978 (Fofonoff and Millard, 1983) from measured specific conductance; values are unitless.

Drought conditions in the region affect water quality in the bay by reducing freshwater inflow from the watershed. To study the effects of differences in freshwater inflows and to compare WY 2015 values to those from previous years, we used annual freshwater inflow volume from the delta, which was estimated with the DAYFLOW model (California Department of Water Resources, http://www.water.ca.gov/dayflow/). Output from this model includes the daily rate of freshwater flow from the delta to the bay, from which we calculated the annual volume of freshwater inflow from the delta. The annual volume of inflow from the delta is affected by hydrologic conditions and management actions but is generally smaller during drought conditions and, thus, provides context for the severity of the drought and its effect on water quality in the bay.

Table 1. Water-quality monitoring stations included in this report, listed from north to south.

[U and L refer to the upper and lower sensor elevations in the water column, respectively, at stations equipped with two instruments. Station water depths are reported relative to mean lower low water]

Station name and number	Water depth, in meters	Sensor elevation above bottom, in meters	Year monitoring began
Suisun Bay at Benicia Bridge 11455780	24	23 U 7.6 L	2001
Carquinez Strait at Carquinez Bridge[1] 11455820	24	15 U 1.8 L	1999
San Francisco Bay at Richmond/San Rafael Bridge 375607122264701	14	9.1 U 1.5 L	2006
San Francisco Bay at Alcatraz Island 374938122251801	4.9	3.0	2003
San Francisco Bay at Pier 17 374811122235001	8.5	1.2	2013
San Francisco Bay at San Mateo Bridge near Foster City 11162765	15	13 U 3.0 L	1990
South San Francisco Bay at Dumbarton Bridge[2] 373015122071000	14	7.6 U 1.2 L	2011
Alviso Slough near Alviso 11169750	1.0	0.5	2010

[1]Station temporarily discontinued during bridge construction June 10, 2012–April 23, 2014.

[2]Station temporarily discontinued during bridge construction October 1, 2011–March 16, 2013.

Water Year 2015 Records

During WY 2015, the monitoring network recorded instantaneous values of specific conductance and water temperature at several stations that exceeded all previous values in the period of record. Between water years 2014 and 2015, every station in the network saw a new record for one or both of these parameters. Record-high values for specific conductance were measured in WY 2015 at Benicia Bridge, Carquinez Bridge, Dumbarton Bridge, and Alviso Slough (fig. 3). Record-high water temperatures in WY 2015 were measured at Carquinez Bridge, Richmond/San Rafael Bridge, Alcatraz Island, Pier 17, San Mateo Bridge, and Dumbarton Bridge (fig. 4).

Annual Mean Values and Relation to Freshwater Inflow

Annual mean values of specific conductance and water temperature varied spatially within the bay (fig. 5). The Alcatraz Island station (fig. 1) is closest to the Golden Gate, which is the ocean boundary of the San Francisco estuary. As noted, the Sacramento–San Joaquin River Delta, to the northeast, serves as the major source of freshwater to the estuary (fig. 1). From the ocean boundary toward the delta, specific conductance generally decreased (fig. 1, fig. 5*A*), whereas water temperature generally increased (fig. 5*B*). Specific conductance in the southern part of the bay (San Mateo Bridge, fig. 1) was similar to that near the ocean boundary (Alcatraz Island station, fig. 5*A*), but water temperature was warmer than at the ocean boundary (fig. 5*B*). This was due, in part, to relatively little freshwater inflow from the adjacent watershed and to the relatively

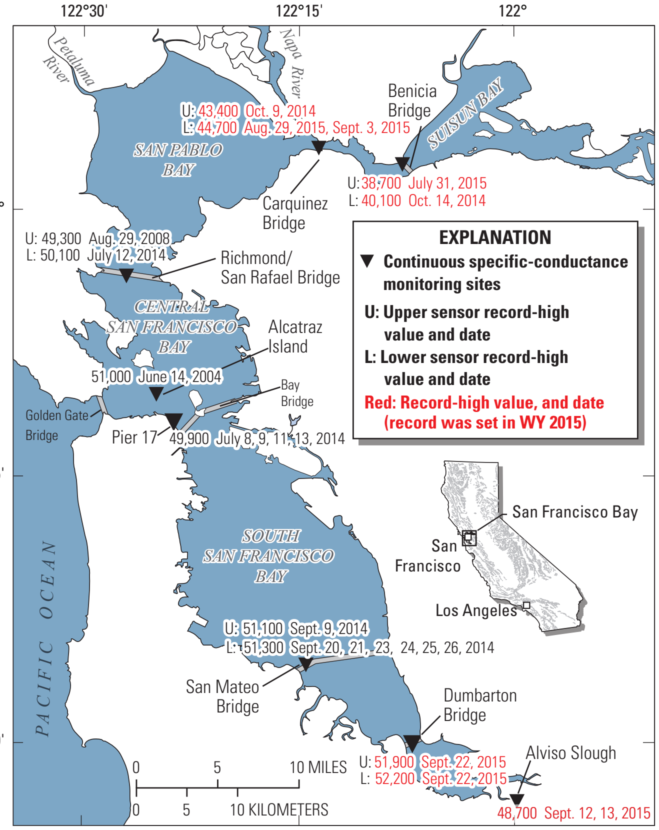


Figure 3. Maximum (record-high) instantaneous specific conductance from all data at each site sensor. Measured in microsiemens per centimeter.

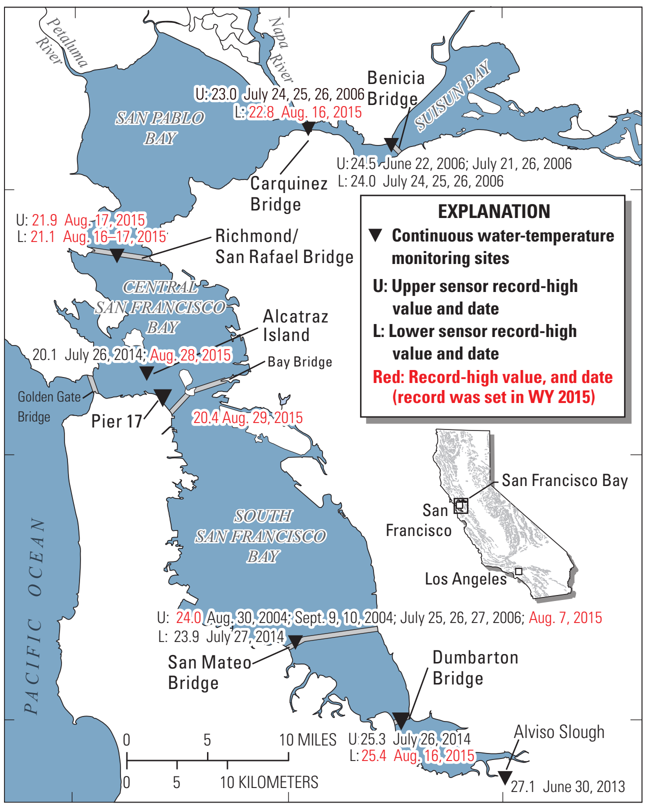
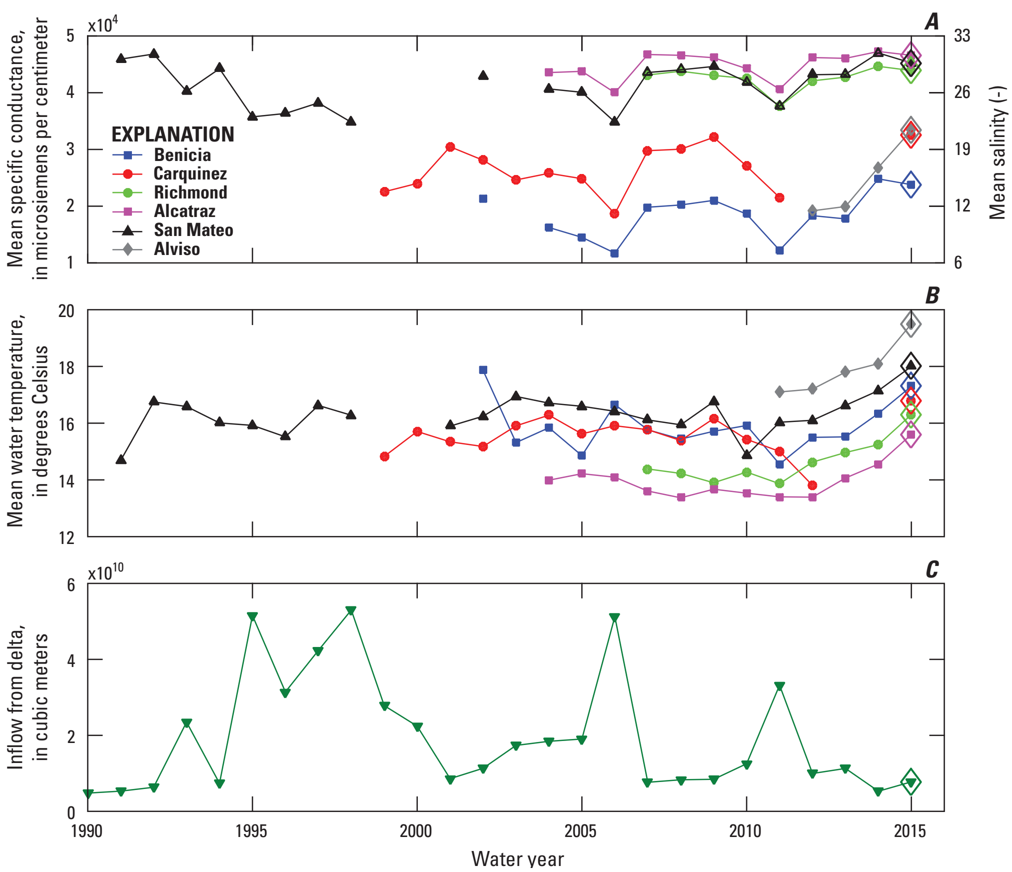


Figure 4. Maximum (record-high) instantaneous water temperature from all data at each site sensor. Measured in degrees Celsius.

shallow water depths in the southern part of the bay. Variability in annual volume of freshwater inflow from the delta over the preceding 25 years was high (fig. 5*C*). Total volume of inflow from the delta in WY 2015 was only slightly higher than the WY 2014 value, revealing continued drought conditions.

Of the six stations with sufficient WY 2015 data to compute annual means, record-high annual mean specific conductance and water-temperature values were recorded at two (fig. 5*A*) and five (fig. 5*B*) of the stations, respectively. Variability in annual mean specific conductance can be partially attributed to variability in the annual volume of freshwater inflow from the delta (fig. 6), which affects flushing rates across the bay (Walters and others, 1985). For all stations, annual mean specific conductance and the annual volume of inflow from the delta were inversely related, such that lower inflow volumes were associated with greater annual mean specific conductance values (fig. 6). Stations farthest from the major source of freshwater inflow (Alcatraz Island, Richmond Bridge, and San Mateo Bridge; fig. 1) converged to nearly equivalent, high, mean specific conductance values during years with the lowest inflow volumes, indicating that the bay is more influenced by inflow of coastal ocean waters during drought, when freshwater inflows from the delta are low.

In the past decade, the 2 years featuring the greatest annual inflow from the delta (2006 and 2011) coincided with clear reductions in annual mean specific conductance in the bay (fig. 5*A*). In WY 2015, the increase in inflow from the delta, compared to the previous year, was very slight, and most sites saw annual mean values of specific conductance that were similar to the previous year. Annual mean water temperatures, however, again increased notably in WY 2015. Changes in annual mean ocean seawater or air temperature could both have contributed to this trend.



For reference, specific conductances of 5,000 and 50,000 microsiemens per centimeter (µS/cm) at 25 degrees Celsius (°C) are equivalent to salinities of 2.7 and 32.7, respectively. Specific conductance and salinity of freshwater are both near 0; coastal ocean water has a specific conductance of about 52,000 µS/cm at 25 °C and a salinity of about 34.

Figure 5. Annual mean values from 1990 to 2015. Where two sensors were available, the upper sensor is shown: *A*, annual mean specific conductance and salinity, by station; *B*, annual mean water temperature, by station; and *C*, annual volume of freshwater inflow from the Sacramento–San Joaquin River Delta (delta) to the San Francisco Bay, based on DAYFLOW model output. Years with insufficient data were excluded (for example, Carquinez Bridge during water years 2012–14). Diamonds indicate the most recent (water year 2015) data.

The Alviso Slough specific conductivity dataset is shorter in length, but the data appear to be somewhat anomalous when plotted against delta inflow (fig. 6). This site is located near several heavily managed former salt ponds, and management activities can affect annual mean salinities independently of drought impacts, for example, if the outflow volume of salt pond water is sufficiently large compared to the receiving body. The temperature time series, however, displays a trend consistent with the other sites (fig. 5*B*).

Water temperature and salinity (computed from observed water temperature and specific conductivity) are important to human and ecological issues in the bay (see Shellenbarger and Schoellhamer, 2011) and elsewhere. These two water-quality parameters impact aquatic habitats and can affect the distribution and abundance of aquatic vegetation and organisms in the bay. Only consistent long-term monitoring data can reveal trends resulting from changing hydrologic conditions and management actions and from responses to disturbances, such as the severe California drought that began in 2012.

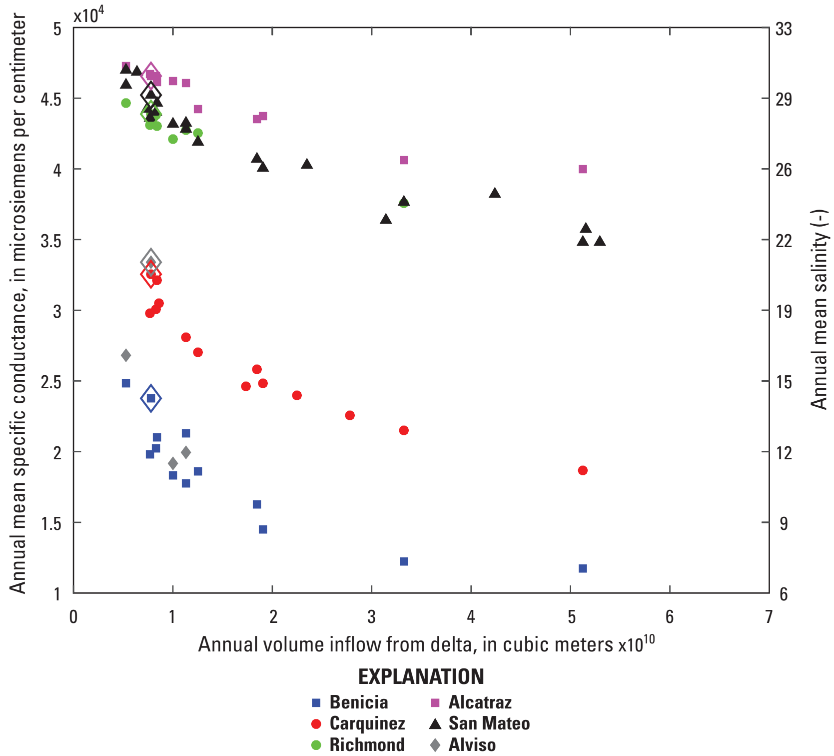


Figure 6. Annual means of specific conductance (left axis) and salinity (right axis) at each station as a function of annual volume of freshwater inflow from the Sacramento–San Joaquin River Delta (delta) to the San Francisco Bay. For stations with two sensors (table 1), only the upper sensor is shown. Diamonds indicate the most recent (water year 2015) data.

References Cited

Buchanan, P.A., Downing-Kunz, M.A., Schoellhamer, D.H., Shellenbarger, G.G., and Weidich, K.W., 2014, Continuous water-quality and suspended-sediment transport monitoring in the San Francisco Bay, California, water years 2011–13: U.S. Geological Survey Fact Sheet 2014–3090, 4 p., https://dx.doi.org/10.3133/fs20143090.

Downing-Kunz, M.A., Work, P.A., and Shellenbarger, G.G., 2015, Record-high specific conductance and temperature in San Francisco Bay during water year 2014 (ver. 1.1, December 28, 2015): U.S. Geological Survey Open-File Report 2015–1213, 4 p., accessed at http://pubs.usgs.gov/of/2015/1213/ofr20151213.pdf.

Fofonoff, N.P., and Millard, R.C., 1983, Algorithms for computation of fundamental properties of seawater: UNESCO Technical Papers in Marine Science, v. 44, p. 6–9.

Shellenbarger, G.G., and Schoellhamer, D.H., 2011, Continuous salinity and temperature data from San Francisco Estuary, 1982–2002—Trends and salinity-freshwater inflow relationship: Journal of Coastal Research, v. 27, no. 6, p. 1191–1201.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p., 8 attachments, accessed at http://pubs.water.usgs.gov/tm1d3.

Walters, R.A., Cheng, R.T., and Conomos, T.J., 1985, Time scales of circulation and mixing processes in San Francisco Bay waters: Hydrobiologia, v. 129, no. 1, p. 13–36.

Suggested Citation

Work, P.A., Downing-Kunz, M.A., and Livsey, D., 2017, Record-high specific conductance and water temperature in San Francisco Bay during water year 2015: U.S. Geological Survey Open-File Report 2017–1022, 4 p., https://doi.org/10.3133/ofr20171022.

Acknowledgments

Collection of these data was supported by the U.S. Army Corps of Engineers, San Francisco District, as part of the Regional Monitoring and Regional Sediment Management Programs; Interagency Ecological Program; California State Coastal Conservancy; Bureau of Reclamation; U.S. Geological Survey—San Francisco Bay Pilot Study for the National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries; U.S. Geological Survey—Priority Ecosystems Science Program; and the U.S. Geological Survey Federal/State Cooperative Program.

For Additional Information

Visit: http://ca.water.usgs.gov/projects/baydelta/
Contact:

Paul A. Work at pwork@usgs.gov,
Maureen A. Downing-Kunz at mdowning-kunz@usgs.gov,
or Daniel Livsey at dlivsey@usgs.gov.
U.S. Geological Survey
California Water Science Center
6000 J Street, Placer Hall
Sacramento, CA 95819