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SUMMARY REPORT FOR THE SACRAMENTO WATERSHED COORDINATED MONITORING PROGRAM: BASELINE DATA ASSESSMENT

(November 2008 – August 2014)

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SWAMP
Surface Water Ambient Monitoring Program

California Water Boards

www.waterboards.ca.gov/swamp

SUMMARY REPORT FOR THE SACRAMENTO WATERSHED COORDINATED MONITORING PROGRAM: BASELINE DATA ASSESSMENT (November 2008 – August 2014)

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Regional Report

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Acronyms and Abbreviations

µg/L	micrograms per liter
mg/L	milligrams per liter
ml	milliliter
µmhos/cm	micromhos per centimeter
DO	dissolved oxygen
DWR	California Department of Water Resources
EC	electrical conductivity
FLIMS	Field and Laboratory Information Monitoring System
MCL	maximum contaminant level
MPN	most probably number
n	sample size
NH_3	un-ionized ammonia
NH_4^+	ammonia ion
NTU	nephelometric turbidity units
pH	acidity
QA/QC	quality assurance/quality control
RPD	relative percentage difference
SWCMP	Sacramento Watershed Coordinated Monitoring Program
SPoT	Surface Water Ambient Monitoring Program Stream Pollution Trends
SWAMP	Surface Water Ambient Monitoring Program
WDL	Water Data Library
WY	water year

Forward

This report summarizes water quality data collected under the Sacramento Watershed Coordinated Monitoring Program (SWCMP) from November 2008 through August 2014. The SWCMP is a coordinated effort between the California Department of Water Resources (DWR) Northern Region Office and the Central Valley Regional Water Quality Control Board (Central Valley Water Board), to monitor and assess the ambient (environmental) water quality of the Sacramento River and its larger tributaries.

The SWCMP supports a variety of state-wide plans and programs. Water quality monitoring under the SWCMP helps meet goals and objectives under the *California Water Action Plan* and the *Department of Water Resources Strategic Business Plan* to ensure reliable and sustainable water for humans and the environment and manage water resources in cooperation with other agencies. The SWCMP is an important component of DWR's role in assessing water quality, supporting regional water management assessments, maintaining strategic partnerships, and building capacity for regional water sustainability through technical assistance. The SWCMP supports the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP), which evaluates the condition of waterbodies throughout the state using the best available science. The SWAMP also assists entities statewide in the generation of comparable data that can be brought together in integrated assessments that provide answers to current management questions. The SWCMP also assists the Central Valley Water Board with determining the effectiveness of actions to improve water quality.

The Sacramento River is a dominant source of fresh water for California and is critical to the long-term health of the Sacramento-San Joaquin Delta. The Sacramento River provides most of the water for the State Water Project and federal Central Valley Project. The Sacramento River has significant economic and ecological importance, providing water for irrigated agriculture, drinking and industrial water supplies, fisheries and wildlife habitat, and recreation. These beneficial uses of water are affected by both human-related activities (such as timber harvesting, mining, and polluting discharges) and natural climatic factors (such as drought).

The SWCMP data are used by a variety of stakeholders, including municipal water districts, Resource Conservation Districts, federal, State, and local agencies, agricultural water quality coalitions, the public, and consultants. These data help DWR, Central Valley Water Board, and stakeholders determine water quality conditions over time for rivers and streams throughout the Sacramento River watershed, including during periods of drought and flood. The SWCMP helps identify problems in water quality, such as pollution sources, and helps evaluate the effectiveness of projects, management actions, and regulatory programs aimed at improving water quality.

Under an ongoing agreement, the SWCMP will continue to collect accurate water quality data for one of the most important rivers in California. Water quality results in this report provide baseline field-measured, chemical, and biological information to document current conditions and to compare future monitoring data. The data within this report and future follow-up reports can inform water resource management and policy decisions in California, leading to a more sustainable water future.

Chapter 1. Introduction

1.1 Background

1.1.1 DWR's Northern Region Office Water Quality Program

The California Department of Water Resources (DWR) has monitored water quality throughout Northern California since its formation in 1956. Water quality data had been collected previously by the DWR's water quality predecessor, the Division of Water Resources of the Department of Public Works, since the early 1900s. The assessment of water quality is a key component of DWR's Northern Region Office's role in supporting water management assessments and contributing to the capacity for regional water sustainability. Water quality data collected by DWR is used by a wide range of public and private water management entities, and is ultimately the foundation on which these entities base water development planning and management decisions. Long-term water quality data can be used to identify changes in water quality over time or to determine water quality impacts from catastrophic events (e.g., flood, fire, landslides) and human-related activities. Regular water quality monitoring helps determine if water quality meets objectives established by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) in their *Water Quality Control Plan for the Sacramento and San Joaquin River Basin* (State Water Resources Control Board 2016). The SWCMP has allowed DWR to maintain a decades-long monitoring network in the Sacramento River watershed while helping the Central Valley Water Board assess the effectiveness of actions to improve water quality conditions in waterbodies identified as impaired.

1.1.2 Sacramento River Watershed

The Sacramento River is the longest and largest river in California, extending 327 miles (526 kilometers) with an annual average stream flow volume of 22 million acre-feet (27 cubic kilometers) (California Department of Water Resources 2009a). The Sacramento River watershed covers 27,000-square-miles and includes the Sacramento Valley, Sacramento-San Joaquin Delta, and portions of the Coast Ranges, Cascade Ranges, Klamath Ranges, and the Sierra Nevada (California Department of Water Resources 2009a). The Feather, Yuba, American, and Pit rivers are major tributaries to the Sacramento River, although numerous creeks and smaller rivers also contribute a substantial volume of water to the Sacramento River. Several dams exist on the Sacramento River and its tributaries, which allow water storage and flood protection but also block migration routes of anadromous fish.

Climate varies across the Sacramento River watershed. Watershed elevations range from sea level to over 14,000 feet on Mount Shasta in the Southern Cascade Mountains. Precipitation ranges from 15 inches in drier portions of the Sacramento Valley floor to more than 80 inches in montane areas. Most precipitation in the Sacramento River watershed occurs as rain and snow November through March (California Department of Water Resources 2009a). The accumulation of snow in mountains during cool and moist winters helps to alleviate the predictably dry summer conditions that characterize California's Mediterranean-type climate. Cities, farms, and some natural ecosystems depend on the gradual release of water from snowmelt and are thus vulnerable to altered climate patterns under climate change.

The Sacramento River watershed is very important to California's economy. Large areas of the Sacramento Valley are dedicated to irrigated agriculture and urban development. Both agricultural and urban land-uses are concentrated in the Sacramento Valley; with Yolo, Placer, and Sacramento Counties representing the most urbanized portions of the Sacramento River watershed (California Department of Water Resources 2009a). Dams on major tributaries to the Sacramento River provide flood protection and store water; and a complex system of water diversions and canals (e.g. Anderson-Cottonwood Irrigation District, Glenn-Colusa Irrigation District, Tehama-Colusa Canal Authority, etc.) transfer water to agricultural and municipal users throughout the state. The Sacramento River watershed contributes water to both the Federal Central Valley Project and the California State Water Project, both of which redistribute water from Northern California reservoirs to farms and urban areas across California.

1.1.3 Sacramento Watershed Coordinated Monitoring Program

To maintain important water quality data collection within the Sacramento River watershed, a coordinated monitoring program was initiated between the Central Valley Water Board and DWR's Northern Region Office. The SWCMP was designed to coincide with many of DWR's historical water quality stations, although several new stations, which are of interest to the Central Valley Water Board, have been added. Although the Sacramento River watershed continues to the Sacramento-San Joaquin Delta and includes inputs from such waterbodies as Cache Creek and the American River, the southernmost limit of monitoring for the SWCMP occurs just downstream of the confluence of the Sacramento and Feather rivers, near the town of Verona in Sutter County.

DWR staff prepared the *Sacramento Watershed Coordinated Monitoring Program Monitoring Plan* and are responsible for coordinating and performing the sampling events, including providing sampling equipment, recording field observations, and ensuring delivery of samples to appropriate analytical laboratories (California Department of Water Resources 2009a). The Central Valley Water Board is responsible for providing containers for processing bacteria, bioassessment, and water-column toxicity samples when these are collected.

1.1.4 Water Data Library

Because of the evolving importance and scope of water quality regulations in California, the public are provided with easily accessible, current, and defensible water quality data through DWR's Water Data Library (WDL). Water-chemistry results, field-measured parameters, and continuous water-temperature data can be queried and downloaded from the WDL (http://www.water.ca.gov/waterdatalibrary/).

1.2. SWCMP Goals and Objectives

The four primary objectives of the SWCMP monitoring effort are to:

1. Create an ambient monitoring program using consistent and objective monitoring, sampling, and analytical methods with consistent data quality assurance protocols.
2. Document ambient water quality conditions in both potentially clean and polluted areas.
3. Provide data to identify specific water quality problems and evaluate the overall effectiveness of water quality regulatory programs in protecting the beneficial uses of water.
4. Provide baseline environmental water quality data and establish a database that can be used to track long-term changes in ambient water quality.

SWCMP monitoring provides critical water quality data needed to determine if stream and river conditions are improving or degrading. Three key questions that the SWCMP addresses are:

1. What are the ambient water quality conditions?
2. Are current management activities protecting beneficial uses?
3. What does the evaluation of water quality trends and biological communities tell us about the state of the watershed?

The SWCMP supports both the *California Water Action Plan* (Natural Resources Agency 2014) and the *Department of Water Resources Strategic Business Plan* (California Department of Water Resources 2016). The SWCMP assists *California Water Action Plan* objectives to restore species and habitats, and to provide a water supply that is sustainable and resilient to future challenges. The SWCMP aids DWR's Strategic Business Plan by assessing water quality, supporting regional water management assessments, maintaining strategic partnerships, and building capacity for regional water sustainability through technical assistance.

The SWCMP addresses long-term water quality issues and support the federal Clean Water Act Sections 303(d) and 305(b) reporting requirements for the Sacramento River watershed. Section 303(d) requires the State to provide a list of waterbodies that are impaired (i.e., are not meeting water quality standards). Section 305(b) requires the State to provide an overall water quality condition assessment of surface water and is used to inform water quality management decisions.

1.3. Anticipated Use of This Summary Report

The purpose of this report is to describe SWCMP water quality monitoring and summarize ambient water quality data for the Sacramento River watershed for the period of November 2008 through August 2014. SWAMP staff and other regional stakeholders can use these data as baseline information to track changes in water quality over time. These data can be viewed in conjunction with SWAMP biological community datasets to support environmentally sound management actions.

Chapter 2. Monitoring Design

This section details the SWCMP monitoring design, including monitoring stations, sampling methods, and water quality parameters (See the *Sacramento Watershed Coordinated Monitoring Program Monitoring Plan* for additional information [California Department of Water Resources 2009a]). A separate document, *Surface Water Ambient Monitoring Program Quality Assurance Program Plan*, details how the samples are collected to provide data that are representative, comparable, and scientifically defensible (State Water Resources Control Board 2008).

2.1 Monitoring Stations

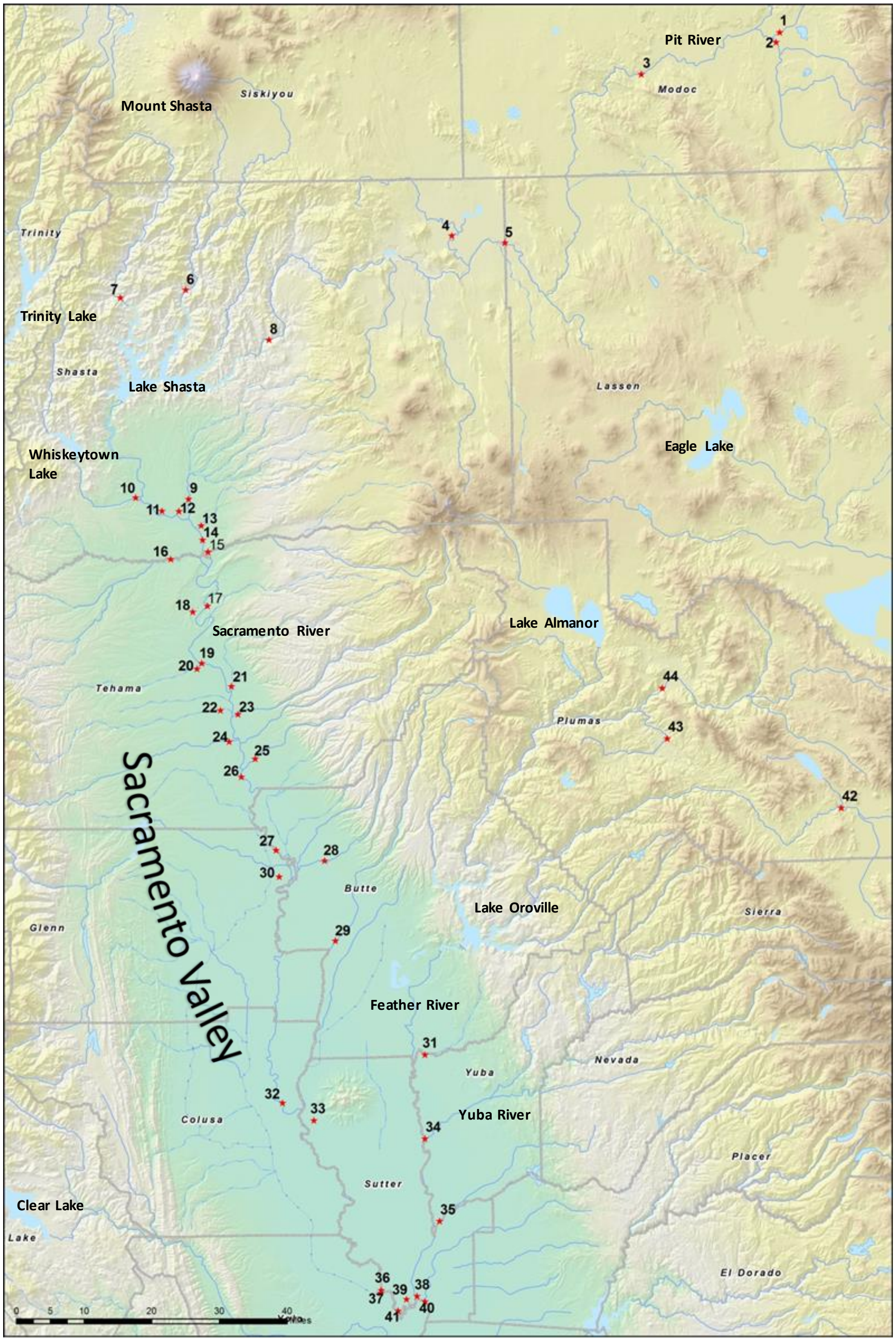
Between 2008 and 2014, 44 stations were monitored for the SWCMP (Figure 1 and Table 1). Monitoring station selection was based on several factors including accessibility, historical data collection, and hydrography. For all station locations, safety and all-weather access were priorities, so many stations are located at bridges from which sampling devices can be suspended during periods of high flow. On occasion, sampling locations were modified slightly to account for sampling crew safety and these changes were documented. Wherever possible, stations were selected that had established county, State, or U.S. Geological Survey gaging stations, as these are usually associated with historical water quality and flow data. For hydrographic considerations, at least one station was identified in every major tributary to the Sacramento River to quantify the potential effects of each of several subwatersheds (described as subregions) on Sacramento River water quality. Many stations are located at the primary discharge point of these tributaries. Some stations are located along the mainstem of the Sacramento River, typically upstream of major tributary inputs. Some stations are paired so that a station exists above and below areas of significant human activity, including urban development, agriculture, or point-source discharges. Additional information on station selection is discussed in the *Surface Water Ambient Monitoring Program Quality Assurance Program Plan* (State Water Resources Control Board 2008). The SWCMP stations are organized by subregion (i.e., subwatershed) (Figures 2–6), as outlined by the Sacramento River Watershed Program (2017).

2.2 Sampling Methods

The SWCMP sampling design includes quarterly monitoring in February, May, August, and November. By collecting water quality samples at the same time every year, data are consistent and comparable between years. The quarterly sampling design also helps capture water quality parameters during important periods of winter runoff, spring snowmelt, and dry season (summer/fall) irrigation runoff (See Table 2 for all parameters measured for the SWCMP).

Field data, which include multi-analyte probe and turbidimeter readings, data logger maintenance notes, and environmental characterizations (weather, flows, etc.), are recorded on SWAMP-compatible field sheets printed on waterproof paper in the field. Other noteworthy indicators of water quality and environmental condition, such as algal growth and odors, are included on field sheets. These notes can be used to explain atypical results from laboratory water quality assays. Field sheets are later scanned to PDF format and archived electronically after being returned to the office. Field measurements of basic water quality parameters are included on the Bryte Laboratory "Chain-of-Custody" data form for use by lab personnel.

Figure 1 Map of the Sacramento River Watershed Showing Relative Locations of the SWCMP Monitoring Stations (red stars) Sampled from 2008 to 2014



Notes: Sacramento Watershed Coordinated Monitoring Program (SWCMP) station names are shown in Table 1. The southern limit of the SWCMP monitoring is near the Sacramento River's confluence with the Feather River, and tributaries such as Cache Creek and the American River are not part of the SWCMP.

Table 1 **The Sacramento Watershed Coordinated Monitoring Program Monitoring Stations Organized by Subregion**

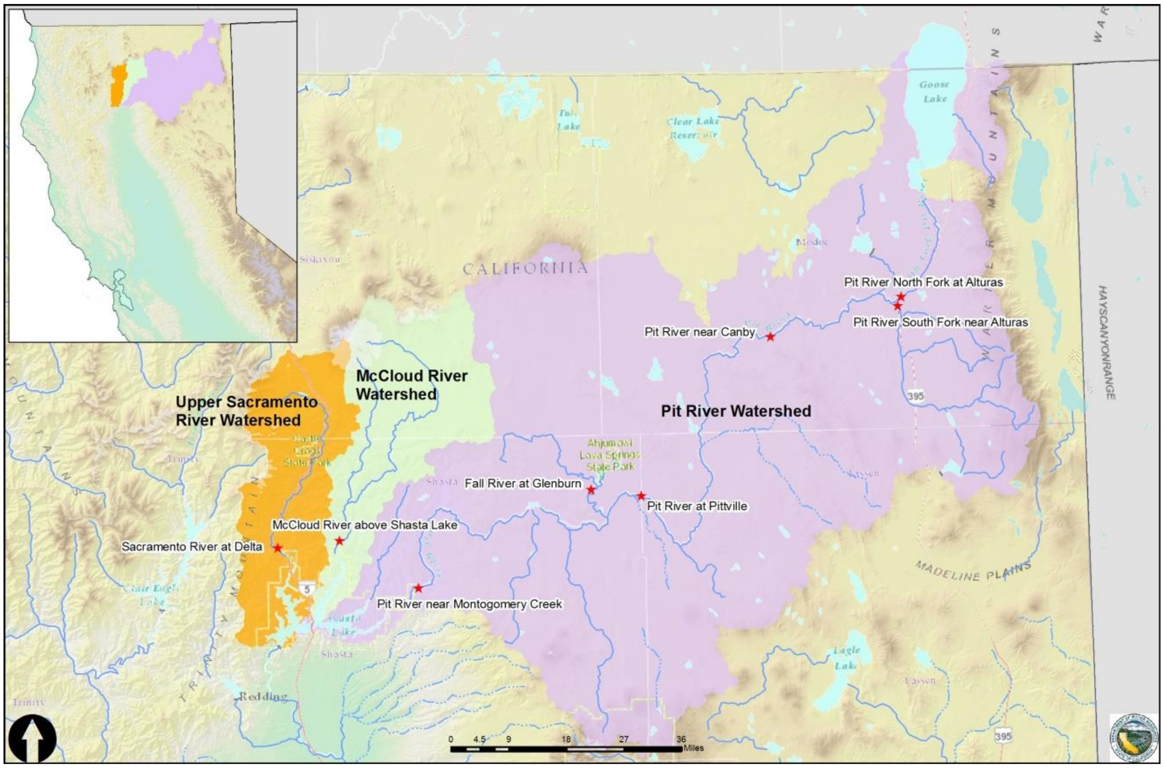
Station Name	DWR Station Number	Latitude	Longitude	Map number shown in Figure 1
Northeast Subregion				
FALL RIVER AT GLENBURN	A1723000	41.0624	-121.4811	4
MCCLOUD RIVER ABOVE SHASTA LAKE	A2215000	40.9542	-122.2347	6
PIT RIVER NORTH FORK AT ALTURAS	A1210000	41.4820	-120.5386	1
PIT RIVER SOUTH FORK NEAR ALTURAS	A1415000	41.4612	-120.5500	2
PIT RIVER NEAR CANBY	A1168000	41.3998	-120.9349	3
PIT RIVER AT PITTVILLE*	A1127000	41.0456	-121.3318	5
PIT RIVER NEAR MONTGOMERY CREEK	A1102000	40.8450	-122.0009	8
SACRAMENTO RIVER AT DELTA	A2130000	40.9382	-122.4189	7
Eastside Tributary Subregion				
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	A0452050	40.1032	-122.1168	21
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	A4708000	40.3920	-122.1786	15
BEAR CREEK NEAR ANDERSON	A0407000	40.4481	-122.1972	13
BIG CHICO CREEK AT CHICO*	A0425000	39.7272	-121.8631	28
BUTTE CREEK DOWNSTREAM WESTERN CANAL	A0416000	39.5557	-121.8364	29
CHURN CREEK NEAR ANDERSON	A0079000	40.4808	-122.3068	11
COW CREEK NEAR MILLVILLE	A4811000	40.5053	-122.2322	9

Station Name	DWR Station Number	Latitude	Longitude	Map number shown in Figure 1
Eastside Tributary Subregion				
DEER CREEK AT HWY 99E NEAR VINA	A0432101	39.9471	-122.0532	25
MILL CREEK MOUTH NEAR LOS MOLINOS	A0442050	40.0430	-122.0999	23
NORTH HONCUT CREEK AT HWY 70	A0571001	39.3088	-121.5938	31
PAYNES CREEK AT PAYNES CROSSING	A4602000	40.2758	-122.1814	17
STILLWATER CREEK NEAR ANDERSON	A0079500	40.4798	-122.2591	12
Westside Tributary Subregion				
CLEAR CREEK NEAR MOUTH NEAR REDDING	A3601000	40.5092	-122.3800	10
COTTONWOOD CREEK AT COTTONWOOD	A0352050	40.3781	-122.2738	16
ELDER CREEK AT GERBER	A0332000	40.0522	-122.1483	22
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	A0025800	40.1416	-122.2123	20
STONY CREEK AT THE NATURE CONSERVANCY	A0290000	39.6941	-121.9902	30
THOMES CREEK AT HALL ROAD	A0321800	39.9850	-122.1247	24
Upper Feather River Subregion				
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	A5539000	39.8174	-120.4279	42
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	A5430010	40.0843	-120.9170	44
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	A5423000	39.9758	-120.9059	43

Station Name	DWR Station Number	Latitude	Longitude	Map number shown in Figure 1
Sacramento Valley Subregion				
BEAR RIVER NEAR MOUTH*	A6501050	38.9512	-121.5608	35
BUTTE SLOUGH NEAR MERIDIAN*	A0297200	39.1701	-121.9005	33
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING*	A0294710	38.7994	-121.7251	37
FEATHER RIVER NEAR VERONA*	A5101050	38.7911	-121.6261	38
SACRAMENTO RIVER AT VERONA	A0215000	38.7797	-121.6037	40
SACRAMENTO RIVER AT BEND BRIDGE	A0278500	40.2639	-122.2230	18
SACRAMENTO RIVER AT COLUSA*	A0242000	39.2091	-122.0003	32
SACRAMENTO RIVER AT HAMILTON CITY*	A0263000	39.7511	-121.9980	27
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	A0270000	39.9088	-122.0923	26
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	A0223002	38.8052	-121.7237	36
SACRAMENTO RIVER BELOW KNIGHTS LANDING	A0219501	38.7606	-121.6782	41
SACRAMENTO RIVER BELOW RED BLUFF	A0275890	40.1536	-122.1991	19
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK*	A0292700	38.7852	-121.6543	39
YUBA RIVER AT MOUTH*	A6101050	39.1286	-121.5974	34

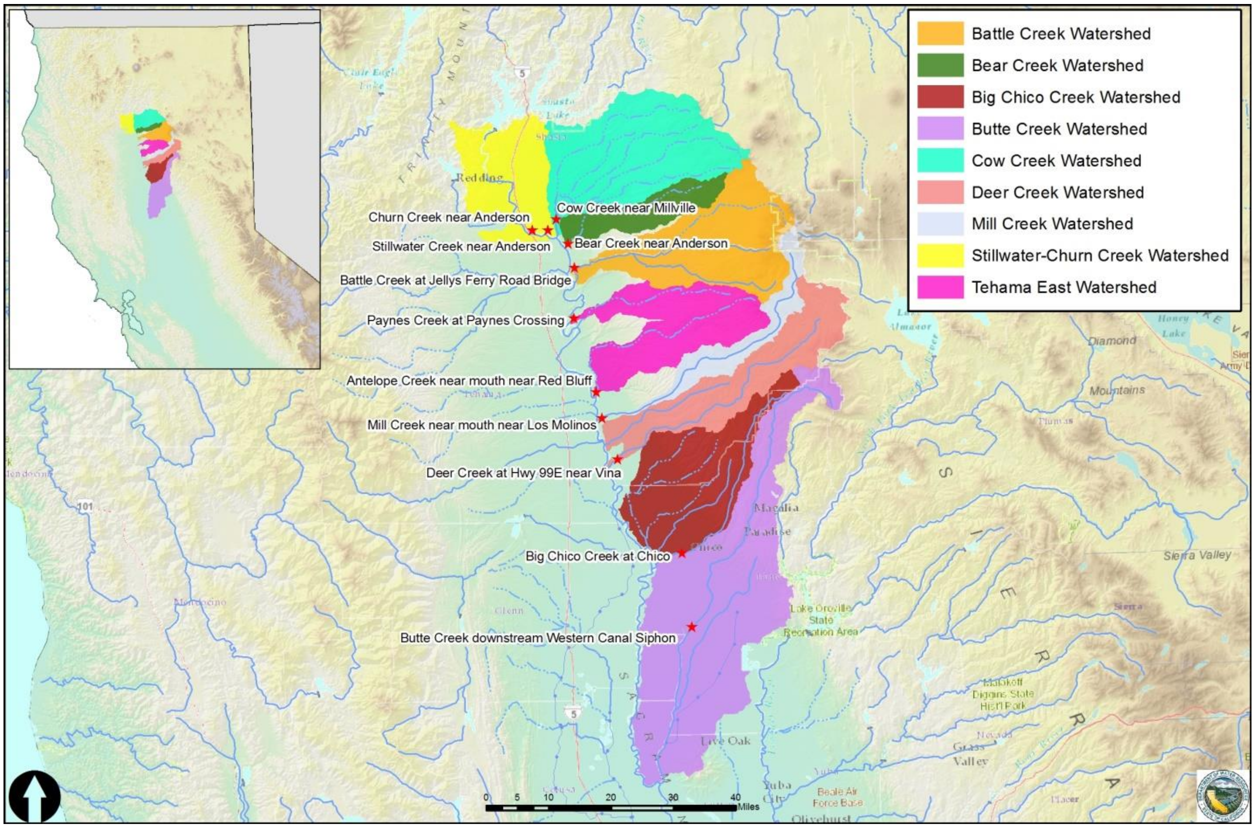
Notes: Each station is associated with a unique California Department of Water Resources station number. Station location coordinates are shown along with a number that corresponds to the numbers depicted in Figure 1. Asterisks denote Integrator Stations for statewide Surface Water Ambient Monitoring Program Stream Pollution Trends (SPoT) monitoring (State Water Resources Control Board 2011).

Figure 2 Map of the Northeast Subregion, a Subwatershed of the Larger Sacramento River Watershed



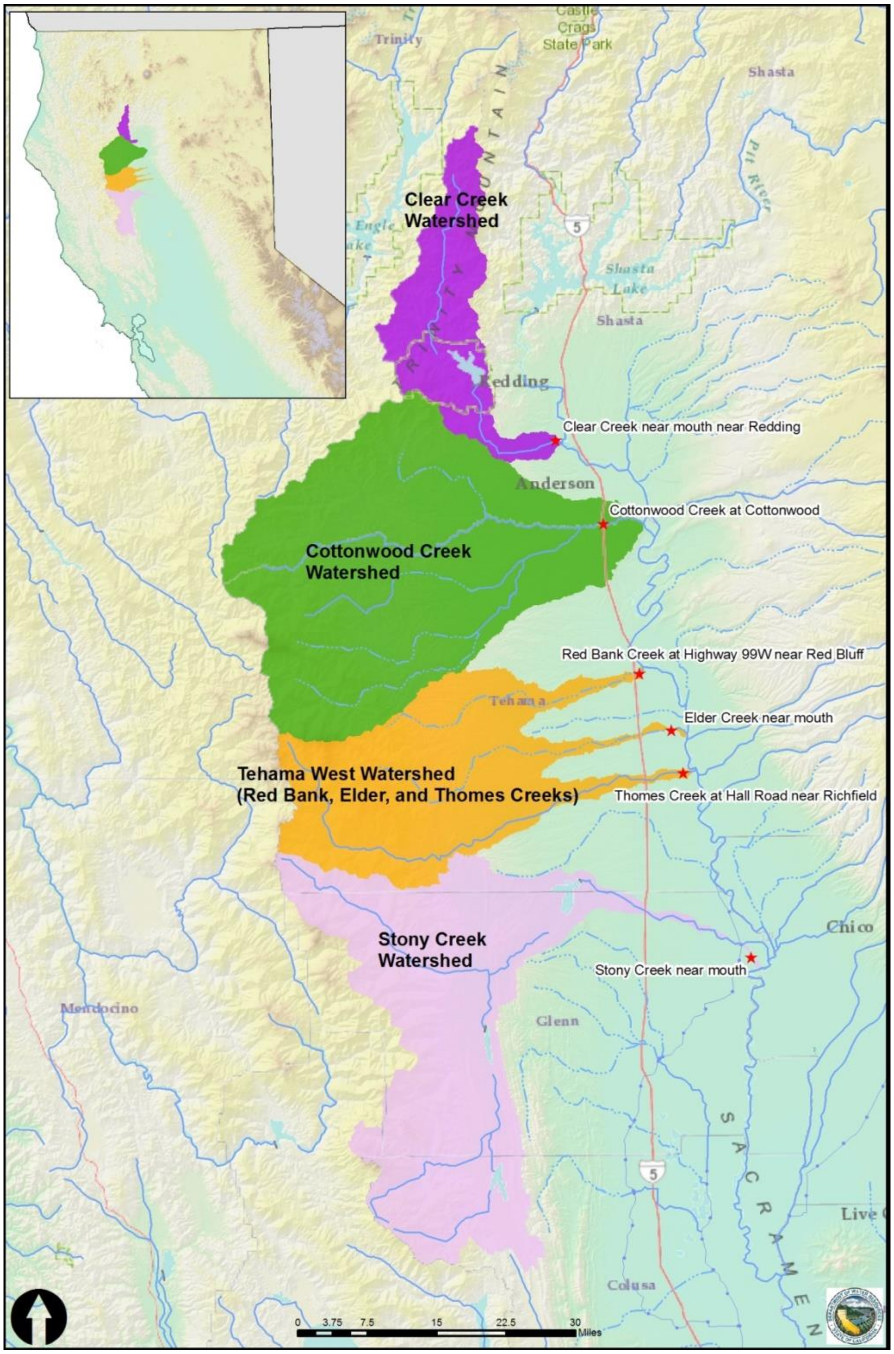
Notes: The Northeast Subregion, which encompasses tributaries to Shasta Reservoir, includes five monitoring stations on the Pit River, one on the Fall River, one on the McCloud River, and one on the upper Sacramento River (refer to Figure 1).

Figure 3 **Map of the Eastside Tributary Subregion, a Subwatershed of the Larger Sacramento River Watershed**



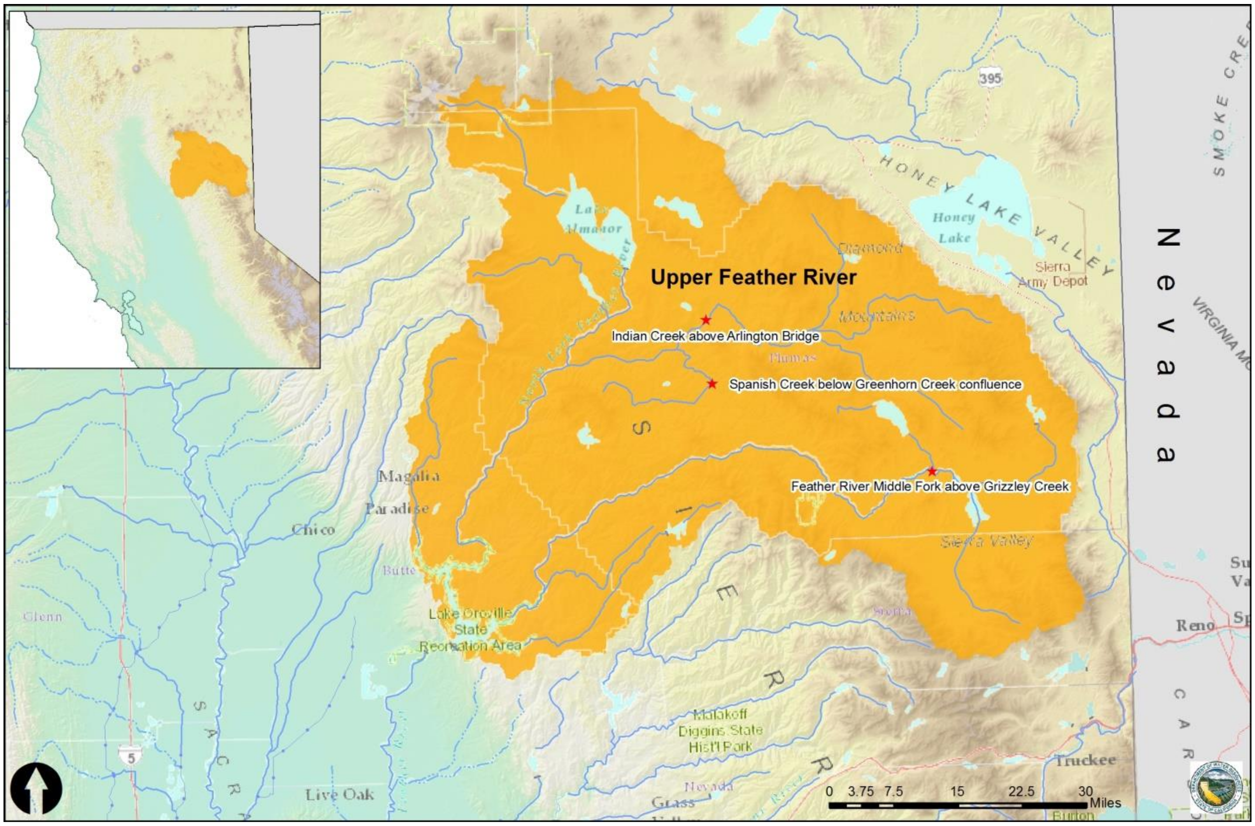
Notes: The Eastside Tributary Subregion includes 11 monitoring stations on the east side of the Sacramento River mainstem. These streams flow from the Cascade foothills and include locations near their confluence with the Sacramento River.

Figure 4 Map of the Westside Tributary Subregion, a Subwatershed of the Larger Sacramento River Watershed



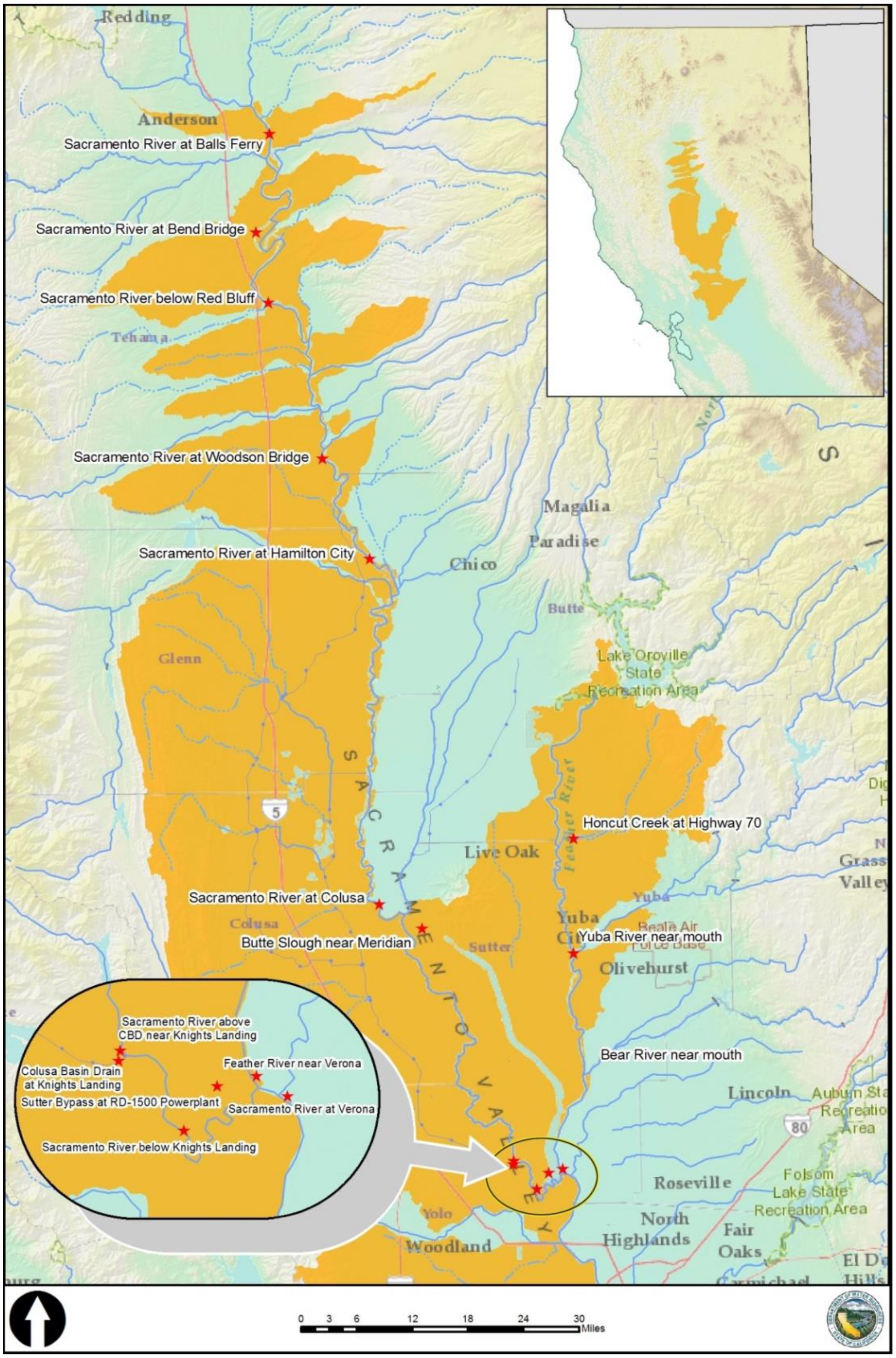
Notes: The Westside Tributary Subregion includes six monitoring stations on the westside of the Sacramento River mainstem. Clear Creek water quality is influenced by water imported from the Trinity River Basin as part of the federal Central Valley Project. Westside tributary streams originate from the Coast Range, which has distinctly different geology than the mostly volcanic eastside tributary watersheds. Uplifted marine sediments west of the Sacramento River are highly erosive and contribute large volumes of sediment to westside Sacramento River tributaries during high-flow events. Most tributary monitoring stations are located near their confluence with the Sacramento River.

Figure 5 Map of the Upper Feather River Subregion, a Subwatershed of the Larger Sacramento River Watershed



Notes: All waterbodies in this subregion are tributary to Lake Oroville Reservoir. The three upper Feather River stations in this subregion were added to the Sacramento Watershed Coordinated Monitoring Program monitoring grid in 2011.

Figure 6 Map of the Sacramento Valley Subregion, a Subwatershed of the Larger Sacramento River Watershed



Notes: The Sacramento Valley Subregion includes low-elevation stations from Clear Creek (a westside tributary) to the Yuba River (an eastside tributary). This subregion also includes one monitoring station each on the mainstem Feather River, Yuba River, and Colusa Basin Drain, and eight monitoring stations on the Sacramento River.

2.3 Water Quality Parameters

Monitoring data can be divided into several types: field-measured water quality, continuous temperature data, water chemistry, and bacteria. Field-measured water quality parameters include water temperature, dissolved oxygen levels, turbidity, specific conductance, and pH (acidity). Continuous temperature data are recorded by using continuously logging temperature probes. Water chemistry includes a suite of analytes tested for in-laboratory assays. Similarly, bacteria samples are delivered to a laboratory for analysis. DWR field staff have the ability to collect additional data as well when funding is available.

2.3.1 Field-Measured Water Quality

Field-measured water quality parameters are instantaneous measurements recorded in the field by using portable water quality monitoring equipment. A multi-analyte probe (manufactured by YSI Professional Plus) measures specific conductance (measured as micromhos per centimeter [µmhos/cm]), pH, dissolved oxygen (measured as milligrams per liter [mg/L]), and temperature (measured as degrees Celsius [°C]). A turbidimeter, by using a Hach 2100P turbidimeter, measures turbidity (measured as nephelometric turbidity units [NTU]). Field data are uploaded to DWR's WDL and can be viewed along with laboratory water chemistry results.

Instantaneous field measurements are especially important for parameters, such as pH, temperature, and dissolved oxygen, because they have a short hold-time and cannot be measured retroactively. These parameters are also important indicators of ecological health and can have direct impacts on biological communities. These data are available in DWR's WDL.

2.3.2 Continuous Temperature Data

Water temperature is recorded at all SWCMP monitoring stations using continuous temperature data loggers, an Onset Hobo Water Temperature Pro v2 Data Logger, that are attached to a cable near the stream bank. Temperature is logged at 15-minute intervals and downloaded quarterly during sampling events by using a portable shuttle, a Hobo Optic USB Base Station. These data are uploaded to DWR's WDL.

2.3.3 Water Chemistry

DWR can analyze a wide range of physical, chemical, and biological parameters at its in-house laboratory, Bryte Laboratory, in West Sacramento. For a select few constituents not analyzed at Bryte Laboratory, DWR employs a contract laboratory (Weck Laboratories, Incorporated, City of Industry, CA) to perform analyses. DWR collects additional water samples for water-chemistry assays not required for the SWCMP. Other monitoring approaches are occasionally applied when funding is available, including water-column toxicity, bacteria, and bioassessment.

Water samples for chemical analyses are collected by using EPA-approved sample collection methods defined in the *Surface Water Ambient Monitoring Program quality assurance program plan* (State Water Resources Control Board 2008). Samples are collected from moving water, targeting representative portions of a stream. Samples are immediately placed in chilled coolers and transported to an appropriate lab within the hold-time of the sample. Results of water chemistry assays, once reviewed for completeness and accuracy, are uploaded to DWR's WDL.

2.3.4 Bacteria

The presence of coliform bacteria can be used as an indicator of water sanitary condition. Coliforms are a diverse group of bacteria, and although most strains are harmless, others can cause illness in humans. Coliform bacteria, such as *Escherichia coli* (*E. coli*), can be found in the environment, foods, and intestines of people and animals.

Bacteria samples are collected at every SWCMP station during water-sampling events and analyzed for water-borne *E. coli* and total coliform bacteria. Bacteria samples are collected in 120 milliliter (ml) sterile containers supplied by the SWAMP. All bacteria samples are delivered on the day they are collected to Central Valley Water Board staff for processing at either the Redding or Rancho Cordova office.

Table 2 Sacramento Watershed Coordinated Monitoring Program Water Quality Parameters and Their Purpose in Water Quality Assessments

Constituent	Purpose
Field measured water quality parameters	
Water temperature	One of the most important water quality parameters. Temperature affects water chemistry and aquatic organisms.
pH (acidity)	High pH can affect water taste, can lead to crust formation on conveyance systems, and requires more chlorine for disinfection. Water with low pH can corrode some materials. Some aquatic organisms tolerate only a narrow pH range. Changes in pH can influence concentrations of pollutants (e.g., the solubility of mercury) or convert pollutants to more toxic forms (e.g., ammonia ion [NH_4^+] to un-ionized ammonia [NH_3]).
Electrical conductivity (EC)	Indicator of salts and other dissolved solids in water.
Dissolved oxygen (DO)	Constituent of concern for aquatic habitat degradation. Important parameter for evaluating biochemistry.
Turbidity	Constituent of concern for aquatic habitat. Aesthetically undesirable in drinking water.
Minerals	
Total suspended solids	Constituent of concern for aquatic habitat.
Total dissolved solids	Indicator of substances potentially affecting health and/or taste of drinking water.
Alkalinity	Constituent of concern for aquatic habitat degradation. Buffering capacity against acid pollution.
Total and dissolved hardness	Determines the toxicity of certain metals. Calcium and magnesium salts can affect water conveyance and storage infrastructure.
Total and dissolved calcium	Contributes to water hardness calculation and important for some aquatic organisms.
Total and dissolved magnesium	Constituent contributes to water hardness calculation.
Dissolved sodium	Possible health effects. Affects usability for irrigation.
Dissolved potassium	Essential element in humans. Found naturally in water but can also be introduced during water treatment.
Dissolved sulfate	Influences water taste and can form deposits.
Dissolved chloride	Influences water taste and can corrode materials.

Constituent		Purpose
Minerals		
	Dissolved boron	Impacts usability of water for irrigation.
Nutrients		
	Total ammonia as nitrogen	Constituent of concern for aquatic habitat degradation.
	Total Kjeldahl nitrogen	Constituent of concern for aquatic habitat degradation.
	Total organic nitrogen	Constituent of concern for aquatic habitat degradation.
	Total and dissolved ammonia	Constituent of concern for aquatic habitat degradation. Affects hatching and development of fish. Can have human health effects.
	Dissolved nitrate + nitrite	Constituent of concern for aquatic habitat degradation and drinking water quality and is harmful to newborn babies.
	Dissolved orthophosphate	Constituent of concern for aquatic habitat degradation.
	Total phosphorus	Constituent of concern for aquatic habitat degradation and is a limiting nutrient for plant growth.
	Total organic carbon	Nonspecific indicator of water quality, which has natural and synthetic sources (e.g., detergents, agricultural chemicals).
	Dissolved organic carbon	Nonspecific indicator of water quality. Affects the transport of metals in water.
Trace elements and metals		
	Total and dissolved copper	Taste effects and potential toxin for humans and plants.
	Total and dissolved aluminum	Monitored water quality constituent that at high concentrations could be linked to neurological disorders.
	Total and dissolved cadmium	Monitored toxin.
	Total and dissolved chromium	Monitored toxin.
	Total and dissolved arsenic	Monitored toxin and carcinogen. Constituent of concern for aquatic habitat degradation and drinking water quality.
	Total and dissolved iron	Taste effects.
	Total and dissolved lead	Toxin for adults and affects developing children. It is probably a carcinogen.
	Total and dissolved manganese	Toxic to some plants. Taste and economic effects to water.

Constituent	Purpose
Trace elements and metals	
Total and dissolved nickel	Potential toxin at high concentrations.
Total and dissolved selenium	Toxic at high levels to humans and livestock.
Total and dissolved silver	Affects humans and livestock at chronically high levels.
Total and dissolved zinc	Undesirable taste and toxic to plants at high concentrations.
Mercury	Monitored toxin.

Notes: Field-measured water quality parameters are measured with a calibrated multi-parameter probe, with the exception of water temperature, which is measured every 15 minutes via continuous recording temperature data loggers. All other parameters are collected as grab samples and analyzed by a laboratory.

Chapter 3. SWCMP Quality Assurance/ Quality Control

The SWCMP quality assurance/quality control (QA/QC) process involves activities that ensure the program matches guidelines described in the *Sacramento Watershed Coordinated Monitoring Program Monitoring Plan* (California Department of Water Resources 2009a) and allows for performance measures to take place based on standards outlined in the *Quality Assurance Project Plan for the Sacramento Watershed Coordinated Monitoring Program* (California Department of Water Resources 2009b). Multiple QA/QC checks help ensure accurate data collection and consistent sample collection methods. Multiple QA/QC assessments also help narrow the number of sources of contamination and identify sampling errors. Adaptive management has resulted in an evolving sample collection procedure, and QA/QC processes are periodically refined to report only the most accurate water quality data. The QA/QC process for the SWCMP can be divided into eight steps described in detail below.

3.1 Field Data Sheet Review

Field data sheets are reviewed for completeness by both field personnel and the QA/QC officer. The QA/QC officer addresses and corrects discrepancies, when possible, by consulting with field personnel and by reviewing station photographs. Unexplained discrepancies are documented. Explanations for un-sampled stations (e.g., dry waterbody, safety concerns) and unretrieved temperature data from temperature data loggers (e.g., missing or inaccessible data loggers) are also documented. Field data are entered manually into DWR's Field and Laboratory Information Monitoring System (FLIMS) database.

3.2 Duplicate Sample Evaluation

Duplicate samples are analyzed to measure the consistency of sample collection. The QA/QC process for evaluating duplicates involves calculating the relative percentage difference (RPD) between a normal sample and its duplicate. The RPD is the difference between the two samples divided by the average of the two samples, multiplied by 100. When a normal sample and its associated duplicate have a RPD greater than or equal to 25 percent, the duplicate sample QA/QC check is considered to have failed and the accuracy of all samples collected with that duplicate is questioned. Failure of the duplicate sample QA/QC check can be attributed to a variety of factors, including contaminated equipment, inconsistent sampling procedure, and heterogeneity of the waterbody being sampled. The following equation is used to calculate RPD.

$$RPD = \frac{(Sample\ A - Sample\ B)}{\left(\frac{Sample\ A - Sample\ B}{2}\right)} \times 100$$

3.3 Blank Sample Evaluation

Blank samples are also used to ensure the accuracy of water quality results. Blank samples contain ultra-pure deionized water (blank water), so when they are analyzed they should not contain substantial concentrations of any of the measured parameters unless contamination is occurring somewhere in the sample collection or filtration process. The QA/QC process for blank samples involves a calculation comparing the blank sample concentration to the ambient sample concentration for each of the parameters analyzed. For each parameter, if the ambient sample concentration is found to be less than or equal to five times the blank sample concentration, the blank sample QA/QC check is considered to have failed and the accuracy of all results for that parameter from samples collected by the same field personnel during that day of the run is questioned (U.S. Environmental Protection Agency 1994, 2017). The ambient sample concentration must be greater than five times the blank sample concentration to be considered present in the sample and not be a result of contamination. If an analyte is not detected in a blank sample, all ambient sample results for that analyte are considered to have passed the blank sample QA/QC check.

Zinc and aluminum are known contaminants of blank water because they are not sufficiently removed by laboratory filtration equipment. The source of these contaminants is likely the plumbing system that delivers water to the filtration equipment. Because zinc is present at relatively high concentrations in blank water and relatively low concentrations in environmental samples, the blank sample QA/QC check results in elevated fail rates for zinc, which incorrectly questions the validity of ambient sample results. This limits the reporting value of the blank water QA/QC check for zinc. The blank water contamination issue will be addressed in future SWCMP runs using purchased blank water from ACS Reagent Grade Water and ASTM Type I and Type II Water, Ricca Chemical Company, Arlington, TX.

3.4 Data Completeness Calculation

The percentage complete is a measure of the amount of accurate data collected compared to an expected amount, which indicates the ability of the program to reliably assess water quality (California Department of Water Resources 2009b). For each analyte, the percentage complete is calculated as the number of samples that passed a QA/QC check divided by the total number of samples collected, multiplied by 100. To comply with SWAMP measurement quality objectives, a percentage complete goal for the program is 90 percent, meaning 90 percent of samples collected for a particular analyte have usable results based on a QA/QC check (California Department of Water Resources 2009b).

Completeness is measured three different ways by using duplicate samples, blank samples, and the overall number of sampling events. For duplicate and blank samples, the percentage complete is calculated for each analyte assessed in the duplicate and blank QA/QC checks. The overall percentage complete is the number of samples collected throughout the entire program duration compared with the number of scheduled sampling events. This number includes dewatered stations, which cannot be sampled when dry.

3.5 Continuously Recorded Water Temperature Data Review

Water temperature is recorded at all SWCMP station locations by using continuous temperature data loggers, an Onset Hobo Water Temperature Pro v2 Data Logger, attached to a cable near the stream bank. Temperature is logged at 15-minute intervals and downloaded quarterly during sampling events. Under certain circumstances, such as data collection in intermittent streams or in locations subject to vandalism or theft, continuous data logging is not consistent or obtainable. All recorded temperature data are quality controlled and assessed through the time-series data management program in Hydstra version 12.0, developed by Kisters AG Pioneering Technologies, Citrus Heights, CA. Suspicious data are flagged with various quality codes (e.g., unreliable data, dry/no flow, missing data). The resulting reliable data are then uploaded to the WDL for public viewing.

3.6 Review of Laboratory Quality Control Reports

Laboratory quality control reports are reviewed to monitor the laboratory's internal QA/QC process. The batch numbers and number of blanks are documented. The report is carefully reviewed to ensure RPDs are less than or equal to 25 percent. Internal laboratory quality control is available upon request.

3.7 Data Validation, Archival, and Distribution

When steps one to five of the QA/QC process are complete, these data are made available to the public via the WDL at http://www.water.ca.gov/waterdatalibrary/. Currently, the WDL includes data that failed to meet all QA/QC checks because there is no ability to flag individual failed samples without removing an entire sample set. This issue is being addressed by updating the software associated with the WDL. When completed, a thorough review of reported data will be performed, and all data that fail one or more of the QA/QC checks will be updated with a qualifying statement.

3.8 Corrective Action

Corrective action is necessary to address incorrect or missing data. When there are issues with data quality, the QA/QC officer follows up on these issues so that they are documented and corrected during future sampling efforts. When possible, the WDL is updated with relevant information involving sample quality. Corrective action includes modifications to the sample collection protocol, program design, analytical methodology, or QA/QC process.

Chapter 4. Monitoring Data Results

This section summarizes monitoring data collected during water years (WYs) 2009–2014, a period which captures a wide variety of water year type classifications from wet to critically dry. A water year classifies surface water supply or total unimpaired runoff, and is the 12-month period from October 1, for any given year, through September 30 of the following year (California Department of Water Resources 2017). The water year is designated by the calendar year in which it ends. During the six water years summarized in this section, one year was classified as critically dry (WY 2014), two years were dry (WYs 2009 and 2013), two years were below normal (WYs 2010 and 2012), and one year was wet (WY 2011). Monitoring data collected under the SWCMP, as well as DWR water-chemistry assays not required under the SWCMP, are summarized in sections 4.1–4.4 and are presented by subregion (refer to Table 1 for a list of subregions). The QA/QC check results for the water quality data parameters, as well as for the data quality for continuous temperature data loggers, are in Appendix A.

It should be noted that the blank sample QA/QC check, described in section 3.3, was applied as accurately as possible for the period November 2008 through August 2014, when sampling protocols included only one blank sample collection per week. The current standard calls for one blank sample collection per crew per day. Because blank samples were limited during the November 2008 through August 2014 period, each blank was used to perform the QA/QC check on ambient samples collected within a day or more after the blank sample was collected, or on samples collected by a separate field crew. Current (post-2014) SWCMP monitoring efforts incorporate daily blank sample collections by each field crew to increase the reporting value of the blank sample QA/QC check.

4.1 Field-Measured Water Quality Results: Dissolved Oxygen

Dissolved oxygen measurements from the field were compared to dissolved oxygen water quality objectives outlined by the State Water Resources Control Board (2016) to allow for the “preservation and enhancement of fish, wildlife, and other aquatic resources or preserves” (California Water Code Section 13050[f]). Different standards exist for dissolved oxygen in warm and cold freshwater habitats. There are also specific dissolved oxygen water quality objectives for the portion of the Sacramento River from Keswick Dam to Hamilton City during June 1 through August 31.

4.1.1 Northeast Subregion

All stations within the Northeast Subregion (Figure 2) showed seasonal variation, with higher dissolved oxygen levels measured during the colder months (November and February sampling events; Figure 7). All Pit River stations are Clean Water Act 303(d)-listed as impaired for low dissolved oxygen. The upper Pit River stations failed to meet water quality objectives during the May and August sampling runs in most years. The South Fork Pit River station failed to meet the standard for cold-water ecosystems in 42 percent of measurements and for warm-water ecosystems in 22 percent of measurements. This station was dewatered during the station visit on August 12, 2014, but this sampling event is not included in the analysis. Dissolved oxygen was low during May through November of each year, with the lowest readings occurring from 2012–2014 at the North Fork Pit, South Fork Pit, and Canby stations.

4.1.2 Eastside Tributary Subregion

All stations within the Eastside Tributary Subregion (Figure 3) showed seasonal variation, with higher dissolved oxygen levels measured during the cooler months. All stations met the warm-water ecosystem dissolved oxygen standard of 5 milligrams per liter (mg/L) year-round (Figure 8). Measured dissolved oxygen was lower than the cold-water ecosystem standard during August through November each year, with the lowest readings occurring during 2009 and 2012–2014 at the Churn, Paynes, Big Chico, and Antelope stations.

4.1.3 Westside Tributary Subregion

All stations within the Westside Tributary Subregion (Figure 4) varied seasonally in dissolved oxygen levels, with higher levels associated with cooler months. Most stations met the cold-water ecosystem dissolved oxygen standard of 7 mg/L year-round (Figure 9). However, Red Bank and Thomes Creek failed to meet the cold-water ecosystem dissolved oxygen standard at times when reduced flows were observed.

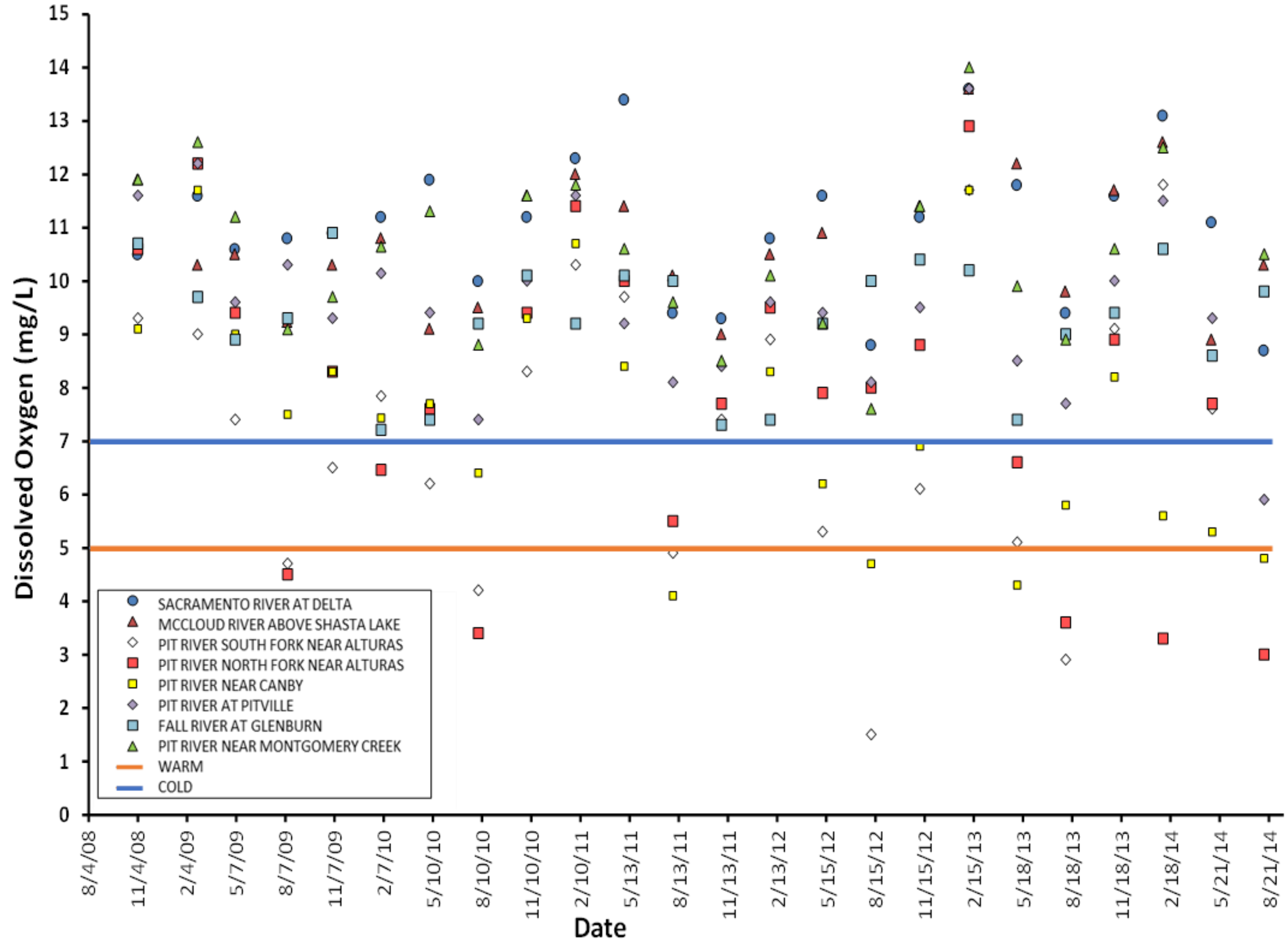
4.1.4 Upper Feather River Subregion

All stations within the Upper Feather River Subregion (Figure 5) showed seasonal variation, with higher dissolved oxygen levels measured during cooler months. All but the Middle Fork Feather River site met the warm-water ecosystem dissolved oxygen standard of 5 mg/L year-round (Figure 10). All three stations failed to meet the cold-water ecosystem dissolved oxygen standard of 7 mg/L during the May and August sampling periods in 2012 and 2014.

4.1.5 Sacramento Valley Subregion

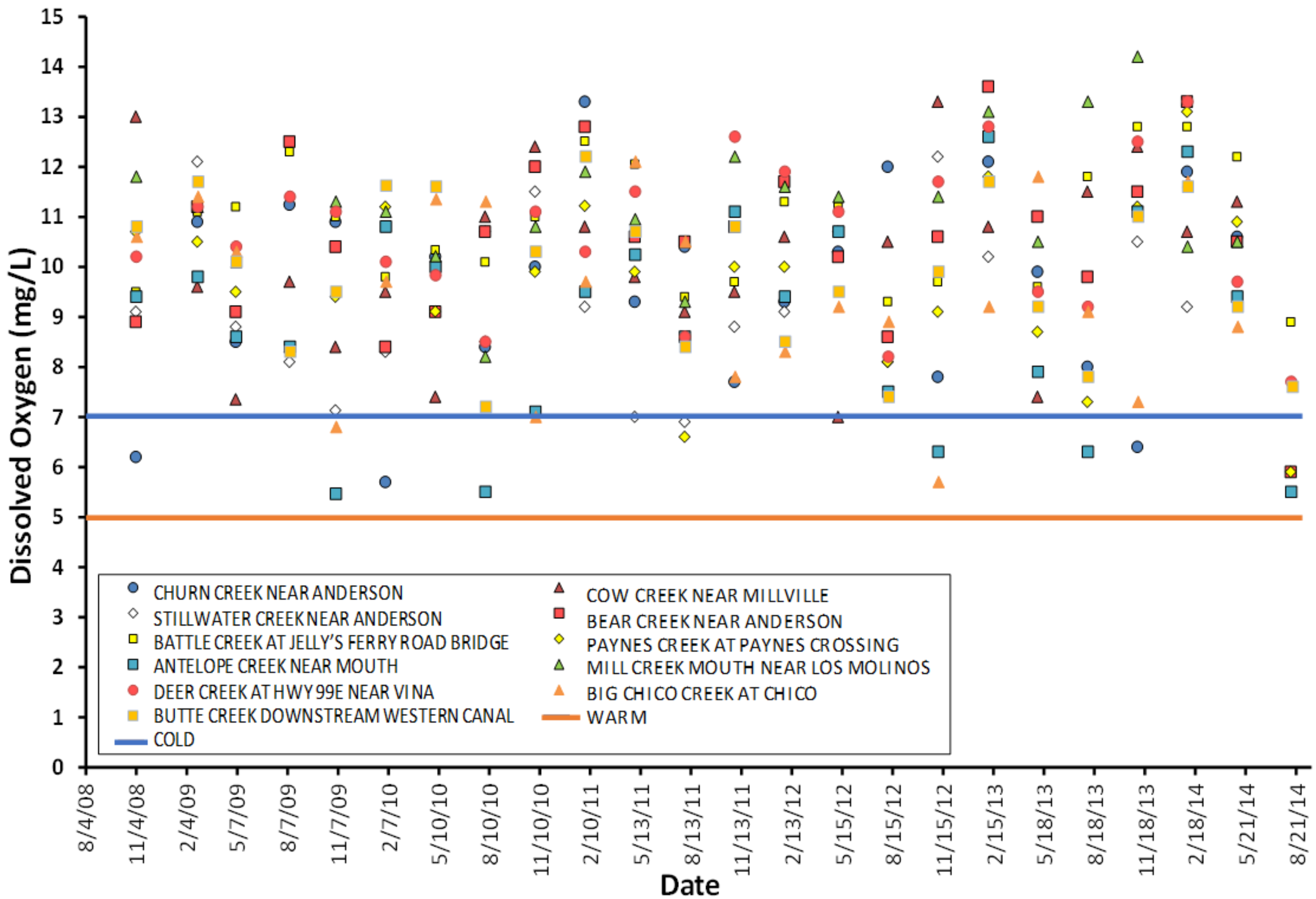
All stations within the Sacramento Valley Subregion (Figure 6) varied seasonally in dissolved oxygen levels. The Butte Slough, Colusa Basin Drain, and Sutter Bypass stations had particularly low dissolved oxygen levels (Figure 11). Even during cool season sampling (fall/winter), the Colusa Basin Drain and Butte Slough stations failed to meet the warm-water ecosystem dissolved oxygen standard of 5 mg/L, and these two stations were often below the cold-water ecosystem dissolved oxygen standard of 7 mg/L. Many stations were below the 9 mg/L Keswick-to-Hamilton City dissolved oxygen standard during June–August when these levels are intended to be maintained.

Figure 7 Dissolved Oxygen Results for the Northeast Subregion



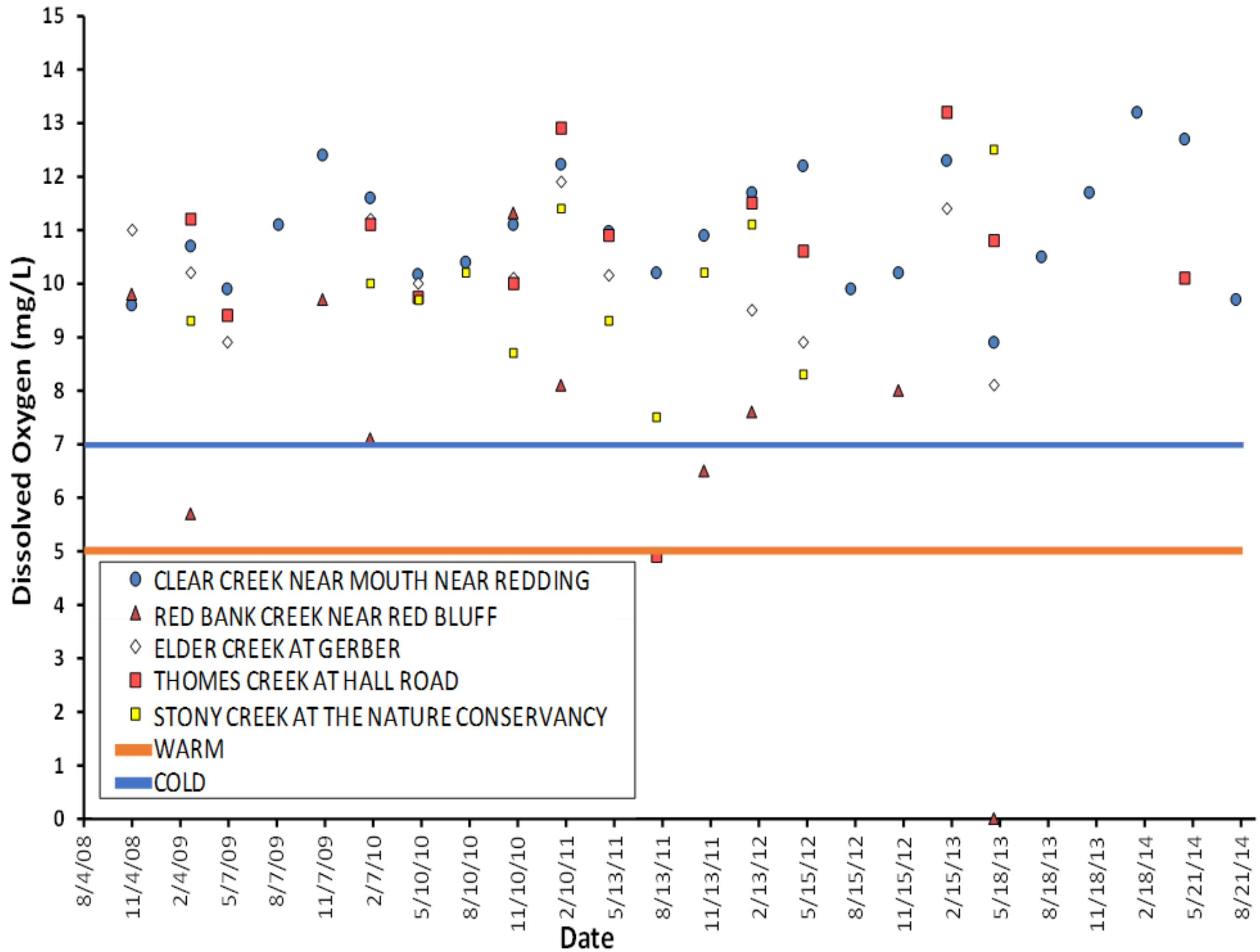
Notes: mg/L = milligrams per liter. Monitoring stations are distinguished using different colors and shapes. The horizontal lines designate the dissolved oxygen standard for supporting warm (orange) and cold (blue) water ecosystems (State Water Resources Control Board 2016). Note the lowest dissolved oxygen concentrations occur mostly during August sampling events.

Figure 8 Dissolved Oxygen Results for the Eastside Tributary Subregion



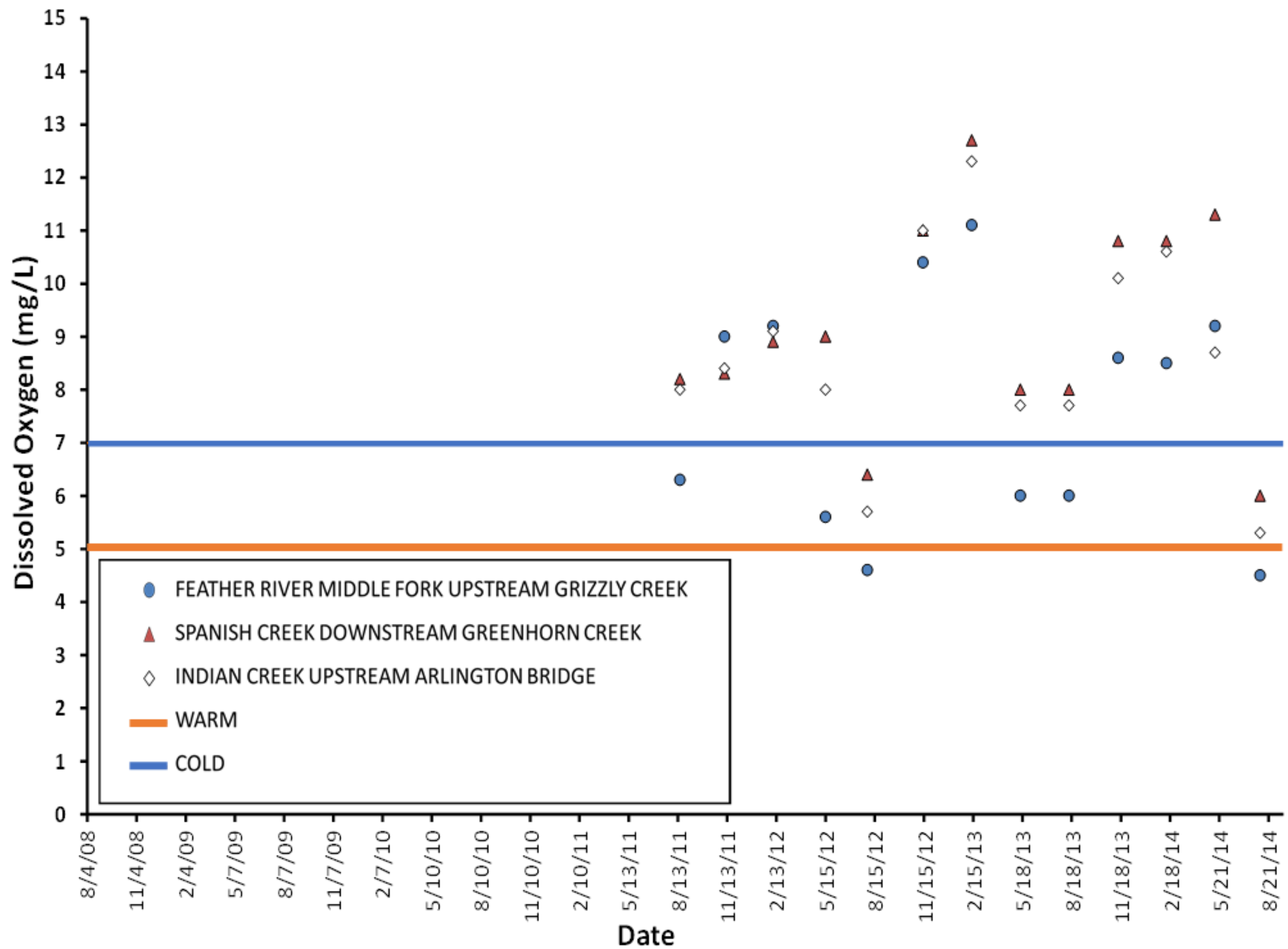
Notes: mg/L = milligrams per liter. Monitoring stations are distinguished using different colors and shapes. The horizontal lines designate the dissolved oxygen standard for supporting warm (orange) and cold (blue) water ecosystems (State Water Resources Control Board 2016).

Figure 9 Dissolved Oxygen Results for the Westside Tributary Subregion



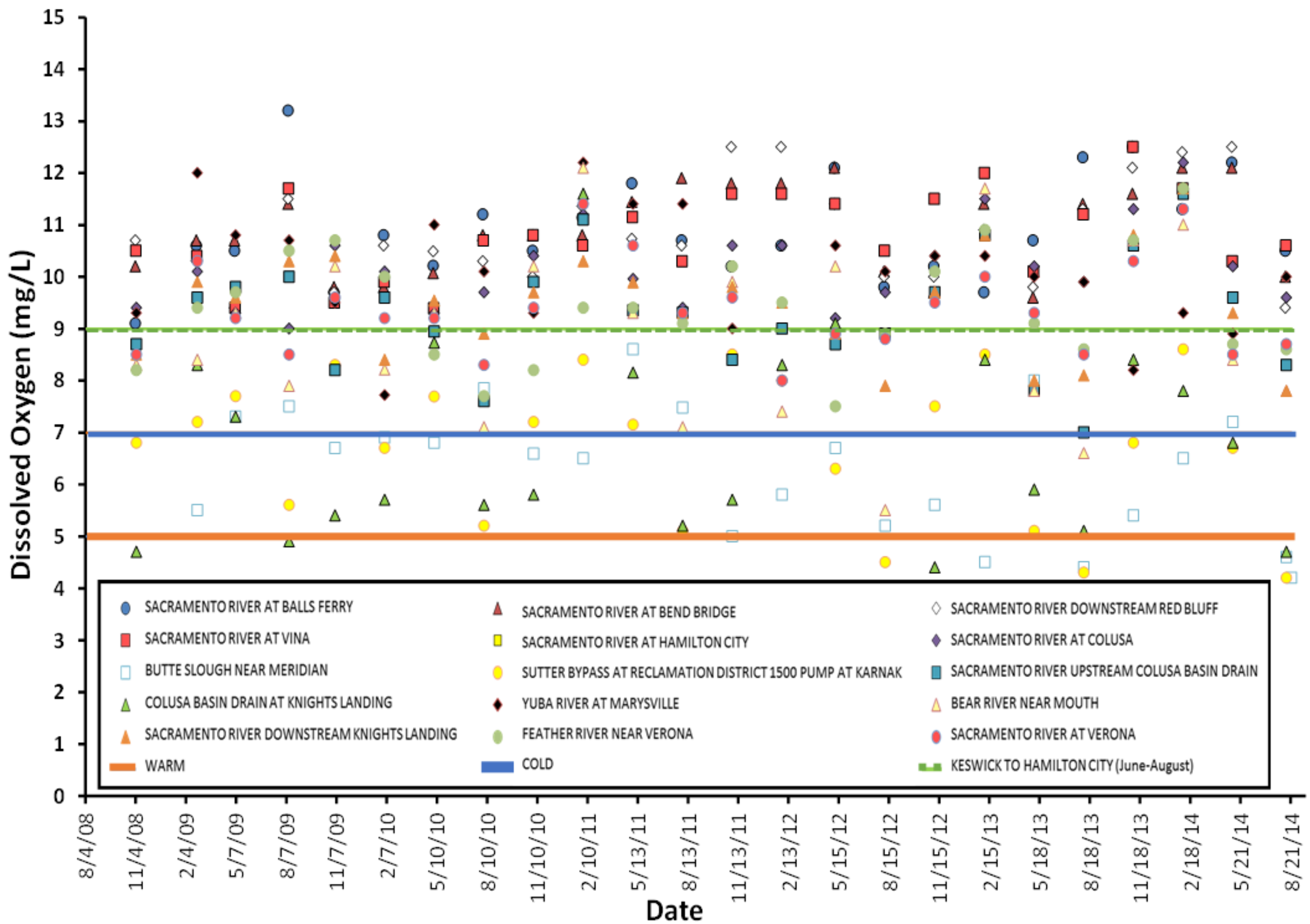
Notes: mg/L = milligrams per liter. Monitoring stations are distinguished using different colors and shapes. The horizontal lines designate the dissolved oxygen standard for supporting warm (orange) and cold (blue) water ecosystems (State Water Resources Control Board 2016). Note the outliers for Thomes Creek and Red Bank Creek were collected during low flows in August 2011 and May 2013.

Figure 10 Dissolved Oxygen Results for the Upper Feather River Subregion



Notes: mg/L = milligrams per liter. Monitoring stations are distinguished using different colors and shapes. The horizontal lines designate the dissolved oxygen standard for supporting warm (orange) and cold (blue) water ecosystems (State Water Resources Control Board 2016). Note that the sampling period for the Upper Feather River Subregion did not begin until August 2011.

Figure 11 Dissolved Oxygen Results for the Sacramento Valley Subregion



Notes: mg/L = milligrams per liter. Monitoring stations are distinguished using different colors and shapes. The horizontal blue and orange lines designate the dissolved oxygen standard for supporting warm (orange) and cold (blue) water ecosystems (State Water Resources Control Board 2016). The horizontal dashed green line designates the June through August dissolved oxygen standard between Keswick Dam and Hamilton City (State Water Resources Control Board 2016).

4.2 Field-Measured Water Quality Results: Continuous Water Temperature

Continuous daily water temperature was recorded at 15-minute intervals for many SWCMP stations, and these data were used to calculate the mean daily water temperature. Continuous temperature monitoring was not possible at stations where vandalism and theft occurred. Temperatures were compared to thresholds for salmonid egg and in-gravel larvae mortalities (Figures 12–17). Reviewed literature (Myrick and Cech 2004) suggests there is no salmonid egg loss below 13.3 °C (56 °F), while 100 percent mortality of in-gravel larvae occurs at temperatures above 16.6 °C (62 °F). Comparisons with these thresholds are made only for stations located along waterways that support anadromous salmonids or are being investigated for the possible reintroduction of salmonids.

4.2.1 Northeast Subregion

At the McCloud River and Sacramento River stations, maximum daily temperatures recorded at data logger locations were above the temperature thresholds for Chinook salmon egg and in-gravel larvae survival (Figure 12). Still, these temperatures would support emerged fry and juvenile salmon (Myrick and Cech 2004). The Pit River is not being considered for the re-introduction of anadromous salmonids.

4.2.2 Eastside Tributary Subregion

Churn and Stillwater creeks support anadromous salmonids during times of year when water temperatures are in a suitable range (usually mid to late fall and winter). Cow and Bear creeks support anadromous salmonids, but high temperatures recorded under the SWCMP suggest challenging temperatures for these species in the vicinity of data loggers, especially during low flows in summer and fall seasons (Figure 13). Paynes, Antelope, Deer, and Big Chico creeks are known to support anadromous salmonids (Johnson et al. 2014), but mean water temperatures were above thresholds for salmonid egg and fry and in-gravel larvae survival during the fall spawning period. The Mill Creek station recorded temperatures outside temperature thresholds, but the location of the recording station does not represent areas where adult salmonids hold or spawn during periods of high temperature. Similarly, although the Butte Creek station was above temperature thresholds, salmonid spawning occurs several miles upstream of the monitoring station. Battle Creek supports anadromous salmonids and temperatures are rarely above thresholds during spawning events within the monitored section of the creek.

4.2.3 Westside Tributary Subregion

Clear Creek supports anadromous salmonids, but temperatures recorded at data logger locations were above the egg-mortality threshold several times during the fall spawning season. Cottonwood Creek's fall-run Chinook salmon would similarly be negatively affected by the warm water temperatures that were above the thresholds during fall spawning seasons (Figure 14). Red Bank, Elder, and Thomes creeks experienced significant periods where there was either no stream flow or the creek was completely dry.

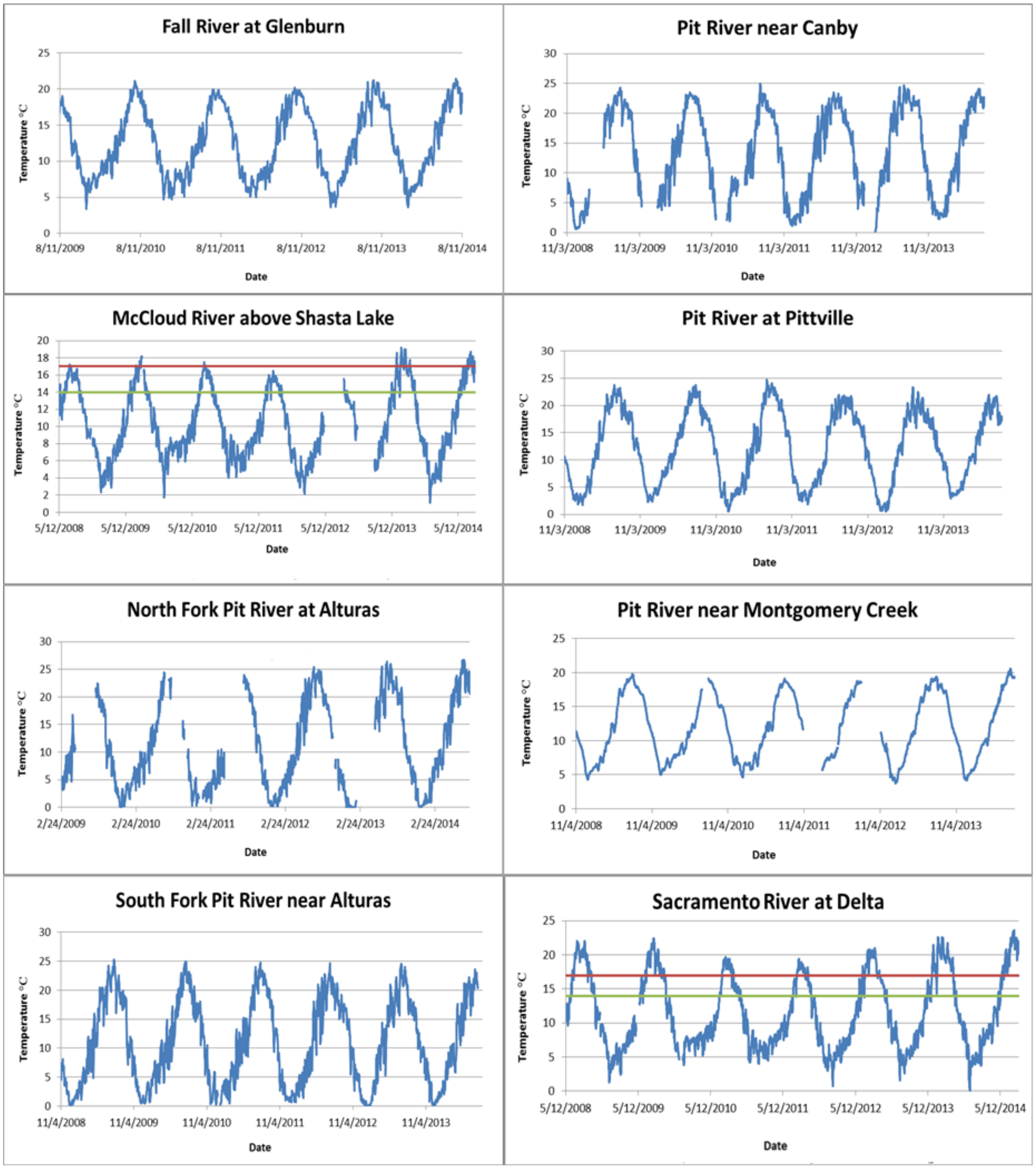
4.2.4 Upper Feather River Subregion

The Upper Feather River Subregion does not support anadromous salmonids. Accordingly, results of continuous temperature monitoring (Figure 15) are not discussed in detail in this report.

4.2.5 Sacramento Valley Subregion

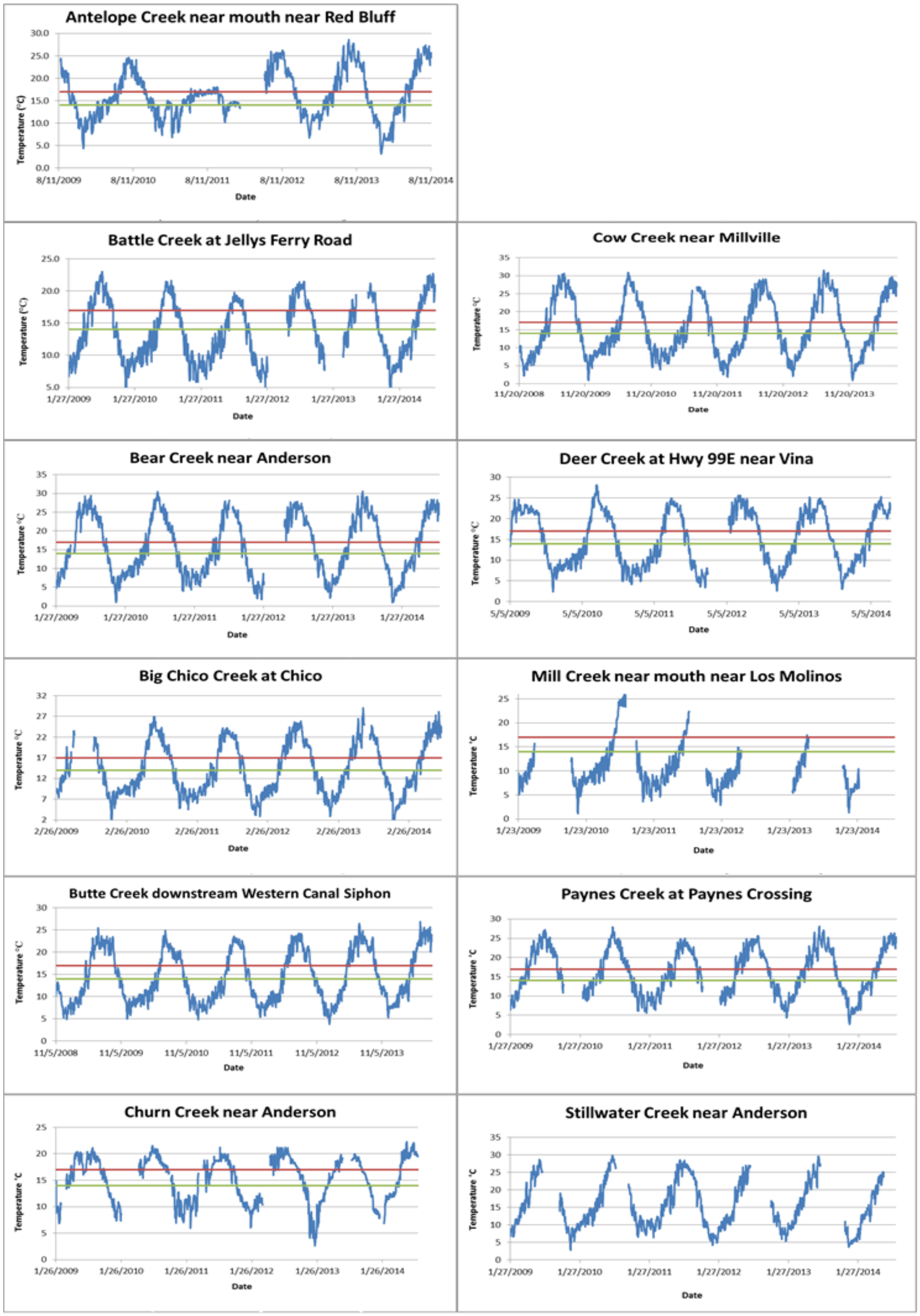
All mainstem Sacramento River SWCMP stations support some life-stage (migration, spawning, incubation, or rearing) of all four runs of Chinook salmon, as well as steelhead and sturgeon. Releases from Shasta Lake help maintain temperatures protective of winter-run Chinook salmon spawning and egg incubation/emergence. However, the ability to meet the 12.8–13.3 °C (55–56 °F) target for the winter-run inhabited reach depends on available cold-water pool storage in Shasta Lake and ambient air temperatures. Results of continuous temperature monitoring in this subregion are shown in Figures 16 and 17.

Figure 12 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at Eight Stations in the Northeast Subregion



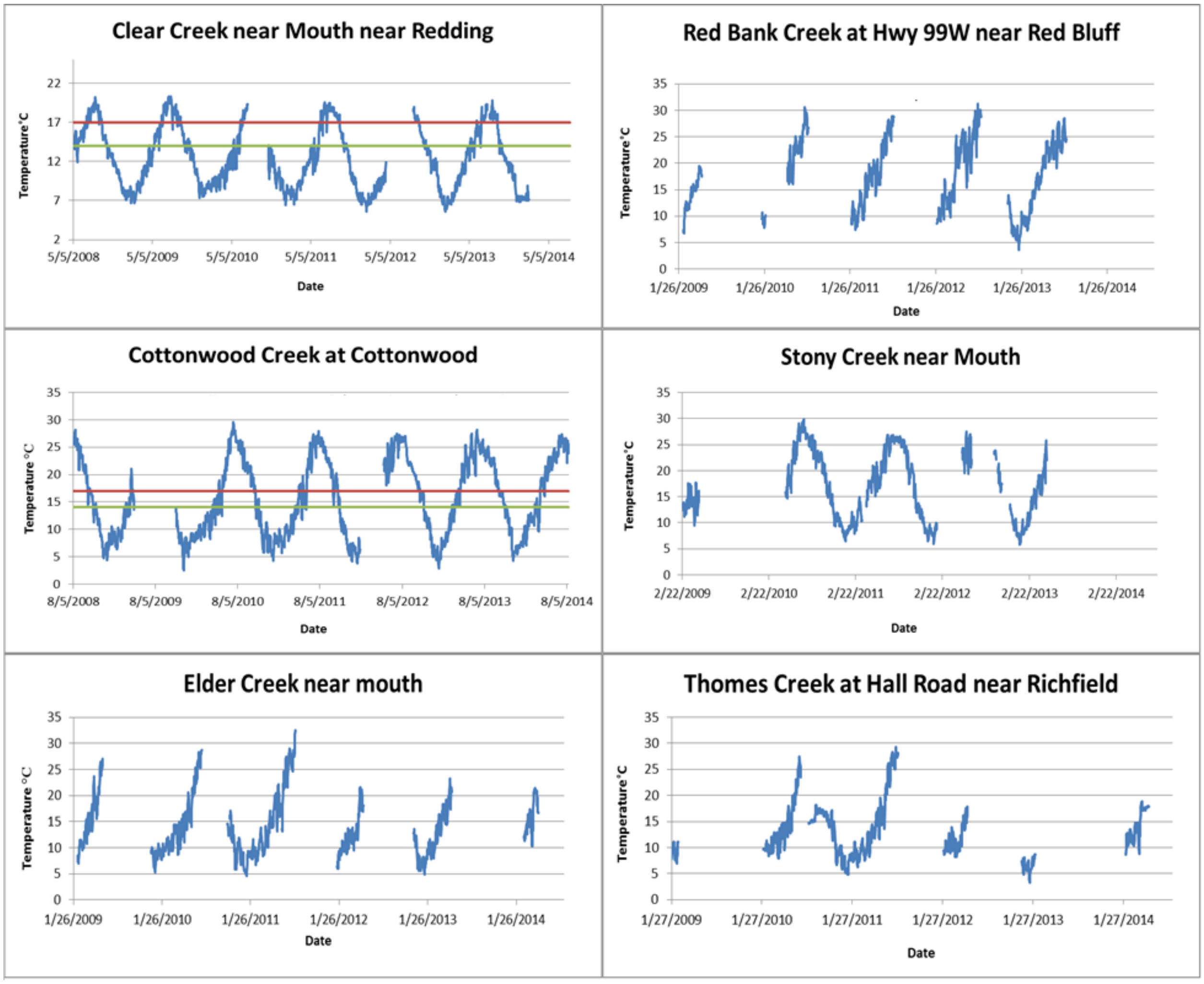
Notes: Date ranges for temperature records vary by station. Some graphs contain two horizontal lines, which represent the upper temperature limit for egg (green = 13.3 °C) and in-gravel larvae (orange = 16.6 °C) survival. Graphs lacking these horizontal lines represent stations that do not support anadromous salmonid spawning. The McCloud River above Shasta Lake and the Sacramento River at Delta stations are located upstream of Keswick Dam, which blocks migration of anadromous fish. Data gaps reflect lost or stolen data loggers.

Figure 13 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at 11 Stations in the Eastside Tributary Subregion



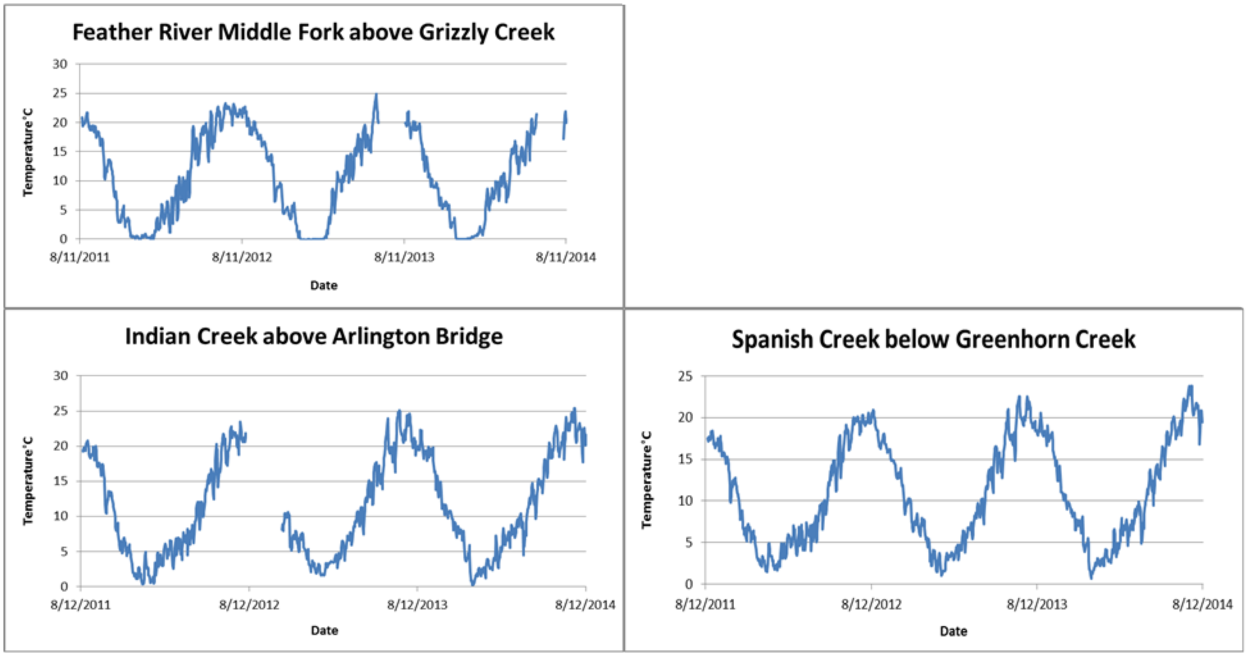
Notes: Date ranges for temperature records vary by station. Some graphs contain two horizontal lines, which represent the upper temperature limit for egg (green = 13.3 °C) and in-gravel larvae (orange = 16.6 °C) survival. Graphs lacking these horizontal lines represent stations located on waterways that do not support anadromous salmonid spawning. Data gaps reflect lost or stolen data loggers or periods of dewatering.

Figure 14 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at Six Stations in the Westside Tributary Subregion



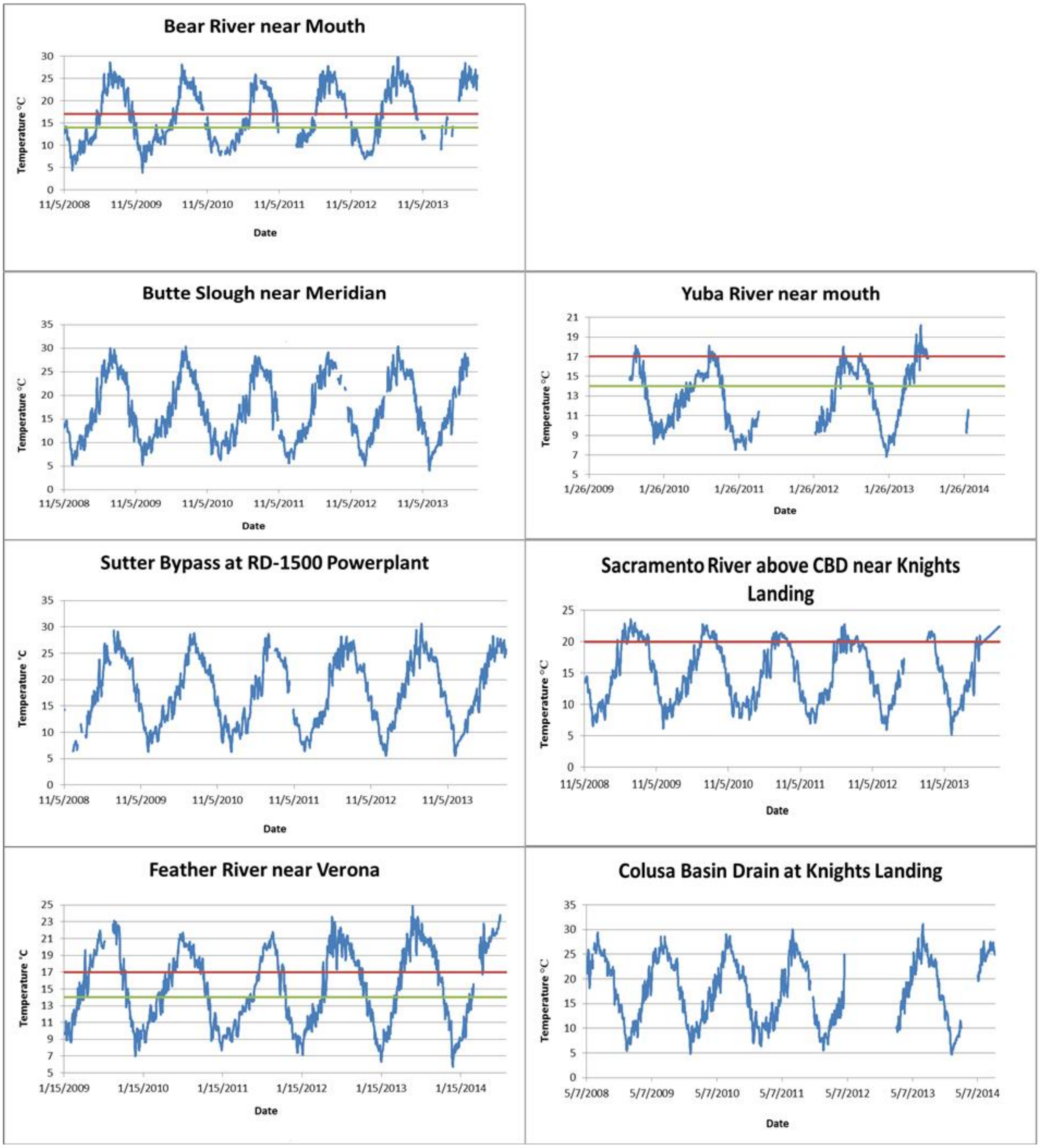
Notes: Date ranges for temperature records vary by station. Some graphs contain two horizontal lines, which represent the upper temperature limit for egg (green = 13.3 °C) and in-gravel larvae (orange = 16.6 °C) survival. Graphs lacking these horizontal lines represent stations located along waterways that do not support anadromous salmonid spawning. Data gaps reflect lost or stolen data loggers or periods of dewatering.

Figure 15 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at Three Stations in the Upper Feather River Subregion



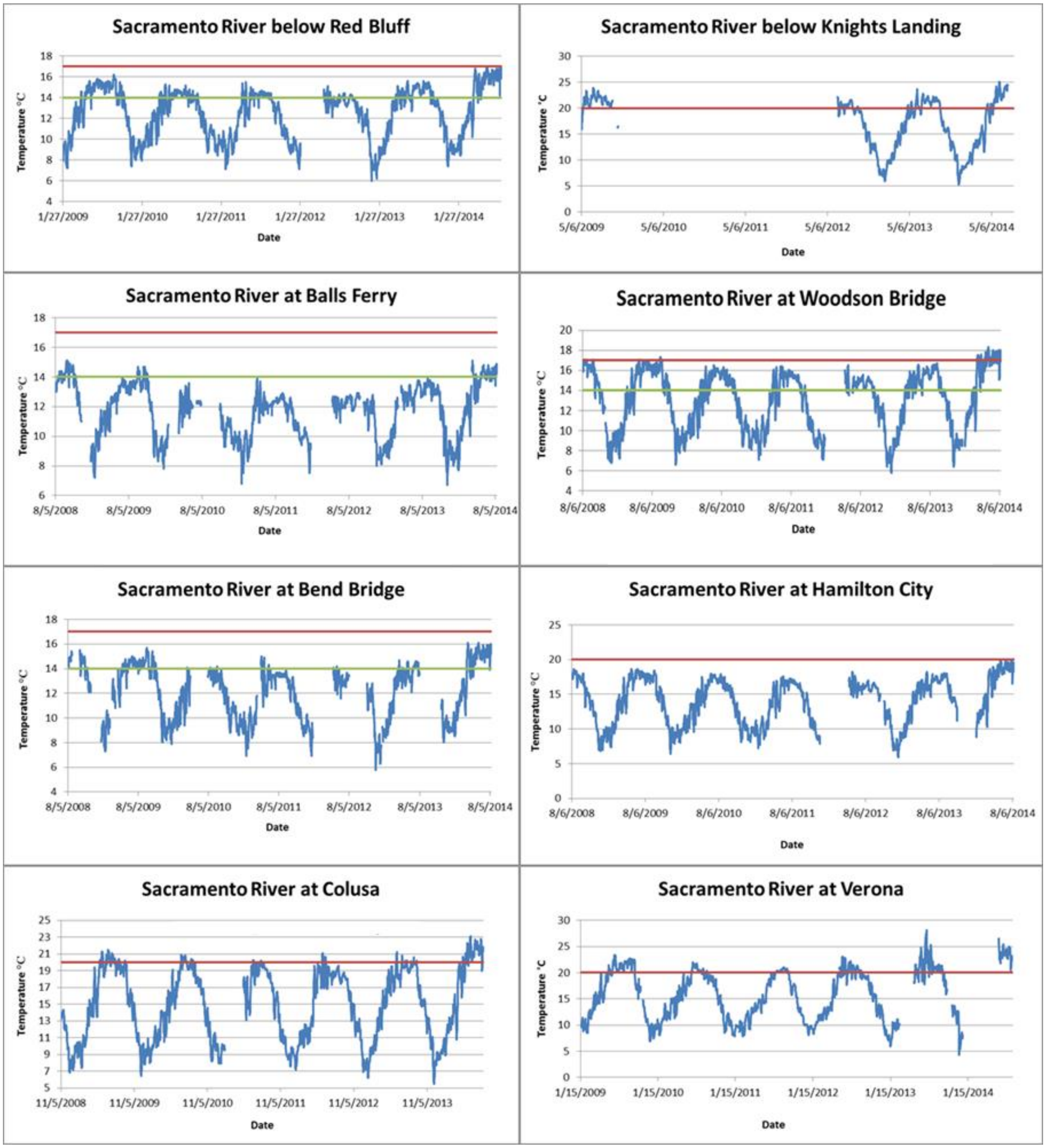
Notes: Date ranges for temperature records vary by station. Stations in the Upper Feather River Subregion are located along waterways that do not support anadromous salmonids due to the Feather River Fish Hatchery fish barrier dam. Data gaps reflect lost or stolen data loggers.

Figure 16 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at Seven Stations in the Sacramento River Subregion



Notes: For the remaining stations in the Sacramento River Subregion, see Figure 17. Note date ranges for temperature records vary by station. Some graphs contain two horizontal lines which represent the upper temperature limit for egg (green = 13.3 °C) and in-gravel larvae (orange = 16.6 °C) survival. Graphs lacking these horizontal lines represent stations located along waterways that do not support anadromous salmonid spawning. Data gaps reflect lost or stolen data loggers.

Figure 17 Daily Mean Temperature Data from Continuously Recording Temperature Data Loggers Deployed at Eight Stations in the Sacramento River Subregion



Notes: For the additional seven stations in the Sacramento River Subregion, see Figure 16. Note date ranges for temperature records vary by station. Some graphs contain two horizontal lines, which represent the upper temperature limit for egg (green = 13.3 °C) and in-gravel larvae (orange = 16.6 °C) survival. Graphs lacking these horizontal lines represent stations located along waterways that do not support anadromous salmonid spawning. Data gaps reflect lost or stolen data loggers.

4.3 Water Chemistry Results

There are a variety of published water quality thresholds that can be used to assess the condition of ambient water. These published assessment thresholds can be accessed via the State Water Resources Control Board website (http://www.waterboards.ca.gov/water_issues/ programs/water_quality_goals/). For SWCMP water quality data, the thresholds used are the California-mandated maximum contaminant levels (MCLs) pursuant to the California Safe Drinking Water Act, the agricultural water quality goals established by the Food and Agriculture Organization of United Nations, and the U.S. Environmental Protection Agency recommended and/or California Toxics Rule criteria for fish consumption and freshwater aquatic life protection.

This report addresses both the California-mandated primary MCLs, which relate to human health concerns, and the California secondary MCLs, which relate to palatability of water (e.g., taste and odor) (State Water Resources Control Board 2017). Agricultural limits are also addressed, as they are designed to protect crop irrigation and stock watering, which are beneficial uses for much of the surface water monitored under the SWCMP. The fish consumption and aquatic life protection criteria are also addressed, as they help gauge the biological health of aquatic systems and the value they have for human use. Although additional criteria can be used to analyze water quality data, the sources mentioned above are the most relevant for waterbodies monitored by the SWCMP.

Results of water chemistry are briefly summarized below by subregion. Summaries refer to the descriptive water-chemistry data in Tables 3–7. Actual constituent concentrations (i.e., raw data) for every sample collection event are available on the WDL (http://www.water.ca.gov/waterdatalibrary/).

4.3.1 Northeast Subregion

Water samples from the Northeast Subregion were above water quality assessment thresholds based on the California-mandated primary and secondary MCLs, agricultural limits, fish consumption criteria, and freshwater aquatic life-protection criteria (Tables 3–7). For California-mandated primary MCLs, most of the Pit River stations were above the MCL for aluminum, and arsenic levels were above the MCL for one station (South Fork Pit River near Alturas; Table 3). Most stations had at least one collection event that was above California secondary MCLs for aluminum, iron, and manganese (Table 4). The Northeast Subregion had a few collection events with results above the agricultural limits for aluminum, boron, manganese, and sodium. For all stations, nearly every collection event was above the U.S. Environmental Protection Agency recommended and/or California Toxics Rule fish consumption criteria for arsenic, and most of the Pit River stations also did not meet fish consumption criteria for manganese (Table 6). Two Northeast Subregion stations had results above the hardness-dependent freshwater aquatic life protection criteria (Table 7).

4.3.2 Eastside Tributary Subregion

Water samples from the Eastside Tributary Subregion were above water quality assessment thresholds based on the California-mandated primary and secondary MCLs, agricultural limits, fish consumption criteria, and freshwater aquatic life-protection criteria (Tables 3–7). At several stations, aluminum levels were above the California-mandated primary MCL, and a large proportion of samples collected from two stations (Antelope Creek and Mill Creek near Los Molinos) were above the California-mandated primary MCL for arsenic (Table 3). Most stations had at least one collection event above the California secondary MCL for aluminum and iron (Table 4). Four stations had collection events that were above the California secondary MCL for manganese. The Eastside Tributary Subregion had a few collection events that were above agricultural limits for aluminum, boron, and iron (Table 5). Most collection events did not meet U.S. Environmental Protection Agency recommended and/or California Toxics Rule fish consumption criteria for arsenic, and two stations were above fish consumption criteria for either manganese or mercury (Table 6). Two Eastside Tributary Subregion stations were above hardness-dependent freshwater aquatic life protection criteria (Table 7).

4.3.3 Westside Tributary Subregion

Water samples from the Westside Tributary Subregion were above water quality assessment thresholds based on the California-mandated primary MCLs, the California secondary MCLs, agricultural limits, fish consumption criteria, and freshwater aquatic life-protection criteria (Tables 3–7). For all stations, at least one collection event was above the California-mandated primary MCL for aluminum (Table 3). Most stations had at least one collection event that was above the California secondary MCLs for aluminum, iron, and manganese (Table 4). The Westside Tributary Subregion had one station with collections that were above agricultural limits for aluminum, iron, and manganese (Table 5). Many collection events did not meet U.S. Environmental Protection Agency recommended and/or California Toxics Rule fish consumption criteria for arsenic, and several stations also did not meet fish consumption criteria for manganese (Table 6). Two Westside Tributary Subregion stations were above hardness-dependent freshwater aquatic life protection criteria (Table 7).

4.3.4 Upper Feather River Subregion

Water samples from the Upper Feather River Subregion were above water quality assessment thresholds based on the California secondary MCLs, agricultural limits, fish consumption criteria, and freshwater aquatic life-protection criteria (Tables 3–7). At most stations, at least one collection event was above the California secondary MCLs for aluminum, iron, and manganese (Table 4). The upper Feather River Subregion had one station with collections that were above agricultural limits for manganese (Table 5). Nearly every collection event at all stations was above the U.S. Environmental Protection Agency recommended and/or California Toxics Rule fish consumption criteria for arsenic, and two stations were also above fish consumption criteria for manganese (Table 6). One upper Feather River Subregion station did not meet hardness-dependent freshwater aquatic life protection criteria (Table 7).

4.3.5 Sacramento Valley Subregion

Water samples from the Sacramento Valley Subregion were above water quality assessment thresholds based on the California-mandated primary and secondary MCLs, agricultural limits, fish consumption criteria, and freshwater aquatic life-protection criteria (Tables 3–7). At all stations, at least one collection event was above the California-mandated primary MCL for aluminum, and one station (Sutter Bypass) had a collection event that was above the California-mandated primary MCL for arsenic (Table 3). Most stations had at least one collection event that was above California secondary MCLs for aluminum, iron, and manganese (Table 4). One station (Colusa Basin Drain near Knights Landing) had collection events that were above the California secondary MCLs for specific conductance and total dissolved solids (Table 4). The Sacramento Valley Subregion had a few collection events that were above agricultural limits for manganese, and one station (Colusa Basin Drain) was above agricultural limits for specific conductance, manganese, sodium, and total dissolved solids (Table 5). Nearly every collection event at all stations was above U.S. Environmental Protection Agency recommended and/or California Toxics Rule fish consumption criteria for arsenic, and most stations were also above fish consumption criteria for manganese (Table 6). One station (Yuba River) did not meet fish consumption criteria for mercury. Eleven Sacramento Valley Subregion stations had results above hardness-dependent freshwater aquatic life protection criteria (Table 7).

Table 3 Percentage of Samples Equal to or Above the California-Mandated Drinking Water Primary Maximum Contaminant Levels Established by the State Water Resources Control Board

Station Name	Aluminum (%)	Arsenic (%)
Northeast Subregion		
FALL RIVER AT GLENBURN	0	0
MCCLOUD RIVER ABOVE SHASTA LAKE	4	0
PIT RIVER NORTH FORK AT ALTURAS	21	0
PIT RIVER SOUTH FORK NEAR ALTURAS	30	4
PIT RIVER NEAR CANBY	54	0
PIT RIVER AT PITTVILLE	33	0
PIT RIVER NEAR MONTGOMERY CREEK	4	0
SACRAMENTO RIVER AT DELTA	0	0
Eastside Tributary Subregion		
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	0	46
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE**	0	0
BEAR CREEK NEAR ANDERSON	4	0
BIG CHICO CREEK AT CHICO**	0	0
BUTTE CREEK DOWNSTREAM WESTERN CANAL **	0	0
CHURN CREEK NEAR ANDERSON	0	0
COW CREEK NEAR MILLVILLE	4	0
DEER CREEK AT HWY 99E NEAR VINA	0	0
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	10	95

Station Name	Aluminum (%)	Arsenic (%)
Eastside Tributary Subregion		
NORTH HONCUT CREEK AT HWY 70	8	0
PAYNES CREEK AT PAYNES CROSSING	4	0
STILLWATER CREEK NEAR ANDERSON	5	0
Westside Tributary Subregion		
CLEAR CREEK NEAR MOUTH NEAR REDDING	4	0
COTTONWOOD CREEK AT COTTONWOOD	8	0
ELDER CREEK AT GERBER	5	0
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	5	0
STONY CREEK AT THE NATURE CONSERVANCY**	11	0
THOMES CREEK AT HALL ROAD**	22	0
Upper Feather River Subregion		
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	0	0
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	0	0
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	0	0
Sacramento Valley Subregion		
BEAR RIVER NEAR MOUTH	17	0
BUTTE SLOUGH NEAR MERIDIAN**	21	0
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING**	29	0

Station Name	Aluminum (%)	Arsenic (%)
Sacramento Valley Subregion		
FEATHER RIVER NEAR VERONA	8	0
SACRAMENTO RIVER AT VERONA	13	0
SACRAMENTO RIVER AT BALLS FERRY	4	0
SACRAMENTO RIVER AT BEND BRIDGE	4	0
SACRAMENTO RIVER AT COLUSA	8	0
SACRAMENTO RIVER AT HAMILTON CITY	2	0
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	8	0
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	13	0
SACRAMENTO RIVER BELOW KNIGHTS LANDING	17	0
SACRAMENTO RIVER BELOW RED BLUFF	4	0
SUTTER BYPASS A RECLAMATION DISTRICT 1500 PUMP AT KARNAK**	21	4
YUBA RIVER AT MOUTH**	4	0

Notes: Sampling occurred November 2008 through August 2014. Parameters that were not above the California-mandated primary maximum contaminant limits (MCLs) for any of the sampled stations were omitted. Asterisks denote stations without municipal and domestic supply beneficial use (State Water Resources Control Board 2016). Although MCLs do not apply to these waterbodies, they represent possible sources to the Sacramento River.

Table 4 **Percentage of Samples Equal to or Above the California Secondary Maximum Contaminant Levels Established by the State Water Resources Control Board**

Station Name	Aluminum (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)
Northeast Subregion				
FALL RIVER AT GLENBURN	4	0	0	0
MCCLOUD RIVER ABOVE SHASTA LAKE	4	0	4	4
PIT RIVER NORTH FORK AT ALTURAS	38	0	38	83
PIT RIVER SOUTH FORK NEAR ALTURAS	91	0	91	70
PIT RIVER NEAR CANBY	80	0	80	100
PIT RIVER AT PITTVILLE	83	0	79	54
PIT RIVER NEAR MONTGOMERY CREEK	21	0	8	0
SACRAMENTO RIVER AT DELTA	4	0	4	0
Eastside Tributary Subregion				
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	21	0	17	8
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	8	0	4	0
BEAR CREEK NEAR ANDERSON	17	0	17	0
BIG CHICO CREEK AT CHICO	5	0	0	0
BUTTE CREEK DOWNSTREAM WESTERN CANAL	17	0	8	0
CHURN CREEK NEAR ANDERSON	9	0	13	0
COW CREEK NEAR MILLVILLE	22	0	17	0
DEER CREEK AT HWY 99E NEAR VINA	8	0	4	0
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	24	0	14	10

Station Name	Aluminum (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)
Eastside Tributary Subregion				
NORTH HONCUT CREEK AT HWY 70	25	0	71	50
PAYNES CREEK AT PAYNES CROSSING	4	0	4	4
STILLWATER CREEK NEAR ANDERSON	25	0	15	0
Westside Tributary Subregion				
CLEAR CREEK NEAR MOUTH NEAR REDDING	13	0	4	0
COTTONWOOD CREEK AT COTTONWOOD	21	0	17	8
ELDER CREEK AT GERBER	10	0	10	5
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	5	0	5	5
STONY CREEK AT THE NATURE CONSERVANCY	28	0	17	6
THOMES CREEK AT HALL ROAD	28	0	22	17
Upper Feather River Subregion				
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	31	0	69	8
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	23	0	69	77
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	0	0	23	15
Sacramento Valley Subregion				
BEAR RIVER NEAR MOUTH	42	0	67	42
BUTTE SLOUGH NEAR MERIDIAN	75	0	100	100

Station Name	Aluminum (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)
Sacramento Valley Subregion				
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING	92	4	92	96
FEATHER RIVER NEAR VERONA	29	0	33	8
SACRAMENTO RIVER AT VERONA	38	0	33	21
SACRAMENTO RIVER AT BALLS FERRY	21	0	4	0
SACRAMENTO RIVER AT BEND BRIDGE	17	0	13	4
SACRAMENTO RIVER AT COLUSA	28	0	28	8
SACRAMENTO RIVER AT HAMILTON CITY	12	0	7	2
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	17	0	13	8
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	29	0	25	8
SACRAMENTO RIVER BELOW KNIGHTS LANDING	50	0	42	17
SACRAMENTO RIVER BELOW RED BLUFF	17	0	13	4
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK	54	0	79	100
YUBA RIVER AT MOUTH	17	0	13	0

Notes: Sampling occurred November 2008 through August 2014. Parameters that were not above the California-mandated secondary maximum contaminant levels (MCLs) for any of the sampled stations were omitted.

Table 5 Percentage of Samples Equal to or Above Agricultural Water Quality Goals Established by the Food and Agriculture Organization of the United Nations

Station Name	Aluminum (%)	Boron (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)	Sodium (%)
Northeast Subregion						
FALL RIVER AT GLENBURN	0	0	0	0	0	0
MCCLOUD RIVER ABOVE SHASTA LAKE	0	0	0	0	0	0
PIT RIVER NORTH FORK AT ALTURAS	0	0	0	0	0	0
PIT RIVER SOUTH FORK NEAR ALTURAS	0	4	0	0	4	4
PIT RIVER NEAR CANBY	2	0	0	0	24	0
PIT RIVER AT PITTVILLE	0	0	0	0	0	0
PIT RIVER NEAR MONTGOMERY CREEK	0	0	0	0	0	0
SACRAMENTO RIVER AT DELTA	0	0	0	0	0	0
Eastside Tributary Subregion						
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	**0**	25	0	0	0	0
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	0	0	0	0	0	0
BEAR CREEK NEAR ANDERSON	0	0	0	0	0	0
BIG CHICO CREEK AT CHICO	0	0	0	0	0	0
BUTTE CREEK DOWNSTREAM WESTERN CANAL	0	0	0	0	0	0
CHURN CREEK NEAR ANDERSON	0	0	0	0	0	0
COW CREEK NEAR MILLVILLE	0	0	0	0	0	0
DEER CREEK AT HWY 99E NEAR VINA	0	0	0	0	0	0

Station Name	Aluminum (%)	Boron (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)	Sodium (%)
Eastside Tributary Subregion						
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	5	29	0	5	0	0
NORTH HONCUT CREEK AT HWY 70	0	0	0	0	0	0
PAYNES CREEK AT PAYNES CROSSING	0	0	0	0	0	0
STILLWATER CREEK NEAR ANDERSON	0	0	0	0	0	0
Westside Tributary Subregion						
CLEAR CREEK NEAR MOUTH NEAR REDDING	0	0	0	0	0	0
COTTONWOOD CREEK AT COTTONWOOD	0	0	0	0	0	0
ELDER CREEK AT GERBER	0	0	0	0	0	0
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	0	0	0	0	0	0
STONY CREEK AT THE NATURE CONSERVANCY	0	0	0	0	0	0
THOMES CREEK AT HALL ROAD	11	0	0	11	6	0
Upper Feather River Subregion						
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	0	0	0	0	0	0
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	0	0	0	0	8	0
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	0	0	0	0	0	0
Sacramento Valley Subregion						
BEAR RIVER NEAR MOUTH	0	0	0	0	4	0

Station Name	Aluminum (%)	Boron (%)	Electrical Conductivity (%)	Iron (%)	Manganese (%)	Sodium (%)
Sacramento Valley Subregion						
BUTTE SLOUGH NEAR MERIDIAN	0	0	0	0	0	0
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING	0	0	17	0	25	21
FEATHER RIVER NEAR VERONA	0	0	0	0	0	0
SACRAMENTO RIVER AT VERONA	0	0	0	0	0	0
SACRAMENTO RIVER AT BALLS FERRY	0	0	0	0	0	0
SACRAMENTO RIVER AT BEND BRIDGE	0	0	0	0	0	0
SACRAMENTO RIVER AT COLUSA	0	0	0	0	0	0
SACRAMENTO RIVER AT HAMILTON CITY	0	0	0	0	0	0
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	0	0	0	0	0	0
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	0	0	0	0	0	0
SACRAMENTO RIVER BELOW KNIGHTS LANDING	0	0	0	0	0	0
SACRAMENTO RIVER BELOW RED BLUFF	0	0	0	0	0	0
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK	0	0	0	0	4	0
YUBA RIVER AT MOUTH	0	0	0	0	0	0

Notes: Sampling occurred November 2008 through August 2014. Parameters that were not above the agricultural goals for any of the sampled stations were omitted.

Table 6 Percentage of Samples Equal to or Above the U.S. Environmental Protection Agency Recommended and/or California Toxics Rule Criteria for Fish Consumption Established by the U.S. Environmental Protection Agency

Station Name	Arsenic (%)	Manganese (%)	Mercury (%)
Northeast Subregion			
FALL RIVER AT GLENBURN	100	0	0
MCCLOUD RIVER ABOVE SHASTA LAKE	96	0	0
PIT RIVER NORTH FORK AT ALTURAS	100	21	0
PIT RIVER SOUTH FORK NEAR ALTURAS	100	13	0
PIT RIVER NEAR CANBY	100	63	0
PIT RIVER AT PITTVILLE	100	8	0
PIT RIVER NEAR MONTGOMERY CREEK	96	0	0
SACRAMENTO RIVER AT DELTA	100	0	0
Eastside Tributary Subregion			
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	100	0	0
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	100	0	0
BEAR CREEK NEAR ANDERSON	100	0	4
BIG CHICO CREEK AT CHICO	100	0	0
BUTTE CREEK DOWNSTREAM WESTERN CANAL	100	0	0
CHURN CREEK NEAR ANDERSON	100	0	0
COW CREEK NEAR MILLVILLE	100	0	0
DEER CREEK AT HWY 99E NEAR VINA	100	0	0

Station Name	Arsenic (%)	Manganese (%)	Mercury (%)
Eastside Tributary Subregion			
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	95	5	0
NORTH HONCUT CREEK HWY 70	100	13	0
PAYNES CREEK AT PAYNES CROSSING	100	0	0
STILLWATER CREEK NEAR ANDERSON	90	0	0
Westside Tributary Subregion			
CLEAR CREEK NEAR MOUTH NEAR REDDING	100	0	0
COTTONWOOD CREEK AT COTTONWOOD	100	8	0
ELDER CREEK AT GERBER	57	0	0
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	45	5	0
STONY CREEK AT THE NATURE CONSERVANCY	67	0	0
THOMES CREEK AT HALL ROAD	72	11	0
Upper Feather River Subregion			
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	100	0	0
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	92	23	0
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	100	8	0
Sacramento Valley Subregion			
BEAR RIVER NEAR MOUTH	100	8	0
BUTTE SLOUGH NEAR MERIDIAN	100	38	0

Station Name	Arsenic (%)	Manganese (%)	Mercury (%)
Sacramento Valley Subregion			
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING	96	92	0
FEATHER RIVER NEAR VERONA	100	0	0
SACRAMENTO RIVER AT VERONA	100	4	0
SACRAMENTO RIVER AT BALLS FERRY	100	0	0
SACRAMENTO RIVER AT BEND BRIDGE	100	0	0
SACRAMENTO RIVER AT COLUSA	100	8	0
SACRAMENTO RIVER AT HAMILTON CITY	100	2	0
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	100	8	0
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	100	0	0
SACRAMENTO RIVER BELOW KNIGHTS LANDING	100	0	0
SACRAMENTO RIVER BELOW RED BLUFF	100	4	0
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK	100	46	0
YUBA RIVER AT MOUTH	96	0	4

Notes: Sampling occurred November 2008 through August 2014. Parameters that were not above fish consumption criteria for any of the sampled stations were omitted. Note the high percentage of samples above the arsenic threshold is due to the arsenic threshold being very low (0.14 µg/L) to protect people that consume fish.

Table 7 Samples Equal to or Above California Toxics Rule Criteria for Freshwater Aquatic Life Protection Established by the U.S. Environmental Protection Agency

Station Name	Dissolved Copper (µg/L)		Total Copper (µg/L)		Total Nickel (µg/L)		Total Lead (µg/L)		Sample Date (month/ year)	Turbidity (NTU)	Total Suspended Solids (mg/L)
	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)			
MCCLOUD RIVER ABOVE SHASTA LAKE	0	0	0	0	0	0	0	0	2/09	36.9	36
PIT RIVER NEAR CANBY	0	0	4.3	0	0	0	0	0	2/09	195	198
COW CREEK NEAR MILLVILLE	4.3	0	4.3	0	0	0	0	0	2/09	38.6	7
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	0	0	4.5	0	0	0	4.5	0	5/09	426	448
CLEAR CREEK NEAR MOUTH NEAR REDDING	0	0	0	0	0	0	4.2	0	2/09	35.2	26
COTTONWOOD CREEK AT COTTONWOOD	0	0	4.2	0	0	0	0	0	2/09	231	98
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	0	0	7.7	0	0	0	0	0	2/10	20	19
BEAR RIVER NEAR MOUTH	8.3	0	12.5	4.2	0	0	4.2	0	2/09, 2/10, 2/12	59.6, 101, 76	33, 29, 47
NORTH HONCUT CREEK AT HWY 70	4.2	0	8.3	0	0	0	0	0	2/09, 5/09	40.9, 43.1	16,15
SACRAMENTO RIVER AT BALLS FERRY	0	0	4.2	4.2	0	0	0	0	2/09	64.3	31
SACRAMENTO RIVER AT BEND BRIDGE	0	0	4.2	0	0	0	4.2	0	2/09	127	80
SACRAMENTO RIVER AT COLUSA	0	0	8.0	8.0	0	0	8.0	0	2/09	140	204
SACRAMENTO RIVER AT DELTA	0	0	0	0	4.2	0	0	0	2/09	32.4	27
SACRAMENTO RIVER AT HAMILTON CITY	0	0	2.3	0	0	0	0	0	2/09	109	135

Station Name	Dissolved Copper (µg/L)		Total Copper (µg/L)		Total Nickel (µg/L)		Total Lead (µg/L)		Sample Date (month/ year)	Turbidity (NTU)	Total Suspended Solids (mg/L)
	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)	Continuous concentration (4 days)	Maximum concentration (1 hour)			
SACRAMENTO RIVER AT VERONA	0	0	4.2	4.2	0	0	4.2	0	2/09	68.4	41
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	0	0	8.3	4.2	0	0	8.3	0	2/09, 5/09	102, 263	83, 232
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	0	0	4.2	4.2	0	0	0	0	2/09	108	80
SACRAMENTO RIVER BELOW KNIGHTS LANDING	0	0	8.3	4.2	0	0	0	0	2/09, 5/09	71.5, 23.1	66, 55
SACRAMENTO RIVER BELOW RED BLUFF	0	0	4.2	4.2	0	0	4.2	0	2/09	214	136

Notes: µg/L = micrograms per liter, mg/L = milligrams per liter, NTU = nephelometric turbidity units
Freshwater aquatic life thresholds are hardness-dependent criteria. Results are shown for continuous concentration (four-day average) and maximum concentration (one-hour average). Sampling occurred November 2008 through August 2014. Stations and parameters that were not above freshwater aquatic life protection criteria were omitted. Note that all sampling events with results above recommended criteria occurred during high winter/spring flows in February or May.

4.4 Bacteria Results

Results for *E. coli* are reported as most probable number (MPN) per 100 mL and are displayed in Table 8. The MPN is a statistical method used to estimate the number of viable microorganisms living in a test sample. The 320 MPN/100 mL recommended criteria is a statistical threshold value that approximates the 90th percentile and is intended to be a value that should not be exceeded by more than ten percent of samples to protect recreational use of water (US Environmental Protection Agency 2012).

4.4.1 Northeast Subregion

Of the 205 bacteria samples collected in the Northeast Subregion, only one sample was above the 320 MPN/100 mL recommended criteria. A value of 547.5 MPN/100 mL was calculated for a sample collected on May 8, 2013 at the South Fork Pit River near Alturas (Table 8). The highest *E. coli* numbers within the subregion were concentrated near the town of Alturas, with slightly lower numbers at Canby. Sample maximum increased slightly near the town of Pittville as well, before decreasing again in lower elevation stations in the Pit River watershed.

4.4.2 Eastside Tributary Subregion

Of the 240 bacteria samples collected in the Eastside Tributary Subregion, 15 samples were above the 320 MPN/100 mL recommended criteria. The Butte and Battle Creek stations were the only locations that were not above the recommended criteria. Of all stations, Antelope Creek had the greatest number of samples above the recommended criteria.

4.4.3 Westside Tributary Subregion

Of the 89 bacteria samples collected in the Westside Tributary Subregion, seven were above the 320 MPN/100 mL recommended criteria. Clear Creek was the only station that had no samples above the recommended criteria.

4.4.4 Upper Feather River Subregion

Of the 36 bacteria samples collected in the Upper Feather River Subregion, three were above the 320 MPN/100 mL recommended criteria. The middle fork of the Feather River had no samples above the recommended criteria.

4.4.5 Sacramento Valley Subregion

Of the 344 bacteria samples collected in the Sacramento Valley Subregion, 14 were above the 320 MPN/100 mL recommended criteria. Sacramento River at Balls Ferry, Butte Slough near Meridian, Sutter Bypass, Yuba River, and Feather River near Verona were the only stations that had no samples above the recommended criteria.

Table 8 Summary of *E. Coli* Results Reported as the Most Probable Number per 100 milliliter (ml) (MPN/100 ml)

Station Name	n	Samples > 320 MPN/100 ml (%)	Sample Minimum (MPN/100 ml)	Sample Maximum (MPN/100 ml)	Sample Mean (MPN/100 ml)
Northeast Subregion total	205	0.5	1.0	548	31.3
FALL RIVER AT GLENBURN	26	0	1	37	26
MCCLOUD RIVER ABOVE SHASTA LAKE	26	0	1	21	65
PIT RIVER NORTH FORK AT ALTURAS	26	0	7	179	39
PIT RIVER SOUTH FORK NEAR ALTURAS	25	4	1	548	27
PIT RIVER NEAR CANBY	26	0	1	105	33
PIT REAR AT PITTVILLE	26	0	1	172	33
PIT RIVER NEAR MONTGOMERY CREEK	24	0	1	91	7
SACRAMENTO RIVER AT DELTA	26	0	1	28	71
Eastside Tributary Subregion total	240	6.3	2.0	1553	117.7
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	23	13	12	1553	224
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	23	0	8	152	40
BEAR CREEK NEAR ANDERSON	23	9	12	727	160
BIG CHICO CREEK AT CHICO	21	10	91	411	201
BUTTE CREEK DOWNSTREAM WESTERN CANAL	23	0	16	140	55

Station Name	n	Samples > 320 MPN/100 ml (%)	Sample Minimum (MPN/100 ml)	Sample Maximum (MPN/100 ml)	Sample Mean (MPN/100 ml)
Eastside Tributary Subregion total					
CHURN CREEK NEAR ANDERSON	22	5	3	687	91
COW CREEK NEAR MILLVILLE	23	4	31	921	126
DEER CREEK AT HWY 99E NEAR VINA	23	4	3	387	79
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	19	11	2	411	83
PAYNES CREEK AT PAYNES CROSSING	23	9	8	613	133
STILLWATER CREEK NEAR ANDERSON	17	6	4	816	103
Westside Tributary Subregion total	89	7.9	0.0	2419	159.5
CLEAR CREEK NEAR MOUTH NEAR REDDING	23	0	3	37	16
COTTONWOOD CREEK AT COTTONWOOD	23	4	6	727	77
ELDER CREEK AT GERBER	10	20	38	1120	259
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	9	11	9	727	140
STONY CREEK AT THE NATURE CONSERVANCY	11	9	4	2420	247
THOMES CREEK AT HALL ROAD	13	15	0	1414	219

Station Name	n	Samples >320 MPN/100 ml (%)	Sample Minimum (MPN/100 ml)	Sample Maximum (MPN/100 ml)	Sample Mean (MPN/100 ml)
Upper Feather River Subregion total	36	8.3	2.0	517	105.6
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	12	0	2	173	42
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	12	17	4	435	153
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	12	8	8	517	122
Sacramento Valley Subregion total	344	4.1	1.0	980	55.6
BEAR RIVER NEAR MOUTH	23	9	15	649	135
BUTTE SLOUGH NEAR MERIDIAN	23	0	19	157	73
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING	22	5	6	387	60
FEATHER RIVER NEAR VERONA	23	0	2	248	31
SACRAMENTO RIVER AT VERONA	23	4	4	517	51
SACRAMENTO RIVER AT BALLS FERRY	23	0	6	179	36
SACRAMENTO RIVER AT BEND BRIDGE	23	9	9	344	48
SACRAMENTO RIVER AT COLUSA	23	9	1	816	60
SACRAMENTO RIVER AT HAMILTON CITY	23	4	4	345	41
SAC RIVER AT VINA	23	9	1	866	83

Station Name	n	Samples >320 MPN/100 ml (%)	Sample Minimum (MPN/100 ml)	Sample Maximum (MPN/100 ml)	Sample Mean (MPN/100 ml)
Sacramento Valley Subregion total					
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	23	4	1	687	45
SACRAMENTO RIVER BELOW KNIGHTS LANDING	23	4	2	548	41
SACRAMENTO RIVER BELOW RED BLUFF	23	4	8	980	70
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK	23	0	6	119	33
YUBA RIVER AT MOUTH	23	0	1	261	27

Source: State Water Resources Control Board 2008.
Notes: ml = milliliter, MPN = most probable number, n = sample size
The 320 MPN/100 ml standard is a threshold value that should not be exceeded by more than ten percent of samples to protect recreational uses of water (U.S Environmental Protection Agency 2012). Table shows the number of bacteria samples collected between November 2008–August 2014 (n) and the proportion of these samples that were above the recommended criteria (%). Minimum, maximum, and mean MPN/100 ml are shown for each station, as well as for each subregion.

Chapter 5. Discussion and Conclusion

5.1 Sampling Period Considerations

Water quality during the SWCMP monitoring period was very likely affected by drought conditions, which began in 2011 and continued for the duration of the monitoring period summarized in this report. A reduced number of sampling events was one of the most obvious effects of drought on the SWCMP. Even though some tributaries are ephemeral streams that normally become dry during the summer/fall dry season, some of these streams were dry even during May and November sampling events. Water quality parameters most likely affected by drought were temperature, dissolved oxygen, and water chemistry. Lower flows and warm air temperature influenced water temperatures captured by continuously recording data loggers; and because warm water holds less oxygen than cold water, these high-water temperatures likely contributed to low dissolved oxygen levels as well. A longer and warmer growing season may also have contributed to greater growth of aquatic vegetation and algae, which while decaying could have further depressed dissolved oxygen levels. Lower flows during drought may have provided less dilution for solutes, leading to higher concentrations of certain pollutants. Alternatively, it is possible that because there was less precipitation runoff during drought years, the input of dissolved contaminants may have been reduced. Drought conditions may have allowed some contaminants to accumulate on land surfaces and be released during heavy rain events.

5.2 Subregion Summaries

5.2.1 Northeast Subregion

Most of the SWCMP monitoring stations within the Northeast Subregion are above or below major dams that influence hydrology and water quality. Most of the dams are operated for hydropower generation, so water released from reservoirs does not usually match the typical timing and extent of flows characterizing unaltered hydrological conditions. Because fish passage is blocked by Keswick Dam on the Sacramento River, no anadromous salmonid populations exist in this region of the Sacramento River watershed.

For some Northeast Subregion streams (Pit River stations), dissolved oxygen levels were depressed during the May through November monitoring events. The lowest dissolved oxygen levels were measured between 2012–2014. This period was also characterized by drought, which likely had an influence on the observed dissolved oxygen levels.

Water samples from the Northeast Subregion were above assessment thresholds based on California-mandated primary and secondary MCLs, agricultural limits, and fish consumption criteria. Relatively high measurements for aluminum, iron, manganese, and arsenic found at some stations in this subregion are likely a result of natural weathering of rock and soil. Metals are typically bound to fine-sediment particles transported through the system during the increased flows created by rain events. The highest measured levels of these metals were in the upper watershed relative to the remaining stations in the subregion. Elevated levels of boron and sodium can probably also be attributed to the natural condition of water in this subregion, or to agricultural sources and less likely to industrial sources. Most bacteria samples met criteria for contact recreation.

5.2.2 Eastside Tributary Subregion

Most of the SWCMP monitoring stations within the Eastside Tributary Subregion are on the Central Valley floor near their confluence with the mainstem Sacramento River. Eastside Tributary Subregion streams can contain anadromous salmonids, including fall-run Chinook salmon, federally and State-listed spring-run Chinook salmon, and federally threatened Central Valley steelhead. Streams, including Butte, Big Chico, Deer, Mill, and Antelope creeks, provide important remnant habitat to spring-run Chinook salmon in the Central Valley. Most eastside tributary streams are diverted by low-head diversion dams to serve irrigated agriculture and pasture. During drought years, several streams in this subregion were dewatered during the summer and fall months at SWCMP monitoring stations.

Water samples from the Eastside Tributary Subregion were above assessment thresholds based on the California-mandated primary and secondary MCLs, agricultural limits, and fish consumption criteria. Relatively high measurements for aluminum, iron, manganese, and boron found at some stations are most likely a result of the natural geology of the watershed, although anthropogenic sources do exist for some of these parameters. High arsenic levels in Antelope Creek and Mill Creek are a result of these watersheds' volcanic geology. One station (Bear Creek) was above fish consumption criteria for mercury, which is a legacy of the gold mining era. Bacteria results were unremarkable, with most samples meeting criteria for contact recreation.

5.2.3 Westside Tributary Subregion

Westside tributaries originate from the Coast Ranges, which have distinctly different geology than the mostly volcanic eastside tributary watersheds. Clear Creek contains habitat for spring-run and fall-run Chinook salmon as well as steelhead and has had extensive habitat restoration projects completed to support these species, including dam removal. Cottonwood Creek also supports salmonids. Red Bank, Elder, Thomes, and Stony creeks are ephemeral and are dewatered during the summer/fall dry season. However, these streams may provide non-natal rearing habitat to juvenile salmonids during the wet season (Maslin et al. 1996).

Water samples from the Westside Tributary Subregion were above assessment thresholds based on the California-mandated primary MCLs, California secondary MCLs, agricultural limits, and fish consumption criteria. Relatively high concentrations of aluminum, iron, and manganese at some stations are most likely part of the natural geology and condition of many westside tributary streams. Arsenic levels above fish consumption criteria for all stations are also probably because of natural sources, but human sources of arsenic do exist from agricultural pesticides and preserved wood products. Bacteria results were unremarkable, with most samples meeting criteria for contact recreation.

5.2.4 Upper Feather River Subregion

The Upper Feather River Subregion lies upstream of a major system of hydroelectric dams and Oroville Dam. Oroville Dam and the associated Orville Fish Hatchery fish barrier dam are the lowest dams in the system and completely block passage of anadromous fish species from entering this subregion. Water quality is still important for these streams, which support a robust recreational fishery.

Water samples from the Upper Feather River Subregion were above assessment thresholds based on the California secondary MCLs, agricultural limits, and fish consumption criteria. Relatively high concentrations of aluminum, iron, manganese, and arsenic are most likely a result of the local geology, rather than anthropogenic sources. Bacteria results were unremarkable, with most samples meeting criteria for contact recreation.

5.2.5 Sacramento Valley Subregion

The Sacramento Valley Subregion includes monitoring stations on the mainstem Sacramento River, on large southern Sacramento Valley tributaries (Yuba, Bear, and Feather rivers), as well as on floodways (Sutter Bypass and Butte Slough) and an agricultural drain (Colusa Basin Drain). The Colusa Basin Drain carries return flows from water diverted upstream to irrigate farm and pastureland, mostly in the westside subregion. In addition to intensive agriculture, water quality in the Sacramento Valley Subregion is also influenced by urban centers, such as Redding, Red Bluff, Corning, Chico, and Colusa, which contribute urban runoff and treated wastewater to the system.

The Sacramento River is home to four distinct runs of Chinook salmon (fall-, late-fall-, winter- and spring-run) as well as steelhead and green and white sturgeon; yet, much of the historic habitat for these species is no longer accessible because of several dams (Shasta Dam on the Sacramento River, Oroville Dam on the Feather River, and Bullards Bar Dam and Englebright Dam on the Yuba River). These dams, along with several major diversions and pumping plants, modify the natural hydrology in the remaining anadromous fish habitat.

Water samples from the Sacramento Valley Subregion were above assessment thresholds based on the California-mandated primary and secondary MCLs, agricultural limits, and fish consumption criteria. Relatively high concentrations of aluminum, arsenic, iron, and manganese are mostly a result of natural weathering of minerals present in the surrounding watershed. Elevated results for specific conductance, total dissolved solids, and arsenic at some stations could be because of natural sources or the intensive agricultural activities surrounding some of the monitoring stations. Mercury levels above fish consumption criteria at one station (Yuba River) are a legacy effect from the gold mining era. Bacteria results were unremarkable, with most samples meeting criteria for contact recreation.

5.2.6 Conclusion

The data in this report provide baseline field-measured, chemical, and biological information with which to compare future monitoring data. Based on the water year types that occurred during the sampling period, the data contained in this report may also be used to demonstrate water quality during mostly dry (drought) conditions and to compare with future water quality data during normal or wet water years. These baseline data could eventually contribute to the identification of climate-influenced patterns in Sacramento River water quality.

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Appendix A
Quality Assurance/ Quality Control Results

Table A-1 Percentage of Acceptable Results Based on a "Five Times" Analysis for Parameters Analyzed in Water Samples Collected November 2008 through August 2014

Parameter	Percentage Acceptance (%)
Individual Nutrient Parameters	
Dissolved ammonia mg/L as N †	89.7
Dissolved nitrate + Nitrite mg/L as N †	99.9
Dissolved organic carbon mg/L as C †	100
Dissolved organic nitrogen mg/L as N †	100
Dissolved orthophosphate mg/L as P †	100
Total phosphorus mg/L as P †	100
Total Kjeldahl nitrogen mg/L as N †	100
Individual trace elements	
Dissolved aluminum µg/L	91.9
Total aluminum µg/L	98.0
Dissolved arsenic µg/L †	99.9
Total arsenic µg/L	99.9
Dissolved cadmium µg/L	100
Total cadmium µg/L	100
Dissolved chromium µg/L	99.8
Total chromium µg/L	99.8
Dissolved copper µg/L	98.1

Parameter	Percentage Acceptance (%)
Individual trace elements	
Total copper µg/L	99.0
Dissolved iron µg/L	99.9
Total iron µg/L	99.9
Dissolved lead µg/L	100
Total lead µg/L	100
Dissolved manganese µg/L	99.9
Total manganese µg/L	99.9
Total mercury ng/L	73.6*
Dissolved nickel µg/L	99.7
Total nickel µg/L	99.8
Dissolved selenium µg/L	100
Total selenium µg/L	100
Dissolved silver µg/L	100
Total silver µg/L	100
Dissolved zinc µg/L	85.8*
Total zinc µg/L	27.8*

Parameter	Percentage Acceptance (%)
Overall Percentage Acceptance	
Entire sample suite	95.9
Entire sample suite with zinc and aluminum removed	99.1
Nutrient parameters	97.9
Trace elements	95.5
Trace elements with zinc and aluminum removed	99.4

Notes: mg/L = milligrams per liter, µg/L = micrograms per liter.

The "five times analysis" assigns a qualifier to any result that is less than or equal to five times the blank result. Samples with a qualifier are considered to have failed the "five times analysis," and prompt further investigation into potential causes of blank sample contamination, such as improper sample collection methods. Samples lacking a qualifier are considered to have passed the "five times analysis." The percentage acceptance was calculated for each parameter by dividing the total number of samples that passed the "five times analysis" by the total number of samples collected for that particular parameter. Parameters not analyzed in blank samples were omitted from the table. Asterisks denote a percentage complete value that fails to meet the 90 percent goal. Daggers (**†)** denote parameters required to be sampled under the Sacramento Watershed Coordinated Monitoring Program. Nutrient and trace element parameters are listed separately (see Table 2 for parameters). The overall percentage acceptance shows results for the entire suite of parameters analyzed (nutrient and trace element categories combined). Because zinc is a known contaminant in blank water, it had an elevated fail rate. Aluminum is another contaminant in blank water, although it still exhibited a high-percentage acceptance. Because the "five times analysis" is not an appropriate Quality Assurance/Quality Control process for evaluating parameters present in blank water, the overall percentage acceptance is shown with and without zinc and aluminum incorporated into the calculation. Total mercury had low percentage acceptance because it is detectable at very low concentrations.

Table A-2 Duration of Temperature Data Logging and Data Quality for Continuous Temperature Data Loggers

Station Name	Duration (years)	Reliability (%)
Northeast Subregion total		
FALL RIVER AT GLENBURN	5.77	100
MCCLOUD RIVER ABOVE SHASTA LAKE	6.25	90.56
PIT RIVER NORTH FORK AT ALTURAS	5.46	79.12
PIT RIVER SOUTH FORK NEAR ALTURAS	5.77	98.46
PIT RIVER NEAR CANBY	5.77	86.05
PIT RIVER AT PITTVILLE	5.77	100
PIT RIVER NEAR MONTGOMERY CREEK	5.77	89.59
SACRAMENTO RIVER AT DELTA	6.25	98.61
Eastside Tributary Subregion total		
ANTELOPE CREEK NEAR MOUTH NEAR RED BLUFF	4.98	93.26
BATTLE CREEK AT JELLY'S FERRY ROAD BRIDGE	5.54	86.55
BEAR CREEK NEAR ANDERSON	5.54	92.86
BIG CHICO CREEK AT CHICO	5.45	93.23
BUTTE CREEK DOWNSTREAM WESTERN CANAL	5.76	100
CHURN CREEK NEAR ANDERSON	5.54	86.47
COW CREEK NEAR MILLVILLE	5.72	98.49
Eastside Tributary Subregion total		
DEER CREEK AT HWY 99E NEAR VINA	5.27	94.31

Station Name	Duration (years)	Reliability (%)
Eastside Tributary Subregion total		
MILL CREEK NEAR MOUTH NEAR LOS MOLINOS	5.55	53.91
NORTH HONCUT CREEK AT HWY 70	5.46	74.49
PAYNES CREEK AT PAYNES CROSSING	5.54	89.68
STILLWATER CREEK NEAR ANDERSON	5.54	77.63
Westside Tributary Subregion total		
CLEAR CREEK NEAR MOUTH NEAR REDDING	6.27	81.70
COTTONWOOD CREEK AT COTTONWOOD	6.02	86.91
ELDER CREEK AT GERBER	5.54	45.90
RED BANK CREEK AT OLD HWY 99 NEAR RED BLUFF	5.54	39.86
STONY CREEK AT THE NATURE CONSERVANCY	5.54	45.83
THOMES CREEK AT HALL ROAD	5.54	39.18
Upper Feather River Subregion total		
FEATHER RIVER MIDDLE FORK UPSTREAM GRIZZLY CREEK	2.99	89.24
INDIAN CREEK UPSTREAM ARLINGTON BRIDGE	2.99	92.93
SPANISH CREEK DOWNSTREAM GREENHORN CREEK	2.99	100
Sacramento Valley Subregion total		
BEAR RIVER NEAR MOUTH	5.77	84.07
BUTTE SLOUGH NEAR MERIDIAN	5.76	93.95
COLUSA BASIN DRAIN NEAR KNIGHTS LANDING	6.26	82.16

Station Name	Duration (years)	Reliability (%)
Sacramento Valley Subregion total		
FEATHER RIVER NEAR VERONA	5.56	96.61
SACRAMENTO RIVER AT VERONA	5.57	86.75
SACRAMENTO RIVER AT BALLS FERRY	6.01	84.19
SACRAMENTO RIVER AT BEND BRIDGE	6.01	75.31
SACRAMENTO RIVER AT COLUSA	5.76	95.68
SACRAMENTO RIVER AT HAMILTON CITY	6.01	88.46
SACRAMENTO RIVER AT VINA BRIDGE NEAR CORNING	6.01	93.97
SACRAMENTO RIVER ABOVE COLUSA BASIN DRAIN	5.76	94.29
SACRAMENTO RIVER BELOW KNIGHTS LANDING	5.26	46.87
SACRAMENTO RIVER BELOW RED BLUFF	5.54	94.81
SUTTER BYPASS AT RECLAMATION DISTRICT 1500 PUMP AT KARNAK	5.76	94.26
YUBA RIVER AT MOUTH	5.54	58.48

Notes: Reliability is the proportion of data that were valid, excluding data from loggers that were out of water, missing/vandalized, or logging after a stream became dewatered.