

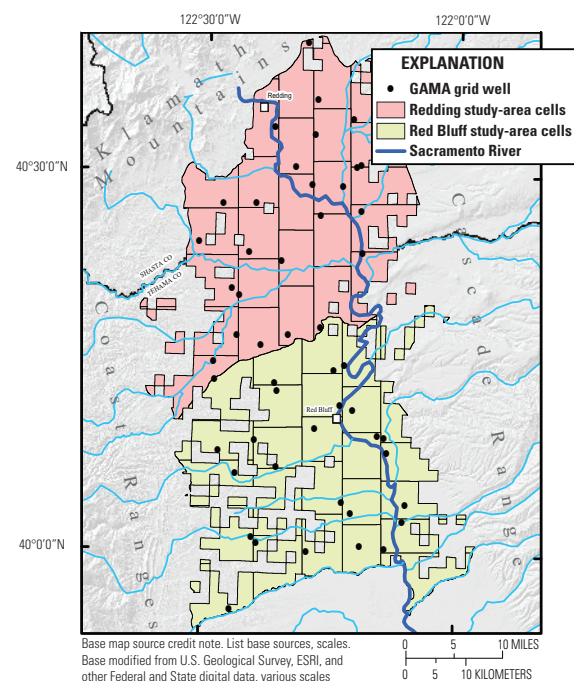
U.S. Geological Survey and the California State Water Resources Control Board

Groundwater Quality in the Redding–Red Bluff Shallow Aquifer Study Unit of the Northern Sacramento Valley, California

Groundwater provides more than 40 percent of California’s drinking water. To protect this vital resource, the State of California created the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The Priority Basin Project of the GAMA Program provides a comprehensive assessment of the State’s groundwater quality and increases public access to groundwater-quality information. Private domestic and small system drinking water wells in the Redding–Red Bluff study unit primarily draw from shallow aquifers which are the target for this assessment.



The Redding–Red Bluff Shallow Aquifer Study Unit



The Redding–Red Bluff study unit covers approximately 1,200 square miles in Shasta and Tehama Counties, California, at the northern end of the Sacramento Valley. The study unit covers groundwater basins in the Redding area and the northern Sacramento Valley. The Sacramento River flows through the study area.

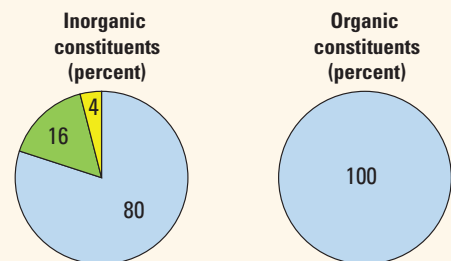
Groundwater aquifers within the regional study area are composed of marine, continental, and volcanic alluvial sediments derived from the surrounding mountain ranges: The Cascade Range to the east, the Klamath Mountains to the north, and the Coast Ranges to the west. The study unit is dominated by natural land use (60 percent),

with urban use more common in the Redding study area (36 percent) and agricultural land use more common in the Red Bluff study area (20 percent).

This study was designed to provide a statistically representative assessment of the quality of groundwater resources used for domestic drinking water in the Redding–Red Bluff study unit. A total of 50 wells were sampled between December 2018 and April 2019 (Shelton and others, 2020). Domestic wells in the study unit typically are drilled to depths of 80–338 feet (10th–90th percentiles; Shelton and others, 2020), which are shallower ($p < 0.001$) than the depths of public-supply wells in the same area (typically 115–450 feet deep; Bennett and others, 2011). Water levels in domestic wells in the study unit typically are 15–163 feet below land surface (10th–90th percentiles; Shelton and others, 2020).

Previous investigations of public supply wells in the study area found relatively low concentrations of inorganic and volatile organic compounds compared to state and national benchmarks, except for arsenic (4.6 percent; Bennett and others, 2011). A State Water Resources Control Board GAMA survey of domestic wells in Tehama County (223 wells), which includes the Red Bluff study area, reported arsenic concentrations above the benchmark (see page 3) in 13 percent of wells, primarily in the southeast part of the study area (California State Water Resources Control Board, 2009). However, these wells were not spatially distributed and do not represent aquifer-scale portions as described herein.

Overview of Water Quality



CONSTITUENT CONCENTRATIONS

High Moderate Low or not detected

Values indicate percentages of the area of the groundwater resources used for domestic drinking water with concentrations in the specified categories.

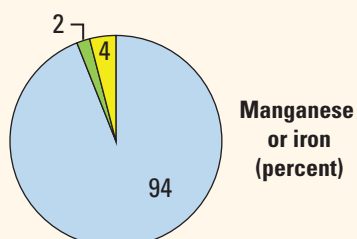
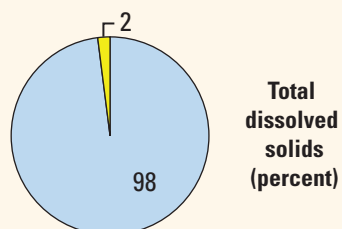
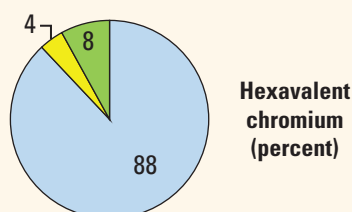
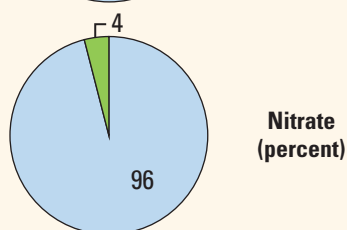
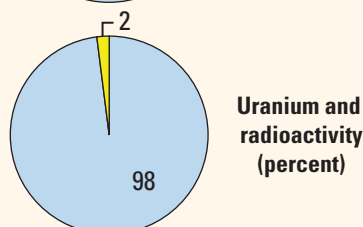
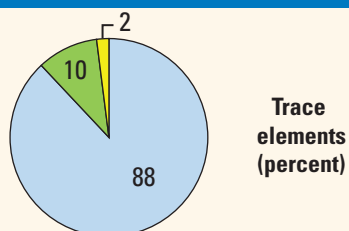
GAMA’s Priority Basin Project evaluates the quality of untreated groundwater. For the purpose of this study, concentrations measured in groundwater are compared to benchmarks established for drinking water quality, such as maximum contaminant levels (MCL). In this study, a concentration above a benchmark is defined as high. Benchmarks and definitions of moderate and low concentrations are discussed under “Methods for Evaluating Groundwater Quality.”

Many inorganic constituents naturally occur in groundwater, and the concentrations of the inorganic constituents can be affected by natural processes as well as by human activities. In the Redding–Red Bluff study unit, one or more inorganic constituents were present at high concentrations in about 4 percent of the groundwater resources used for domestic drinking water.

Human-made organic constituents are found in products used in the home, business, industry, and agriculture and can enter the environment through normal usage, spills, or improper disposal. Organic constituents were not present at high concentrations in the groundwater resources used for domestic drinking water in the Redding–Red Bluff study unit.

RESULTS: Groundwater Quality in Shallow Aquifers in the Western Mojave Desert, California

INORGANIC CONSTITUENTS



Inorganic Constituents with Human-Health Benchmarks

Trace elements are naturally present in the minerals of rocks and sediment that compose groundwater aquifers and dissolve into groundwater that comes into contact with those materials. About 2 percent of the groundwater resources used for domestic drinking water in the Redding–Red Bluff Shallow Aquifer study unit had high concentrations of one or more trace elements and about 10 percent had moderate concentrations. Two elements were present at concentrations above benchmarks: strontium and barium; and three elements were present at moderate concentrations (half the benchmark): arsenic, boron, and chromium.

Radioactivity is the release of energy or energetic particles during spontaneous decay of unstable atoms. Most of the radioactivity in groundwater comes from the decay of isotopes of uranium and thorium in aquifer materials. In 2 percent of domestic wells from the study unit, gross alpha particle activities were above the benchmark.

Nutrients, including nitrate, are naturally present at low concentrations in groundwater, and high concentrations generally result from human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. Nitrate was present at moderate concentrations in about 4 percent of the groundwater resources used for domestic drinking water in the study unit.

Hexavalent Chromium

(Not included in water quality overview charts shown on the front page)

Hexavalent chromium Cr(VI) is a species of the trace metal chromium that may be toxic to humans. Hexavalent chromium can be naturally present in groundwater interacting with sediments derived from ultramafic rocks (or serpentinites) or released from anthropogenic uses such as stainless-steel manufacturing or other industrial processes. The drinking-water benchmark used for hexavalent chromium comparisons in this study is the USGS health-based screening level of 20 parts per billion (ppb), because the California MCL of 10 ppb was withdrawn in 2017 (California State Water Resources Control Board, 2017).

Hexavalent chromium was present at high concentrations above the benchmark in 4 percent of groundwater resources used for domestic drinking water in the Redding–Red Bluff study unit and moderate concentrations above half the benchmark in 8 percent of groundwater resources.

Inorganic Constituents with Non-Health Benchmarks

(Not included in water-quality overview charts shown on the front page)

Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or can create nuisance problems, such as staining and scaling. The benchmarks used for these constituents were non-regulatory secondary maximum contaminant level benchmarks.

Total dissolved solids (TDS) concentration is an indicator of groundwater salinity, and all water naturally contains TDS as a result of interactions with rocks and sediments such as the weathering and dissolution of minerals. The State of California has a recommended and an upper limit for TDS in drinking water. Total dissolved solids concentrations were high (greater than the upper limit) in about 2 percent of the groundwater resources used for domestic drinking water in the Redding–Red Bluff study unit.

Anoxic conditions, defined as having a dissolved oxygen concentration less than 0.5 parts per million (ppm), can result in release of manganese, iron, and other associated trace elements from minerals into groundwater (McMahon and Chapelle, 2007). Manganese or iron was present at concentrations above benchmarks set for aesthetic concerns in about 4 percent of the groundwater resources used for domestic drinking water.

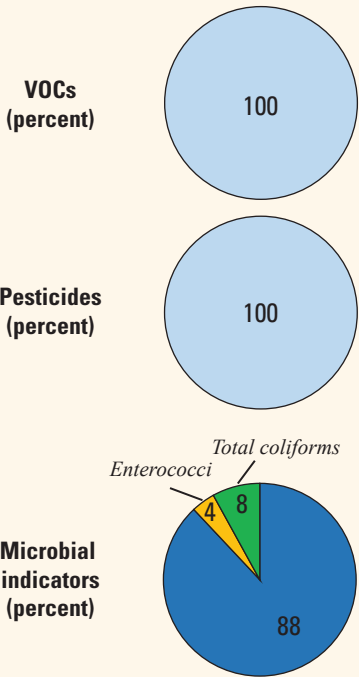
RESULTS: Groundwater Quality in Shallow Aquifers in the Western Mojave Desert, California

Organic Constituents with Human-Health Benchmarks

The Priority Basin Project uses laboratory methods that can detect low concentrations of volatile organic compounds (VOCs) and pesticides that are far below human-health benchmarks. The VOCs and pesticides detected at these very low concentrations can be used to help trace the movement of water from the landscape into the aquifer system.

Many household, commercial, and industrial products, including solvents, gasoline components, and refrigerants, contain VOCs. Pesticides, including herbicides, insecticides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation, insects, fungi, and other pests. There were no VOCs or pesticides found at high or moderate concentrations. Volatile organic compounds were detected at low concentrations in 16 percent and pesticides were detected in 4 percent of domestic wells. The most common VOCs detected were disinfection by-products and the most common pesticides were atrazine and simazine.

ORGANIC CONSTITUENTS



Microbial Indicator Constituents

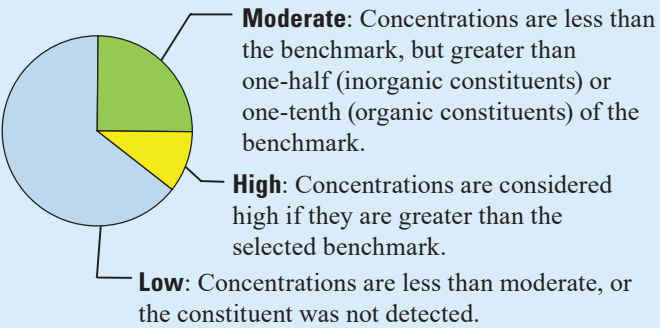
(Not included in water-quality overview charts shown on the front page)

Microbial indicator constituents are used to evaluate the potential for fecal contamination of water sources. Total coliforms and *Enterococci* are naturally present in soils and digestive tracts of animals. In the Redding–Red Bluff Shallow Aquifer study unit, total coliforms were present in 8 percent of the domestic drinking water wells. *Enterococci* was present in 4 percent of the wells but not in the wells with total coliforms present. *Escherichia coli* (*E. coli*), analyzed as part of the total coliform measurements, were not detected. The pie diagram for microbial constituents uses different colors because the benchmarks for microbial constituents specify repeat sampling to confirm detections, which was not done in this study.

Methods for Evaluating Groundwater Quality

GAMA’s Priority Basin Project uses benchmarks established for drinking water to provide context for evaluating the quality of groundwater. The quality of drinking water can differ from the quality of groundwater because of contact with household plumbing, exposure to the atmosphere, or water treatment. The U.S. Environmental Protection Agency (EPA) and California State Water Resources Control Board Division of Drinking Water (CA) regulatory benchmarks set for the protection of human health (maximum contaminant level, MCL) were used when available. Otherwise, non-regulatory benchmarks set for the protection of aesthetic properties, such as taste and odor (secondary maximum contaminant level, SMCL) and nonregulatory benchmarks set for the protection of human health (health-based screening levels, HBSL; response levels, RL; notification levels, NL; and lifetime health advisory levels, HAL) were used (Shelton and others, 2020). Water quality in private domestic wells is not regulated in California.

Pie diagrams are used to summarize groundwater-quality results. The pie slices represent the percentage of the domestic water wells with high, moderate, and low concentrations of a constituent. Methods for calculating the percentages shown in the pie diagrams are discussed by Bennett and others (2011).



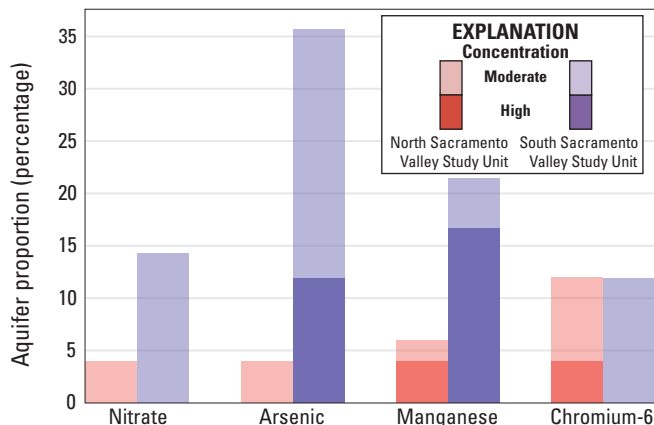
Benchmark type and value for selected constituents.

[Benchmark types: EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; USGS, U.S. Geological Survey; HBSL, health-based screening level; HAL, lifetime health advisory; CA, California State Water Resources Control Board Division of Drinking Water; SMCL, secondary maximum contaminant level. Abbreviations: ppb, parts per billion; ppm, parts per million; pCi/L, picocuries per liter; TT, treatment technique; >, greater than]

Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	EPA-MCL	10 ppb	Iron	CA-SMCL	300 ppb
Nitrate, as nitrogen	EPA-MCL	10 ppm	Manganese	CA-SMCL	50 ppb
Hexavalent chromium (non-cancer and cancer)	USGS-HBSL	20 ppb and 4 ppb	Total dissolved solids (TDS) (upper and recommended)	CA-MCL	1,000 ppm and 500 ppm
Strontium	EPA-HAL	4,000 ppb	Perchlorate	CA-MCL	6 ppb
Barium	EPA-MCL	1,000 ppb	Enterococci	EPA-TT	No bacteria
Boron	EPA-HAL	6,000 ppb	<i>Escherichia coli</i> (<i>E. coli</i>)	EPA-MCL	Repeat detection at a site
Chromium	CA-MCL	50 ppb			
Adjusted gross alpha particle activity	EPA-MCL	15 pCi/L	Total coliforms	EPA-TT	>5 percent of samples with detections per month

Comparison of Water Quality Between North and South Sacramento Valley Shallow Aquifer Study Units

Aquifer proportions (percentages of wells) with moderate with high concentrations in domestic drinking-water wells were lower in the Redding–Red Bluff study unit in the northern Sacramento Valley for some groundwater constituents with water-quality benchmarks compared to domestic wells in the southern Sacramento Valley (Bennett, 2019).



The nutrient nitrate was found at moderate concentrations in about 14 percent of the southern Sacramento Valley domestic wells but only about 4 percent of the northern Sacramento Valley domestic wells; the higher nitrate in the south likely is related to higher agriculture land use in the study unit (Bennett and others, 2011). Arsenic occurred at moderate or high concentrations in about 36 percent of the domestic wells in the southern Sacramento Valley but was only present at moderate concentrations (4 percent) in the domestic wells in the northern Sacramento Valley. Manganese was at moderate or high concentrations in about 22 percent of the southern Sacramento Valley domestic wells, more frequently than for the northern Sacramento Valley (6 percent), which reflects widespread low oxygen (anoxic) in the sampled wells in the south. The more frequent anoxia observed in the southern Sacramento Valley wells is a likely mechanism for higher and more widespread arsenic concentrations (Bennett and others, 2011).

Moderate or high hexavalent chromium was found in about 12 percent of domestic drinking water wells in both shallow aquifer study areas. Hexavalent chromium in groundwater can be derived from natural sources through water-rock interactions but also has been linked to industrial releases in some areas. It is most commonly found in oxygenated (oxic) groundwaters since hexavalent chromium is more soluble under these conditions (California State Water Resources Control Board, 2017).

By Jennifer S. Harkness and Jennifer L. Shelton

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Proirority Basin Assessments

GAMA's Priority Basin Project (PBP) assesses water quality in groundwater resources used for drinking water supply. This study in the Northern Sacramento Valley focused on groundwater resources used for domestic drinking water. Domestic wells typically tap shallower parts of aquifer systems than public-supply wells, and water quality can vary with depth in aquifer systems. Ongoing assessments are being carried out in more than 120 basins and areas outside of basins throughout California. The PBP assessments compare constituent concentrations in untreated groundwater with benchmarks established for the protection of human health and for aesthetic concerns. The PBP does not evaluate the quality of drinking water that arrives at the tap following filtration or treatment.

The PBP uses two scientific approaches for assessing groundwater quality. The first approach uses a network of wells to statistically assess the status of groundwater quality. The second approach combines water-quality, hydrologic, geographic, and other data to help assess the factors that affect water quality. In the Redding–Red Bluff Shallow Aquifer study unit, data were collected by the PBP in 2018–2019. The PBP includes chemical analyses generally not available as part of regulatory compliance monitoring, including measurements at concentrations lower than human-health benchmarks and measurements of constituents that can be used to trace the sources and movement of groundwater.

For more information

Technical reports and hydrologic data collected for the GAMA Program may be obtained from:

GAMA Project Chief

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