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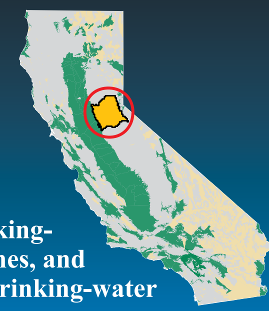
CALIFORNIA Water Boards

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

Groundwater Quality in the Mokelumne, Cosumnes, and American River Watersheds, Sierra Nevada, California

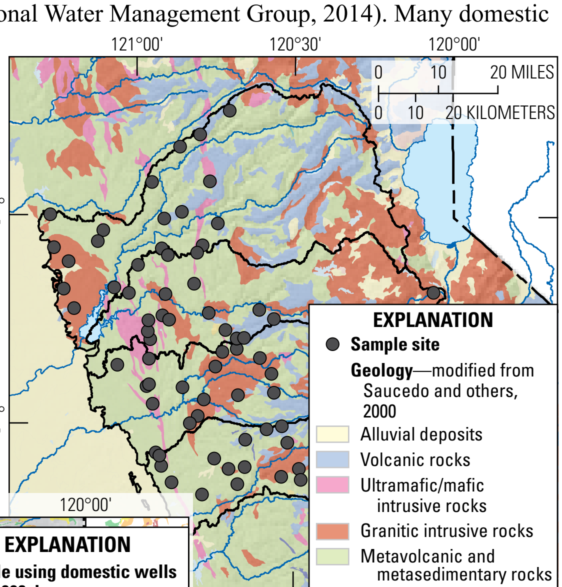


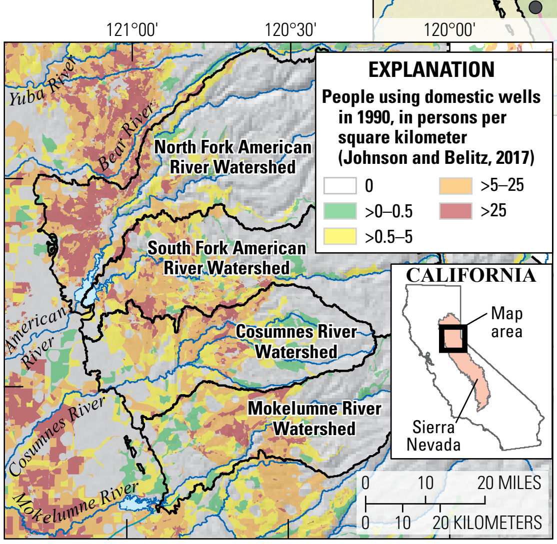
Groundwater provides more than 40 percent of California's drinking water. To protect this vital resource, the State of California created the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The GAMA Program's Priority Basin Project assesses the quality of groundwater resources used for drinking-water supply and increases public access to groundwater-quality information. In the Mokelumne, Cosumnes, and American River Watersheds of the Sierra Nevada, many rural households rely on private wells for their drinking-water supplies.

The Mokelumne, Cosumnes, and American River Watersheds

The Mokelumne, Cosumnes, and American River Watersheds (MCAW) study unit covers approximately 9,000 square kilometers on the western slope of the Sierra Nevada. Groundwater composes about 10 percent of overall water use in the region, but is the sole supply for many individual homes outside the public water-supply infrastructure (Cosumnes, American, Bear, Yuba Integrated Regional Water Management Group, 2014). Many domestic wells in the MCAW study unit were deepened during the recent drought (California Department of Water Resources, 2014), highlighting the vulnerability of groundwater supplies and prompting increased interest in studies of Sierra Nevada groundwater systems.

Well water in the MCAW study unit mostly comes from fractured-rock aquifers. The quality of groundwater in these aquifers primarily depends on the type of rock, the age of the groundwater, and the type of human activities at the land surface. Previous groundwater studies in this area found elevated concentrations of nitrate, microbial indicators, and some trace elements in some wells (California State Water Resources Control Board, 2005; Fram and Belitz, 2014).

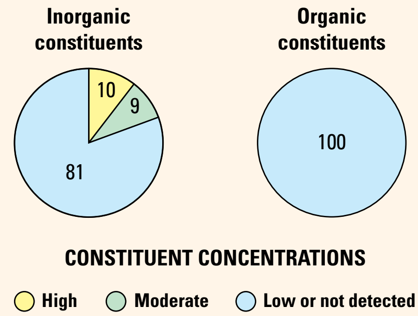




Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Albers Equal-Area Conic projection, standard parallels are 29°30' N and 45°30' N; North American Datum of 1983

This study was designed to provide a statistically representative assessment of the quality of groundwater resources used for domestic drinking water in the MCAW study unit. A total of 67 domestic wells and 1 domestic spring were sampled between August 2016 and January 2017 (Shelton and others, 2018). The wells in the study unit typically were 30 to 150 meters deep, and water levels typically were 2 to 42 meters below land surface.

Overview of Water Quality



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

The GAMA Priority Basin Project evaluates the quality of untreated groundwater. For context, concentrations measured in groundwater are compared to a constituent benchmark established for drinking-water quality, such as maximum contaminant levels (MCL). A concentration above the benchmark is defined as high. Benchmarks and definitions of moderate and low concentrations are discussed on page 3.

Many inorganic constituents are present naturally in groundwater, and their concentrations can be affected by natural processes and by human activities. In the MCAW study unit, one or more inorganic constituents were present at high concentrations in about 10 percent of the groundwater resources used for domestic drinking water.

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 MCAW study unit.

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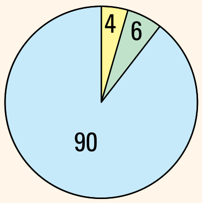
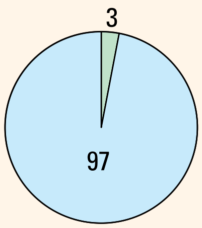
INORGANIC CONSTITUENTS

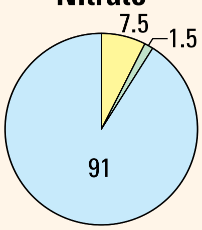
Trace elements



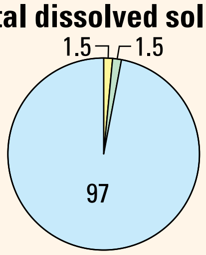
Uranium and radioactive constituents



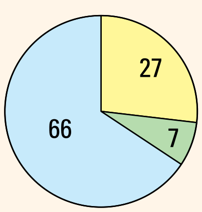
Nitrate



Total dissolved solids



Manganese or iron



Inorganic Constituents with Human-Health Benchmarks

Historical mining activity in the MCAW study unit and adjacent Yuba and Bear River watersheds has resulted in elevated concentrations of mercury and arsenic in water, sediments, and fish in some waterways and reservoirs (Alpers, 2017). Trace elements also are naturally present in the minerals of rocks and sediments and in the groundwater that comes in contact with those materials. About 4 percent of the groundwater resources used for domestic drinking water in the MCAW study unit had high concentrations of one or more trace elements, and about 6 percent had moderate concentrations. Three trace elements were present at high concentrations (arsenic, boron, and molybdenum), and three were present at moderate concentrations (arsenic, fluoride, and vanadium). Mercury was detected at low concentrations in about 1 percent of the groundwater resources.

As with trace elements, uranium and other radioactive constituents are naturally present in some minerals of rocks and sediments and in the groundwater that comes into contact with those materials. Radioactive constituents were not present at high levels in the groundwater resources used for domestic drinking water. Gross alpha-particle activity was present at moderate levels in about 3 percent of the groundwater resources.

Nitrate is naturally present at low concentrations in groundwater, but moderate and high concentrations generally indicate contamination from human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. About 8 percent of the groundwater resources used for domestic drinking water had high concentrations of nitrate, and less than 2 percent had moderate concentrations.

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.

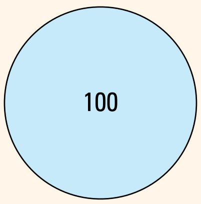
Total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater, and all water naturally contains TDS as a result of the weathering and dissolution of minerals in rocks and sediments. The State of California has a recommended and an upper limit for TDS in drinking water (see box on page 3). Concentration of TDS were high (greater than the upper limit) in less than 2 percent of the groundwater resources used for domestic drinking water and moderate (between the recommended and upper limits) in less than 2 percent as well.

Anoxic conditions (low amounts of dissolved oxygen) can result in the release of natural manganese, iron, and other associated trace elements from minerals into groundwater. Anoxic conditions also can promote degradation of nitrate. About one-third of the wells sampled for the MCAW had anoxic conditions.

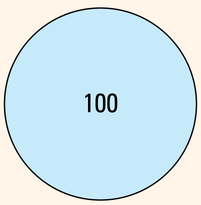
Manganese, iron, or both were present at high concentrations in about 27 percent of the groundwater resources used for domestic drinking water. In samples from the entire Sierra Nevada, groundwater from wells in metamorphic rocks more commonly had high or moderate concentrations of manganese or iron than groundwater from wells in granitic, volcanic, or sedimentary rocks (Fram and Belitz, 2014). More than half of the wells sampled for the MCAW were in metamorphic rocks.

ORGANIC CONSTITUENTS

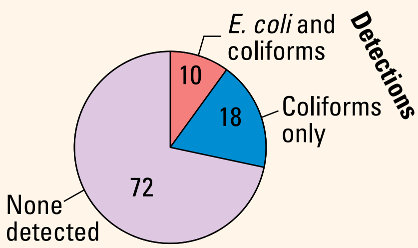
VOCs



Pesticides



Microbial Indicators



Organic Constituents with Human-Health Benchmarks

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

Volatile organic compounds are present in many household, commercial, and industrial products. No VOCs were detected at high or moderate concentrations in the groundwater resources used for domestic drinking water in the MCAW. Low concentrations of VOCs present in commonly used solvents or in gasoline were detected in about 21 percent of the groundwater resources.

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. Pesticides were not detected at high or moderate concentrations in the groundwater resources of the MCAW used for domestic drinking water. Low concentrations of insecticides or herbicides were detected in about 18 percent of the groundwater resources.

Microbial Indicators

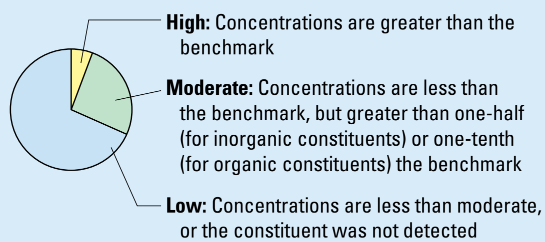
(Not included in water-quality overview charts shown on the front page)

Microbial indicators are used to evaluate the potential for fecal contamination of water sources. In the MCAW, total coliforms and *Escherichia coli* (*E. coli*) were detected in 10 percent of the wells sampled, and total coliforms alone were detected in another 18 percent of the wells sampled. Total coliforms are present naturally in soils and in digestive tracts of animals, whereas *E. coli* specifically indicate contamination with animal (or human) fecal waste (California State Water Resources Control Board, 2016). The pie diagram for microbial constituents uses different colors than the other pie diagrams because the benchmarks for microbial constituents specify repeat sampling to confirm detections, which was not done in this study.

Methods for Evaluating Groundwater Quality

This study uses comparison to 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, and treatment technique, TT) are used for comparison when available. Otherwise, non-regulatory benchmarks set for protection of aesthetic and technical properties, such as taste and odor (secondary maximum contaminant level, SMCL) and non-regulatory benchmarks set for the protection of human health (notification levels, NL, and lifetime health advisory levels, HAL) are used. Water quality in domestic wells is not regulated in California.

Pie diagrams are used to summarize groundwater quality results. The pie slices represent the percentages of the groundwater resources with high, moderate, and low concentrations of a constituent. Methods for calculating these percentages are discussed by Fram and Belitz (2014).



Benchmark type and value for selected constituents.

[Benchmarks are listed as EPA if the EPA and CA values are the same, and as CA if the CA value is lower or if no EPA value exists. **Abbreviations**: pCi/L, picocuries per liter; ppb, parts per billion (equivalent to micrograms per liter); ppm, parts per million (equivalent to milligrams per liter); >, greater than]

Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	EPA MCL	10 ppb	Manganese	CA SMCL	50 ppb
Boron	CA NL	1,000 ppb	Iron	CA SMCL	300 ppb
Molybdenum	EPA HAL	40 ppb	Total dissolved solids, upper	CA SMCL	1,000 ppm
Fluoride	CA MCL	2 ppm	Total dissolved solids, recommended	CA SMCL	500 ppm
Vanadium	CA NL	50 ppb	*Escherichia coli* (*E. coli*)	EPA MCL	Repeat detection at a site
Gross alpha-particle activity	EPA MCL	15 pCi/L	Total coliform	EPA TT	>5 percent of samples with detections per month
Nitrate, as nitrogen	EPA MCL	10 ppm			

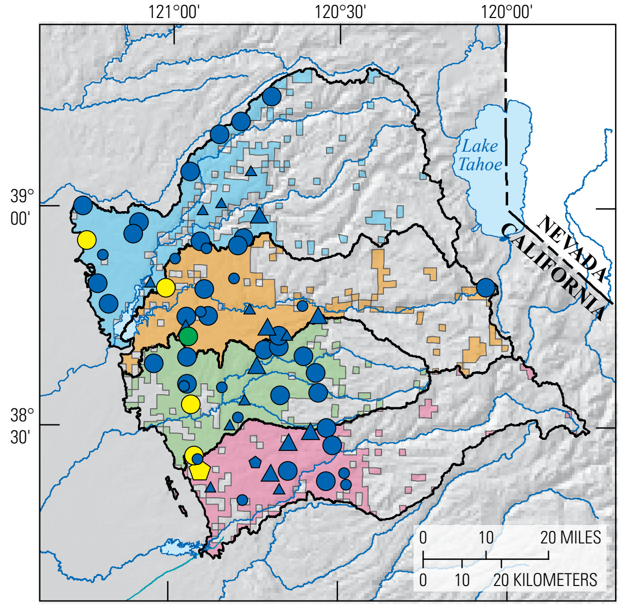
Factors that Affect Groundwater Quality

Of the constituents with maximum contaminant level (MCL) benchmarks, nitrate was the constituent present at high concentrations in the largest percentage of groundwater resources used for domestic drinking-water supply in the MCAW study unit (8 percent). Nitrate was present at concentrations above the EPA MCL of 10 ppm as nitrogen in all four watersheds in the MCAW study unit. High nitrate concentrations in groundwater generally require the three following conditions: anthropogenic sources of nitrate to groundwater, oxic geochemical conditions, and wells that tap “young” groundwater (Dubrovsky and others, 2010).

High nitrate concentrations were measured in samples from wells in the more populated western side of the MCAW study unit, where potential sources of nitrate are more common, including use of fertilizer on landscaping or for agriculture, seepage from septic and sewage systems, and recharge of surface water that does not meet water-quality standards (“impaired”).

Tritium concentrations in groundwater can be used to estimate whether the groundwater was recharged primarily before 1950 (“old”) or after 1950 (“young”). About three-quarters of MCAW study-unit well samples had tritium concentrations indicating “young” groundwater (Shelton and others, 2018; Jurgens and others, 2012). Young groundwater can be vulnerable to water-quality degradation from human activities and anthropogenic inputs at the land surface. The wells in the MCAW study unit with high and moderate concentrations of nitrate in the samples had young groundwater.

The percentage of groundwater resources used for domestic drinking water affected by contamination from anthropogenic sources of nitrate could be greater than the 8 percent estimated in this study. About one-third of the groundwater resources had anoxic geochemical conditions that could promote degradation of nitrate to reduced forms of nitrogen (ammonia, nitrite, and nitrogen gas). Only a few anoxic samples contained measureable concentrations of ammonia and nitrite (Shelton and others, 2018), however, indicating nitrate degradation was not widespread. All groundwater from MCAW study-unit wells with high and moderate concentrations of nitrate also had oxic geochemical conditions under which nitrate does not degrade rapidly.



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

EXPLANATION

Watershed boundary

Study area

Cosumnes watershed — North Fork American watershed

Mokelumne watershed — South Fork American watershed

Nitrate concentration, in milligrams per liter of nitrogen	**Tritium concentration, in tritium units** Greater than 1.3 (”young”)	Less than 1.3 (”old” or mixed)	No data
Greater than 10 (high)	●	—	⬠
5 to 10 (moderate)	●	—	—
Less than 5 (low)	● •	▲ ▴	—

Large symbols indicate oxic conditions; small symbols indicate anoxic conditions

By Miranda S. Fram and Jennifer L. Shelton

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For more information

Technical reports and hydrologic data collected for the GAMA Program’s Priority Basin Project may be obtained from:

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