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Water Boards

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

Groundwater Quality in the Central 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 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. Two small watersheds of the Fresno and San Joaquin Rivers in the Central Sierra Nevada constitute one of the study units being evaluated.

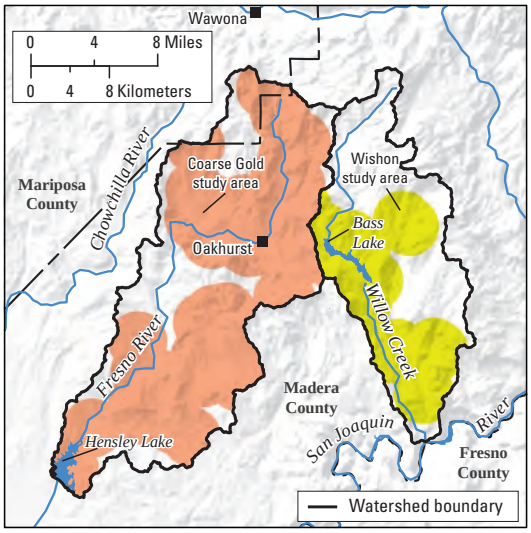
The Central Sierra Nevada Study Unit

The Central Sierra Nevada study unit is approximately 370 square miles and includes no California Department of Water Resources defined groundwater basins. The study unit was divided into two study areas: the Coarse Gold study area corresponding to the watershed of the Fresno River above Hensley Lake, and the Wishon study area corresponding to the watershed of Willow Creek, a tributary of the San Joaquin River (Ferrari and others, 2008).

The primary aquifers in the study unit are fractured bedrock. Most of the bedrock is granitic rock, which is the most abundant rock type in the Sierra Nevada, with the remainder being metamorphic rock. Groundwater occurs in open joints, fractures, and exfoliation planes in the bedrock. These fracture systems may be interconnected or isolated, resulting in variability in water levels, well yields, and water quality on local and regional scales (California Department of Water Resources, 2003).

The primary aquifers in the study unit are defined as those parts of the aquifers corresponding to the open intervals of wells listed in the California Department of Public Health database. In the Central Sierra Nevada study unit, these wells typically are drilled to depths between 300 and 750 feet, consist of solid casing from land surface to a depth of about 50 to 75 feet, and are open below the solid casing.

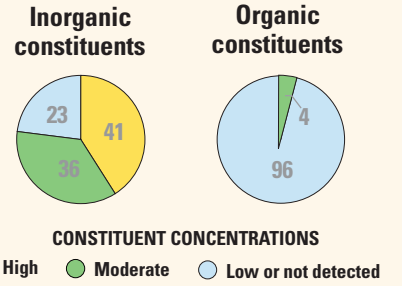
In the Sierra Nevada, ore deposits commonly are associated with the contacts between granitic and metamorphic rocks. The Central Sierra Nevada study unit contains many small mining prospect sites (nearly all inactive), mainly for gold or tungsten (U.S. Geological Survey, 2005). Minerals associated with naturally-occurring ore deposits commonly contain high concentrations of constituents that may adversely affect groundwater quality.



The Central Sierra Nevada study unit has warm, dry summers and cold, wet winters. Average annual precipitation ranges from 20 inches at Hensley Lake to 50 inches in the mountains in the northern part of the study unit. Land use in the Central Sierra Nevada study unit is approximately 95 percent (%) undeveloped (forests and grasslands), and 5% urban. The undeveloped lands are used mostly for recreation and open-range grazing. The largest urban area is the city of Oakhurst.

Municipal and community water supply accounts for nearly all of the total water use in the Central Sierra Nevada study unit. Groundwater provides nearly all of the water supply, with limited use of surface water in some areas. Recharge to the groundwater flow system is mainly from stream-channel infiltration and direct infiltration of precipitation. Groundwater leaves the aquifer system mainly when it is pumped for water supply or flows into streams or lakes.

Overview of Water Quality



Values are a percentage of the area of the primary aquifers with concentrations in the three specified categories. Values on pie chart may not equal 100 due to rounding of percentages.

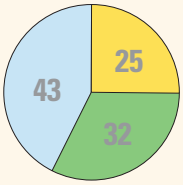
GAMA's Priority Basin Project evaluates the quality of untreated groundwater. However, for context, benchmarks established for drinking-water quality are used for comparison. Benchmarks and definitions of *high*, *moderate*, and *low* concentrations are discussed in the inset box on page 3.

Many inorganic constituents occur naturally in groundwater. The concentrations of the inorganic constituents can be affected by natural processes as well as by human activities. In the Central Sierra Nevada study unit, one or more inorganic constituents were present at high concentrations in about 41% of the primary aquifers and at moderate concentrations in 36%.

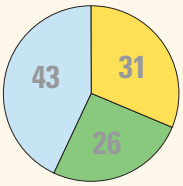
Human-made organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal usage, spills, or improper disposal. In this study unit, organic constituents were not present at high concentrations in the primary aquifers, and were present at moderate concentrations in about 4%.

RESULTS: Groundwater Quality in the Central Sierra Nevada Study Unit

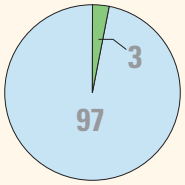
INORGANIC CONSTITUENTS



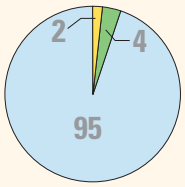
Trace elements



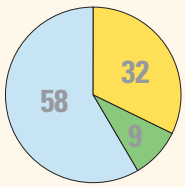
Radioactive constituents



Nutrients

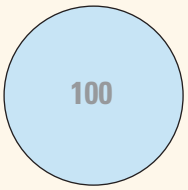


Total dissolved solids



Manganese

SPECIAL-INTEREST CONSTITUENTS



Perchlorate

Inorganic Constituents with Human-Health Benchmarks

Trace and minor elements are naturally present in the minerals in rocks and soils, and in the water that comes into contact with those materials. In the Central Sierra Nevada study unit, trace elements were present at high concentrations in about 25% of the primary aquifers, and in moderate concentrations in about 32%. Arsenic, molybdenum, and fluoride were the trace elements that most frequently occurred at high and moderate concentrations. Chromium and selenium also were detected at high concentrations, but in less than (<) 1% of the primary aquifers.

Radioactivity is the emission of energy or particles during spontaneous decay of unstable atoms. Humans are exposed to small amounts of natural radioactivity every day. Most of the radioactivity in groundwater comes from decay of naturally-occurring isotopes of uranium and thorium in minerals in the rocks or sediments of the aquifers. Radioactive constituents occurred at high levels in about 31% of the primary aquifers, and at moderate levels in about 26%. Gross alpha particle activity, and uranium were the radioactive constituents that most frequently occurred at high and moderate levels.

Nutrients, such as nitrogen and phosphorous, are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. In the Central Sierra Nevada study unit, nutrients were not detected at high concentrations in the primary aquifers, and were present at moderate concentration in about 3%.

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 may create nuisance problems, such as staining and scaling. The State of California has a recommended and an upper limit for total dissolved solids (TDS) in drinking water. All water naturally contains TDS as a result of the weathering and dissolving of minerals in soils and rocks. Iron and manganese are naturally-occurring constituents that commonly occur together in groundwater. Anoxic conditions in groundwater (very low amounts of dissolved oxygen) may result in release of manganese and iron from minerals into groundwater.

In the Central Sierra Nevada study unit, TDS were present at high concentrations (greater than the upper limit) in about 2% of the primary aquifers, and at moderate concentrations (between the upper and recommended limits) in about 3%. Manganese, with or without iron, was present at high concentrations in about 32% of the primary aquifers, and at moderate concentrations in about 9% of the primary aquifers.

Perchlorate

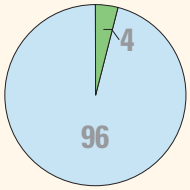
(Not included in water-quality overview charts shown on the front page)

Perchlorate is an inorganic constituent that has been regulated in California drinking water since 2007. It is an ingredient in rocket fuel, fireworks, safety flares, and other products, may be present in some fertilizers, and occurs naturally at low concentrations in groundwater. Perchlorate was not detected in the primary aquifers.

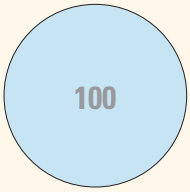
RESULTS: Groundwater Quality in the Central Sierra Nevada Study Unit

ORGANIC CONSTITUENTS

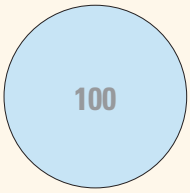
Gasoline additives and oxygenates



Other volatile organic compounds



Pesticides



Organic Constituents

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

Volatile Organic Compounds with Human-Health Benchmarks

VOCs are in many household, commercial, industrial, and agricultural products, and are characterized by their tendency to volatilize (evaporate) into the air.

Gasoline additives and oxygenates are used to increase the efficiency of fuel combustion. In the Central Sierra Nevada study unit, gasoline additives and oxygenates were not present at high concentrations, but were detected at moderate concentrations in about 4% of the primary aquifers, and at low concentrations (or not detected) in about 96%.

Other VOCs include trihalomethanes, solvents, refrigerants, and organic synthesis reagents. Trihalomethanes form during disinfection of water supplies, and may enter groundwater by the infiltration of landscape irrigation water, the leaking of distribution lines, or the disinfection of wells. Solvents are used for a number of purposes, including manufacturing and cleaning. Other VOCs were not detected at high or moderate concentrations in the primary aquifers. Trihalomethanes and solvents, when detected, were at low concentrations.

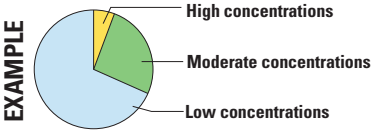
Pesticides with Human-Health Benchmarks

Pesticides, including herbicides, insecticides, fungicides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. In the Central Sierra Nevada study unit, pesticides were not detected at high or moderate concentrations in the primary aquifers. Herbicides occasionally were detected at low concentrations.

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

GAMA's Priority Basin Project uses benchmarks established for drinking water to provide context for evaluating the quality of untreated groundwater. After withdrawal, groundwater may be disinfected, filtered, mixed, and exposed to the atmosphere before being delivered to consumers. Federal and California regulatory benchmarks for protecting human health (Maximum Contaminant Level, MCL) were used when available. Nonregulatory benchmarks for protecting aesthetic properties, such as taste and odor (Secondary Maximum Contaminant Level, SMCL), and nonregulatory benchmarks for protecting human health (Notification Level, NL, and Lifetime Health Advisory, HAL) were used when Federal or California regulatory benchmarks were not available.

CONSTITUENT CONCENTRATIONS



Values are a percentage of the area of the primary aquifers with concentrations in the three specified categories. Values on pie chart may not equal 100 due to rounding of percentages.

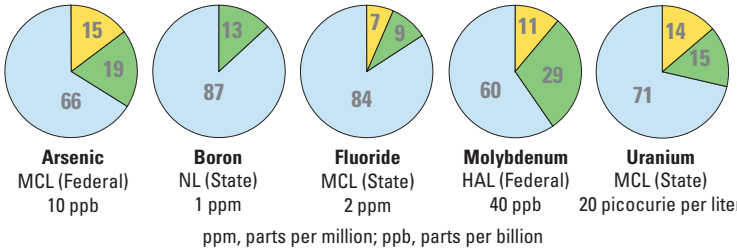
High, moderate, and low concentrations are defined relative to benchmarks

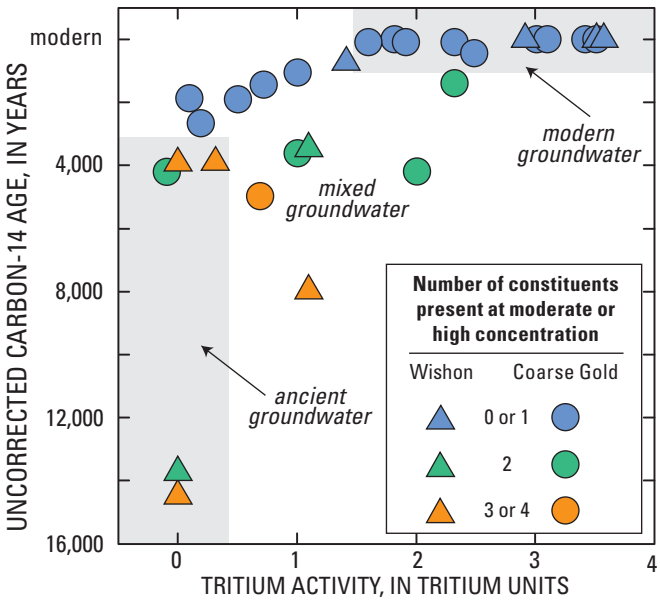
Concentrations are considered *high* if they are greater than a benchmark. For inorganic constituents, concentrations are *moderate* if they are greater than one-half of a benchmark. For organic constituents and perchlorate, concentrations are *moderate* if they are greater than one-tenth of a benchmark; this lower threshold was used because organic constituents are generally less prevalent and have smaller concentrations relative to benchmarks than inorganic constituents. *Low* values include nondetections and values less than moderate concentrations. Methods for evaluating water quality are discussed in Fram and Belitz (2012).

Factors that Affect Groundwater Quality

In the Central Sierra Nevada study unit, inorganic constituents were present at high or moderate concentrations in about 77% of the primary aquifers. Arsenic, boron, fluoride, molybdenum, and uranium were the constituents most frequently present at high or moderate concentrations (pie charts above the graph show porpotions for study unit). These constituents are derived from dissolution of naturally-occurring minerals in the granitic and metamorphic rocks of the aquifers. Dissolution requires appropriate groundwater geochemical conditions (such as pH and dissolved oxygen concentration), enough time for dissolution to occur, and presence of minerals containing these constituents. Mining activities may increase dissolution rates by exposing rocks to air and increasing porosity and permeability, thereby increasing contact between minerals and groundwater.

Tritium and carbon-14 are radioactive tracers produced in the atmosphere and present in precipitation. They are used to estimate the time since groundwater recharged into aquifers. In the Central Sierra Nevada study unit, high and moderate concentrations of arsenic, boron, fluoride, molybdenum, and uranium were associated with longer time since recharge. Modern groundwater (recharged in the last 60 years) had one or none of the five constituents present at high or moderate concentrations. Ancient groundwater (recharged thousands of years ago) and mixtures of modern and ancient groundwater had two or more constituents present at high or moderate concentrations.





By Miranda S. Fram and Kenneth Belitz

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California Department of Water Resources, 2003, California's groundwater: California Department of Water Resources Bulletin 118, 246 p. *http://www.water.ca.gov/groundwater/bulletin118/update2003.cfm*.

Ferrari, M.J., Fram, M.S., and Belitz, Kenneth, 2008, Groundwater quality data in the Central Sierra study unit, 2006—Results from the California GAMA Program: U.S. Geological Survey Data Series 335, 59 p. (Also available at *http://pubs.usgs.gov/ds/335/*.)

Fram, M.S., and Belitz, Kenneth, 2012, Status and understanding of groundwater quality in the Tahoe-Martis, Central Sierra, and Southern Sierra study units, 2006–2007—California GAMA Program Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2011-5216, 222 p. (Also available at *http://pubs.usgs.gov/sir/2011/5216*.)

U.S. Geological Survey, 2005, Mineral Resources Data System: U.S. Geological Survey. *http://tin.er.usgs.gov/mrds/*

Priority Basin Assessments

GAMA's Priority Basin Project (PBP) assesses water quality in that part of the aquifer system used for drinking water, primarily public supply. Water quality in the primary aquifers, assessed by the PBP, may differ from that in the deeper parts of the aquifer, or from the shallower parts, which are being assessed by GAMA's Domestic Well Project. Ongoing assessments are being conducted in more than 120 basins throughout California.

The PBP assessments are based on a comparison of constituent concentrations in untreated groundwater with benchmarks established for protection of human health and for aesthetic concerns. The PBP does not evaluate the quality of drinking water delivered to consumers.

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 Central Sierra Nevada study unit, data were collected by the PBP in 2006, and from the CDPH database for 2003–2006. The PBP includes chemical analyses generally not available as part of regulatory compliance monitoring, including measurements at concentrations much lower than human-health benchmarks, and measurement 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 PBP Program may be obtained from:

GAMA Project Chief
U.S. Geological Survey
California Water Science Center
4165 Spruance Road, Suite 200
San Diego, CA 92101
Telephone number: (619) 225-6100
WEB: http://ca.water.usgs.gov/gama

GAMA Program Unit
State Water Resources Control Board
Division of Water Quality
PO Box 2231, Sacramento, CA 95812
Telephone number: (916) 341-5779
WEB: http://www.waterboards.ca.gov/gama