

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

Groundwater Quality in the Northern Coast Ranges Groundwater Basins, 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 (PBP) of the GAMA Program provides a comprehensive assessment of the State's groundwater quality and increases public access to groundwater-quality information. The basins in the Coast Ranges of northern California constitute one of the study units being evaluated.



The Northern Coast Ranges Study Unit

The Northern Coast Ranges (NOCO) study unit is 633 square miles and consists of 35 groundwater basins and subbasins (California Department of Water Resources, 2003; Mathany and Belitz, 2015). These basins and subbasins were grouped into two study areas based primarily on locality. The groundwater basins and subbasins located inland, not adjacent to the Pacific Ocean, were aggregated into the Interior Basins (NOCO-IN) study area. The groundwater basins and subbasins adjacent to the Pacific Ocean were aggregated into the Coastal Basins (NOCO-CO) study area (Mathany and others, 2011).



The primary aquifer system in the NOCO-IN study area occurs in alluvial basins made up of sand, silt, gravel, clay, and thin volcanic ash layers or lenses. Groundwater movement in the NOCO-IN study area follows the topography and direction of surface-water features. In the NOCO-CO study area, groundwater is present in alluvial fan, floodplain, and terrace deposits. Groundwater movement in the NOCO-CO study area is from east to west towards the Pacific Ocean.

The primary aquifer system in the study unit generally is defined as those parts of the aquifer system corresponding to the perforated intervals of sites listed in the California Department of Public Health (CDPH) database of public drinking-water supply sources. Well depths in the NOCO-IN study area ranged from 36 to 400 feet below land surface (ft bls), and depths to top-of-perforations ranged from 15 to 148 ft bls. In the NOCO-CO study area, well depths ranged from 15 to 400 ft bls, and depths to top-of-perforations ranged from 10 to 356 ft bls. Water quality in the primary aquifer system may differ from that in the shallower and deeper parts of the aquifer system.

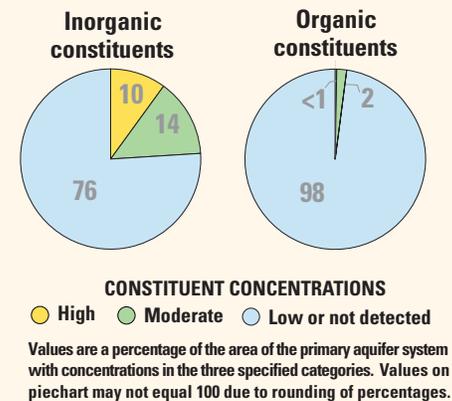
Average annual rainfall in the NOCO study unit ranges from 22 to 79 inches. In the NOCO-IN study area, the climate is classified as Mediterranean, with warm to hot, dry summers

and cold, wet winters. In the NOCO-CO study area, the climate is influenced by the Pacific Ocean and is characterized by cool to mild summers and cold, wet winters. The study unit is drained by several rivers and their principal tributaries: the Eel, Russian, Mad, Navarro, Smith, Klamath, Noyo, and Big Rivers.

Land use in the study unit is about 60 percent (%) natural (mostly grassland and forest), 29% agricultural, and 11% urban. The primary uses of agricultural lands are pasture, row crops, hay, vineyards, and timberlands. The largest urban areas are the cities of Crescent City, Arcata, Eureka, Fort Bragg, Willits, Ukiah, and Lakeport.

Recharge to the groundwater system is primarily from mixture of ambient sources, including direct percolation of precipitation and irrigation waters, infiltration of runoff from surrounding hills/areas, seepage from rivers and creeks, and subsurface inflow (from non-alluvial geologic units that bound the alluvial basins). The primary sources of discharge are evaporation, discharge to streams, and water pumped for municipal supply and irrigation.

Overview of Water Quality



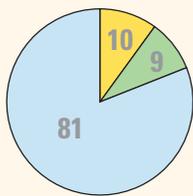
GAMA's Priority Basin Project evaluates the quality of untreated groundwater. However, for context, groundwater quality was compared to benchmarks established for drinking-water quality. Benchmarks and definitions of *high*, *moderate*, and *low* relative-concentrations are discussed in the inset box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

Many inorganic constituents occur naturally in groundwater. The concentrations of inorganic constituents can be affected by natural processes as well as by human activities. In the NOCO study unit, one or more inorganic constituents were present at high concentrations in about 10% of the primary aquifer system and at moderate concentrations in about 14% of the primary aquifer system.

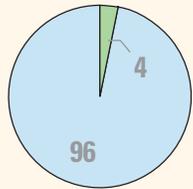
Human-made organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal usage, spills, or improper disposal. In the NOCO study unit, organic constituents were present at high concentrations in less than 1% of the primary aquifer system. One or more organic constituents were present at moderate concentrations in about 2% of the primary aquifer system.

RESULTS: Groundwater Quality in the Northern Coast Ranges Study Unit

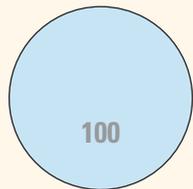
INORGANIC CONSTITUENTS



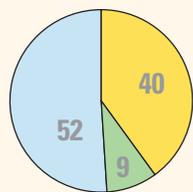
Trace elements



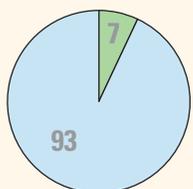
Nutrients



Uranium and radioactive constituents

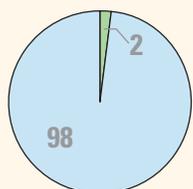


Manganese or iron



Total dissolved solids

SPECIAL-INTEREST CONSTITUENT



Perchlorate

Inorganic Constituents with Health-Based Benchmarks

Trace elements and major and minor ions are naturally present in the minerals in rocks and soils and in the water that comes into contact with those materials. In the NOCO study unit, trace elements were detected at high concentrations in about 10% of the primary aquifer system. Boron and arsenic were the trace elements that most frequently occurred at high concentrations. Barium also was detected at a high concentration, but in less than 2% of the primary aquifer system.

Nutrients, such as nitrate and nitrite, are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities. Common sources of nutrients, aside from soils, include fertilizers applied to crops and landscaping, seepage from septic systems, and human and animal waste. Nutrients were not present at high concentrations in the primary aquifer system. Nitrate was present at moderate concentrations in about 4% of the primary aquifer system.

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 naturally occurring isotopes of uranium and thorium in minerals in the sediments of the aquifer. Uranium and other radioactive constituents were not present at high or moderate levels in the primary aquifer system.

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. Anoxic conditions in groundwater (very low amounts of dissolved oxygen) may result in the release of naturally occurring elements, such as iron and manganese, from minerals and into groundwater. In the NOCO study unit, iron and manganese (one or both) were present at high concentrations in about 40% of the primary aquifer system and at moderate concentrations in about 9%.

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 dissolution of minerals in soils. TDS was not present at high concentrations (above the upper limit) but was present at moderate concentrations (between the recommended and upper limit) in about 7% of the primary aquifer system.

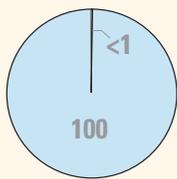
Constituent of Special Interest: Perchlorate

(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 fuels, fireworks, and other products, may be present in some fertilizers, and occurs naturally at low concentrations in groundwater. In the NOCO study unit, perchlorate was present at moderate concentrations in about 2% of the primary aquifer system.

RESULTS: Groundwater Quality in the Northern Coast Ranges Study Unit

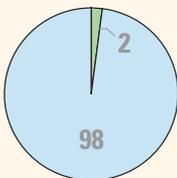
ORGANIC CONSTITUENTS



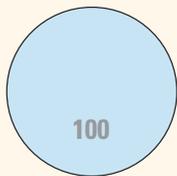
Gasoline components



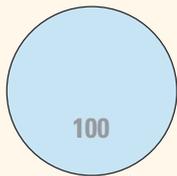
Trihalomethanes



Organic synthesis reagents



Solvents



Pesticides

Organic Constituents

The GAMA-PBP uses laboratory methods that can detect volatile organic compounds (VOCs) and pesticides and pesticide degradates at low concentrations far below human-health benchmarks. VOCs and pesticides and pesticide degradates detected at these very low concentrations can be used to 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. In the NOCO study unit, VOCs were detected at high concentrations in less than 1% of the primary aquifer system and at moderate concentrations in about 2% of the primary aquifer system.

Gasoline components include gasoline hydrocarbons and oxygenates. The gasoline oxygenate methyl *tert*-butyl ether (MTBE) was detected at high relative-concentrations in less than 1% of the primary aquifer system.

Trihalomethanes can form during municipal water disinfection and may enter groundwater by the infiltration of landscape irrigation water. Trihalomethanes were present at moderate concentrations in about 2% of the primary aquifer system.

Organic synthesis reagents are compounds used in the manufacture or preparation of organic compounds and are commonly used to make polyvinyl chloride (PVC) pipes. The organic synthesis reagent vinyl chloride was detected at moderate concentrations in about 2% of the primary aquifer system.

Solvents were not detected at either high or moderate concentrations in the primary aquifer system.

Pesticides with Human-Health Benchmarks

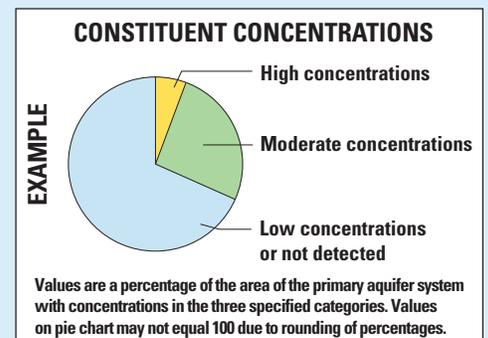
Pesticides and pesticide degradates, including herbicides, insecticides, fungicides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. In the NOCO study unit, pesticides and pesticide degradates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

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

The GAMA-PBP 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) are used when available. Otherwise, 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) are used.

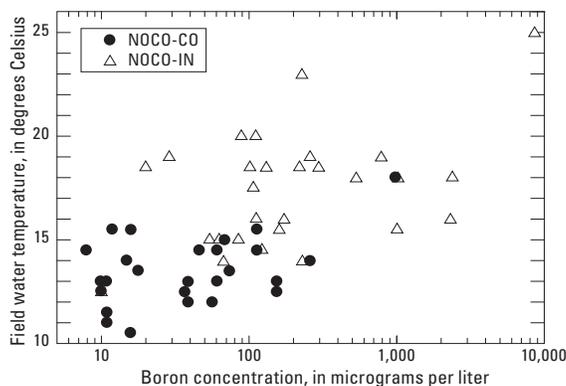
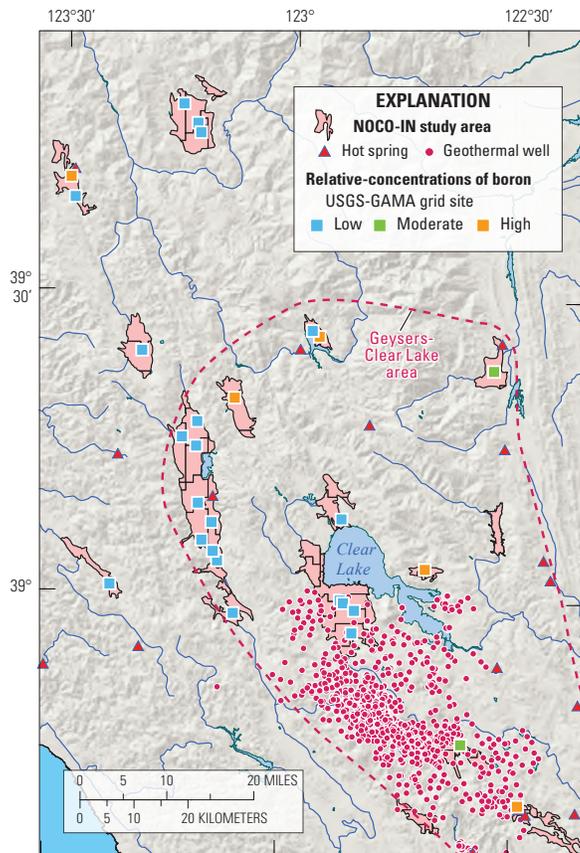
High, moderate, and low concentrations are defined relative to benchmarks

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 and special-interest constituents, concentrations are *moderate* if they are greater than one-tenth of a benchmark; this lower threshold was used because organic constituents generally are less prevalent and have smaller concentrations relative to benchmarks than inorganic constituents. *Low* concentrations include non-detections and values less than moderate concentrations. Methods for evaluating water quality are discussed by Mathany and Belitz (2015).



Factors that Affect Groundwater Quality

In the NOCO study unit, boron was the constituent that most frequently occurred at high concentrations. About 7% of the primary aquifer system had boron concentrations



By Timothy M. Mathany and Kenneth Belitz

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Priority Basin Assessments

The GAMA-PBP assesses water quality in that part of the aquifer system used for drinking water, primarily public supply. Water quality in shallow and deep parts may differ from that in the primary aquifer system assessed by the GAMA-PBP. GAMA's Domestic Well Project assesses water quality in the shallower parts of the aquifer system. Ongoing assessments are being conducted in more than 120 basins throughout California.

The GAMA-PBP assessments are based on a comparison of 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 delivered to consumers.

The GAMA-PBP uses two scientific approaches for assessing groundwater quality. The first approach uses a network of sites 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 NOCO study unit, data were collected by the GAMA-PBP in 2009 and from the CDPH database for 2006–2009. The GAMA-PBP includes chemical analyses not generally 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 Program may be obtained from

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