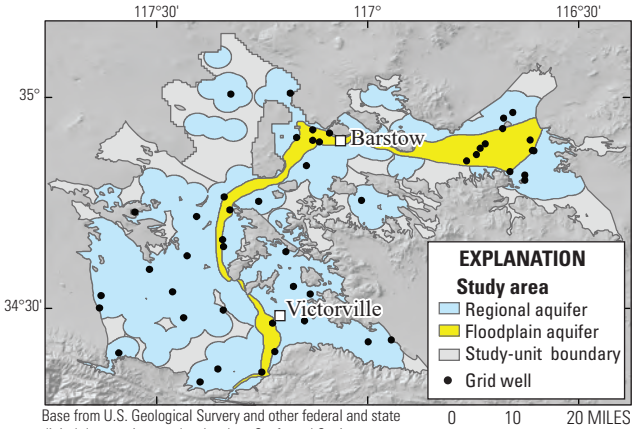
U.S. Geological Survey and the California State Water Resources Control Board

Groundwater Quality in Shallow Aquifers in the Western Mojave Desert, 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. One GAMA-PBP study unit is in the western part of the Mojave Desert, where shallow aquifers provide drinking water for many rural households.

The Mojave Basin Shallow Aquifer Study Unit

The Mojave Basin Shallow Aquifer study unit (Mojave) covers approximately 4,680 square kilometers (2,908 square miles) in the western part of the Mojave Desert in San Bernardino County. The study unit consists of groundwater basins along the Mojave River, the El Mirage Valley groundwater basin, and part of the Harper Valley groundwater basin. The Mojave study unit was divided into two study areas—the floodplain study area along the Mojave River and the regional study area surrounding and underlying the floodplain study area. Aquifers in the floodplain study area consist of coarse granitic river-channel and floodplain alluvium deposited by the Mojave River. Aquifers in the regional study area consist of alluvium derived from older stream deposits, locally derived alluvial fans, playa lake deposits, and fractured bedrock (Stamos and others, 2001; Groover and Izbicki, 2019).

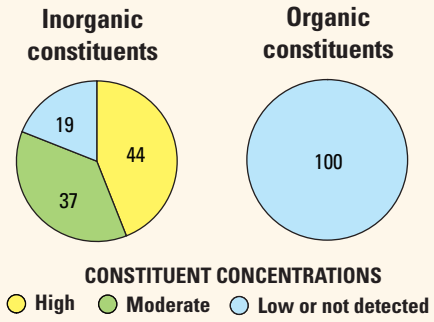


Base from U.S. Geological Survey and other federal and state digital data, various scales; Lambert Conformal Conic projection, standard parallels are 34.0333 and 35.4667; North American Datum of 1983

This study examined the quality of groundwater resources used for domestic drinking-water supply. Previous studies of groundwater resources used for public drinking-water supply in the Mojave Desert have observed elevated concentrations of some constituents, primarily trace elements, in some wells (Dawson and Belitz, 2012; Metzger and others, 2015). Domestic wells in the study unit typically are drilled to depths of 27–186 meters (Groover and others, 2019), which is shallower than the depths of public-supply wells in the same area (typically 90–300 meters deep; Dawson and Belitz, 2012). Water levels in domestic wells in the study unit typically are 9–140 meters below land surface (Groover and others, 2019).

This study was designed to provide a statistically representative assessment of the quality of groundwater resources used for domestic drinking water. A total of 48 domestic wells were sampled between January and May 2018 (Groover and others, 2019). Eleven additional wells were sampled to evaluate processes affecting groundwater quality, but these wells are not included in this assessment.

Overview of Water Quality



Values are a percentage of the area of the groundwater resources used for domestic drinking water with concentrations in the three specified categories.

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

Many inorganic constituents naturally occur in groundwater. The concentrations of the inorganic constituents can be affected by natural processes as well as human activities. In the Mojave study unit, one or more inorganic constituents were present at high concentrations in about 44 percent of the groundwater resources used for domestic drinking water.

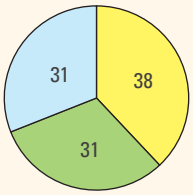
Organic constituents are found in products used in the home, business, industry, and agriculture and can enter the environment through normal usage, spills, or improper disposal. Organic constituents were not present at moderate or high concentrations in the groundwater resources used for domestic drinking water in the Mojave study unit.

U.S. Department of the Interior
U.S. Geological Survey

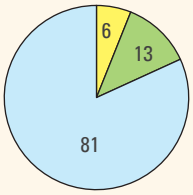
ISSN 2327-6916 (print)
ISSN 2327-6932 (online)
https://doi.org/10.3133/fs20193033

Fact Sheet 2019–3033
May 2019

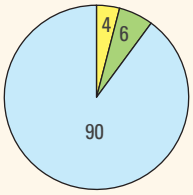
INORGANIC CONSTITUENTS



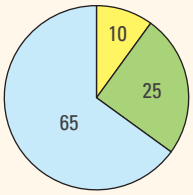
Trace elements



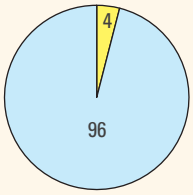
Uranium and radioactivity



Nitrate



Total dissolved solids



Manganese or iron

Inorganic Constituents with Human-Health Benchmarks

Trace elements are naturally present in the minerals of rocks and sediment that compose groundwater aquifers and can dissolve into the groundwater that comes in contact with those materials. About 38 percent of the groundwater resources used for domestic drinking water in the Mojave study unit had high concentrations of one or more trace elements and about 31 percent had moderate concentrations. Five elements were present at concentrations above benchmarks: arsenic (29 percent), fluoride (15 percent), hexavalent chromium (4 percent), molybdenum (12 percent), and strontium (2 percent). Boron and vanadium were present at moderate concentrations in 8 percent of groundwater. Hexavalent chromium was present at moderate concentrations in 25 percent of groundwater. About 6 percent of groundwater resources used for domestic drinking water in the Mojave study unit had hexavalent chromium concentrations above the former California MCL of 10 ppb, compared to 4 percent of groundwater resources used for public drinking water statewide (Izbicki and others, 2015). Groundwater in the Mojave study unit typically had a neutral to alkaline pH. Wells with acidic pH values (6 percent of groundwater) had lower concentrations of hexavalent chromium than neutral to alkaline wells, similar to the correlation between chromium and pH statewide (Izbicki and others, 2015; Groover and others, 2019).

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 uranium and thorium isotopes that are naturally present in aquifer materials. Uranium concentrations and 72-hour adjusted gross alpha particle activities were above benchmarks in about 6 percent of the groundwater resources used for domestic drinking water.

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 high concentrations in about 4 percent of the groundwater resources used for domestic drinking water in the Mojave study unit.

Inorganic Constituents with Non-Health Benchmarks

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

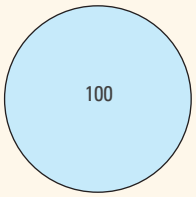
Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or can create nuisance problems, such as staining and scaling. The benchmarks used for these constituents are non-regulatory secondary maximum contaminant level benchmarks.

Total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater. All water naturally contains TDS as a result of the weathering and dissolution of minerals in rocks and sediment. The state of California has a recommended and an upper limit for TDS in drinking water. Total dissolved solids were present at high concentrations (greater than the upper limit) in about 10 percent and at moderate concentrations (between the upper and recommended limits) in about 25 percent of the groundwater resources used for domestic drinking water.

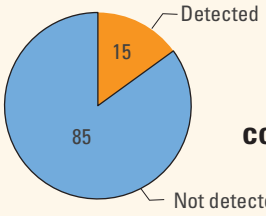
Anoxic conditions defined as having a dissolved oxygen concentration less than 0.5 ppm can result in the release of manganese, iron, and other associated trace elements from minerals into groundwater. Most groundwater in the Mojave study unit had dissolved oxygen concentrations greater than 0.5 ppm. Iron was present at concentrations above benchmarks set for aesthetic concerns in about 4 percent of the groundwater resources used for domestic drinking water. Manganese was not present at high concentrations.

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

ORGANIC CONSTITUENTS



Volatile organic compounds



Total coliforms

Different colors are used for this pie diagram because the benchmarks for microbial constituents specify repeat sampling to confirm detections, which was not done in this study.

Organic Constituents with Human-Health Benchmarks

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

Many household, commercial, and industrial products, including solvents, gasoline components, and refrigerants, contain VOCs. No VOCs were detected at high or moderate concentrations in the Mojave study unit, and VOCs were detected at low concentrations in 23 percent of the groundwater resources used for domestic drinking water. The most common VOCs detected were disinfection by-products (15 percent), followed by solvents (10 percent).

Microbial Indicators

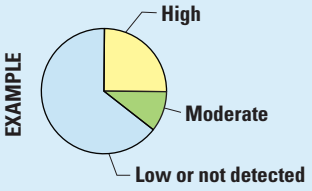
(*Not included in water-quality overview charts shown on the front page*)

Microbial indicator constituents are used to evaluate the potential for fecal contamination of water sources. In the Mojave study unit, total coliforms were detected in 15 percent of the groundwater resources used for domestic drinking water and Escherichia coli (*E. coli*) were not detected. Total coliforms are naturally present in soils and digestive tracts of animals, whereas *E. coli* specifically indicate contamination with animal (or human) fecal waste (California State Water Resources Control Board, 2016).

Benchmarks 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) 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 non-regulatory 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. Water quality in domestic wells is not regulated in California.

CONSTITUENT CONCENTRATIONS



Values are a percentage of the area of the groundwater resources used for domestic drinking water with concentrations in the three specified categories.

High, Moderate, and Low Concentrations are Defined Relative to Benchmarks

Concentrations are considered high if they are greater than the selected benchmark. For most inorganic constituents, concentrations between the benchmark and one-half of the benchmark are moderate. For most organic constituents, concentrations between the benchmark and one-tenth of the benchmark are moderate. For constituents with California response and notification levels, concentrations between the RL and the NL are moderate. For constituents with health-based screening levels (Toccalino and Norman, 2006), concentrations above the upper level are high and concentrations between the upper and lower levels are moderate. Low concentrations include non-detections and values less than moderate concentrations. Methods for calculating the percentages shown in the pie diagrams are discussed by Dawson and Belitz (2012).

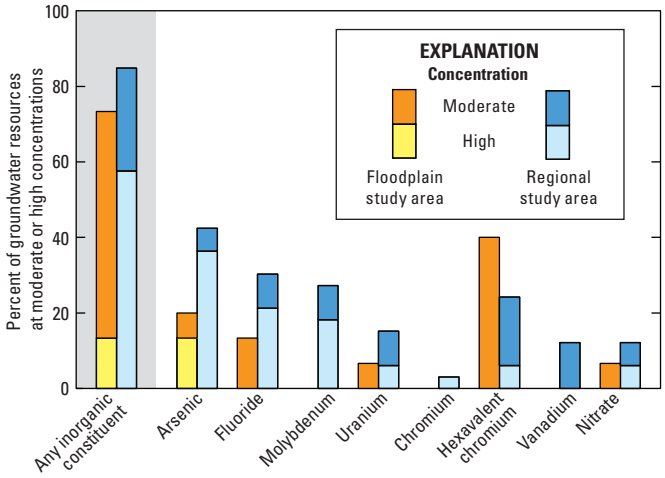
Benchmark type and value for selected constituents.

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

Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	EPA-MCL	10 ppb	Nitrate, as nitrogen	EPA-MCL	10 ppm
Hexavalent chromium (*non-cancer and cancer*)	USGS-HBSL	20 ppb and 4 ppb	Molybdenum	EPA-HAL	40 ppb
Fluoride	CA-MCL	2 ppm	Iron	CA-SMCL	300 ppb
Total dissolved solids (TDS) (*upper and recommended*)	CA-MCL	1,000 ppm and 500 ppm	Manganese	CA-SMCL	50 ppb
Strontium	EPA-HAL	4,000 ppb	Chromium	CA-MCL	50 ppb
Vanadium	CA-RL and CA-NL	500 ppb and 50 ppb	Boron	EPA-HAL and CA-NL	6 ppm and 1 ppm
Uranium	EPA-MCL	30 ppb	*Escherichia coli (E. coli)*	EPA-MCL	Repeat detection at a site
Adjusted gross alpha particle activity	EPA-MCL	15 pCi/L	Total coliforms	EPA-TT	>5 percent of samples with detections per month

Distribution of Selected Constituents

More inorganic constituents were present at high concentrations above MCLs in the regional study area compared to the floodplain study area in the Mojave Basin Shallow Aquifer study unit. Arsenic, fluoride, molybdenum, and uranium were the constituents most commonly present at concentrations above MCLs in the Mojave study unit and were present at high concentrations nearly twice as often in the regional study area than in the floodplain study area. Total chromium, vanadium, and nitrate also were present at concentrations above benchmarks more often in the regional study area. Hexavalent chromium was present at moderate concentrations more often in the floodplain study area compared to the regional study area (Groover and others, 2019).



By Krishangi D. Groover and Dara A. Goldrath

References Cited

California State Water Resources Control Board, 2016, Groundwater information sheet—Bacterial indicators: State Water Resources Control Board Division of Water Quality GAMA Program, 7 p., http://www.waterboards.ca.gov/gama/docs/coc_bacteria_indicators.pdf.

Dawson, B.J.M., and Belitz, K., 2012, Status of groundwater quality in the California Desert Region, 2006–2008—California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2012–5040, 110 p., https://doi.org/10.3133/sir20125040.

Groover, K.D., and Izbicki, J.A., 2019, Selected trace-elements in alluvium and rocks, western Mojave Desert, southern California: Journal of Geochemical Exploration, v. 200, p. 234–248, https://doi.org/10.1016/j.gexplo.2018.09.005.

Groover, K.D., Goldrath, D.A., Bennett, G.L., Johnson, T.D., and Watson, E.E., 2019, Groundwater-quality data in the Mojave Basin Shallow Aquifer study unit, 2018—Results from the California GAMA Priority Basin Project: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9C7U6DW.

Izbicki, J.A., Wright, M.T., Seymour, W.A., McCleskey, R.B., Fram, M.S., Belitz, K., and Esser, B.K., 2015, Cr(VI) occurrence and geochemistry in water from public-supply wells in California: Applied Geochemistry, v. 63, p. 203–217, https://doi.org/10.1016/j.apgeochem.2015.08.007.

Metzger, L.F., Landon, M.K., House, S.F., and Olsen, L.D., 2015, Mapping selected trace elements and major ions, 2000–2012, Mojave River and Morongo Groundwater Basins, Southwestern Mojave Desert, San Bernardino County, California: U.S. Geological Survey Data Release, https://doi.org/10.5066/F7Q23X95.

Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F., 2001, Simulation of ground-water flow in the Mojave River Basin, California: U.S. Geological Survey Water-Resources Investigations Report 2001–4002, 113 p., https://doi.org/10.3133/wri014002.

Toccalino, P.L., and Norman, J.E., 2006, Health-based screening levels to evaluate U.S. Geological Survey groundwater quality data: Risk analysis, v. 26, no. 5, p. 1339–1348, https://doi.org/10.1111/j.1539-6924.2006.00805.x.

Priority Basin Assessments

GAMA's Priority Basin Project (PBP) assesses water quality in groundwater resources used for drinking-water supply. This study in the western part of the Mojave Desert 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 done in more than 120 basins and areas outside of 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 GAMA-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 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 Mojave Basin Shallow Aquifer study unit, data were collected by the GAMA-PBP in 2018. The GAMA-PBP includes chemical analyses not generally 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's Priority Basin Project may be obtained from:

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