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

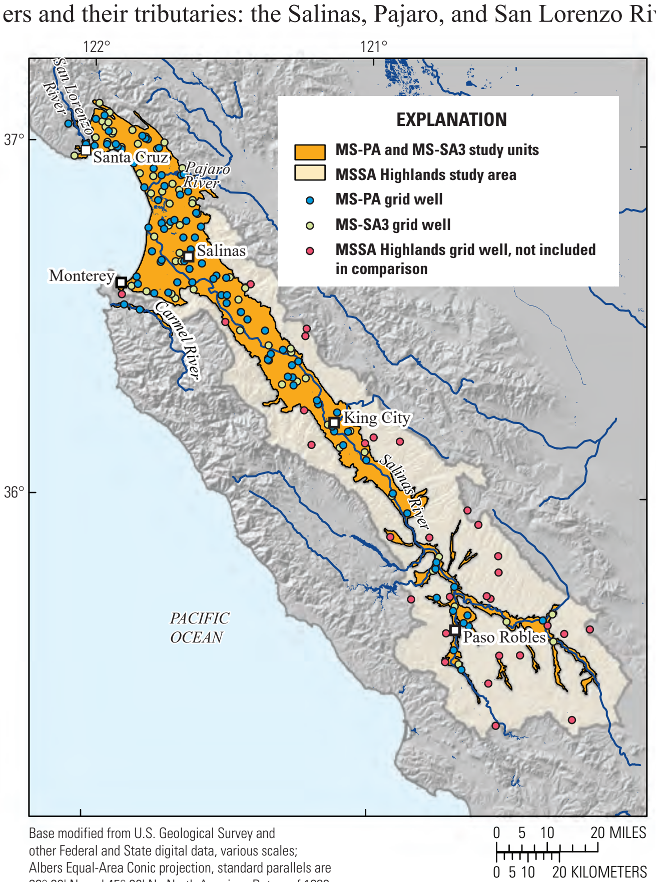
Comparing Groundwater Quality in Public-Supply and Shallow Aquifers in the Monterey Bay and Salinas Valley Basins, California

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 of the GAMA Program (GAMA-PBP) provides a comprehensive assessment of the State's groundwater quality and increases public access to groundwater-quality information.

The Monterey–Salinas Valley Study Units

Groundwater quality in the Monterey–Salinas Valley Public-Supply and Shallow Aquifer Systems was investigated by the GAMA-PBP. The Monterey–Salinas Valley Public-Supply Aquifer System study unit (MS-PA) initially was assessed in 2005 (Kulongoski and Belitz, 2011). The Monterey–Salinas Valley Shallow Aquifer System study unit (MS-SA) was sampled in 2012–13 (Burton and Wright, 2018). The MS-PA and the MS-SA largely coincide areally; however, they represent different parts of the aquifer system vertically. The MS-PA examined deeper groundwater primarily used for public supply, whereas the MS-SA examined relatively shallow groundwater primarily used for domestic supply. The MS-SA was divided into four study areas. Three of these study areas combined (MS-SA3) were equivalent to the MS-PA study unit excluding a small sliver along the Carmel River. The fourth MS-SA study area, Highlands, is composed of the hills and mountains bordering the Salinas Valley.

The MS-PA and the MS-SA study units have warm, dry summers and cool, moist winters. The average annual rainfall is 331 millimeters (mm; 13 inches, in.) with average annual temperatures of 14 degrees Celsius (57 degrees Fahrenheit) in Salinas. The study units are drained by three main rivers and their tributaries: the Salinas, Pajaro, and San Lorenzo Rivers.



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

Groundwater-quality status and understanding assessments of the study units were based on data collected by the U.S. Geological Survey (USGS). In the MS-PA, additional inorganic data was obtained from the California State Water Resources Control Board Division of Drinking Water Public-Supply Well Water-Quality Database (Kulongoski and Belitz, 2011).

A grid-based method to select wells was applied in both study units, which allows for an estimation of the proportions of the aquifer system with constituents at low, moderate, or high concentrations relative to regulatory and non-regulatory benchmarks for drinking-water quality established by the U.S. Environmental Protection Agency (EPA) or California State Water Resources Control Board Division of Drinking Water. The grid-based method provides statistically unbiased results and permits comparison of those results to other GAMA Priority Basin Project study areas (Belitz and others, 2010).

DEFINITIONS

Public-Supply Aquifer System

The GAMA-PBP uses well depths and construction characteristics (where the well perforations or screens are) for public-supply wells in a study unit to define that study unit's "Public-Supply" aquifer system. Public-supply wells generally are drilled to deeper depths than domestic wells and are screened over large portions of the aquifer or multiple aquifers. Public-supply wells are constructed to have high yields in terms of groundwater production.

Shallow Aquifer System

The GAMA-PBP defines the "Shallow" aquifer system as that part of an aquifer upstream from the productive zones of the Public-Supply Aquifer system. The shallow aquifer system is generally utilized by domestic well owners and small systems. Domestic and small system wells typically produce enough water to meet the needs of a household and as such are of relatively low yield when compared to public-supply wells.

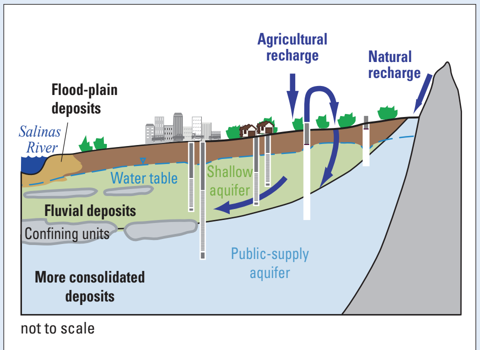


Figure showing a conceptual model of the Public-Supply and Shallow Aquifers Systems (modified from Kulongoski and Belitz, 2011).

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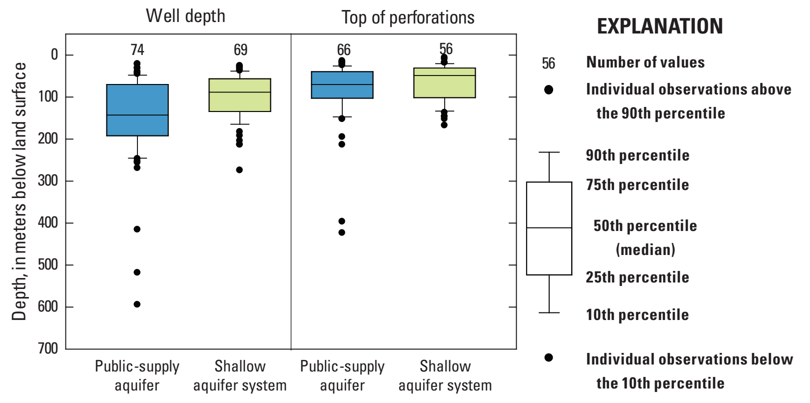
Comparison of Study-Unit Characteristics

Study-unit characteristics of the MS-PA and the MS-SA3 study units, such as well construction, groundwater age, and land use were compared to identify significant differences that could affect interpretations of water-quality results. Further discussion of the differences observed among these and other characteristics between the MS-PA and the MS-SA3 is presented in Burton and Wright (2018). Mann-Whitney tests were used as the test of significance (α=0.05).

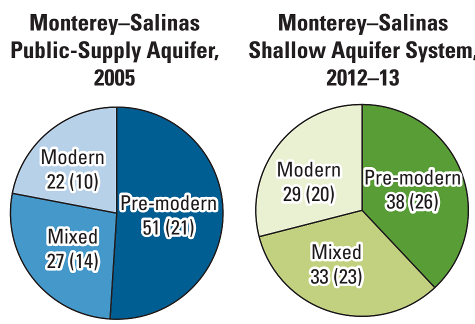
Well-Construction Comparison

Well depth is an important variable and is often used when assessing a well's vulnerability to contamination. Shallow wells generally are more vulnerable to potential contaminants than deeper wells. Well depths in the MS-PA were much deeper than in the MS-SA3 (p=0.002). Well depths in the MS-PA ranged from 21 to 594 meters (m) below land surface with a median well depth of 143 m. Well depths in the MS-SA3 ranged from 26 to 274 m with a median well depth of 88 m. Depth to the top of perforations in the MS-PA, while not significant, tended to be deeper than in the MS-SA3 (p=0.056). Median depth to the top of perforations in the MS-PA was 70 m, whereas median depth to the top of perforations in the MS-SA3 system was 49 m.



Groundwater-Age Comparison

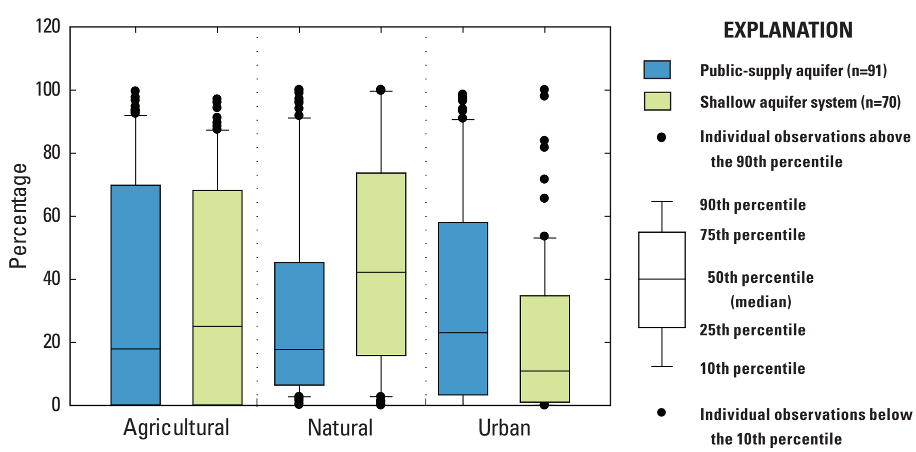
Groundwater "age" is the amount of time that has passed between when groundwater was recharged into the aquifer system and when it was collected as a sample. This "residence time" can be an important explanatory factor when discussing water-quality results. For example, older groundwater would have more time for water-rock interactions to occur. A simplified age-classification system was constructed using tritium and carbon-14 activities to compare groundwater ages of samples from the MS-PA and the MS-SA3 (Burton and Wright, 2018). Tritium is a short-lived radioactive isotope of hydrogen with a half-life of 12.3 years. Carbon-14 has a half-life of 5,730 years. Carbon-14 and tritium have been detected in our atmosphere in amounts that greatly exceed natural levels as a result of above-ground nuclear weapons testing in the mid-1950s. Groundwater samples with tritium activities less than 0.3 tritium units (TU) and carbon-14 values less than 90-percent modern carbon (pmc) were classified as "pre-modern" groundwater; samples with tritium activities greater than or equal to 0.3 TU and carbon-14 values greater than or equal to 90 pmc were classified as "modern" groundwater. Samples with tritium activities greater than or equal to 0.3 TU and carbon-14 values less than 90 pmc, or with tritium activities less than 0.3 TU and carbon-14 values greater than or equal to 90 pmc, were classified as "mixed" groundwater. A higher percentage of wells with groundwater identified as modern age were observed in the MS-SA3 than in the MS-PA; a higher percentage of wells with groundwater identified as pre-modern were observed in the MS-PA than in the MS-SA3.



(The number in parentheses is the number of samples classified as modern, mixed, or pre-modern in each study area)

Land-Use Comparison

Land-use characteristics within a 500-m radius surrounding sampled wells derived from the National Land Cover Database 1992 (Nakagaki and others, 2007) was another important factor for understanding and characterizing water-quality results. Many potential contaminants in water quality are expected to vary among urban, natural, and agricultural land uses. In general, urban land use around wells in the MS-PA was greater than for the MS-SA3 (*p*=0.036) as public-supply wells typically are near population centers. Natural land use around wells in the MS-SA3 was greater than in the MS-PA (*p*=0.008) showing that domestic wells generally exist in less developed areas than public-supply wells. The percentage of agricultural land use was similar (*p*=0.651) for both study units.

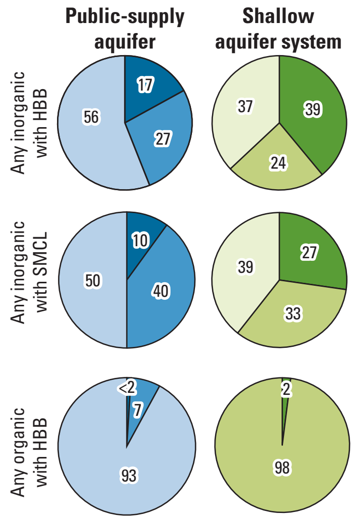


Comparison of Water Quality

Overview of Water Quality

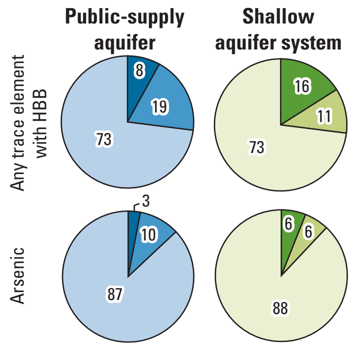
Proportions of high, moderate, and low concentrations of constituent groups and select constituents were compared to evaluate differences in water quality between the MS-PA and the MS-SA3. Many inorganic constituents are naturally present in groundwater. Concentrations of inorganic constituents can be affected by natural processes as well as by human activities. Inorganic constituents with health-based benchmarks (HBBs) or secondary maximum contaminant levels (SMCLs) were compared between study units as classes (groups of common constituents) and as individual constituents. Human-made organic constituents are found in products used in the home, business, industry, and agriculture.

In general, inorganic constituents with HBBs and SMCLs were detected at high concentrations in a greater proportion in the MS-SA3 than in the MS-PA. In contrast, organic constituents were detected at high or moderate concentrations in a greater proportion of the MS-PA than in the MS-SA3.



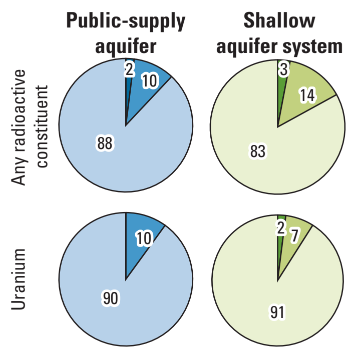
Trace Elements

Trace elements are naturally present in the minerals of rocks and sediments and in the water that comes in contact with those materials. Trace elements were present at high concentrations in a greater proportion in the MS-SA3 than in the MS-PA. In contrast, trace elements were present at moderate concentrations in a greater proportion of the MS-PA than the MS-SA3. One trace element that contributed most often to high concentrations in the MS-PA and MS-SA3 was arsenic. High and moderate concentrations of arsenic in MS-PA were attributed to the release of arsenic from the dissolution of iron or manganese oxides under reducing conditions (Kulongoski and Belitz, 2011). High and moderate concentrations of arsenic in MS-SA3 were attributed to desorption from iron and manganese oxyhydroxides under high-pH, oxic conditions or geothermal sources (Burton and Wright, 2018).



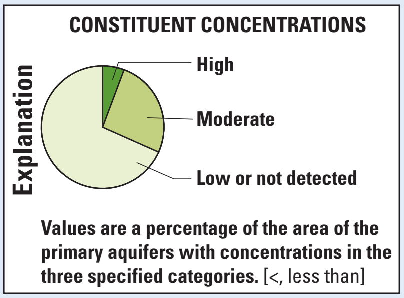
Radioactive

Most of the radioactivity in groundwater comes from the decay of natural isotopes of uranium and thorium in minerals in the aquifer materials. Radioactive constituents were present at high or moderate concentrations in greater proportions in the MS-SA3 than MS-PA. Uranium was the primary radioactive constituent detected at high or moderate concentrations; it was detected in high concentrations in MS-SA3 and not in MS-PA. The higher concentrations in MS-SA3 were attributed to the enhanced desorption from sediments and mobilization of uranium by irrigation recharge having high-bicarbonate concentrations.



Evaluating Water Quality

The GAMA Priority Basin Project evaluates the quality of untreated groundwater. However, for context, benchmarks established for drinking-water quality are used for comparison. 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. Federal and California regulatory benchmarks for protecting human health (Maximum Contaminant Level, MCL) are used when available. Otherwise, non-regulatory benchmarks for protecting human health (lifetime health advisory level, HAL; notification level, NL) are used. These benchmarks (MCL, HAL, and NL) are collectively referred to as HBB. Non-regulatory benchmarks for protecting aesthetic properties, such as taste and odor (SMCL) were used if HBBs were not available.

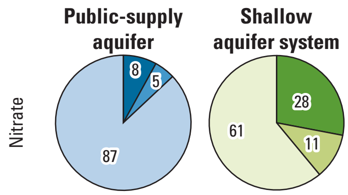


High, Moderate, and Low Concentrations are Defined Relative to Benchmarks

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, concentrations are moderate if they are greater than one-tenth of a benchmark. Low concentrations include non-detections as well as measured values less than moderate concentrations. Methods for evaluating water quality are discussed by Burton and Wright (2018).

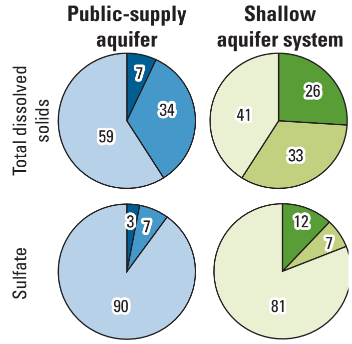
Nutrients

Nutrients are naturally present; however, in the MS-PA and MS-SA3, concentrations are primarily elevated from the leaching of excess nitrogen fertilizers to the groundwater. Of the nutrients sampled, nitrate was the primary nutrient detected at high or moderate concentrations. High concentrations of nitrate were detected greater than three times more frequently in samples collected in the MS-SA3 than in the MS-PA. The shallower, oxic aquifer sampled in the MS-SA3 was more susceptible to the effects of agricultural land-use practices because it is closer to the land surface and therefore closer to the agricultural sources of nitrate. Nitrate concentrations are likely to increase in some areas of the MS-PA aquifer system as a result of the downward movement of nitrate.



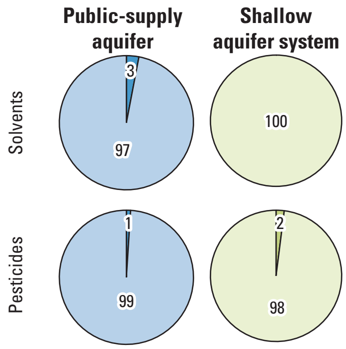
Inorganic Constituents with a Secondary Maximum Contaminant Level

Four inorganic constituents with SMCLs were detected at high relative concentrations in the MS-PA and MS-SA3; these constituents are iron and the salinity indicators are chloride, sulfate, and total dissolved solids (TDS). These constituents are naturally present, but some concentrations can be elevated by human activities. The salinity indicators had greater proportions of high concentrations in the MS-SA3 than in MS-PA. The higher proportion with elevated concentrations of chloride in the MS-SA3 system was most likely a result of seawater intrusion near the coast, evaporative concentration, and dissolution from marine rocks. Sulfate and TDS were detected at high concentrations in the interior parts of the MS-SA3 study unit. These high concentrations most likely were a result from dissolution of natural marine sediments and from agricultural practices. The predominance of high concentrations of the salinity indicators in the MS-SA3 indicated that the shallow aquifer system was more susceptible than the MS-PA to the effects of anthropogenic activities at the land surface, such as irrigated agriculture.



Organic Constituents (Volatile Organic Compounds and Pesticides)

Volatile organic compounds (VOCs) are characterized by their tendency to evaporate and are present in paints, solvents, fuels, fuel additives, refrigerants, fumigants, and disinfected water. The VOCs typically persist longer in groundwater than in surface water because groundwater is isolated from the atmosphere. Pesticides are used to control weeds, fungi, or insects in agricultural and urban settings. Most of the detections of organic constituents in MS-SA3 and MS-PA were at low relative concentrations. No organic constituents were detected at high relative concentrations. The VOCs were detected more frequently in MS-PA than in MS-SA3 most likely because more MS-PA wells were near urban sources. Solvents (carbon tetrachloride, tetrachloroethene [PCE], and trichloroethene [TCE]) are the VOCs detected most frequently and at moderate concentrations in the MS-PA. Dieldrin was the pesticide detected at moderate concentrations in MS-PA, whereas the fumigant 1,2-dichloropropane was detected at moderate concentrations in MS-SA3. Simazine was the pesticide detected most frequently in MS-PA and MS-SA3 but only at low concentrations. Simazine detections were correlated to agricultural land use in MS-SA3 but not in MS-PA.



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For more information

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

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