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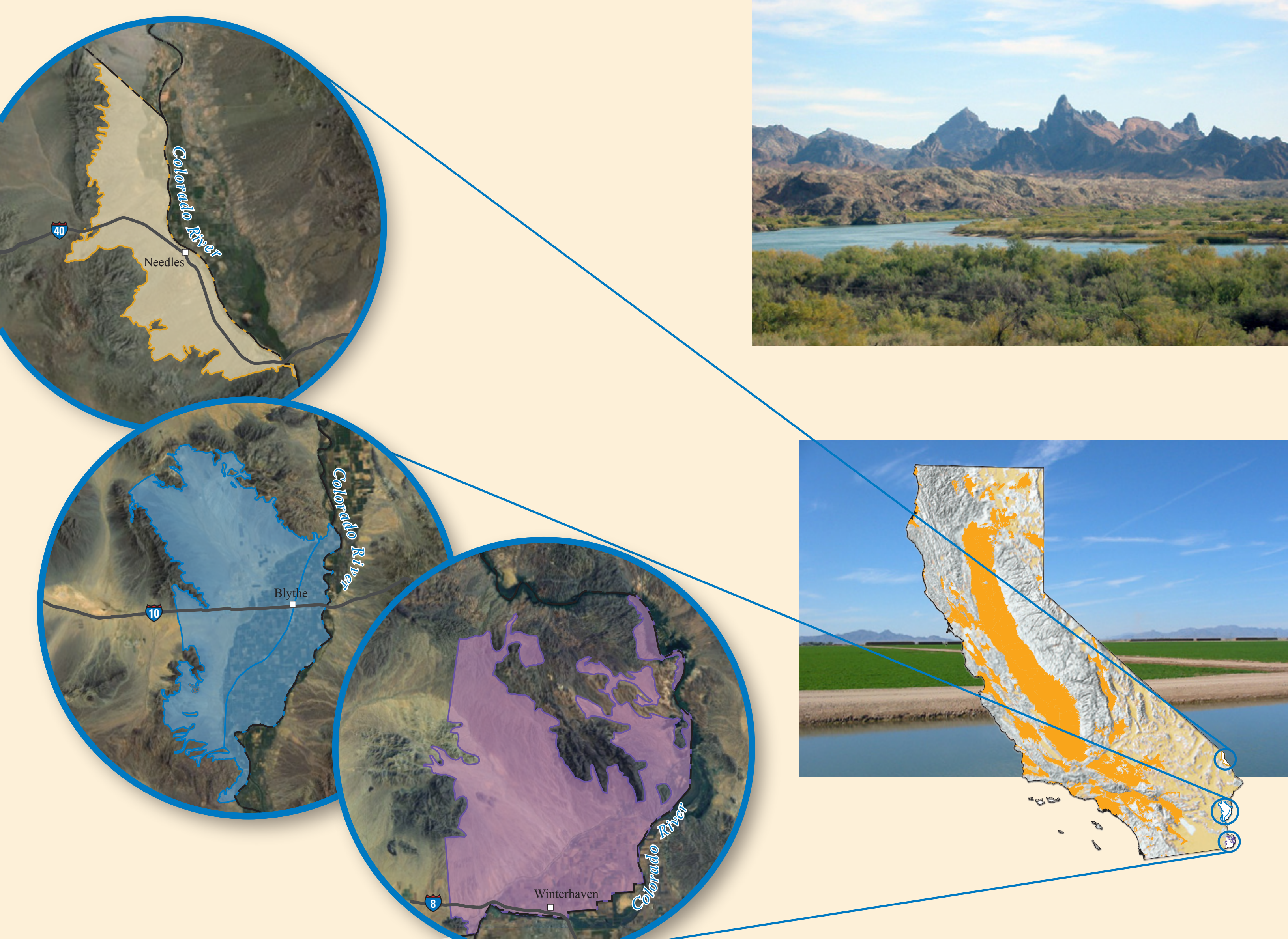
Groundwater-Quality Data in the Colorado River Study Unit, 2007: Results from the California GAMA Program



Data Series 474

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Cover photographs:
Top: Colorado River and Needles Mountains, California. (Photograph taken by Mary Ray, U.S. Geological Survey.)
Middle: Irrigation canal and field near Blythe, California. (Photograph taken by Michael Wright, U.S. Geological Survey.)
Bottom: Well sampled near Palo Verde, California. (Photograph taken by Jill Densmore, U.S. Geological Survey.)

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U.S. Department of the Interior
KEN SALAZAR, Secretary

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Contents

Figures

Tables

Appendix Tables:

Abbreviations and Acronyms

(Additional information or clarification given in parentheses)

AB	Assembly Bill (through the California State Assembly)
CAS	Chemical Abstract Service (American Chemical Society)
COLOR	Colorado River Study unit or Colorado River Study unit grid well
COLORU	Colorado River Study unit understanding well
CSU	combined standard uncertainty
E	estimated or having a higher degree of uncertainty
GAMA	Groundwater Ambient Monitoring and Assessment program
GPS	Global Positioning System
HAL-US	lifetime health advisory level (USEPA)
HPLC	high-performance liquid chromatography
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL-US	maximum contaminant level (USEPA)
MCL-CA	maximum contaminant level (CDPH)
MDL	method detection limit
MRL	minimum reporting level
MU	method uncertainty
N	Normal (1-gram-equivalent per liter of solution)
NL-CA	notification level (CDPH)
NWIS	National Water Information System (USGS)
PCFF	personal computer field forms program designed for USGS sampling
QC	quality control
RPD	relative percent difference
RSD	relative standard deviation
RSD5	risk-specific dose at 10^{-5} (USEPA)
SMCL-CA	secondary maximum contaminant level (CDPH)
ssLC	sample-specific critical level
US	United States
VPDB	Vienna Pee Dee Belemnite
VSMOW	Vienna Standard Mean Ocean Water

Organizations

CDPH	California Department of Public Health
DWR	California Department of Water Resources
USEPA	U.S. Environmental Protection Agency
LLNL	Lawrence Livermore National Laboratory
MWH	Montgomery Watson Harza
NAWQA	National Water Quality Assessment (USGS)
NWQL	National Water Quality Laboratory (USGS)
SWRCB	State Water Resources Control Board (California)
USGS	U. S. Geological Survey
WECK	Weck Laboratories, Inc.

Selected chemical names

$CaCO_3$	calcium carbonate
CFC	chlorofluorocarbon
CO_3^{-2}	carbonate
HCl	hydrochloric acid
HCO_3^-	bicarbonate
MTBE	methyl *tert*-butyl ether
NDMA	*N*-nitrosodimethylamine
PCE	perchloroethene, tetrachloroethene
TCP	trichloropropane
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound

Units of measurement

cm^3 STP/g	cubic centimeters of gas at standard temperature and pressure (0 degrees Celsius and 1 atmosphere of pressure) per gram of water
ft	foot (feet)
km	kilometer
L	liter
mg	milligram
mg/L	milligram per liter (parts per million)
mi	mile
mL	milliliter
μg/L	microgram per liter (parts per billion)
μL	microliter
μm	micrometer
pCi/L	picocurie per liter
δiE	delta notation, the ratio of a heavier isotope of an element (iE) to the more common lighter isotope of that element, relative to a standard reference material, expressed as per mil

Notes

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Well depths in are given in feet below land-surface datum (LSD), which is a datum plane that is approximately at land surface. The LSD for each well is referenced to NAVD 88.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is equivalent to parts per million (ppm) and micrograms per liter is equivalent to parts per billion (ppb)

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Abstract

Groundwater quality in the 188-square-mile Colorado River Study unit (COLOR) was investigated October through December 2007 as part of the Priority Basin Project of the California State Water Resources Control Board (SWRCB) Groundwater Ambient Monitoring and Assessment (GAMA) Program. The GAMA Priority Basin Project was developed in response to the Groundwater Quality Monitoring Act of 2001, and the U.S. Geological Survey (USGS) is the technical project lead.

The Colorado River study was designed to provide a spatially unbiased assessment of the quality of raw groundwater used for public water supplies within COLOR, and to facilitate statistically consistent comparisons of groundwater quality throughout California. Samples were collected from 28 wells in three study areas in San Bernardino, Riverside, and Imperial Counties. Twenty wells were selected using a spatially distributed, randomized grid-based method to provide statistical representation of the Study unit; these wells are termed 'grid wells'. Eight additional wells were selected to evaluate specific water-quality issues in the study area; these wells are termed 'understanding wells.'

The groundwater samples were analyzed for organic constituents (volatile organic compounds [VOC], gasoline oxygenates and degradates, pesticides and pesticide degradates, pharmaceutical compounds), constituents of special interest (perchlorate, 1,4-dioxane, and 1,2,3-trichlorpropane [1,2,3-TCP]), naturally occurring inorganic constituents (nutrients, major and minor ions, and trace elements), and radioactive constituents. Concentrations of naturally occurring isotopes (tritium, carbon-14, and stable isotopes of hydrogen and oxygen in water), and dissolved noble gases also were measured to help identify the sources and ages of the sampled groundwater. In total, approximately 220 constituents and water-quality indicators were investigated.

Quality-control samples (blanks, replicates, and matrix spikes) were collected at approximately 30 percent of the wells, and the results were used to evaluate the quality of the data obtained from the groundwater samples. Field blanks rarely contained detectable concentrations of any constituent, suggesting that contamination was not a significant source of bias in the data. Differences between replicate samples were within acceptable ranges and matrix-spike recoveries were within acceptable ranges for most compounds.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, raw groundwater typically is treated, disinfected, or blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to water that is served to the consumer, not to raw groundwater. However, to provide some context for the results, concentrations of constituents measured in the raw groundwater were compared to regulatory and nonregulatory health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH) and to thresholds established for aesthetic concerns by CDPH. Comparisons between data collected for this study and drinking-water thresholds are for illustrative purposes only and do not indicate compliance or noncompliance with those thresholds.

The concentrations of most constituents detected in groundwater samples were below drinking-water thresholds. Volatile organic compounds (VOC) were detected in approximately 35 percent of grid well samples; all concentrations were below health-based thresholds. Pesticides and pesticide degradates were detected in about 20 percent of all samples; detections were below health-based thresholds. No concentrations of constituents of special interest or nutrients were detected above health-based thresholds. Most of the major and minor ion constituents sampled do not have health-based thresholds; the exception is fluoride. Concentrations of chloride, sulfate, and total dissolved solids detected in some of the well samples were above the nonenforceable thresholds for aesthetic concerns. Concentrations of fluoride were detected in 5 samples (from 4 grid wells and 1 understanding well) above the maximum contaminant level for California (MCL-CA). Concentrations of most of the trace elements in samples from the COLOR were below health-based thresholds; exceptions included arsenic above the MCL-US, boron above the notification level for California (NL-CA), iron and manganese above the secondary maximum contaminant level for California (SMCL-CA), and molybdenum and strontium above the lifetime health advisory level (HAL-US) threshold. Most detections of radioactive constituents were below health-based thresholds; exceptions were alpha, uranium, and radon radioactivity. Alpha radioactivity with 72 hour count detections occurred in four grid wells and one understanding well, and 30-day count detections in two grid wells above the MCL-US. Uranium was detected twice in grid wells above the MCL-US threshold. Also, radon-222 was detected at concentrations above the proposed MCL-US in 19 samples (14 grid and 5 understanding wells). No radon-222 was detected above the proposed MCL-US upper threshold.

Introduction

Groundwater comprises nearly half of the water used for public supply in California (Hutson and others, 2004). To assess the quality of groundwater in aquifers used for drinking-water supply and to establish a program for monitoring trends in groundwater quality, the State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory (LLNL), implemented the Groundwater Ambient Monitoring and Assessment (GAMA) Program (http://www.waterboards.ca.gov/gama). The GAMA Program consists of three projects: Priority Basin Project, conducted by the USGS (http://ca.water.usgs.gov/gama/); Voluntary Domestic Well Assessment, conducted by the SWRCB; and Special Studies, conducted by LLNL.

The SWRCB initiated the GAMA Priority Basin Project in response to the Groundwater Quality Monitoring Act of 2001 (Sections 10780–10782.3 of the California Water Code, Assembly Bill 599). AB 599 is a public mandate to assess and monitor the quality of groundwater used as public supply in California. The project is a comprehensive assessment of statewide groundwater quality designed to help better understand and identify risks to groundwater resources and to increase the amount of information about groundwater quality available to the public. As part of the AB 599 process, the USGS, in collaboration with the SWRCB, developed the monitoring plan for the project (Belitz and others, 2003; State of California State Water Resources Control Board, 2003). Key aspects of the project are interagency collaboration and cooperation with local water agencies and well owners. Local participation in the project was entirely voluntary.

The GAMA Priority Basins Project is unique because it includes many chemical analyses that otherwise are not available in statewide water-quality monitoring datasets. A broader understanding of groundwater composition will be especially useful for providing an early indication of changes in water quality and for identifying the natural and human factors affecting water quality. Additionally, the GAMA Priority Basin Project will analyze a broader suite of constituents than required by the California Department of Public Health (CDPH; formerly California Department of Health Services, renamed on July 1, 2007). An understanding of the occurrence and distribution of these constituents is important for the long-term management and protection of groundwater resources.

The range of hydrologic, geologic, and climatic conditions that exist in California must be considered when assessing groundwater quality. Belitz and others (2003) partitioned the state into ten hydrogeologic provinces, each with distinctive hydrologic, geologic, and climatic characteristics (fig.1), and representative regions in all 10 provinces were included in the project design. Eighty percent of California's approximately 16,000 public-supply wells are located in groundwater basins within these hydrologic provinces. These groundwater basins, defined by the California Department of Water Resources, generally consist of relatively permeable, unconsolidated deposits of alluvial or volcanic origin (California Department of Water Resources, 2003). Groundwater basins were prioritized for sampling on the basis of the number of public-supply wells in the basin, with secondary consideration given to municipal groundwater use, agricultural pumping, the number of formerly leaking underground fuel tanks, and pesticide applications within the basins (Belitz and others, 2003). In addition, some groundwater basins or groups of similar adjacent basins with relatively few public-supply wells were assigned high priority so that all hydrogeologic provinces would be represented in the subset of basins sampled as part of the project. The 116 priority basins were grouped into 37 study units. Some areas not in DWR-defined groundwater basins were included in their nearest respective study units to represent the 20 percent of public-supply wells not located in the groundwater basins.

Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006.
Albers Equal Area Conic Projection

Provinces from Belitz and others, 2003.

Figure 1. Map of the hydrogeologic provinces of California and the location of the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study unit and study areas.

Three types of water-quality assessments are being conducted using the data collected in each study unit: (1) Status: assessment of the current quality of the groundwater resource, (2) Trends: detection of changes in groundwater quality, and (3) Understanding: identification of the natural and human factors affecting groundwater quality (Kulongoski and Belitz, 2004). This report is one of a series of reports presenting water-quality data collected in each study unit (Wright and others, 2005; Bennett and others, 2006; Kulongoski and others, 2006; Fram and Belitz, 2007; Kulongoski and Belitz, 2007; Burton and Belitz, 2008; Dawson and others, 2008; Ferrari and others, 2008; Land and Belitz, 2008; Landon and Belitz, 2008; Mathany and others, 2008; Schmitt and others, 2008; Shelton and others, 2008; Fram and others, 2009; Kent and Belitz, 2009; Goldrath and others, 2009; Montrella and Belitz, 2009; and, Ray and others, 2009; Mathany and Belitz, 2009). Subsequent reports will address the status, trends, and understanding aspects of the water-quality assessments.

The Colorado River GAMA Study unit, hereinafter referred to as COLOR, covers targeted areas of four small groundwater basins: the Needles Valley study area, the Palo Verde study area including both the Palo Verde Valley and Mesa, and the Yuma Valley study area. COLOR was considered a high priority for sampling because it provides representation of the Desert Hydrologic Province and the Colorado River Basins (Belitz and others, 2003). COLOR was the 21st study unit sampled as part of the GAMA Program.

Purpose and Scope

The purposes of this report are (1) to describe the study design, including the hydrogeologic setting of COLOR and the study methods; (2) to present the results of quality-control tests; and (3) to present the analytical results for groundwater samples collected in the COLOR. Groundwater samples were analyzed for organic and inorganic constituents, field parameters, and chemical tracers. The chemical data presented in this report were evaluated by comparing these data to State and Federal drinking water regulatory and nonregulatory health-based standards that are applied to treated drinking water. Regulatory and nonregulatory thresholds considered for this report are those established by the United States Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH). The data presented in this report are intended to characterize the quality of untreated (raw) groundwater resources within the study unit, not the treated drinking water delivered to consumers by water purveyors. Discussion of the factors that influence the distribution and occurrence of the constituents detected in groundwater samples will be the subject of subsequent publications.

Hydrogeologic Setting

Knowledge of the hydrogeologic setting is important in the design of a groundwater-quality investigation. The Colorado River Study unit (COLOR) lies within the Desert Hydrologic Province, described by Belitz and others (2003), in southeastern California and is bounded on the east by the Colorado River, on the west by various desert mountain ranges, on the north by Nevada, and on the south by Mexico (figs. 1,2,3,4). The climate is marked by high summer temperatures and low amounts of precipitation. The annual average precipitation ranges from six inches in the northern area to 3 inches in the southern area (National Climate data Center, 2008). Precipitation falls primarily during the summer monsoon season; a lesser amount occurs during the winter as storms come in from the Pacific Ocean (Hely and Peck, 1964; Pyke, 1972).

Although the COLOR is approximately 150 miles from end to end, the actual area of study is small, only 188 square miles. The COLOR is divided into three small study areas: Needles Valley, Palo Verde, and Yuma Valley (fig.1). The boundaries of the study areas correspond to those of the California Department of Water Resources (DWR) groundwater basins (California Department of Water Resources, 2004a,b,c,d). The Palo Verde study area includes the California DWR delineated Palo Verde Valley and the Palo Verde Mesa groundwater basins (fig. 3).

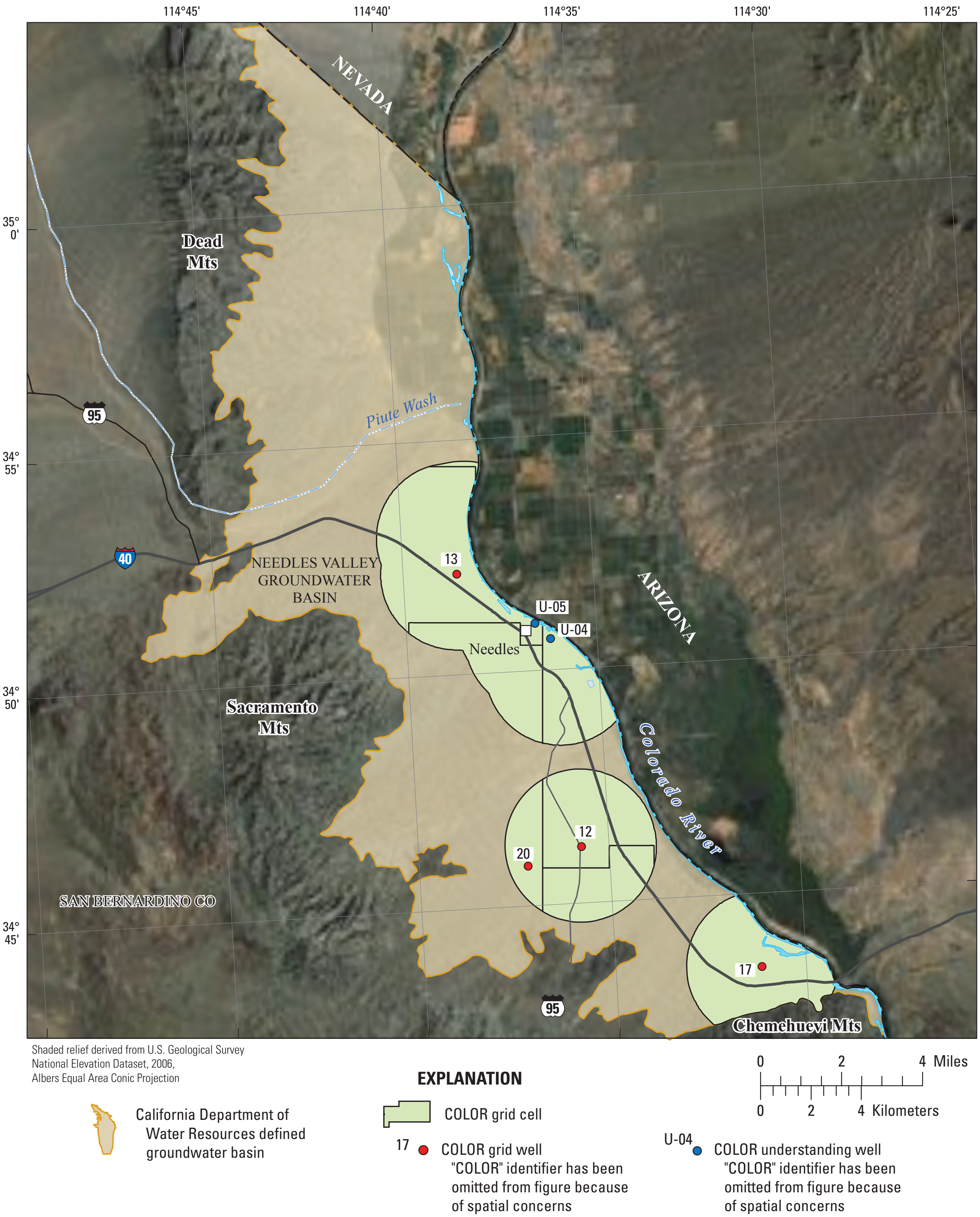
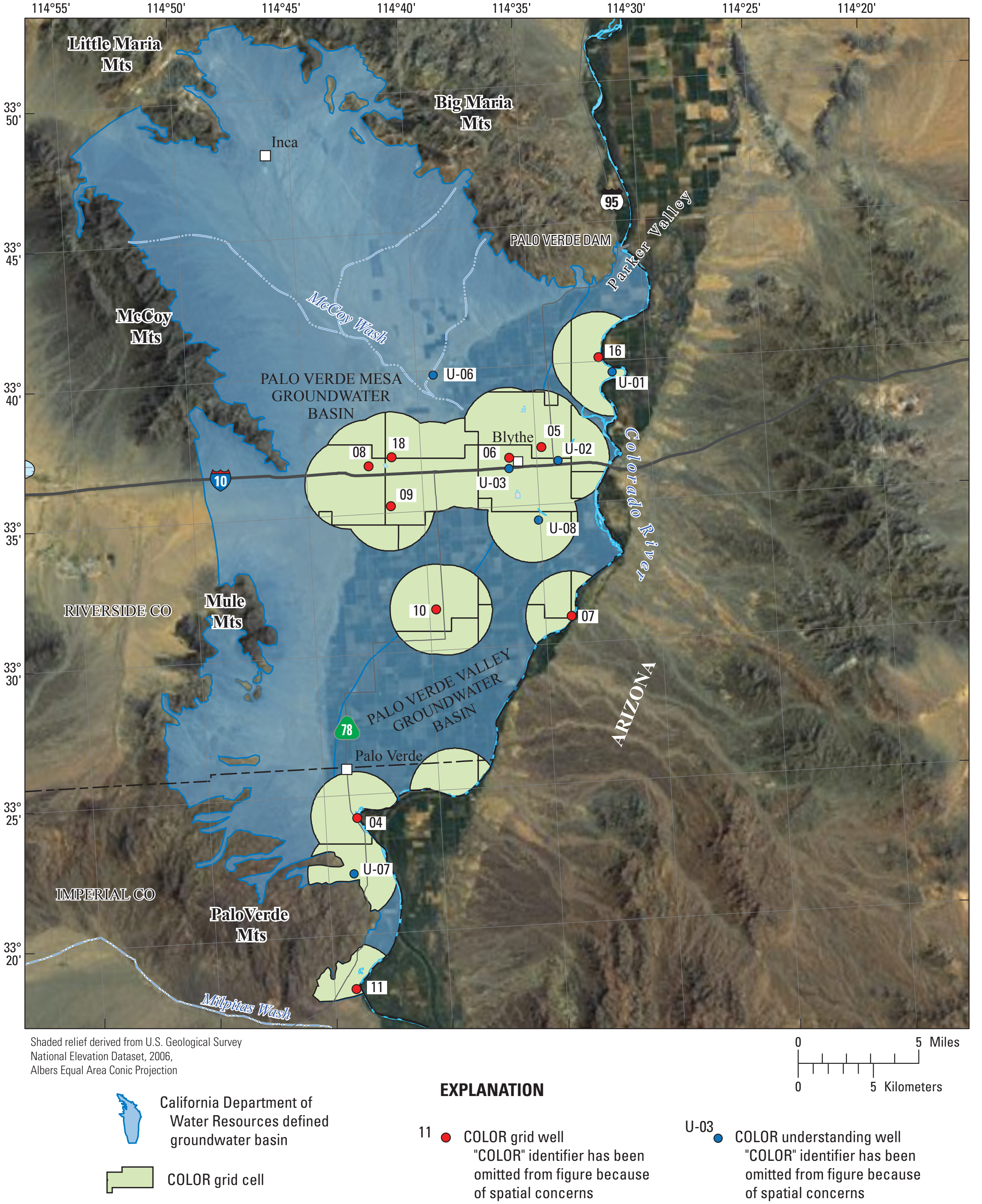


Figure 2. Map of the Needles Valley study area of the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) Study unit showing the 3-km buffer zones around all public-supply wells, the distribution of study-area grid cells, and the locations of sampled grid wells and understanding wells. Alphanumeric identification numbers for grid wells have the prefix “COLOR.” Alphanumeric identification numbers for understanding wells have the prefix “COLORU.”



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006, Albers Equal Area Conic Projection

Figure 3. Map of the Palo Verde study area of the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) Study unit showing the 3-km buffer zones around all public-supply wells, the distribution of study-area grid cells, and the locations of sampled grid wells and understanding wells. Alphanumeric identification numbers for grid wells have the prefix "COLOR." Alphanumeric identification numbers for understanding wells have the prefix "COLORU."

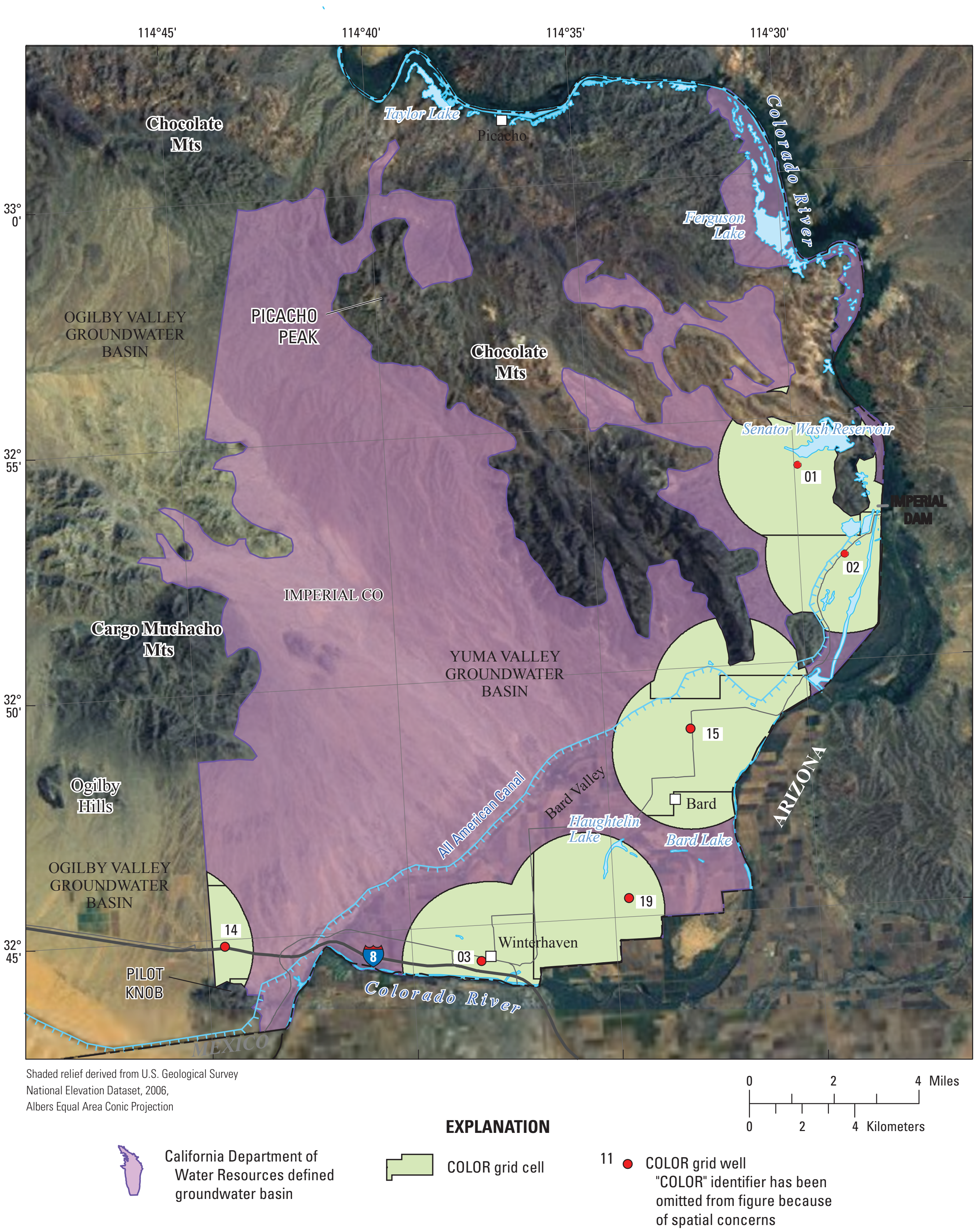
The 36-square-mile Needles Valley study area is underlain by the Needles Valley groundwater basin, which is located in the eastern part of the Mojave Valley in San Bernardino County (fig. 1, 2). The basin is bounded by the Colorado River to the east, the Dead Mountains to the northwest, the Sacramento Mountains to the southwest, and the Chemehuevi Mountains to the south (Bishop, 1963). The average annual precipitation ranges from 4 to 6 inches, and surface water drains eastward through the Piute Wash to the Colorado River (California Department of Water Resources, 2004a). Two main water-bearing units exist within the Needles Valley groundwater basin: the alluvium (younger and older) and the Bouse Formation. The younger alluvium, Holocene in age, is in washes and in the floodplain area of the Colorado River and is composed of sand, silt, and gravel (Metzger and Loeltz, 1973). The older alluvium, considered to be late Pliocene or older, consists of unconsolidated, fine to coarse grained sand, pebbles, and boulders with inclusions of silt and clay (California Department of Water Resources, 2004a). The alluvial units in this part of the study area are more than 310 feet thick (Metzger and Loeltz, 1973). The Pliocene-age Bouse Formation is as much as 254 feet thick, and is composed of a basal limestone bed that is overlain by interbedded clay, silt sand, and tufa (Metzger and Loeltz, 1973). The Bouse Formation is underlain by a locally derived fanglomerate (California Department of Water Resources, 2004a). An unnamed fault outside of the study area traverses the southern side of the basin (Bishop, 1963); it is not known if the fault impedes the flow of groundwater. Recharge processes in the Needles Valley basin include percolation of the Colorado River, agricultural returns, precipitation, and a minor subsurface inflow from the mountains and uplands on the western side of the study area (Metzger and Loeltz, 1973). The groundwater levels in this basin range from 9 to 12 feet below land surface (Metzger and Loeltz, 1973).

The 108-square-mile Palo Verde study area is underlain by the Palo Verde Valley and the Palo Verde Mesa groundwater basins, which are located in the southeastern portion of Riverside County and the northeastern corner of Imperial County (fig. 3). The basins are bounded by the Colorado River to the east, and the non-water-bearing rocks of the Big Maria and Little Maria Mountains to the north, the McCoy and Mule Mountains to the west, and the Palo Verde Mountains to the south (Jennings, 1967; California Department of Water Resources, 1979). The average annual precipitation ranges up to 6 inches, and surface water drains eastward through the McCoy wash to the Colorado River (California Department of Water Resources, 2004b). In the Palo Verde Mesa groundwater basin, the main water-bearing unit consists of alluvial deposits, Quaternary in age, approximately 600 feet thick (Metzger and others, 1973) and is composed of lenticular beds of sand, gravel, silt, and clay in the basin and coarse-grained angular rock detritus near the mountains (California Department of Water Resources, 1961, 1979). In the Palo Verde Valley groundwater basin, the main water-bearing units include the alluvium deposits, ranging from 130 to 600 feet thick, and the upper Bouse Formation (Metzger and others, 1973). Recharge processes in the Palo Verde Valley and Palo Verde Mesa groundwater basins include mountain side runoff, percolation of the Colorado River, agricultural return through irrigated land and canal seepage (Metzger and others, 1973), precipitation, and a minor component of subsurface inflow from the mountains and uplands on the western side of the study area (California Department of Water Resources, 1979). The groundwater levels in the study areas range from about 5 feet near the Colorado River to about 25 feet in the western edge of the basin (Metzger and others, 1973).

The 44-square-mile Yuma Valley study area is underlain by the Yuma Valley groundwater basin, which is located in Bard Valley, a southeast trending valley in the southeast portion of Imperial County (fig. 4) (Olmsted and others, 1973). The basin is bounded by the Colorado River to the east and south, the non-water-bearing rocks of the Cargo Muchacho Mountains to the west, and the Chocolate Mountains to the north and northeast. The average annual precipitation ranges from 1 to 3 inches, and surface water drains southeast towards the Colorado River (California Department of Water Resources, 1954). The main water bearing unit is comprised of alluvium deposits: an unconsolidated Quaternary alluvium underlain by an unconsolidated to semi-consolidated Tertiary to Quaternary alluvial deposit (California Department of Water Resources, 2004c). The maximum depth of the valley fill alluvium deposits is at least 200 feet (California Department of Water Resources 1954, 1975). Recharge in the Yuma Valley groundwater basin occurs naturally from subsurface inflow through the Ogilby groundwater basin to the west, mountainside runoff infiltrating through the alluvial deposits, and percolation from the Colorado River. Recharge occurs also through seepage loss from the All American Canal and other unlined canals as well as through the percolation of irrigation return flows (California Department of Water Resources, 2004c). Groundwater levels in areas near the Colorado River floodplain south and east of the All American Canal range from 5 to 20 feet, and groundwater levels north or west of the canal range from 40 to 240 feet (California Department of Water Resources, 2004c).

Methods

Methods used for the GAMA program were selected to achieve the following objectives: (1) design a sampling plan suitable for statistical analysis, (2) collect samples in a consistent manner, (3) analyze samples using proven and reliable laboratory methods, (4) assure the quality of the groundwater data, and (5) maintain data securely and with relevant documentation. The Appendix to this report contains detailed descriptions of the sample collection protocols and analytical methods, the quality-assurance plan, and the results of analyses of quality-control samples.



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006, Albers Equal Area Conic Projection

Figure 4. Map of the Yuma Valley study area of the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) Study unit showing the 3-km buffer zones around all public-supply wells, the distribution of study-area grid cells, and the locations of sampled grid wells. Alphanumeric identification numbers for grid wells have the prefix “COLOR.”

Study Design

The wells selected for sampling in this study reflect the combination of two well selection strategies. Twenty wells, called "grid" wells, were selected to provide a statistically unbiased, spatially distributed assessment of the quality of groundwater resources used for public drinking-water supply, and eight additional wells, called "understanding" wells, were selected to provide greater sampling density in areas where specific groundwater-quality issues needed to be addressed.

The spatially distributed grid wells were selected using a randomized grid-based method (Scott, 1990). COLOR had relatively few public-supply wells, and these wells were not evenly distributed. To minimize the number of cells without any wells, only the portion of COLOR near a public-supply well was included in the grid area. Locations of public-supply wells listed in the statewide database maintained by the CDPH were plotted, and a 1.86-mi (3-kilometer) radius circle was drawn to form a buffer zone around each well. The areas encompassed by all the circles were then divided into 20 grid cells, approximately 9.7 mi^2 in area (figs. 2–4). The objective was to select one public-supply well per grid cell.

If a grid cell contained more than one public-supply well, each well was randomly assigned a rank. The highest ranking well that met basic sampling criteria (for example, sampling point located before treatment, capability to pump for several hours, and available well-construction information), and for which permission to sample could be obtained, was then sampled. If a grid cell contained no accessible public-supply wells, domestic and irrigation-use wells were considered for sampling. An attempt was made to select domestic and irrigation wells with depths and screened intervals similar to those in public-supply wells in the area. One well was selected in each cell to provide a spatially distributed, randomized monitoring network for each study area. Grid wells in COLOR were numbered in the order of sample collection with the prefix "COLOR" (figs. 2–4). Two wells, COLOR-07 and COLOR-18, are located next to the boundary of grid-cells, and water quality in these wells represents that of both cells (fig. 3). With this additional cell coverage, all of the 20 grid cells are considered to be represented in the grid cell network in COLOR.

Additional wells were sampled to evaluate differences in water chemistry between shallow and deep parts of the aquifers, to study the movement of MTBE, and to collect water-quality data in areas where little or no data previously existed. These additional wells are referred to as "understanding wells," and were numbered in the order of sample collection and designated with the prefix "COLORU" (figs.2–3). Understanding wells sampled were not included in the statistical characterization of the water quality in COLOR because including these wells would have caused certain cells to be overrepresented.

Table 1 (all tables are in back of report) provides the GAMA alphanumeric identification number for each well, along with the date sampled, well elevation, and well-construction information. Groundwater samples were collected from 19 public-supply wells, 6 domestic wells, 2 irrigation wells, and 1 industrial well from October through December 2007.

Well locations and identifications were verified using a GPS, 1:24,000-scale USGS topographic map, existing well information in USGS and CDPH databases, and information provided by well owners. Driller's logs for wells were obtained when available. Well information was recorded by hand on field sheets and electronically using specialized software on field laptop computers. All information was verified and then uploaded into the USGS National Water Information System (NWIS). Well owner information is confidential. Well location information and all chemical data are currently inaccessible from NWIS's public website.

The wells in COLOR were sampled for a standard set of constituents, VOCs, pesticides and pesticide degradates, pharmaceutical compounds, perchlorate, 1,2,3-TCP, nutrients, major and minor ions, trace elements, stable isotopes of hydrogen and oxygen in water, carbon isotopes, radioactive constituents (radon-222, radium isotopes, and gross alpha and gross beta radioactivity), and dissolved noble gases. In the Palo Verde area, 1,4-dioxane was collected at all of the Palo Verde study area wells and gasoline oxygenates and degradates were collected at two of the Palo Verde study area wells as part of a special study (table 2).

Sample Collection and Analysis

Samples were collected in accordance with the protocols established by the USGS National Water Quality Assessment (NAWQA) program (Koterba and others, 1995) and the USGS National Field Manual (U.S. Geological Survey, variously dated). These sampling protocols ensure that a representative sample of groundwater is collected at each site and that potential contamination of samples during collection and handling is minimized. The methods used to collect samples are described in the Appendix section "Sample Collection and Analysis."

Tables 3A–J list the compounds analyzed in each constituent class. Groundwater samples were analyzed for 85 VOCs (table 3A); 8 gasoline oxygenates and degradates (table 3B); 62 pesticides and pesticide degradates (table 3C); 14 pharmaceutical compounds (table 3D); 3 constituents of special interest (table 3E); 5 nutrients (table 3F); 10 major and minor ions and total dissolved solids (table 3G); 25 trace elements (table 3G); arsenic, chromium, and iron species (table 3H); stable isotopes of hydrogen and oxygen of water, 7 radioactive constituents, including tritium and carbon-14 (table 3I); and noble gases and tritium (table 3J). The methods used for sample analysis are described in the Appendix section "Sample Collection and Analysis."

Data Reporting

The methods and conventions used for reporting the data are described in the Appendix. More than one method was used at the USGS National Water Quality Laboratory (NWQL) to analyze five constituents in this study: acetone, TAME, DIPE, ETBE, and MTBE (table A2). Only the results from the preferred method are reported; see Appendix section “Constituents on Multiple Analytical Schedules.” Arsenic, chromium, and iron concentrations, 1,2,3-TCP concentrations, and tritium activities were measured by more than one laboratory; both sets of laboratory results are reported for these constituents. For field water-quality indicators that were also measured in the laboratory (alkalinity, pH, and specific conductance), the field analyses were preferred, although both sets of results are reported.

Quality Assurance

The quality-assurance and quality-control procedures used for this study followed the protocols used by the USGS NAWQA program (Koterba and others, 1995) and those described in the USGS National Field Manual (U.S. Geological Survey, variously dated). The quality-assurance plan followed by the NWQL, the primary laboratory used to analyze samples for this study, is described by Maloney (2005) and Pirkey and Glodt (1998). Quality-control (QC) samples collected in the COLOR include source-solution blanks, field blanks, replicates, and matrix and surrogate spikes. QC samples were collected to evaluate potential contamination, and bias and variability of the data that may have resulted from collecting, processing, storing, transporting, and analyzing the samples. Quality-control procedures and quality-control sample results are described in the Appendix section “Quality Assurance.”

Water-Quality Results

Quality-Control Results

Results of quality-control analyses (blanks, replicates, matrix spikes, and surrogates) were used to evaluate the quality of the data for the groundwater samples. Of the approximately 220 constituents analyzed, 3 were detected in at least 1 field blank. Data from replicates indicated that variability between measurements was generally low; the relative standard deviations (RSDs) were below 5 percent for most replicate analyses. Of the 12 pairs of samples analyzed that had RSDs above the acceptable limit of 20 percent, most had concentrations of constituents near their LRLs, and at these low concentrations, small differences in the measured concentrations in the replicate pairs account for the large RSDs. Results from analyses of the replicate samples confirm that the procedures used to collect and analyze the samples were consistent. Median matrix-spike recoveries for 14 organic constituents analyzed were lower than the acceptable limits, which may indicate that these constituents might not have been detected in some samples if they were present at very low concentrations. The quality-control results are described in the Appendix section “Quality-Control Results”.

Comparison Thresholds

Concentrations of constituents detected in groundwater samples were compared with CDPH and USEPA regulatory and non regulatory drinking-water health-based thresholds and thresholds established for aesthetic purposes (California Department of Public Health, 2008a,b; U.S Environmental Protection Agency, 2008a,b,c). The chemical composition of treated drinking water may differ from that of untreated groundwater because treated drinking water may be disinfected, filtered, mixed with other waters, and exposed to the atmosphere before being delivered to consumers. Comparisons between concentrations of constituents in raw (untreated) groundwater and drinking-water thresholds are for illustrative purposes only and do not indicate compliance or noncompliance with drinking-water regulations.

The following thresholds were used for comparisons:

- MCL—Maximum Contaminant Level. Legally enforceable standards that apply to public water systems and are designed to protect public health by limiting the levels of contaminants in drinking water. MCLs established by the USEPA are the minimum standards with which states are required to comply, and individual states may choose to set more stringent standards. CDPH has established MCLs for additional constituents not regulated by the USEPA, as well as lowered the threshold concentration for a number of constituents with MCLs established by the USEPA. In this report, a threshold set by the USEPA and adopted by CDPH is labeled “MCL-US” and one set by CDPH that is more stringent than the MCL-US is labeled “MCL-CA.” CDPH is notified when constituents are detected at concentrations greater than an MCL-US or MCL-CA thresholds in samples collected for the GAMA Priority Basin Project, but these detections do not constitute violations of CDPH regulations.

- AL—Action Level. Legally enforceable standards that may apply to the public water systems and are designed to protect public health by limiting the levels of copper and lead in drinking water. Detections of copper or lead above the action-level thresholds trigger requirements for mandatory water treatment to reduce the corrosive effects of the water to the transfer pipelines. The action levels established by the USEPA and CDPH currently are the same; thus, the thresholds are labeled "AL-US" in this report.

- SMCL—Secondary Maximum Contaminant Level. Non-enforceable standards applied to constituents that affect the aesthetic qualities of drinking water, such as taste, odor and color, or technical qualities of drinking water, such as scaling and staining. Both the USEPA and CDPH defined SMCLs, but unlike MCLs, SMCLs established by CDPH are not required to be as stringent as those established by USEPA. SMCLs established by CDPH are used in this report (SMCL-CA) for all constituents that have SMCL-CA values. The SMCL-US is used for pH because no SMCL-CA has been defined.

- NL—Notification Level. Health-based notification levels established by CDPH for some of the constituents in drinking water that lack MCLs (NL-CA). If a constituent is detected above its NL-CA, California state law requires timely notification of local governing bodies and recommends consumer notification.

- HAL—Lifetime Health Advisory Level. The maximum concentration of a constituent at which its presence in drinking water is not expected to cause any adverse carcinogenic effects for a lifetime of exposure. HALs are established by the USEPA (HAL-US) and are calculated assuming consumption of 2 liters (2.1 quarts) of water per day over a 70-year lifetime by a 70-kilogram (154-pound) adult and that 20 percent of a person's exposure comes from drinking water.

- RSD5—Risk-Specific Dose. The concentration of a constituent in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 100,000. RSD5 is an acronym for risk-specific dose at 10^{-5}. RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by ten (RSD5-US).

For constituents having MCLs, concentrations in groundwater samples were compared to the MCL-US or MCL-CA. Constituents having SMCLs were compared with the SMCL-CA. For chloride, sulfate, specific conductance, and total dissolved solids, CDPH defines a "recommended" and an "upper" SMCL-CA; concentrations of these constituents in groundwater samples were compared with both levels. The SMCL-US for these constituents corresponds with the recommended SMCL-CA. Detected concentrations of constituents that lack an MCL or an SMCL were compared to the NL-CA. For constituents that lack an MCL, SMCL, or NL-CA, detected concentrations were compared with the HAL-US. For constituents that lack an MCL, SMCL, NL-CA, or HAL-US, detected concentrations were compared with the RSD5-US. Note that this hierarchy of selecting comparison thresholds means that for constituents having multiple types of established thresholds, the threshold used for comparison purposes may not be the one with the lowest concentration. The comparison thresholds used in this report are listed in tables 3A–J for all constituents and in tables 4–13 for constituents detected in groundwater samples from COLOR. Not all constituents analyzed for this study have established thresholds. Detections of concentrations of constituents greater than the selected comparison thresholds are marked with asterisks in associated results tables.

Groundwater-Quality Data

Results from analyses of raw (untreated) groundwater samples collected from COLOR during October through December 2007 are given in tables 4 through 13. These results tables list only the constituents that were detected and only the samples in which at least one constituent was detected. The tables containing organic constituent classes that were analyzed at all of the grid wells include the number of wells at which each analyte was detected, the frequency at which it was detected (in relation to the number of grid wells), and the total number of constituents detected at each well. Results from the understanding wells are presented in the tables, but these results were excluded from the detection frequency calculations to avoid statistically over-representing the areas near understanding wells.

Table 4 gives water-quality indicators measured in the field and at the NWQL, and tables 5 through 13 present the results of groundwater analyses organized by the compound classes:

- Organic constituents
  - Volatile organic compounds VOCs (table 5)
  - Gasoline oxygenates and degradates (no detections in the wells for which they were sampled)
  - Pesticides and pesticide degradates (table 6)
  - Pharmaceuticals (not presented in this report)
- Constituents of special interest (table 7)

- Inorganic constituents
    - Nutrients (table 8)
    - Major and minor ions, silica, and total dissolved solids (table 9)
    - Trace elements (table 10)
    - Arsenic, iron, and chromium speciation (table 11)
- Isotopic tracers, tritium, and carbon-14 (table 12)
- Radioactive constituents (tables 13A,B,C)

Results for pharmaceutical compounds, dissolved noble gases, and tritium helium age dates are not presented in this report; they will be included in subsequent publications.

Field Parameters

Field and laboratory measurements of dissolved oxygen, water temperature, pH, specific conductance, and alkalinity are given in table 4. Alkalinity and dissolved oxygen are used as indicators of natural processes that affect water chemistry. Specific conductance is a measure of electrical conductivity of water and is proportional to the amount of total dissolved solids (TDS) in the water. Most wells had specific-conductance values above the recommended SMCL-CA threshold of 600 µS/cm, and many were above the upper threshold of 1,600 µS/cm. The pH value indicates the acidity or basicity of the water. One well had field and laboratory pH values outside of the SMCL-US range (6.5–8.5) for pH. Laboratory pH values may differ from field pH values because the pH of groundwater may change upon exposure to the atmosphere (see Appendix).

Organic Constituents

Volatile organic compounds (VOC) can be in paints, solvents, fuels, fuel additives, refrigerants, fumigants, and disinfected water and are characterized by their tendency to evaporate. VOCs generally persist longer in groundwater than in surface water because groundwater is isolated from the atmosphere. Of the 85 VOCs analyzed on Schedule 2020, three were detected in grid well samples; 1,2-Dichloropropane, a fumigant; chloroform, a byproduct of disinfecting drinking water; and 1,2,4-trimethylbenzene, a constituent of gasoline, were detected in grid well samples. All concentrations were below health-based thresholds (table 5). Chloroform is among the most commonly detected VOCs in groundwater nationally (Zogorski and others, 2006), and was detected in 2 grid and 2 understanding wells. MTBE, another constituent of gasoline, was detected in one understanding well. Overall, one or more VOCs were detected in 35 percent of the grid wells. Of the eight VOCs analyzed on Schedule 4024 for gasoline oxygenates and degradates at two understanding wells, COLORU-02 and COLORU-03, none were detected in groundwater samples.

Pesticides include herbicides, insecticides, and fungicides and are used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. Of the 62 pesticides and pesticide degradates analyzed, five were detected in groundwater samples; all concentrations were below health-based thresholds (table 6). The herbicides atrazine, simazine, and deethylatrazine (a degradate of atrazine) were detected; these pesticides are among those most commonly detected in groundwater nationally (Gilliom and others, 2006). Deethylatrazine was detected in 2 grid wells and 1 understanding well. Atrazine, prometryn, and simazine were detected in one grid well. Terbuthylazine was detected in one understanding well. Overall, one or more pesticides were detected in 20 percent of the grid wells.

Constituents of Special Interest

Perchlorate and1,2.3-TCP are constituents of special interest in California because they may adversely affect water quality and have recently been found in water supplies (California Department of Public Health, 2008c). Perchlorate was detected in nine grid wells (45 percent) and two understanding wells (table 7). All concentrations were below the MCL-CA. One grid well contained a low concentration of 1,2,3-TCP. 1,4-dioxane was not detected in grid wells or understanding wells.

Inorganic Constituents

Unlike organic constituents and the constituents of special interest, most inorganic constituents exist naturally in groundwater, although their concentrations may be influenced by human activities.

Nutrients (nitrogen and phosphorus) present in groundwater can affect biological activity in aquifers and in surface-water bodies that receive groundwater discharge. Nitrogen may exist in the form of ammonia, nitrite, or nitrate, depending on the oxidation-reduction state of the groundwater. High concentrations of nitrate can adversely affect human health. All concentrations of nitrate, nitrite, and ammonia measured in samples from COLOR wells were below health-based thresholds (table 8).

The major-ion composition, total dissolved solids (TDS) content, and levels of certain trace elements in groundwater affect the aesthetic properties of water, such as taste, color, and odor, and the technical properties, such as scaling and staining. Although no adverse health effects are associated with these properties, they may reduce consumer satisfaction with the water or may have economic effects. CDPH established nonenforceable thresholds (SMCL-CAs) that are based on aesthetic or technical properties rather than health-based concerns for the major ions chloride and sulfate, TDS, and several trace elements. Chloride was detected above the lower SMCL-CA threshold in 7 grid wells and above the upper threshold in 1 grid well (table 9). In understanding wells, chloride was detected above the lower SMCL-CA in 1 well and above the upper threshold in 1 well. Sulfate was detected above the lower SMCL-CA threshold in 10 grid wells and above the upper threshold in 5 grid wells. In understanding wells, sulfate was detected above the lower SMCL-CA in 3 wells and above the upper threshold in 3 wells. TDS was detected above the lower SMCL-CA in 7 grid wells and above the upper threshold in 11 grid wells. In understanding wells, TDS was detected above the lower SMCL-CA threshold in 5 wells and above the upper threshold in 3 wells.

Iron and manganese are trace elements whose concentrations are affected by the oxidation-reduction state of the groundwater. Precipitation of minerals containing iron or manganese may cause orange, brown, or black staining of surfaces. Concentrations of iron above the SMCL-CA was detected in 4 grid wells and 1 understanding well (table 10). Arsenic was detected above the MCL-US threshold in 1 grid well and 1 understanding well. Boron was detected above the NL-CA threshold in 2 grid wells and 1 understanding well. Manganese was detected above the SMCL-CS in 9 grid wells and 6 understanding wells. Molybdenum was detected above the HAL-US threshold in one grid well. Strontium was detected above the HAL-US threshold in two grid wells. Uranium was detected in two grid wells above the MCL-US threshold. Three of the 24 trace elements analyzed in this study, cobalt, lithium, and tungsten, have no health-based thresholds.

Arsenic, iron, and chromium exist in different species, depending on the oxidation-reduction state of the groundwater. The oxidized and reduced species have different solubilities in groundwater and may have different effects on human health. The relative proportions of the oxidized and the reduced species of each element can be used to help interpret the oxidation-reduction state of the aquifer. Concentrations of arsenic, iron, and chromium, and the concentrations of either the reduced or the oxidized species of each element, are reported in table 11. The concentrations of the other species can be calculated by difference. The concentrations of arsenic, iron, and chromium reported in table 11 may be different from those reported in table 10 because different analytical methods were used (see Appendix). The concentrations reported in table 10 are considered to be more accurate and precise.

Isotopic Tracers and Noble Gases

The isotopic ratios of oxygen and hydrogen of water, the tritium and carbon-14 activities, and the concentrations of dissolved noble gases may be used as tracers of hydrologic processes. The isotopic ratios of hydrogen and oxygen in water (table 12) aid in interpreting the sources of groundwater recharge. These stable-isotope ratios reflect the altitude, latitude, and temperature of precipitation and also the extent of evaporation of the water in surface water bodies or soils before infiltration into the aquifer. Concentrations of dissolved gases are used to estimate the conditions of groundwater recharge, particularly the temperature of the recharge water. Noble-gas analyses were not completed in time to be included in this report; results will be presented in a subsequent publication.

Tritium and carbon-14 activities (table 12), and helium isotope ratios also provide information about the age (time since recharge) of the groundwater. Tritium is a short-lived radioactive isotope of hydrogen that is incorporated into the water molecule. Low levels of tritium are continuously produced by interaction of cosmic radiation with the Earth’s atmosphere, and a large amount of tritium was produced as a result of atmospheric testing of nuclear weapons between 1952 and 1963. Thus, concentrations of tritium above background levels usually indicate the presence of water recharged since the early 1950s. Helium isotope ratios are used in conjunction with tritium concentrations to estimate ages of young groundwater. Helium isotope ratio analyses were not completed in time to be included in this report; results will be presented in a subsequent publication.

Carbon-14 is a radioactive isotope of carbon. Low levels of carbon-14 are continuously produced by interaction of cosmic radiation with the Earth’s atmosphere, and incorporated into the atmospheric carbon dioxide. Carbon dioxide dissolves in precipitation, surface water, and groundwater exposed to the atmosphere, thereby entering the hydrologic cycle. Because carbon-14 decays with a half-life of approximately 5,700 years, activities of carbon-14 that are low relative to modern values generally indicate the presence of groundwater that is several thousand years old.

Of the isotopic tracer constituents analyzed for this study, tritium is the only one that has a health-based threshold. All measured tritium activities in samples from COLOR wells were below the MCL-CA (table 12).

Radioactive Constituents

Radioactivity is the release of energy or energetic particles during changes in the structure of the nucleus of an atom. Most of the radioactivity in groundwater comes from decay of naturally-occurring isotopes of uranium and thorium that exist in minerals in the sediments or fractured rocks of the aquifer. Both uranium and thorium decay in a series of steps, eventually forming stable isotopes of lead. Radium-226, radium-228, and radon-222 are radioactive isotopes formed during the uranium or thorium decay series. In each step in the decay series, one radioactive element turns into a different radioactive element by emitting an alpha or a beta particle from its nucleus. For example, radium-226 emits an alpha particle and therefore turns into radon-222. Radium-228 decays to form actinium-228 by emitting a beta particle. The alpha and beta particles emitted during radioactive decay are hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA increases the risk of getting cancer.

Activity is often used instead of concentration for reporting the presence of radioactive constituents. Activity of radioactive constituents in groundwater is measured in units of picocuries per liter (pCi/L), and one picocurie is approximately equal to two atoms decaying per minute. The number of atoms decaying is equal to the number of alpha or beta particles emitted.

Most of the COLOR samples analyzed for radioactive constituents had activities of radium and gross alpha and gross beta emitters less than their established health-based thresholds (tables 13A–C). Three grid wells and one understanding well had gross alpha (72 hour count) activities above the MCL-US of 15 pCi/L. Two grid wells had gross alpha (30 day count) activities above the MCL-US of 15 pCi/L. Activities of radon-222 in samples from 14 grid wells and 5 understanding wells were above the proposed MCL-US of 300 pCi/L, but no samples had an activity that was also above the proposed alternative MCL-US of 4,000 pCi/L. The proposed alternative MCL-US will apply if the State or local water agency has an approved multimedia mitigation program to address radon levels in indoor air (U.S. Environmental Protection Agency, 1999).

Future Work

Subsequent reports will be focused on assessing the data presented in this report using a variety of statistical, qualitative, and quantitative approaches to evaluate the natural and human factors affecting groundwater quality in the COLOR. Water-quality data contained in the CDPH and the USGS NWIS databases and water-quality data available from other state and local water agencies will be compiled, evaluated, and used to complement the data in this report; the results of these future efforts will appear in one or more subsequent reports.

Summary

Groundwater quality in the 188-square-mile Colorado River Study unit (COLOR) was investigated from October through December 2007 as part of the Priority Basin Project of the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The California State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and the Lawrence Livermore National Laboratory, is implementing the GAMA Program (http://www.waterboards.ca.gov/gama/). The Priority Basin Project was designed by the SWRCB and the USGS in response to the Groundwater Quality Monitoring Act of 2001. The project is a comprehensive assessment of statewide groundwater quality designed to identify and characterize risks to groundwater resources and to increase the availability of public information about groundwater quality. COLOR was the 21st study unit sampled as part of the project.

COLOR is located in the Desert Hydrogeologic Province, along the Colorado River on the southeastern side of California and is divided into three separate study areas: the Needles Valley, the Palo Verde, and the Yuma Valley. The exterior boundaries of the study areas correspond to the delineated California Department of Water Resources groundwater basins (California Department of Water Resources, 2004a,b,c). The COLOR included assessment of the groundwater quality of samples from 28 wells. Twenty wells were selected using a randomized grid approach to achieve a statistically unbiased representation of groundwater used for public drinking-water supplies. Eight more wells were selected to provide additional sampling density to aid in understanding processes affecting groundwater quality in the region.

Groundwater samples were analyzed for VOCs, pesticides and pesticide degradates, pharmaceutical compounds, perchlorate, 1,2,3-TCP, nutrients, major and minor ions, trace elements, and radioactivity. Naturally occurring isotopes (stable isotopes of hydrogen, oxygen, and carbon, and activities of tritium and carbon-14) and dissolved noble gases also were measured to provide a data set that will be used to help interpret the sources and ages of the sampled groundwater. Gasoline oxygenates and degradates and 1,4-dioxane were also collected in the Palo Verde study area of COLOR. In total, approximately 220 constituents and water-quality indicators were investigated for this study. This report describes the sampling, analytical, and quality assurance used in the study and presents the results of the chemical analyses of the groundwater samples collected during the autumn of 2007 in the COLOR.

A suite of quality-control samples (blanks, replicates, and matrix spikes) were collected at approximately 30 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the groundwater samples. Field blanks rarely contained detectable concentrations of any constituents, suggesting that contamination during sample collection was not a noticeable source of bias in the data for the groundwater samples. Differences between most replicate samples were within acceptable ranges and matrix spike recoveries were within acceptable ranges for most constituents. Matrix spike recoveries were within acceptable ranges for most constituents.

This study did not attempt to evaluate the quality of water delivered to consumers; water withdrawn from the ground is typically treated, disinfected, and blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to treated water that is served to the consumer, not to raw groundwater. However, to provide some context for the results, concentrations of constituents measured in the raw groundwater were compared with regulatory and non-regulatory health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH).

The concentrations of most constituents detected in groundwater samples from the 20 grid wells and 8 understanding wells in the COLOR were below regulatory and non-regulatory drinking-water thresholds. Specific conductance was the only constituent measured above the lower and upper SMCL-CA thresholds in most wells. All concentrations of VOCs, pesticides, perchlorate, 1, 2, 3-TCP, and nitrate were below established health-based thresholds. The major ion chloride was detected in some wells above the lower and upper SMCL-CA thresholds. Sulfate and total dissolved solids were detected above the lower and upper SMCL-CA thresholds in some wells. Fluoride was detected above the MCL-CA. The trace element arsenic was detected above the MCL-CA, boron was detected above the NL-CA, iron and manganese were detected above their respective SMCL-CAs, molybdenum and strontium were detected above their respective HAL-USs, and uranium was detected above the MCL-US. Radioactive constituents were below health-based thresholds except gross alpha radioactivity (72-hour count and 30-day count), which was above the MCL-US of 15 pCi/L, and radon-222, which was above the proposed lower MCL-US of 300 pCi/L in some samples.

Subsequent reports will present assessment of the data in this report using a variety of statistical, qualitative, and quantitative approaches to assess the natural and human factors affecting groundwater quality.

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Tables

Table 1. Well identification and sampling and construction information for wells sampled for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[**GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. **Elevation of LSD.** Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The elevation of the LSD is described in feet above the North American Vertical Datum 1988. **Other abbreviations:** ft, foot; NAVD 88, North American Vertical Datum 1988; na, not available]

GAMA well identification number	Sampling information		Construction information		
	Date	Elevation of LSD (ft above NAVD 88)	Well depth (ft below LSD)	Top of opening (ft below LSD)	Bottom of opening (ft below LSD)
		Grid wells			
COLOR-01	10/01/2007	327	na	na	na
COLOR-02	10/01/2007	176	na	na	na
COLOR-03	10/02/2007	132	512	437	497
COLOR-04	10/03/2007	232	90	30	90
COLOR-05	10/22/2007	272	610	380	590
COLOR-06	10/24/2007	269.21	505	na	na
COLOR-07	10/25/2007	258	438	20	438
COLOR-08	11/01/2007	390.73	500	140	480
COLOR-09	11/05/2007	332	na	na	na
COLOR-10	11/06/2007	245	1,000	na	na
COLOR-11	11/07/2007	242	na	na	na
COLOR-12	11/26/2007	732	420	300	420
COLOR-13	11/27/2007	575.23	195	na	195
COLOR-14	11/28/2007	252	na	na	na
COLOR-15	11/29/2007	139	na	na	na
COLOR-16	12/10/2007	281	600	378	382
COLOR-17	12/11/2007	532	210	80.2	200
COLOR-18	12/12/2007	337	600	150	400
COLOR-19	12/17/2007	137.7	143	118	140
COLOR-20	12/18/2007	907	700	na	na
		Understanding wells			
COLORU-01	10/04/2007	279	492	292	492
COLORU-02	10/23/2007	267.19	454	436	na
COLORU-03	10/23/2007	267.21	335	310	335
COLORU-04	10/29/2007	477	240.5	54	160
COLORU-05	10/30/2007	477	105	38	82
COLORU-06	10/31/2007	408	500	160	480
COLORU-07	11/06/2007	232	130	na	na
COLORU-08	12/20/2007	260	na	na	na

Table 2. Classes of chemical constituents and water-quality indicators collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

Analyte classes	Analyte list table	Results table
Water-quality indicators		
Dissolved oxygen, temperature, specific conductance	No table	4
pH, alkalinity	No table	4
Organic constituents		
Volatile organic compounds	3A	5
Gasoline oxygenates and degradates [1]	3B	None detected
Pesticides and pesticide degradates	3C	6
Pharmaceutical compounds	3D	No table [2]
Constituents of special interest		
Perchlorate	3E	7
1,2,3-Trichloropropane	3E	7
1,4 Dioxane [3]	3E	7
Inorganic constituents		
Nutrients	3F	8
Major and minor ions and trace elements	3G	9, 10
Arsenic, chromium, and iron abundances and speciation [4]	3H	11
Stable isotopes		
Stable isotopes of hydrogen and oxygen of water	3I	11
Stable isotopes of carbon and carbon-14 abundance	3I	11
Radioactivity and noble gases		
Tritium	3I	12
Radium isotopes	3I	13A
Gross alpha and gross beta radioactivity	3I	13B
Radon-222	3I	13C
Noble gases	3J	No table [2]

[1] Collected in two wells in the Palo Verde Valley study area.

[2] Samples were collected but not analyzed; data will be presented in subsequent publications.

[3] Collected in the Palo Verde Valley study area only.

[4] Arsenic and iron abundances and speciation samples were collected at 27 of 28 wells.

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2020.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5}. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; THM, trihalomethane; D, detected in groundwater samples (table 5); na, not available; µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number [1]	LRL (µg/L)	Threshold type [2]	Threshold value (µg/L)	Detection
Acetone	Solvent	81552	67-64-1	4	na	na	—
Acrylonitrile	Organic synthesis	34215	107-13-1	0.4	RSD5-US	0.6	—
tert-Amyl methyl ether (TAME)	Gasoline oxygenate	50005	994-05-8	0.06	na	na	—
Benzene	Gasoline hydrocarbon	34030	71-43-2	0.016	MCL-CA	1	—
Bromobenzene	Solvent	81555	108-86-1	0.02	na	na	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.06	HAL-US	90	—
Bromodichloromethane	Disinfection by-product (THM)	32101	75-27-4	0.04	MCL-US	[3] 80	—
Bromoform (Tribromomethane)	Disinfection by-product (THM)	32104	75-25-2	0.08	MCL-US	[3] 80	—
Bromomethane (Methyl bromide)	Fumigant	34413	74-83-9	0.4	HAL-US	10	—
n-Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.14	NL-CA	260	—
sec-Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.04	NL-CA	260	—
tert-Butylbenzene	Gasoline hydrocarbon	77353	98-06-6	0.06	NL-CA	260	—
Carbon disulfide	Organic synthesis	77041	75-15-0	0.06	NL-CA	160	—
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.08	MCL-CA	0.5	—
Chlorobenzene	Solvent	34301	108-90-7	0.02	MCL-CA	70	—
Chloroethane	Solvent	34311	75-00-3	0.1	na	na	—
Chloroform (Trichloromethane)	Disinfection by-product (THM)	32106	67-66-3	0.02	MCL-US	[3] 80	D
Chloromethane	Solvent	34418	74-87-3	0.1	HAL-US	30	—
3-Chloropropene	Organic synthesis	78109	107-05-1	0.08	na	na	—
2-Chlorotoluene	Solvent	77275	95-49-8	0.04	NL-CA	140	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.04	NL-CA	140	—
Dibromochloromethane	Disinfection by-product (THM)	32105	124-48-1	0.12	MCL-US	[3] 80	—
1,2-Dibromo-3-chloropropane (DBCP)	Fumigant	82625	96-12-8	0.5	MCL-US	0.2	—
1,2-Dibromoethane (EDB)	Fumigant	77651	106-93-4	0.04	MCL-US	0.05	—
Dibromomethane	Solvent	30217	74-95-3	0.04	na	na	—
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.02	MCL-CA	600	—
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.04	HAL-US	600	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.02	MCL-CA	5	—
trans-1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	0.6	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.14	NL-CA	1,000	—
1,1-Dichloroethane (1,1-DCA)	Solvent	34496	75-34-3	0.04	MCL-CA	5	—
1,2-Dichloroethane (1,2-DCA)	Solvent	32103	107-06-2	0.06	MCL-CA	0.5	—
1,1-Dichloroethene (1,1-DCE)	Organic synthesis	34501	75-35-4	0.02	MCL-CA	6	—
cis-1,2-Dichloroethene (*cis*-1,2-DCE)	Solvent	77093	156-59-2	0.02	MCL-CA	6	—
trans-1,2-Dichloroethene *(trans*-1,2-DCE)	Solvent	34546	156-60-5	0.018	MCL-CA	10	—
1,2-Dichloropropane	Fumigant	34541	78-87-5	0.02	MCL-US	5	D
1,3-Dichloropropane	Fumigant	77173	142-28-9	0.06	na	na	—
2,2-Dichloropropane	Fumigant	77170	594-20-7	0.06	na	na	—
1,1-Dichloropropene	Organic synthesis	77168	563-58-6	0.04	na	na	—
cis-1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.1	RSD5-US	[4] 4	—

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5}. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; THM, trihalomethane; D, detected in groundwater samples (table 5); na, not available; µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number [1]	LRL (µg/L)	Threshold type [2]	Threshold value (µg/L)	Detection
trans-1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.1	RSD5-US	[4] 4	—
Diethyl ether	Solvent	81576	60-29-7	0.12	na	na	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.06	na	na	—
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.04	MCL-CA	300	—
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.04	na	na	—
Ethyl methacrylate	Organic synthesis	73570	97-63-2	0.14	na	na	—
o-Ethyl toluene (1-Ethyl-2-methyl benzene)	Gasoline hydrocarbon	77220	611-14-3	0.04	na	na	—
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.06	RSD5-US	9	—
Hexachloroethane	Solvent	34396	67-72-1	0.14	HAL-US	1	—
2-Hexanone (*n*-Butyl methyl ketone)	Solvent	77103	591-78-6	0.6	na	na	—
Iodomethane (Methyl iodide)	Organic synthesis	77424	74-88-4	0.4	na	na	—
Isopropylbenzene	Gasoline hydrocarbon	77223	98-82-8	0.04	NL-CA	770	—
4-Isopropyl-1-methyl benzene	Gasoline hydrocarbon	77356	99-87-6	0.08	na	na	—
Methyl acrylate	Organic synthesis	49991	96-33-3	0.6	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.2	na	na	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.1	MCL-CA	13	D
Methyl iso-butyl ketone (MIBK)	Solvent	78133	108-10-1	0.4	NL-CA	120	—
Methylene chloride (Dichloromethane)	Solvent	34423	75-09-2	0.04	MCL-US	5	—
Methyl ethyl ketone (2-Butanone, MEK)	Solvent	81595	78-93-3	1.6	HAL-US	4,000	—
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.2	na	na	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.2	NL-CA	17	—
Perchloroethene (Tetrachloroethene, PCE)	Solvent	34475	127-18-4	0.04	MCL-US	5	—
n-Propylbenzene	Solvent	77224	103-65-1	0.04	NL-CA	260	—
Styrene	Gasoline hydrocarbon	77128	100-42-5	0.04	MCL-US	100	—
1,1,1,2-Tetrachloroethane	Solvent	77562	630-20-6	0.04	HAL-US	70	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.1	MCL-CA	1	—
Tetrahydrofuran	Solvent	81607	109-99-9	1.4	na	na	—
1,2,3,4-Tetramethylbenzene	Gasoline hydrocarbon	49999	488-23-3	0.14	na	na	—
1,2,3,5-Tetramethylbenzene	Gasoline hydrocarbon	50000	527-53-7	0.12	na	na	—
Toluene	Gasoline hydrocarbon	34010	108-88-3	0.018	MCL-CA	150	—
1,2,3-Trichlorobenzene	Organic synthesis	77613	87-61-6	0.08	na	na	—
1,2,4-Trichlorobenzene	Solvent	34551	120-82-1	0.08	MCL-CA	5	—
1,1,1-Trichloroethane (1,1,1-TCA)	Solvent	34506	71-55-6	0.02	MCL-CA	200	—
1,1,2-Trichloroethane (1,1,2-TCA)	Solvent	34511	79-00-5	0.06	MCL-CA	5	—
Trichloroethene (TCE)	Solvent	39180	79-01-6	0.02	MCL-US	5	—
Trichlorofluoromethane (CFC-11)	Refrigerant	34488	75-69-4	0.08	MCL-CA	150	—
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.12	HAL-US [5]	40	—
Trichlorotrifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.04	MCL-CA	1,200	—

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5}. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; THM, trihalomethane; D, detected in groundwater samples (table 5); na, not available; µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number [1]	LRL (µg/L)	Threshold type [2]	Threshold value (µg/L)	Detection
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.08	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	0.04	NL-CA	330	D
1,3,5-Trimethylbenzene	Organic synthesis	77226	108-67-8	0.04	NL-CA	330	—
Vinyl bromide (Bromoethene)	Fire retardant	50002	593-60-2	0.12	na	na	—
Vinyl chloride (Chloroethene)	Organic synthesis	39175	75-01-4	0.08	MCL-CA	0.5	—
m- and *p*-Xylene	Gasoline hydrocarbon	85795	108-38-3/ 106-42-3	0.08	MCL-CA	[6] 1,750	—
o-Xylene	Gasoline hydrocarbon	77135	95-47-6	0.04	MCL-CA	[6] 1,750	—

[1] This report contains CAS Registry Numbers®, which is a Registered Trademark of the American Chemical Society. CAS recommends the verification of the CASRNs through CAS Client Services℠.

[2] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[3] The MCL-US threshold for trihalomethanes is the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

[4] The RSD5 threshold for 1,3-dichloropropene is the sum of its isomers (*cis* and *trans*).

[5] In earlier reports in this series, the NL-CA (0.005 µg/L) was used as the comparison threshold for 1,2,3-TCP.

[6] The MCL-CA threshold for *m*- and *p*-xylene and *o*-xylene is the sum of all three xylene compounds.

Table 3B. Gasoline oxygenates and degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 4024.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in groundwater samples (table 5); na, not available; µg/L, microgram per liter; —, not detected]

Constituent [1]	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type [2]	Threshold value (µg/L)	Detection
Acetone	Degradate	81552	67-64-1	1.8	na	na	—
tert-Amyl alcohol	Oxygenate	77073	75-85-4	0.6	na	na	—
tert-Amyl methyl ether (TAME)	Oxygenate	50005	994-05-8	0.05	na	na	—
tert-Butyl alcohol (TBA)	Degradate	77035	75-65-0	1	NL-CA	12	—
Diisopropyl ether (DIPE)	Oxygenate	81577	108-20-3	0.04	na	na	—
Ethyl *tert*-butyl ether (ETBE)	Oxygenate	50004	637-92-3	0.02	na	na	—
Methyl acetate	Degradate	77032	79-20-9	0.4	na	na	—
Methyl *tert*-butyl ether (MTBE)	Oxygenate	78032	1634-04-4	0.04	MCL-US	13	— [3]

[1] Schedule 4024 was sampled for at two wells.

[2] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[3] This constituent was detected on the preferred analytical Schedule 2020, not Schedule 4024.

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2003.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5}. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in groundwater samples (table 6); na, not available; µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type[1]	Threshold value (µg/L)	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.006	na	na	—
Alachlor	Herbicide	46342	15972-60-8	0.006	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.007	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.12	na	na	—
Azinphos-methyl-oxon	Insecticide degradate	61635	961-22-8	0.042	na	na	—[2]
Benfluralin	Herbicide	82673	1861-40-1	0.004	na	na	—
Carbaryl	Insecticide	82680	63-25-2	0.06	RSD5-US	400	—
2-Chloro-2,6-diethylacetanilide	Herbicide degradate	61618	6967-29-9	0.01	na	na	—
4-Chloro-2-methylphenol	Herbicide degradate	61633	1570-64-5	0.05	na	na	—[2]
Chlorpyrifos	Insecticide	38933	2921-88-2	0.005	HAL-US	2	—
Chlorpyrifos oxon	Insecticide degradate	61636	5598-15-2	0.0562	na	na	—[2]
Cyfluthrin	Insecticide	61585	68359-37-5	0.016	na	na	—
Cypermethrin	Insecticide	61586	52315-07-8	0.014	na	na	—
Dacthal (DCPA)	Herbicide	82682	1861-32-1	0.003	HAL-US	70	—
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-*s*-triazine, CIAT)	Herbicide degradate	04040	6190-65-4	0.014	na	na	D[2]
Desulfinylfipronil	Insecticide degradate	62170	na	0.012	na	na	—
Desulfinylfipronil amide	Insecticide degradate	62169	na	0.029	na	na	—
Diazinon	Insecticide	39572	333-41-5	0.005	HAL-US	1	—
3,4-Dichloroaniline	Herbicide degradate	61625	95-76-1	0.006	na	na	—
Dichlorvos	Insecticide	38775	62-73-7	0.013	na	na	—[2]
Dicrotophos	Insecticide	38454	141-66-2	0.0843	na	na	—[2]
Dieldrin	Insecticide	39381	60-57-1	0.009	RSD5-US	0.02	—
2,6-Diethylaniline	Herbicide degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.006	na	na	—[2]
Ethion	Insecticide	82346	563-12-2	0.006	na	na	—
Ethion monoxon	Insecticide degradate	61644	17356-42-2	0.021	na	na	—
2-Ethyl-6-methylaniline	Herbicide degradate	61620	24549-06-2	0.01	na	na	—
Fenamiphos	Insecticide	61591	22224-92-6	0.029	HAL-US	0.7	—
Fenamiphos sulfone	Insecticide degradate	61645	31972-44-8	0.053	na	na	—
Fenamiphos sulfoxide	Insecticide degradate	61646	31972-43-7	0.04	na	na	—[2]
Fipronil	Insecticide	62166	120068-37-3	0.02	na	na	—
Fipronil sulfide	Insecticide degradate	62167	120067-83-6	0.013	na	na	—
Fipronil sulfone	Insecticide degradate	62168	120068-36-2	0.024	na	na	—
Fonofos	Insecticide	04095	944-22-9	0.01	HAL-US	10	—
Hexazinone	Herbicide	04025	51235-04-2	0.008	HAL-US	400	—
Iprodione	Fungicide	61593	36734-19-7	0.01	na	na	—[2]
Isofenphos	Insecticide	61594	25311-71-1	0.006	na	na	—
Malaoxon	Insecticide degradate	61652	1634-78-2	0.02	na	na	—
Malathion	Insecticide	39532	121-75-5	0.016	HAL-US	100	—
Metalaxyl	Fungicide	61596	57837-19-1	0.0069	na	na	—
Methidathion	Insecticide	61598	950-37-8	0.004	na	na	—
Metolachlor	Herbicide	39415	51218-45-2	0.01	HAL-US	700	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2003.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5}. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in groundwater samples (table 6); na, not available; µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type [1]	Threshold value (µg/L)	Detection
Metribuzin	Herbicide	82630	21087-64-9	0.012	HAL-US	70	—
Myclobutanil	Fungicide	61599	88671-89-0	0.01	na	na	—
1-Naphthol	Insecticide degradate	49295	90-15-3	0.04	na	na	—[2]
Paraoxon-methyl	Insecticide degradate	61664	950-35-6	0.01	na	na	—[2]
Parathion-methyl	Insecticide	82667	298-00-0	0.008	HAL-US	1	—
Pendimethalin	Herbicide	82683	40487-42-1	0.012	na	na	—
cis-Permethrin	Insecticide	82687	54774-45-7	0.01	na	na	—
Phorate	Insecticide	82664	298-02-2	0.04	na	na	—[2]
Phorate oxon	Insecticide degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.0079	na	na	—[2]
Phosmet oxon	Insecticide degradate	61668	3735-33-9	0.0511	na	na	—
Prometon	Herbicide	04037	1610-18-0	0.01	HAL-US	100	
Prometryn	Herbicide	04036	7287-19-6	0.0051	na	na	D
Pronamide (Propyzamide)	Herbicide	82676	23950-58-5	0.004	RSD5-US	20	—
Simazine	Herbicide	04035	122-34-9	0.006	MCL-US	4	D
Tebuthiuron	Herbicide	82670	34014-18-1	0.016	HAL-US	500	—
Terbufos	Insecticide	82675	13071-79-9	0.018	HAL-US	0.4	—
Terbufos oxon sulfone	Insecticide degradate	61674	56070-15-6	0.045	na	na	—
Terbuthylazine	Herbicide	04022	5915-41-3	0.0083	na	na	D
Trifluralin	Herbicide	82661	1582-09-8	0.006	HAL-US	10	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

Table 3D. Pharmaceutical compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 9003.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Thresholds type and threshold levels as of December 20, 2007. The results for pharmaceutical compounds are not presented in this report; they will be included in subsequent publications. **Abbreviations:** CAS, Chemical Abstract Service; MDL, method detection limit; na, not available; µg/L, microgram per liter]

Constituent	Primary use or source	USGS parameter code	CAS number	MDL [1] (µg/L)	Threshold type	Threshold level (µg/L)
Acetaminophen	Analgesic	62000	103-90-2	0.60	na	na
Albuterol	Anti-inflammatory; bronchodilator	62020	18559-94-9	0.03	na	na
Caffeine	Stimulant	50305	58-08-2	0.40	na	na
Carbamazapine	Anticonvulsant; analgesic; mood stabilizer	62793	298-46-4	0.02	na	na
Codeine	Opiod narcotic	62003	76-57-3	0.02	na	na
Cotinine	Nicotine metabolite	62005	486-56-6	0.03	na	na
Dehydronifedipine	Antianginal metabolite	62004	67035-22-7	0.03	na	na
Diltiazem	Antianginal; antihypertensive	62008	42399-41-7	0.02	na	na
1,7-Dimethylxanthine	Caffeine metabolite	62030	611-59-6	0.10	na	na
Diphenhydramine	Antihistamine	62796	58-73-1	0.03	na	na
Sulfamethoxazole	Antibacterial, antiprotozoal	62021	723-46-6	0.05	na	na
Thiabendazole	Anthelmintic	62801	148-79-8	0.02	na	na
Trimethoprim	Antibacterial	62023	738-70-5	0.01	na	na
Warfarin	Anticoagulant	62024	81-81-2	0.03	na	na

[1] The California Groundwater Ambient Monitoring and Assessment (GAMA) program uses more conservative reporting limits for the pharmaceutical compounds than those recommended by the USGS National Water Quality Laboratory. For albuterol, carbamazepine, codeine, dehydronifedipine, diltiazem, sulfamethoxazole, thiabendazole, trimethoprim, and warfarin, the MDL corresponds to the long-term method reporting limit determined by the USGS Branch of Quality Systems in October 2007 (BQS LT-MDL). For acetaminophen, caffeine, cotinine, diphenhydramine, and 1,7-dimethaxanthine, the MDL corresponds to the effective method detection limit determined from assessing quality-control data associated with GAMA samples collected May 2004 through September 2007 (GAMA E-MDL). The GAMA E-MDLs are higher than the BQS LT-MDLs for those compounds. Detections of constituents reported by the USGS National Water Quality Laboratory with concentrations lower than the BQS LT-MDL or the GAMA E-MDL are reported as nondetections by the GAMA program.

Table 3E. Constituents of special interest, primary uses or sources, comparative thresholds, and reporting information for Weck Laboratories, Inc.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; NL-CA, California Department of Public Health notification level. **Other abbreviations:** CAS, Chemical Abstract Service; MRL, minimum reporting level; D, detected in ground-water samples (table 7); µg/L, microgram per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	MRL (µg/L)	Threshold type [1]	Threshold level (µg/L)	Detection
Perchlorate	Rocket fuel, fireworks, flares	63709	14797-73-0	0.5	MCL-CA	6	D
1,2,3-Trichloropropane (TCP)	Fumigant, solvent	77443	96-18-4	0.12	HAL-CA	40	D [2]
1,4-Dioxane	Industrial solvent	81582	123-91-1	2	NL-CA	3	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

Table 3F. Nutrients, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 2755.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in groundwater samples (table 8); na, not available; mg/L, milligram per liter]

Constituent	USGS parameter code	CAS number	LRL (mg/L)	Threshold type[1]	Threshold level (mg/L)	Detection
Ammonia (as nitrogen)	00608	7664-41-7	0.02	HAL-US	[2]24.7	D
Nitrite (as nitrogen)	00613	14797-65-0	0.002	MCL-US	1	D
Nitrite plus nitrate (as nitrogen)	00631	na	0.04	MCL-US	10	D
Nitrogen, total (ammonia, nitrite, nitrate, organic nitrogen)	62854	17778-88-0	0.06	na	na	D
Orthophosphate (as phosphorus)	00671	14265-44-2	0.006	na	na	D

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The HAL-US is 30 mg/L "as ammonia." To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L "as nitrogen."

Table 3G. Major and minor ions and trace elements, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory Schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in groundwater samples (tables 9, 10); na, not available; mg/L, milligram per liter; µg/L, microgram per liter]

Constituent	USGS parameter code	CAS number	LRL	SRL	Threshold type [1]	Threshold value	Detection
Major and minor ions (mg/L)							
Bromide	71870	24959-67-9	0.02	na	na	na	D
Calcium	00915	7440-70-2	0.04	na	na	na	D
Chloride	00940	16887-00-6	0.12	na	SMCL-CA	[2] 250 (500)	D
Fluoride	00950	16984-48-8	0.12	na	MCL-CA	2	D
Iodide	71865	7553-56-2	0.002	na	na	na	D
Magnesium	00925	7439-95-4	0.02	na	na	na	D
Potassium	00935	7440-09-7	0.02	na	na	na	D
Silica	00955	7631-86-9	0.018	na	na	na	D
Sodium	00930	7440-23-5	0.12	na	na	na	D
Sulfate	00945	14808-79-8	0.18	na	SMCL-CA	[2] 250 (500)	D
Residue on evaporation (total dissolved solids, TDS)	70300	na	10	na	SMCL-US	[2] 500 (1,000)	D
Trace elements (µg/L)							
Aluminum	01106	7429-90-5	1.6	1.6	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.14	na	MCL-US	6	D
Arsenic	01000	7440-38-2	0.06	na	MCL-US	10	D
Barium	01005	7440-39-3	0.4	0.79	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.008	na	MCL-US	4	D
Boron	01020	7440-42-8	6	na	NL-CA	1,000	D
Cadmium	01025	7440-43-9	0.04	na	MCL-US	5	D
Chromium	01030	7440-47-3	0.12	0.42	MCL-CA	50	D
Cobalt	01035	7440-48-4	0.02	na	na	na	D
Copper	01040	7440-50-8	1	1.7	MCL-US	1,300	D
Iron	01046	7439-89-6	8	21	SMCL-CA	300	D
Lead	01049	7439-92-1	0.08	0.65	MCL-US	15	D
Lithium	01130	7439-93-2	1	na	na	na	D
Manganese	01056	7439-96-5	0.2	0.2	SMCL-CA	50	D
Mercury	71890	7439-97-6	0.01	0.012	MCL-US	2	D
Molybdenum	01060	7439-98-7	0.2	na	HAL-US	40	D
Nickel	01065	7440-02-0	0.2	0.36	MCL-CA	100	D
Selenium	01145	7782-49-2	0.04	na	MCL-US	50	D
Silver	01075	7440-22-4	0.1	na	SMCL-CA	100	D
Strontium	01080	7440-24-6	0.8	0.99	HAL-US	4,000	D
Thallium	01057	7440-28-0	0.04	na	MCL-US	2	D
Tungsten	01155	7440-33-7	0.06	0.11	na	na	D
Uranium	22703	7440-61-1	0.02	na	MCL-US	30	D
Vanadium	01085	7440-62-2	0.04	0.1	NL-CA	50	D
Zinc	01090	7440-66-6	1.8	4.8	SMCL-CA	5,000	D

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The recommended SMCL-CA thresholds for chloride, sulfate, and TDS are listed with the upper SMCL-CA thresholds in parentheses.

Table 3H. Arsenic, chromium, and iron species, comparative thresholds, and reporting information for the U.S. Geological Survey (USGS) Trace Metal Laboratory, Boulder, Colorado.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level. **Other abbreviations:** CAS, Chemical Abstract Service; MDL, method detection limit; na, not available; µg/L, microgram per liter; D, detected in groundwater samples (table 11)]

Constituent (valence state)	USGS parameter code	CAS number	MDL (µg/L)	Threshold type[1]	Threshold level (µg/L)	Detection
Arsenic(III)	99034	22569-72-8	1	na	na	D
Arsenic(total)	99033	7440-38-2	0.5	MCL-US	10	D
Chromium(VI)	01032	18540-29-9	1	na	na	D
Chromium(total)	01030	7440-47-3	1	MCL-CA	50	D
Iron(II)	01047	7439-89-6	2	na	na	D
Iron(total)	01046	7439-89-6	2	SMCL-US	300	D

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 3I. Isotopic and radioactive constituents, comparative thresholds, and reporting information for laboratories.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of the abundance of a heavier isotope to the more common lighter isotope of that element, relative to a standard reference material. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** C, carbon; H, hydrogen:, O, oxygen; CAS, Chemical Abstract Service; CSU, 1-sigma combined standard uncertainty; 2CSU, 2-sigma combined standard uncertainty; MRL, minimum reporting level; MU, method uncertainty; na, not available; pCi/L, picocurie per liter; Prop., proposed; **s**sL$_{C}$, sample-specific critical level; SSMDC, sample specific minimum detectable concentration; D, detected in groundwater samples (tables 12 and 13A,B,C)]

Constituent	USGS parameter code	CAS number	Reporting level type	Reporting level or uncertainty	Threshold type [1]	Threshold value	Detection
Stable isotope ratios (per mil)							
$\delta^{2}H$ of water [2]	82082	na	MU	2	na	na	D
$\delta^{18}O$ of water [2]	82085	na	MU	0.20	na	na	D
$\delta^{13}C$ of dissolved carbonates [3]	82081	na	1-sigma	0.05	na	na	D
Radioactive constituents (percent modern)							
Carbon-14 [4]	49933	14762-75-5	1-sigma	0.0015	na	na	D
Radioactive constituents (pCi/L)							
Radon-222 [5]	82303	14859-67-7	SSMDC	2CSU	Prop. MCL-US	[6] 300 (4,000)	D
Tritium [7,8]	07000	10028-17-8	MRL	1	MCL-CA	20,000	D
Gross alpha particle activity, 72-hour and 30-day counts [9]	99920, 99921	12587-46-1	SSMDC	CSU	MCL-US	15	D
Gross beta particle activity, 72-hour and 30-day counts [9]	99922, 99923	12587-47-2	SSMDC	CSU	MCL-CA	50	D
Radium-226 [9]	99915	13982-63-3	SSMDC	CSU	MCL-US	[10] 5	D
Radium-228 [9]	99916	15262-20-1	SSMDC	CSU	MCL-US	[10] 5	D

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[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] USGS Stable Isotope Laboratory, Reston, Virginia.

[3] University of Waterloo (contract laboratory).

[4] University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory).

[5] USGS National Water Quality Laboratory.

[6] Two MCLs have been proposed for Radon-222. The proposed alternative MCL is in parentheses.

[7] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California.

[8] Lawrence Livermore National Laboratory.

[9] Eberline Analytical Services (contract laboratory).

[10] The MCL-CA threshold for radium is the sum of radium-226 and radium-228.

Table 3J. Noble gases and tritium, comparison thresholds and reporting information for the Lawrence Livermore National Laboratory.

[The five-digit U.S. Geological survey (USGS) parameter code is used to uniquely identify a specific constituent or property. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** CAS, Chemical Abstract Service; MU, method uncertainty; na, not available; cm^3 STP/g, cubic centimeter of gas at standard temperature and pressure per gram of water; pCi/L, picocurie per liter]

Constituent	USGS parameter code	CAS number	MU (percent)	Reporting units	Threshold type [1]	Threshold value (pCi/L)
Helium-3/Helium-4	61040	na/7440-59-7	0.75	atom ratio	na	na
Argon	85563	7440-37-1	2	cm^3 STP/g	na	na
Helium-4	85561	7440-59-7	2	cm^3 STP/g	na	na
Krypton	85565	7439-90-9	2	cm^3 STP/g	na	na
Neon	61046	7440-01-09	2	cm^3 STP/g	na	na
Xenon	85567	7440-63-3	2	cm^3 STP/g	na	na
Tritium	07000	10028-17-8	1	pCi/L	MCL-CA	20,000

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 4. Water-quality indicators in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five digit number below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed, but only samples with detections are listed. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** LRL, laboratory reporting level; °C, degrees Celsius; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; $CaCO_3$, calcium carbonate; *, value above threshold value or outside threshold range; **, value above upper threshold value]

GAMA well identification number	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Threshold type	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**	**SMCL-CA**	**na**	**na**
Threshold level	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**[1] 900 (1,600)**	**[1] 900 (1,600)**	**na**	**na**
[LRL]	**[0.2]**	**[0.0–38.5]**	**[0–14]**	**[0–14]**	**[5]**	**[5]**	**[5]**	**[1]**
Grid wells								
COLOR-01	6.8	17.5	7.7	7.5	* 1,210	* 1,190	150	136
COLOR-02	4.2	25.0	7.8	7.6	* 1,270	* 1,260	152	137
COLOR-03	0.2	24.0	7.4	7.5	** 2190	** 2,180	284	254
COLOR-04	0.1	22.0	7.8	7.7	* 1,590	* 1,560	273	268
COLOR-05	<0.2	23.0	7.7	7.5	* 1,580	* 1,580	275	230
COLOR-06	0.3	24.5	7.7	7.5	* 1,390	* 1,400	231	192
COLOR-07	<0.2	23.0	7.5	7.3	** 1,950	** 1,950	292	245
COLOR-08	0.7	32.0	8.1	8.0	** 1,980	** 2,020	73	68
COLOR-09	0.2	31.5	7.8	7.8	** 1,830	** 1,880	192	156
COLOR-10	0.3	25.0	7.5	7.4	** 2,320	** 2,360	303	250
COLOR-11	0.6	28.5	7.2	7.0	** 3,930	** 4,000	314	254
COLOR-12	1.6	33.5	8.0	7.9	796	804	109	86
COLOR-13	4.7	29.0	7.7	7.6	*959	*963	153	147
COLOR-14	0.2	27.0	7.7	7.6	*911	*926	159	154
COLOR-15	<0.2	23.0	7.3	7.2	** 2,640	** 2,660	321	315
COLOR-16	0.3	20.5	7.7	7.6	** 2,070	** 2,080	318	315
COLOR-17	3.8	27.0	7.8	7.8	* 1,320	* 1,340	89	85
COLOR-18	0.6	32.0	8.0	8.0	** 1,730	** 1,770	147	141
COLOR-19	1.8	24.0	7.6	7.5	** 2,910	** 2,890	296	293
COLOR-20	7.2	35.5	*8.9	*8.9	665	678	66	62
Understanding wells								
COLORU-01	0.5	21.0	7.8	7.7	* 1,120	* 1,110	175	168
COLORU-02	<0.2	24.0	7.7	7.6	* 1,390	* 1,400	233	197
COLORU-03	4.8	26.0	7.8	7.7	* 1,030	*1,040	187	151
COLORU-04	0.3	20.5	7.3	7.1	** 2,380	** 2,250	253	238
COLORU-05	0.8	20.5	7.7	7.5	** 1,130	* 1,130	157	142
COLORU-06	0.8	29.5	8.0	7.9	* 1,410	* 1,400	189	194
COLORU-07	0.4	30.5	7.9	7.8	** 4,640	** 4,780	107	86
COLORU-08	0.2	21.5	7.8	7.5	** 2,160	2,150	286	285

[1] The SMCL-CA for specific conductance has recommended and upper threshold values. The upper value is shown in parentheses.

Table 5. Volatile organic compounds (VOC) detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed. Analytes are listed in order of decreasing detection frequency in the 20 grid wells. All analytes are listed in tables 3A,B. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** NL-CA, CDPH notification level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** THM, trihalpmethane; E, estimated value; LRL, laboratory reporting level; DBP, disinfection by-product; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Gasoline hydrocarbon	Fumigant	Disinfection by-product (THM)	Gasoline oxygenate	VOC detections per well
	1,2,4-Trimethyl-benzene (µg/L) (77222)	1,2-Dichloro-propane (µg/L) (34541)	Chloroform, (µg/L) (32106)	Methyl *tert*-butyl ether (MTBE), (µg/L) (78032)	
Threshold type [1]	**330**	**5**	**MCL-US**	**MCL-CA**	
Threshold level	**[0.04]**	**[0.02]**	**[2]80**	**13**	
[LRL]	**NL-CA**	**MCL-US**	**[0.04, 0.02]**	**[0.1]**	
Grid wells					
COLOR-03	E0.03	—	—	—	1
COLOR-05	—	0.10	—	—	1
COLOR-06	E0.09	—	—	—	1
COLOR-07	E0.06	0.91	—	—	2
COLOR-08	—	—	E0.02	—	1
COLOR-10	—	0.78	—	—	1
COLOR-11	E0.09	—	E0.01	—	2
Number of detections	4	3	2	0	9
Detection frequency (percentage)	20	15	10	0	[2]35
Understanding wells					
COLORU-04	—	—	—	E0.1	1
COLORU-05	—	—	E0.04	—	1
COLORU-06	—	—	E0.02	—	1

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists..

[2] Frequency of detection of at least one volatile organic compound (VOC) in the grid wells.

Table 6. Pesticides and pesticide degradates detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed, but only samples with detections are listed. Analytes are listed in order of decreasing detection frequency in the 20 grid wells. All analytes are listed in table 3C. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA; California Department of Public Health maximum contaminant level. **Other abbreviations:** E, estimated value; LRL, laboratory reporting level; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Deethylatrazine (µg/L) (04040)	Simazine (µg/L) (04035)	Atrazine (µg/L) (39632)	Prometryn, (µg/L) (04036)	Terbuthylazine, (µg/L) (04022)	Pesticide detections per well
Threshold type [1]	**na**	**MCL-US**	**MCL-CA**	**na**	**na**	
Threshold level	**na**	**4**	**1**	**na**	**na**	
[LRL]	**[0.014]**	**[0.006]**	**[0.007]**	**[0.0059]**	**[0.008]**	
Grid wells						
COLOR-01	E0.005	—	E0.007	—	—	2
COLOR-02	E0.005	—	—	—	—	1
COLOR-11	—	E0.007	—	—	—	1
COLOR-15	—	—	—	E0.005	—	1
Number of detections	2	1	1	1		5
Detection frequency (percent)	10	5	5	5		[2] 20
Understanding wells						
COLORU-05	E0.005	—	—	—	E0.004	2

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Frequency of detection of at least one pesticide or pesticide degradate in the grid wells.

Table 7. Constituents of special interest (perchlorate and 1,2,3-trichloropropane [1,2,3-TCP]) detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Information about the analytes given in table 3E. Samples from all 28 wells were analyzed for perchlorate and 1,2,3-TCP; samples from the Palo Verde study area wells were sampled for 1,4 dioxane, and only wells with at least one detection are listed. **GAMA well identification number:** COLOR; Colorado River study unit grid well; COLORU; Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; HAL-US, USEPA lifetime health advisory. **Other abbreviations:** MRL, minimum reporting level; µg/L, microgram per liter; —, analyzed but not detected]

GAMA well identification number	Perchlorate (µg/L) (63790)	1,2,3-Trichloropropane (µg/L) (77443)
Threshold type [1]	**MCL-CA**	**HAL-US**
Threshold level	**6**	**40**
[MRL]	**[0.10]**	**[0.0050]**
	Grid wells	
COLOR-01	1.5	—
COLOR-02	1.8	—
COLOR-08	0.20	—
COLOR-10	—	0.008
COLOR-11	0.42	—
COLOR-12	0.69	—
COLOR-13	0.82	—
COLOR-17	0.87	—
COLOR-18	2.4	—
COLOR-20	1.2	—
Number of detections	9	1
Detection frequency (percent)	45	5
	Understanding wells	
COLORU-05	1.0	—
COLORU-06	1.6	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 8. Nutrients detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed, but only samples with detections are listed. Information about the analytes is given in table 3F. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold type and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US; U.S. Environmental Protection Agency maximum contaminant level; HAL-US, U.S. Environmental Protection Agency lifetime health advisory level. **Other abbreviations:** E, estimated value; LRL, laboratory reporting level; na, not available; mg/L, milligram per liter; —, not detected]

GAMA well identification number	Ammonia, as nitrogen (mg/L) (00608)	Nitrite plus nitrate, as nitrogen (mg/L) (00631)	Nitrite, as nitrogen (mg/L) (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N), as nitrogen (mg/L) (62854)	Orthophosphate, as phosphorus (mg/L) (00671)
Threshold type [1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**
Threshold level	**[2] 24.7**	**10**	**1**	**na**	**na**
[LRL]	**[0.02]**	**[0.04]**	**[0.002]**	**[0.06]**	**[0.006]**
Grid wells					
COLOR-01	—	0.49	—	0.54	0.007
COLOR-02	—	0.25	E0.001	0.28	0.012
COLOR-03	0.30	—	E0.001	0.38	0.054
COLOR-04	0.98	—	—	1.14	0.055
COLOR-05	0.17	—	—	0.18	0.020
COLOR-06	0.21	—	—	[3]0.19	0.016
COLOR-07	0.20	—	—	0.30	0.009
COLOR-08	—	1.36	E0.001	1.39	0.008
COLOR-09	0.03	—	—	—	0.009
COLOR-10	0.24	—	—	0.34	0.016
COLOR-11	—	0.91	—	0.94	0.021
COLOR-12	—	2.11	—	2.26	E0.006
COLOR-13	—	4.11	—	4.30	0.010
COLOR-14	—	E0.02	0.003	E0.04	0.010
COLOR-15	0.57	—	—	0.75	0.010
COLOR-16	0.31	—	—	0.42	0.026
COLOR-17	—	3.29	—	[3] 3.25	0.007
COLOR-18	0.30	1.26	0.004	[4] 1.24	0.009
COLOR-19	0.55	—	—	0.68	0.059
COLOR-20	E0.02	4.76	E0.002	5.05	0.006
Understanding wells					
COLORU-01	0.06	—	—	—	0.020
COLORU-02	0.06	—	—	[4] E0.05	0.018
COLORU-03	0.22	—	—	[4] 0.19	0.019
COLORU-04	0.06	0.92	0.026	1.16	0.012
COLORU-05	E0.01	0.27	0.004	0.33	0.010
COLORU-06	0.03	0.61	—	0.68	0.009
COLORU-07	—	0.09	—	[3] 0.08	0.011
COLORU-08	0.55	—	0.007	0.71	0.041

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[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The HAL-US is 30 mg/L "as ammonia." To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L "as nitrogen."

[3] Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes and falls outside the U.S. Geological Survey National Water Quality Laboratory acceptance criterion of a 10 percent relative percent difference.

[4] Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes, but falls outside of the U.S. Geological Survey National Water Quality Laboratory acceptance criterion of a 10 percent relative percent difference.

Table 9. Major and minor ions and dissolved solids detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed. Information about the analytes is given in table 3G. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study understanding well. Threshold type and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** E, estimated value; LRL, laboratory reporting level; na, not available; mg/L, milligram per liter; <, less than; *, value above recommended threshold value; **, value above upper threshold value]

GAMA well identification number	Calcium (mg/L) (00915)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Sodium (mg/L) (00930)	Bicarbonate [1] (mg/L)	Carbonate [1] (mg/L)	Bromide (mg/L) (71870)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Silica (mg/L) (00955)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70300)
Threshold type [2]	na	na	na	na	na	na	na	SMCL-CA [3]	MCL-CA	na	na	SMCL-CA [3]	SMCL-CA [3]
Threshold level	na	na	na	na	na	na	na	250 (500)	2	na	na	250 (500)	500 (1,000)
[LRL]	[0.04]	[0.02]	[0.02]	[0.12]	[1]	[1]	[0.02]	[0.12]	[0.12]	[0.002]	[0.018]	[0.18]	[10]
Grid wells													
COLOR-01	84.3	31.2	4.33	110	165	<1.0	0.11	112	0.38	0.004	11.4	* 294	* 776
COLOR-02	57.4	14.2	5.27	174	166	<1.0	0.11	120	0.76	0.003	29	* 285	* 794
COLOR-03	137	32.8	7.57	278	308	<1.0	0.24	* 333	0.33	0.026	19	* 336	** 1,380
COLOR-04	92.0	40.3	6.06	182	323	1.6	0.14	141	0.58	0.018	19.4	* 331	*989
COLOR-05	150	38.6	3.45	139	279	<1.0	0.12	142	0.26	0.009	16.7	* 366	** 1,100
COLOR-06	121	32.9	3.05	134	233	<1.0	0.11	136	0.29	0.009	16.3	* 298	*926
COLOR-07	146	44.1	4.44	214	297	<1.0	0.18	181	0.20	0.013	22.6	* 471	** 1,370
COLOR-08	50.9	8.69	4.74	351	82.4	<1.0	0.33	* 327	1.88	0.167	24.6	* 349	** 1,210
COLOR-09	46.5	7.27	3.58	310	189	<1.0	0.21	* 280	* 2.06	0.016	19.7	* 265	** 1,110
COLOR-10	136	57.5	4.23	275	303	<1.0	0.21	* 281	0.38	0.015	22.4	** 517	** 1,600
COLOR-11	195	61.9	6.68	569	309	<1.0	0.54	** 640	0.85	0.037	63.5	** 908	** 2,780
COLOR-12	28.8	3.51	4.01	124	104	<1.0	0.24	114	0.77	0.004	20.4	80.5	468
COLOR-13	49.3	22.5	9.91	100	178	<1.0	0.18	157	* 2.48	0.003	42.9	57.2	* 567
COLOR-14	57.7	17.7	3.60	102	187	<1.0	0.10	137	0.33	0.008	20.4	87.9	*533
COLOR-15	201	76.2	8.67	304	384	<1.0	0.29	235	0.80	0.011	21.1	** 820	** 1,970
COLOR-16	228	55.5	6.09	161	382	<1.0	0.21	197	0.18	0.021	17.3	** 550	** 1,490
COLOR-17	77.8	16.0	6.34	145	103	<1.0	0.16	* 308	* 2.38	E0.002	20.5	58.4	*736
COLOR-18	43.8	8.55	5.11	294	170	<1.0	0.23	* 258	* 2.64	0.016	20.2	* 281	** 1,050
COLOR-19	237	70.5	7.68	310	356	<1.0	0.30	* 492	0.33	0.013	24.6	** 523	** 1,950
COLOR-20	8.36	0.33	1.55	127	70.9	2.0	0.21	64.1	1.50	0.017	18.1	112	411

Table 9. Major and minor ions and dissolved solids detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.—Continued

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed. Information about the analytes is given in table 3G. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study understanding well. Threshold type and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** E, estimated value; LRL, laboratory reporting level; na, not available; mg/L, milligram per liter; <, less than; *, value above recommended threshold value; **, value above upper threshold value]

GAMA well identification number	Calcium (mg/L) (00915)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Sodium (mg/L) (00930)	Bicarbonate[1] (mg/L)	Carbonate[1] (mg/L)	Bromide (mg/L) (71870)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Silica (mg/L) (00955)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70300)
Threshold type[2]	na	na	na	na	na	na	na	SMCL-CA[3]	MCL-CA	na	na	SMCL-CA[3]	SMCL-CA[3]
Threshold level	na	na	na	na	na	na	na	250 (500)	2	na	na	250 (500)	500 (1,000)
[LRL]	[0.04]	[0.02]	[0.02]	[0.12]	[1]	[1]	[0.02]	[0.12]	[0.12]	[0.002]	[0.018]	[0.18]	[10]
						Understanding wells							
COLORU-01	91.8	24.7	2.87	100	204	<1.0	0.10	94.3	0.27	0.019	16.4	* 253	* 715
COLORU-02	124	33.4	2.85	121	238	1.0	0.12	137	0.28	0.010	17.9	* 300	* 927
COLORU-03	54.7	14.3	2.68	142	182	<1.0	0.08	98.3	0.41	0.008	17.5	187	* 637
COLORU-04	134	55.6	8.80	283	290	<1.0	0.24	* 262	0.91	0.025	27.1	** 612	** 1,680
COLORU-05	83.4	29.7	5.02	102	172	<1.0	0.10	96.4	0.37	0.007	14.4	* 274	* 749
COLORU-06	26.1	7.01	3.18	261	233	1.5	0.16	192	1.36	0.013	17.8	206	* 844
COLORU-07	60.7	13.3	8.65	908	103	<1.0	0.64	** 995	* 5.08	0.057	38.5	** 753	** 2,890
COLORU-08	175	51.9	4.94	244	346	<1.0	0.22	195	0.44	0.015	22.4	** 573	** 1,550

[1] Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values (table 4) using the advanced speciation method (http://or.water.usgs.gov/alk/methods.html) with $pK_1 = 6.35$, $pK_2 = 10.33$, and $pK_W = 14$. pK_a, pK_2, and pK_W are the minus logarithms of the equilibrium constants for the first ionization of carbonic acid, the second ionization of carbonic acid, and the first ionization of water, respectively.

[2] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[3] The SMCL-CA for chloride, sulfate, and total dissolved solids have recommended and upper threshold values. The upper value is shown in parentheses.

Table 10. Trace elements detected in groundwater samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed. All analytes are listed in table 3G. Values less than the study reporting level are reported with a less than or equal to sign (≤). **GAMA well identification number:** COLOR, Colorado River study unit grid-well; COLORU, Colorado River study unit understanding well. Threshold type and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** LRL, laboratory reporting level; SRL, study reporting level; na, not available; E, estimated value; µg/L, microgram per liter; —, not detected; *, value above threshold value]

GAMA well identification number	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Beryllium (µg/L) (01010)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
Threshold type [1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**MCL-US**	**SMCL-CA**	**MCL-US**
Threshold level	**1,000**	**6**	**10**	**1,000**	**4**	**1,000**	**5**	**50**	**na**	**1,300**	**300**	**15**
[LRL]	**[1.6]**	**[0.14]**	**[0.06]**	**[0.4]**	**[0.008]**	**[6]**	**[0.04]**	**[0.12]**	**[0.02]**	**[1]**	**[8]**	**[0.08]**
[SRL] [2,3]	**[1.6]**	**—**	**—**	**[0.79]**	**—**	**—**	**—**	**[0.42]**	**—**	**[1.7]**	**[21]**	**[3] [0.65]**
Grid wells												
COLOR-01	—	0.2	3.1	12	0.010	103	—	≤0.07	0.04	≤0.90	—	≤0.37
COLOR-02	—	0.2	* 11.1	21	E0.01	164	—	0.5	0.05	1.7	≤8	≤0.15
COLOR-03	—	—	0.2	174	E0.01	196	—	—	0.07	—	197	—
COLOR-04	—	—	0.6	142	—	183	—	—	0.05	—	* 419	—
COLOR-05	≤1.0	—	0.1	81	E0.01	132	—	—	0.05	—	75	≤0.06
COLOR-06	≤1.0	—	0.1	54	—	74	—	—	0.04	—	201	≤0.06
COLOR-07	2.6	—	0.7	48	E0.005	68	—	—	0.06	—	* 862	≤0.09
COLOR-08	1.9	—	8.4	25	—	* 1,300	0.16	0.6	E0.02	—	62	—
COLOR-09	1.7	—	3.6	24	E0.01	363	E0.03	≤0.07	E0.02	—	162	—
COLOR-10	—	—	0.1	45	0.010	214	E0.02	≤0.07	0.05	—	206	≤0.05
COLOR-11	—	—	4.6	37	—	* 1,020	—	0.7	0.07	—	—	≤0.39
COLOR-12	1.8	—	5.5	59	—	303	E0.02	1.9	E0.01	4.1	—	≤0.50
COLOR-13	≤0.9	—	7.2	169	—	310	E0.04	9.9	0.02	1.7	—	≤0.63
COLOR-14	≤1.1	—	3.2	62	—	101	—	—	0.03	1.8	—	≤0.31
COLOR-15	—	—	1.1	82	—	—	E0.07	≤0.1	0.23	—	* 1,080	≤0.15
COLOR-16	≤1.2	—	0.2	94	E0.01	116	—	≤0.08	0.17	—	180	—
COLOR-17	≤1.3	—	1.4	143	E0.004	198	—	10.3	0.06	—	≤10	≤0.05
COLOR-18	3.0	—	2.8	25	E0.004	388	E0.03	≤0.3	0.07	≤0.54	66	≤0.26
COLOR-19	—	—	0.5	108	E0.02	202	E0.06	≤0.2	0.11	3.2	* 863	≤0.26
COLOR-20	9.7	—	5.9	21	—	399	E0.04	28.5	—	—	≤9	≤0.57
Understanding wells												
COLORU-01	≤1.1	—	0.1	62	E0.01	83	—	—	0.04	—	78	≤0.16
COLORU-02	≤1.2	—	0.1	72	E0.01	78	—	—	0.04	—	142	≤0.08
COLORU-03	≤1.3	—	0.1	33	E0.01	97	—	—	0.02	—	58	—
COLORU-04	—	—	3.3	31	0.010	88	0.04	—	0.67	2.4	—	0.85
COLORU-05	—	≤0.1	1.9	36	—	137	—	—	0.10	—	140	—
COLORU-06	2.2	—	3.7	27	—	167	—	0.5	E0.01	—	≤10	≤0.20
COLORU-07	—	—	* 36.2	19	—	* 2,180	E0.07	0.9	—	—	25	—
COLORU-08	—	—	0.7	195	—	408	E0.08	—	0.20	—	* 905	—

Table 10. Trace elements detected in groundwater samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.—Continued

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 28 wells were analyzed. All analytes are listed in table 3G. Values less than the study reporting level are reported with a less than or equal to sign (≤). **GAMA well identification number:** COLOR, Colorado River study unit grid-well; COLORU, Colorado River study unit understanding well; Threshold type and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA; California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; AL-US, U.S. Environmental Protection Agency action level; HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** LRL, laboratory reporting level; SRL, study reporting level; na, not available; E, estimated value; µg/L, microgram per liter; —, not detected; ≤, less than or equal to; *, value above threshold value]

GAMA well identification number	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Mercury (µg/L) (71890)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Threshold type [1]	**na**	**SMCL-CA**	**MCL-US**	**HAL-US**	**MCL-CA**	**MCL-US**	**HAL-US**	**MCL-US**	**na**	**MCL-US**	**NL-CA**	**SMCL-CA**
Threshold level	**na**	**50**	**2**	**40**	**100**	**50**	**4,000**	**2**	**na**	**30**	**50**	**5,000**
[LRL]	**[1]**	**[0.2]**	**[0.01]**	**[0.2]**	**[0.2]**	**[0.04]**	**[0.8]**	**[0.04]**	**[0.06]**	**[0.02]**	**[0.04]**	**[1.8]**
[SRL] [2,3]	—	**[0.2]**	**[0.012]**	—	**[0.36]**	—	**[0.99]**	—	**[0.11]**	—	**[0.1]**	**[4.8]**
Grid wells												
COLOR-01	37.5	0.3	—	5.8	0.56	1.80	960	—	0.47	6.52	1.2	15.6
COLOR-02	74.2	E0.4	≤0.007	7.5	0.40	1.50	800	—	1.1	8.83	5.4	12.1
COLOR-03	47.4	* 1,110	—	3.9	0.42	0.04	1,360	—	0.29	1.02	0.3	≤1.3
COLOR-04	57.7	* 157	≤0.008	2.1	0.47	0.11	1,570	E0.03	0.97	0.27	0.4	—
COLOR-05	49.5	* 241	0.013	3.8	0.44	0.04	2,030	—	≤0.05	0.18	0.1	≤1.7
COLOR-06	50.4	* 108	≤0.007	3.1	0.91	E0.03	1,610	—	≤0.07	0.08	0.1	≤2.7
COLOR-07	55.8	* 308	—	1.8	0.54	E0.02	2,820	—	≤0.10	* 33.8	0.2	17
COLOR-08	91.5	17.6	≤0.010	* 79.4	≤E0.16	11.70	1,220	—	0.39	4.43	4.9	≤1.1
COLOR-09	96.2	21.1	0.015	13.3	1.6	E0.03	1,020	—	1.3	0.04	0.3	≤2.6
COLOR-10	74.8	* 276	≤0.010	9.6	0.51	0.05	1,560	—	≤0.04	0.37	0.2	18.9
COLOR-11	263	1.6	0.013	3.7	0.76	2.30	* 4,660	—	—	* 45.4	12.6	—
COLOR-12	50.1	—	—	13.7	≤0.21	2.50	1,290	—	0.12	4.9	9.2	14.1
COLOR-13	53.6	—	≤0.006	8.5	≤0.43	1.20	1,220	—	0.78	6.35	12.9	≤2.9
COLOR-14	24.3	3.6	≤0.010	3.9	0.36	0.05	1,080	—	0.95	6.58	1.9	28.8
COLOR-15	—	* 898	≤0.006	31.3	3.9	0.20	* 4,710	—	0.14	1.11	0.7	≤4.3
COLOR-16	51.5	* 640	—	1.9	2.8	0.06	2,600	—	≤ 0.08	1.53	0.4	—
COLOR-17	77.5	0.5	≤0.008	6.2	1.1	1.90	2,520	—	5.7	1.55	9.3	8.2
COLOR-18	87.9	11.2	≤0.006	15.8	0.71	8.60	1,140	—	0.21	2.0	2.2	≤3.1
COLOR-19	89.9	* 1,150	—	5.2	1.1	—	2,640	—	0.35	0.93	0.3	7.7
COLOR-20	52.9	1.1	0.015	16.8	—	2.70	356	—	1.6	0.97	7.0	17.8
Understanding wells												
COLORU-01	26.9	* 240	≤0.009	5.0	0.38	E0.04	1,300	—	0.11	0.23	0.1	≤1.1
COLORU-02	41.7	* 244	≤0.008	2.2	≤0.3	0.04	1,630	—	≤0.05	0.13	0.1	≤2.2
COLORU-03	35.8	* 58.1	≤0.007	3.0	≤0.18	0.05	781	—	0.13	0.05	0.1	≤2.4
COLORU-04	71.1	* 494	0.013	12.8	2.6	0.89	2,400	E0.03	0.75	12.5	4.8	≤4.7
COLORU-05	39.6	* 99.0	0.019	5.2	0.53	2.20	1,170	—	0.15	4.74	1.6	≤0.91
COLORU-06	93.0	5.9	≤0.010	5.8	≤0.11	0.48	630	—	0.35	1.73	1.0	≤2.4
COLORU-07	817	6.1	0.016	31.3	—	2.60	1,660	—	2.1	1.21	6.8	≤2.7
COLORU-08	106	* 949	≤0.007	33.2	1.8	0.13	1,640	—	0.35	0.77	0.7	15.6

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Study reporting levels (SRL) were defined on the basis of the examination of field blanks collected in GAMA study units from May 2004 through January 2008 (L.D. Olsen and M.S. Fram, U.S. Geological Survey, unpublished data, 2008).

[3] Values equal to or less than the SRL are reported as less than or equal to the value reported by the laboratory (≤). Values reported with a ≤ symbol in this table have the following field comment included in the USGS NWIS database: Result is < or ≤ reported value, based on quality control data (including but not limited to field blanks, source-solution blanks, trip blanks, NWQL set blanks, NWQL blank water certificates, and BQS Blind Blank Program data).

Table 11. Species of inorganic iron, arsenic, and chromium detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[Data in this table were analyzed at U.S. Geological Survey (USGS) Trace Metal Laboratory in Boulder, Colorado, using research methods and are not stored in the USGS National Water Information System database. Samples from all 28 wells were analyzed for iron, arsenic, and chromium species; only wells with at least one detection are listed. Information about the analytes is given in table 3H. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** MDL, method detection limit; na, not available; µg/L, microgram per liter; nc, not collected; —, not detected; *, value above threshold value]

GAMA well identification number	Iron (total) (µg/L)	Iron(II) (µg/L)	Arsenic (total) (µg/L)	Arsenic(III) (µg/L)	Chromium (total) (µg/L)	Chromium(VI) (µg/L)
Threshold type [1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold level	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
Grid wells						
COLOR-01	—	—	2.3	—	—	—
COLOR-02	7	4	4.1	—	—	—
COLOR-03	161	112	—	—	—	—
COLOR-04	* 361	359	—	—	—	—
COLOR-05	66	63	—	—	—	—
COLOR-06	172	17	—	—	—	—
COLOR-07	* 563	454	—	—	—	—
COLOR-08	—	—	nc	nc	nc	nc
COLOR-09	141	35	2.5	2.5	—	—
COLOR-10	175	147	—	—	—	—
COLOR-11	9	8	3.2	—	1	—
COLOR-12	—	—	3.9	—	2	—
COLOR-13	—	—	5.6	—	11	1
COLOR-14	—	—	2.4	—	—	—
COLOR-15	* 913	879	—	—	—	—
COLOR-16	153	138	—	—	—	—
COLOR-17	8	—	0.84	—	10	1
COLOR-18	56	4	1.8	—	—	—
COLOR-19	* 747	546	—	—	—	—
COLOR-20	10	—	4.6	—	30	3
Understanding wells						
COLORU-01	67	51	—	—	—	—
COLORU-02	120	119	—	—	—	—
COLORU-03	50	36	—	—	—	—
COLORU-04	4	3	2.3	—	—	—
COLORU-05	121	63	1.4	—	—	—
COLORU-06	8	4	2.9	—	—	—
COLORU-07	23	6	* 27	—	1	1
COLORU-08	* 741	721	—	—	—	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 12. Stable isotope ratios and activities of tritium and carbon-14 detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all 52 wells were analyzed. Information about the analytes is given in table 3I. Samples from all 28 wells were analyzed. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to the more common lighter isotope of that element, relative to a standard reference material. **GAMA well identification number:** COLOR, Colorado River study unit grid well; COLORU, Colorado River study unit understanding well. Threshold types and threshold levels as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** H, hydrogen; O, oxygen; C, carbon; pCi/L, picocurie per liter; na, not applicable; —, not detected]

GAMA well identification number	δ^{2}H of water (per mil) (82082)	δ^{18}O of water (per mil) (82085)	Tritium (pCi/L) (07000)	δ^{13}C of dissolved carbonates (per mil) (82081)	Carbon-14 (percent modern) [1] (49933)
Threshold type [2]	**na**	**na**	**MCL-CA**	**na**	**na**
Threshold level	**na**	**na**	**20,000**	**na**	**na**
Grid wells					
COLOR-01	–93.7	–11.13	21.8	–7.16	90.15
COLOR-02	–92.7	–11.35	24.6	–8.29	90.61
COLOR-03	–109.5	–14.16	1.3	–12.24	84.15
COLOR-04	–81.3	–8.70	24.3	–12.80	99.21
COLOR-05	–106.2	–13.46	38.7	–11.40	95.33
COLOR-06	–111.4	–14.46	23.4	–10.07	86.42
COLOR-07	–107.2	–13.69	51.5	–13.38	95.85
COLOR-08	–81.5	–10.98	—	–8.26	19.12
COLOR-09	–114.5	–15.01	—	–10.96	59.95
COLOR-10	–105.9	–13.49	63.0	–12.91	101.50
COLOR-11	–88.8	–11.11	28.2	–13.81	100.60
COLOR-12	–62.8	–8.15	—	–8.45	19.19
COLOR-13	–81.9	–11.10	—	–9.28	40.74
COLOR-14	–112.7	–15.00	—	–9.27	66.75
COLOR-15	–94.0	–11.05	23.0	–12.46	104.10
COLOR-16	–106.2	–13.68	36.8	–13.36	92.78
COLOR-17	–63.4	–8.84	—	–11.32	37.25
COLOR-18	–109.4	–14.13	36.2	–10.95	54.16
COLOR-19	–97.8	–12.46	7.0	–11.43	97.78
COLOR-20	–70.0	–9.07	—	–9.86	14.68
Understanding wells					
COLORU-01	–108.0	–14.11	14.7	–9.20	81.75
COLORU-02	–111.2	–14.57	25.6	–10.71	80.87
COLORU-03	–112.6	–14.82	4.8	–9.69	72.55
COLORU-04	–96.9	–12.02	34.2	–9.17	92.53
COLORU-05	–94.5	–11.68	24.3	–7.64	86.45
COLORU-06	–114.2	–15.10	6.1	–10.52	69.10
COLORU-07	–63.9	–7.78	—	–9.97	12.25
COLORU-08	–104.1	–13.12	37.1	–11.94	102.10

[1] 100-percent modern carbon is referenced to atmospheric carbon-14 production rates in 1950. Values of percent modern carbon can be greater than 100 percent because the atmospheric production rate was much higher during the period of above-ground nuclear testing in the 1950s and 1960s.

[2] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 13A. Radium isotopes detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Information about the analytes is given in table 3I. Samples from all 28 wells were analyzed, but only samples with detections are listed. Measured values less than the sample-specific critical level (ssL_C) are reported as nondetections (—). **GAMA well identification number:** COLOR, Colorado River study area grid well; COLORU, Colorado River study area understanding well. Thresholds and threshold values as of December 20, 2007. **Threshold type:** MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** CSU, 1-sigma combined standard uncertainty; pCi/L, picocurie per liter]

GAMA well identification number	Radium-226 (pCi/L) (09511)		Radium-228 (pCi/L) (81366)	
Threshold type [1]	**MCL-CA**		**MCL-CA**	
Threshold level	[2]5		[2]5	
Reporting level method	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**
		Grid wells		
COLOR-01	0.062 ± 0.013	0.014	0.324 ± 0.095	0.21
COLOR-02	0.060 ± 0.013	0.014	—	0.28
COLOR-03	0.502 ± 0.033	0.013	0.405 ± 0.091	0.20
COLOR-04	0.072 ± 0.012	0.012	0.200 ± 0.085	0.20
COLOR-05	0.490 ± 0.031	0.014	0.39 ± 0.09	0.21
COLOR-06	0.188 ± 0.023	0.016	0.25 ± 0.14	0.20
COLOR-07	1.218 ± 0.063	0.016	0.6 ± 0.1	0.23
COLOR-08	0.092 ± 0.015	0.013	—	0.22
COLOR-09	0.101 ± 0.016	0.015	0.19 ± 0.17	0.16
COLOR-10	0.235 ± 0.023	0.016	0.44 ± 0.18	0.16
COLOR-11	0.120 ± 0.018	0.017	0.67 ± 0.19	0.18
COLOR-12	0.057 ± 0.012	0.014	—	0.19
COLOR-13	0.086 ± 0.014	0.015	0.297 ± 0.065	0.16
COLOR-14	0.140 ± 0.019	0.016	0.327 ± 0.075	0.18
COLOR-15	0.043 ± 0.014	0.016	0.24 ± 0.08	0.19
COLOR-16	0.837 ± 0.046	0.018	0.53 ± 0.12	0.27
COLOR-17	0.560 ± 0.013	0.016	0.34 ± 0.18	0.30
COLOR-18	0.104 ± 0.019	0.017	0.26 ± 0.11	0.25
COLOR-19	0.226 ± 0.024	0.018	0.72 ± 0.11	0.23
COLOR-20	0.028 ± 0.013	0.018	—	0.22
		Understanding wells		
COLORU-01	0.296 ± 0.024	0.013	0.26 ± 0.13	0.26
COLORU-02	0.357 ± 0.024	0.014	0.305 ± 0.095	0.20
COLORU-03	0.123 ± 0.016	0.016	0.230 ± 0.095	0.21
COLORU-04	0.079 ± 0.016	0.017	0.263 ± 0.095	0.22
COLORU-05	0.024 ± 0.011	0.016	0.286 ± 0.09	0.22
COLORU-06	0.090 ± 0.019	0.015	—	0.29
COLORU-07	0.147 ± 0.019	0.016	0.28 ± 0.16	0.15
COLORU-08	0.108 ± 0.017	0.018	0.37 ± 0.09	0.20

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for radium is the sum of those for radium-226 and radium-228.

Table 13B. Gross alpha and gross beta radioactivity detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Information about the analytes is given in table 3I. Samples from all 28 wells were analyzed, but only samples with detections are listed. The reference nuclide for measurement of gross alpha particle activity is thorium-230 and the reference nuclide for measuring gross beta particle activity is cesium-137. Measured values less than the sample-specific critical level ($\mathrm{ssL_C}$) are reported as nondetections (—). **GAMA well identification number:** COLOR, Colorado River study area grid well; COLORU, Colorado River study area understanding well. Thresholds and threshold values as of December 20, 2007. **Threshold type:** MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** CSU, 1-sigma combined standard uncertainty; pCi/L, picocurie per liter; *, result above threshold value; ±, plus or minus]

GAMA well identification number	Gross alpha particle activity, 72-hour count (pCi/L) (62636)		Gross alpha particle activity, 30-day count (pCi/L) (62639)		Gross beta particle activity, 72-hour count (pCi/L) (62642)		Gross beta particle activity, 30-day count (pCi/L) (62645)	
Threshold type [1]	**MCL-US**		**MCL-US**		**MCL-CA**		**MCL-CA**	
Threshold value	**15**		**15**		**50**		**50**	
Reporting level method	**Result ± CSU**	**$\mathrm{ssL_C}$**	**Result ± CSU**	**$\mathrm{ssL_C}$**	**Result ± CSU**	**$\mathrm{ssL_C}$**	**Result ± CSU**	**$\mathrm{ssL_C}$**
Grid wells								
COLOR-01	—	2.3	5.3 ± 1.5	1.4	5.93 ± 0.76	0.64	5.87 ± 0.73	0.59
COLOR-02	* 20.3 ± 3.3	2.6	13.3 ± 2.5	2.2	5.09 ± 0.83	0.99	7.41 ± 0.99	0.97
COLOR-03	—	5.2	—	4	8.5 ± 1.2	1.1	7.2 ± 1	1.1
COLOR-04	—	3.1	—	2.5	7.43 ± 0.96	0.84	7.6 ± 1.1	1.3
COLOR-05	—	3.6	—	2.8	3.62 ± 0.66	0.81	3.69 ± 0.62	0.751
COLOR-06	—	3.8	—	3.5	3.04 ± 0.76	1.1	—	1.5
COLOR-07	* 44.1 ± 6.3	3.7	* 22.0 ± 3.8	2.63	SR [2]	—	SR [2]	—
COLOR-08	—	3.3	—	2.8	3.82 ± 0.93	1.3	5.4 ± 1.1	1.5
COLOR-09	—	3.9	—	3.3	4.39 ± 0.74	0.86	3.74 ± 0.71	0.9
COLOR-10	—	4.4	—	3.8	3.41 ± 0.65	0.85	3.94 ± 0.68	0.84
COLOR-11	* 57 ± 10	8.9	* 52.2 ± 9.0	3.68	7.5 ± 1.6	2.1	12.8 ± 2.6	3.6
COLOR-12	3.0 ± 1.1	1.3	2.0 ± 1.2	1.7	3.58 ± 0.57	0.63	5 ± 0.68	0.62
COLOR-13	9.1 ± 1.9	2.1	2.9 ± 1.0	1.2	7.7 ± 1.1	1.2	11.4 ± 1.3	0.72
COLOR-14	10.3 ± 1.8	1.3	9.9 ± 1.8	1.5	3.69 ± 0.68	0.929	5.74 ± 0.7	1
COLOR-15	—	3.4	—	6.6	5 ± 1.4	2.1	7.7 ± 1.1	1.2
COLOR-16	5.1 ± 3.2	4.3	—	3.3	5.32 ± 0.92	1	6.8 ± 1.2	1.5
COLOR-17	3.5 ± 2.0	2.6	—	1.8	5.86 ± 0.73	0.55	4.92 ± 0.78	0.95
COLOR-18	—	3.3	—	4	3.88 ± 0.8	1	4.55 ± 0.68	0.73
COLOR-19	—	4.9	—	5.2	7 ± 1.1	1.3	6.6 ± 1.3	1.7
COLOR-20	—	1.1	—	1.1	1.1 ± 0.4	0.61	1.41 ± 0.44	0.64
Understanding wells								
COLORU-01	—	2	—	1.7	3.48 ± 0.65	0.86	3.39 ± 0.6	0.8
COLORU-02	—	3	—	2.6	1.92 ± 0.82	1.3	4.24 ± 0.73	0.84
COLORU-03	—	2.3	—	1.8	3.01 ± 0.72	1	2.83 ± 0.71	1
COLORU-04	* 19.1 ± 3.8	2.9	—	4.3	8.3 ± 1.3	1.3	11.5 ± 1.4	1.2
COLORU-05	6.3 ± 1.5	1.4	—	2.4	6.4 ± 1	1.1	6.72 ± 0.94	0.96
COLORU-06	6.4 ± 2.2	2.5	—	3.4	1.42 ± 0.62	1	2.35 ± 0.74	1.1
COLORU-07	—	6.8	—	12	6.5 ± 1.7	2.5	9.5 ± 1.9	2.5
COLORU-08	—	5.3	—	3.4	4.4 ± 1	[3] 1.5	4.1 ± 1	1.6

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] 72-hour holding time exceeded by 1 day.

[3] 72-hour holding time exceeded by 3 days.

Table 13C. Radon-222 detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Table 3I contains additional information about the analytes. Samples from all 28 wells were analyzed, but only samples with detections are listed. **GAMA well identification number:** COLOR, Colorado River study area grid well; COLORU, Colorado River study area understanding well. Threshold type and threshold level as of December 20, 2007. **Threshold type:** MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** 2CSU, 2-sigma combined standard uncertainty; pCi/L, picocurie per liter; *, result above threshold value; na, not available]

GAMA well identification number	Radon-222 (pCi/L) (82303)
Threshold type [1]	**MCL-US**
Threshold value	**[2]5**
Reporting level method	**Result ± CSU**
Grid wells	
COLOR-01	* 330 ±22
COLOR-02	* 440 ± 24
COLOR-03	* 1,230 ± 33
COLOR-04	160 ± 19
COLOR-05	* 1,040 ± 35
COLOR-06	* 800 ± 49
COLOR-07	* 2,600 ±66
COLOR-08	* 480 ± 24
COLOR-09	* 560 ± 28
COLOR-10	* 690 ± 28
COLOR-11	280 ± 19
COLOR-12	* 1,090 ± 31
COLOR-13	260 ± 18
COLOR-14	260 ± 20
COLOR-15	300 ± 19
COLOR-16	* 1,470 ± 38
COLOR-17	* 460 ± 26
COLOR-18	* 760 ± 29
COLOR-19	na
COLOR-20	* 670 ± 28
Understanding wells	
COLORU-01	* 1030 ± 30
COLORU-02	* 930 ± 32
COLORU-03	* 1,050 ± 33
COLORU-04	250 ± 19
COLORU-05	270 ± 20
COLORU-06	* 580 ± 28
COLORU-07	* 950 ± 31
COLORU-08	160 ± 17

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for radium is the sum of those for radium-226 and radium-228.

Appendix

This appendix includes discussions of the methods used to collect and analyze groundwater samples and report the resulting water-quality data. These methods were selected to obtain representative samples of the groundwater from each well, and to minimize the potential for contamination of the samples or for bias in the data. Procedures used to collect and assess quality-control data and the results of the quality-control assessments are also discussed.

Sample Collection and Analysis

Groundwater samples were collected using standard and modified USGS protocols from the USGS NAWQA program (Koterba and others, 1995) and the USGS National Field Manual (U.S. Geological Survey, variously dated), and protocols described by Weiss (1968), Shelton and others (2001), Ball and McClesky (2003a,b), and Wright and others (2005).

Before being sampled, each well was pumped continuously in order to purge at least 3 casing-volumes of water from the well (Wilde and others, 1999). Wells were sampled using Teflon tubing with brass and stainless-steel fittings attached to a sampling point on the well discharge pipe as close to the well as possible. The sampling point was always located upstream of any active well-head treatment system or storage tank. If a chlorinating system was attached to the well, the chlorinator was shut off before purging and sampling the well in order to clear all chlorine out of the system. Samples were collected inside an enclosed chamber located within a mobile laboratory and connected to the well head by a 10- to 50-foot length of Teflon tubing (Lane and others, 2003). All fittings and lengths of tubing were cleaned after each sample was collected (Wilde, 2004).

For field measurements, groundwater was pumped through a flow-through chamber fitted with a multi-probe meter that simultaneously measured the water-quality indicators—dissolved oxygen, temperature, pH, and specific conductance. Field measurements were made in accordance with protocols in the USGS National Field Manual (Wilde and Radtke, 2005; Wilde, 2006; Lewis, 2006; Radtke and others, 2005; Wilde and others, 2006). All sensors on the multi-probe meter were calibrated daily. Measured temperature, dissolved oxygen, pH, and specific conductance values were recorded at 5-minute intervals for at least 30 minutes, and after these values remained stable for 20 minutes, samples to be analyzed in a laboratory were collected. Field measurements and instrument calibrations were recorded by hand on field record sheets and electronically in PCFF-GAMA, a software package designed by the USGS with support from the GAMA program. Analytical service requests were also managed by PCFF-GAMA. Information from PCFF-GAMA was uploaded directly into NWIS after samples were collected each week.

For analyses requiring filtered water, groundwater was diverted through a 0.45- µm pore size vented capsule filter, a disk filter, or a baked glass-fiber filter, depending on the protocol for the analysis (Wilde and others, 1999; Wilde and others, 2004). Before samples were collected, polyethylene sample bottles were pre-rinsed two times with deionized water and then once with sample water. Samples requiring acidification were acidified to a pH of 2 or less with the appropriate acids using ampoules of certified, traceable concentrated acids obtained from the USGS National Water Quality Laboratory (NWQL).

Temperature-sensitive samples were stored on ice before and while they were shipped daily to various laboratories. The non-temperature sensitive samples to be analyzed for tritium, noble gases, chromium speciation, and stable isotopes of hydrogen and oxygen of water were shipped monthly. Volatile organic compounds, pesticides, and constituents of special interest are temperature sensitive and were shipped daily. Radium isotopes, gross alpha and gross beta radioactivity, and radon-222 samples are not temperature sensitive and were shipped daily.

Detailed sampling protocols for individual analyses and groups of analytes are described by Koterba and others (1995), in the USGS National Field Manual (Wilde and others, 1999; Wilde and others, 2004), and in the references for analytical methods listed in table A1; only brief descriptions are given here. Volatile organic compounds (VOC) and 1,2.3-trichloropropane (1,2,3-TCP) samples were collected in 40-mL sample vials that were purged with three vial volumes of sample water before bottom-filling to eliminate atmospheric contamination. Six normal (6 N) hydrochloric acid (HCL) was added as a preservative to the VOC samples but not to the 1,2,3-TCP samples. Perchlorate samples to be analyzed at the Montgomery Watson Harza Laboratory (MWH) were collected in 125-mL polyethylene bottles. Perchlorate samples to be analyzed at Weck Laboratories, Inc. (WECK) were collected each into a half-pint plastic bottle and then filtered through a rinsed syringe and 20-µm disk filter into a sterilized 125-mL bottle. Samples to be analyzed for 1,4-dioxane at MWH and WECK were collected in two pre-preserved 1-L glass amber bottles. Tritium samples were collected by bottom-filling two 1-L polyethylene bottles with unfiltered groundwater after overfilling each bottle with three volumes of water. Samples to be analyzed for stable isotopes of hydrogen and oxygen of water were collected in 60-mL clear glass bottles filled with unfiltered water, sealed with conical caps, and secured with electrical tape to prevent leakage and evaporation.

As pesticides and pesticide degradation products and pharmaceutical compound samples were being collected, they were filtered through a glass-fiber filter into 1-L baked amber bottles.

Each groundwater sample to be analyzed for major and minor ions, trace elements, alkalinity, and total dissolved solids analyses required filling one 250-mL polyethylene bottle with filtered groundwater (Wilde and others, 2004). Each sample was filtered through a Whatman capsule filter. Each 250-mL filtered sample was then preserved with 7.5 N nitric acid. Mercury samples were collected by filtering groundwater into 250-mL glass bottles and preserving with 6 N hydrochloric acid. Arsenic and iron speciation samples were filtered into 250-mL polyethylene bottles that were covered with tape to prevent light exposure and preserved with 6 N hydrochloric acid. Each nutrient sample was filtered into a 125-mL brown polyethylene bottle. Samples to be analyzed for radium isotopes and gross alpha and gross beta radioactivity were filtered into 1-L polyethylene bottles and acidified with nitric acid. Carbon isotope samples were filtered and bottom-filled into two 500-mL glass bottles that were first overfilled with three bottle volumes of groundwater. These samples had no headspace and were sealed with septum caps to avoid atmospheric contamination. Samples to be analyzed for field alkalinity titrations were collected by filtering groundwater into a 500-mL polyethylene bottle.

Samples to be analyzed for chromium, radon-222, and noble gases were collected from the hose bib at the well head. Chromium speciation samples were collected using a 10-mL syringe with an attached 0.45-µm disk filter. After the syringe was thoroughly rinsed and filled with groundwater, 4 mL was forced through the disk filter; the next 2 mL of groundwater was slowly filtered into a small centrifuge vial and analyzed for total chromium. Hexavalent chromium, Cr (VI), was then collected by attaching a small cation-exchange column to the syringe filter, and after conditioning the column with 2 mL of sample water, 2 mL were collected in a second centrifuge vial. Vials for both constituents were preserved with 7.5 N nitric acid (Ball and McClesky, 2003a,b).

To collect radon-222, a stainless-steel and Teflon valve assembly was attached to the sampling port at the well head (Wilde and others, 2004). The valve was partially closed to create back pressure, and a 10-mL sample was collected through a Teflon septum on the valve assembly using a glass syringe affixed with a stainless-steel needle. Each sample was then injected into a 25-mL vial partially filled with scintillation mixture (mineral oil) and shaken. Each vial was then placed in a cardboard tube in order to shield it from light during shipping.

Noble gases were collected in 3/8-in copper tubes using reinforced nylon tubing connected to the hose bib at the wellhead. Groundwater was flushed through the tubing to dislodge bubbles before flow was restricted with the back pressure valve. Clamps on both sides of the copper tube were tightened, trapping a sample of groundwater to be analyzed for noble gases (Weiss, 1968).

Field alkalinity was measured in the mobile laboratory at the well site. Alkalinity was measured on filtered samples using Gran's titration method (Gran, 1952). Titration data were entered directly into PCFF-GAMA and the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) were automatically calculated from the titration data using the advanced speciation method (Stumm and Morgan, 1996; Rounds, 2006). Concentrations of HCO_3^- and CO_3^{2-} were also calculated from the laboratory alkalinity and pH measurements. Calculations were made in a spreadsheet using the advanced speciation method (http://or.water.usgs.gov/alk/methods.html) with $pK_1 = 6.35$, $pK_2 = 10.33$, and $pK_W = 14$.

Ten laboratories did chemical analyses for this study (table A1), although most of the analyses were done at the NWQL or by laboratories contracted by the NWQL. The NWQL maintains a rigorous quality-assurance program (all concentrations were below health-based thresholds (table 5). Pirkey and Glodt, 1998; Maloney, 2005). Laboratory quality-control samples, including method blanks, continuing calibration verification standards, standard reference samples, reagent spikes, external certified reference materials, and external blind proficiency samples, are analyzed regularly. Method detection limits are continuously tested and laboratory reporting levels updated accordingly. NWQL maintains the National Environmental Laboratory Accreditation Program (NELAP) and other certifications (http://nwql.usgs.gov/Public/lab_cert.shtml). The Branch of Quality Systems within the USGS Office of Water Quality independently oversees quality assurance at the NWQL and the laboratories contracted by the NWQL. In addition, the Branch of Quality Systems runs the National Field Quality Assurance program that includes annual testing of all USGS field personnel for proficiency in making field water-quality measurements (http://qadata.cr.usgs.gov/nfqa). Results of analyses made at the NWQL or the laboratories contracted by the NWQL are uploaded directly into NWIS by the NWQL. Results of analyses made at other laboratories are compiled in a project Access (Microsoft, Redmond, WA) database and uploaded from there into NWIS.

Data Reporting

The following section details the laboratory reporting conventions and the constituents that are determined by multiple methods of by multiple laboratories.

Reporting Limits

The USGS NWQL uses the laboratory reporting level (LRL) as a threshold for reporting analytical results. The LRL is set to minimize the reporting of false negatives (not detecting a constituent when it is actually present in a sample) to less than 1 percent (Childress and others, 1999). The LRL usually is set at two times the long-term method detection level (LT-MDL). The LT-MDL is derived from the standard deviation of at least 24 MDL determinations made over an extended period of time. LT-MDLs are continually monitored and updated. The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99-percent confidence that the concentration is greater than zero (at the MDL there is less than 1 percent chance of a false positive) (Childress and others, 1999; U.S. Environmental Protection Agency, 2002). The USGS NWQL updates LRL values regularly, and the values listed in this report were in effect during the period analyses were made for groundwater samples from the COLOR area (October to December, 2007).

Concentrations between the LRL and the LT-MDL are reported as estimated concentrations (designated with an "E" before the values in the tables and text). For information-rich methods, concentrations below the LT-MDL have high certainty of being detected but the precise concentration is uncertain. Information-rich methods are those that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection (VOCs and pesticides). Analytes are identified by characteristic fragmentation patterns in their mass spectra and are quantified by measurement of peak areas at their associated chromatographic retention times. E-coded values may also result from detections of concentrations outside the range of calibration standards, for detections that did not meet all laboratory quality-control criteria, and for samples that were diluted before analysis (Childress and others, 1999).

Some constituents in this study are reported using minimum reporting levels (MRLs) or method uncertainties. The MRL is the smallest measurable concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995). The method uncertainty generally indicates the precision of a particular analytical measurement; it gives a range of values wherein the true value will be found.

Results for most constituents are presented using the LRL or MRL values provided by the analyzing laboratories. Results for trace elements are presented using raised study reporting level (SRL) values derived from assessing data derived from quality-control samples associated with groundwater samples collected as part of the GAMA Priority Basin Project. The SRLs were determined by statistically assessing the analyses of the field blanks collected during the first 20 GAMA study units (May 2004 through January 2008) (Olsen and others, 2010). The statistical analysis used order statistical and binomial probabilities to construct an upper confidence limit for the amount of contamination potentially in field blanks and, by inference, groundwater samples (Hahn and Meeker, 1991). Olsen and others (2010) determined SRLs for trace elements that represent a confidence limit of 90 percent for the 90th percentile of concentrations from the set of 86 field blanks used for the assessment. There is at least 90 percent confidence that no more than 10 percent of the groundwater samples would have contamination at concentrations greater than these SRLs as a result of field or laboratory processes. For constituents with SRLs greater than the respective LT-MDLs, concentrations at or below the SRL concentrations were reported as "≤" (less than or equal to) the reported concentration. Concentrations reported with the "≤" symbol are considered to be nondetections in this report.

The methods used to analyze radiochemical constituents (gross-alpha radioactivity, gross-beta radioactivity, and radium isotopes) measure activities by counting techniques (table A1). The reporting limits for radiochemical constituents are based on sample-specific critical levels (ssL_C) (McCurdy and others, 2008). The critical level is analogous to the LT-MDL used for reporting analytical results for organic and non-radioactive inorganic constituents. In this report, the critical level is defined as the minimum measured activity that indicates a positive detection of the radionuclide in the sample with less than a 5 percent probability of a false positive detection. Sample-specific critical levels are used for radiochemical measurements because the critical level is sensitive to sample size and sample yield during analytical processing and depends on instrument background, counting times for the sample and background, and the characteristics of the instrument being used and the nuclide being measured. An ssL_C is calculated for each sample, and the measured activity in the sample is compared with the ssL_C associated with that sample. Measured activities less than the ssL_C are reported as nondetections.

The analytical uncertainties associated with measuring activities are also sensitive to parameters associated with the instrumentation and sample collection. The latter include sample-specific parameters such as ample size, sample yield during analytical processing, and time elapsed between sample collection and steps in the analytical procedure. Therefore, measured activities are reported with sample-specific combined standard uncertainties (CSU). The CSU is reported at the 68 percent confidence level (1-sigma), except for radon-222, which is reported using the 2CSU at the 95-percent confidence level (2-sigma).

Notation

Stable isotopic compositions of oxygen, hydrogen, and carbon are reported as relative isotope ratios in units of per mil using the standard delta notation (Coplen and others, 2002):

$$\delta^{i}E = \left[\frac{R_{\text{sample}}}{R_{\text{reference}}} - 1\right] \bullet 1{,}000 \text{ per mil}$$

where

i is the atomic mass of the heavier isotope of the element;

E is the element (O for oxygen, C for carbon, or H for hydrogen);

R_{sample} is the ratio of the abundance of the heavier isotope of the element (^{18}O, ^{13}C, or ^{2}H) to the lighter isotope of the element, (^{16}O, ^{12}C, or ^{1}H) in the sample; and,

$R_{\text{reference}}$ is the ratio of the abundance of the heavier isotope of the element to the lighter isotope of the element in the reference material.

The reference material for oxygen and hydrogen is Vienna Standard Mean Ocean Water (VSMOW), which is assigned $\delta^{18}O$ and $\delta^{2}H$ values of 0 per mil (note than $\delta^{2}H$ is sometimes referred to as δD because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium). The reference material for carbon is Vienna Peedee Belemnite (VPDB), which is assigned a $\delta^{13}C$ value of 0 per mil. Positive values indicate enrichment of the heavier isotope and negative values indicate depletion of the heavier isotope, compared with the ratios observed in the standard reference material.

Constituents on Multiple Analytical Schedules

Fourteen constituents targeted in this study were measured by more than one analytical schedule or more than one laboratory (table A2). The preferred methods for these constituents were selected on the basis of the procedure recommended by the NWQL (http://wwwnwql.cr.usgs.gov/dyn.shtml?Preferred_method_selection_procedure). Methods with full approval are preferred over those with provisional approval, and approved methods are favored over research methods. The method that is more accurate and precise and has lower LRLs for the overlapping constituents is generally preferred. However, the method having higher LRLs may be selected as the preferred method to provide consistency with historical data analyzed by the same method.

For arsenic, chromium, and iron concentrations, the approved method, Schedule 1948, used by the NWQL is preferred over the research methods used by the USGS Trace Metal Laboratory. The concentrations measured by the Trace Metal Laboratory are used only to calculate ratios of redox species for each element: $\frac{\text{As(V)}}{\text{As(III)}}$ for arsenic, for $\frac{\text{Cr(VI)}}{\text{Cr(III)}}$ chromium, and $\frac{\text{Fe(III)}}{\text{Fe(II)}}$ for iron. For example,

$$\frac{\text{Fe(III)}}{\text{Fe(II)}} = \frac{\text{Fe(T) - Fe(II)}}{\text{Fe(II)}}$$

where

Fe(T) is the total iron concentration (measured),

Fe(II) is the concentration of ferrous iron (measured), and

Fe(III) is the concentration of ferric iron (calculated).

Quality Assurance

The purpose of quality assurance is to identify which data best represent environmental conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, and (or) laboratory analysis. Four types of quality-control (QC) tests were used in this study: blank samples were collected to assess contamination, replicate samples were collected to assess reproducibility, matrix spike tests were done to assess accuracy of laboratory analytical methods, and surrogate compounds were added to samples analyzed for organic constituents to assess bias of laboratory analytical methods. The evaluation of the QC data presented in this report was based on results for QC samples collected for the COLOR and on results for QC samples collected for the 20 GAMA study units May 2004 through January 2008.

The quality-assurance methods used for this study followed the protocols used by the USGS NAWQA program (Koterba and others, 1995) and described in the USGS National Field Manual (U.S. Geological Survey, variously dated). The quality-assurance plan followed by the NWQL, the primary laboratory used to analyze samples for this study, is described by Maloney (2005) and Pirkey and Glodt (1998).

Blanks

The primary purposes of collecting blanks are to evaluate the magnitude of potential contamination of samples with analytes of interest while samples were collected handled, or analyzed, and to identify and mitigate sources of contamination.

Collection and Analysis of Blanks

Two types of blanks were collected: source-solution and field blanks. Source-solution blanks were collected to assess potential contamination of samples during transport and analysis, and potential contamination of the certified blank water obtained from the USGS NWQL. Field blanks were collected to assess potential contamination of samples during collection, processing, transport, and analysis. Blanks were collected using blank water certified by the NWQL to contain less than the LRL or MRL of the analytes investigated in the study. Nitrogen-purged, organic-free blank water was used for field blanks of organic constituents, and inorganic-free blank water was used for field blanks of other constituents. For COLOR, blanks were collected at three sites, which is approximately 11 percent of the sites sampled. The organic constituents analyzed for in field blanks were VOCs, pesticides and pesticide degradates, pharmaceuticals, Perchlorate, 1,4-dioxane, and 1,2,3-TCP. The inorganic constituents analyzed for in field blanks were nutrients; major and minor ions; trace elements; iron, arsenic, and chromium speciation; and radium. Field-blank detections are shown on table A3. Field blanks were not collected for tritium or noble gases because they are in the atmosphere and dissolve into any solution used in collecting a blank. An indirect indicator of the quality of environmental data is tritium, whose activities are expected to be less than 3 pCi/L in water recharged before the 1950s. The presence of tritium activities below the MRL of 1 pCi/L in several samples implies that the sampling methods did not bias the results for tritium. Stable-isotope ratios of oxygen, hydrogen, carbon, nitrogen, boron, chloride, bromide, uranium, and strontium are an intrinsic property of any of these elements; therefore, the concept of a blank does not apply to these ratios.

To collect filed blanks, blank water was either pumped or poured through the sampling equipment (fittings and tubing) used to collect groundwater, then processed and transported using the same protocols used for the groundwater samples. Approximately 12 liters of blank water were pumped or poured through the sampling equipment before each field blank was collected.

Analysis of Blanks

Contamination in blanks may originate from several different types of sources that require different strategies to assess potential contamination of groundwater samples. Three primary types of contamination are assessed in the event of a field-blank or unusual groundwater detection: (1) contamination from a known source, (2) carry-over contamination from the previously collected samples, and (3) systematic and random contamination from field and laboratory equipment and processes. The third type of contamination (systematic and random) is being addressed using a larger set of field-blank results from multiple studies in addition to the results from field blanks collected at COLOR. The development of this approach and its methods are described by Olsen and Fram (2010).

Inorganic constituents are naturally present in groundwater, and the concerns about inorganic constituents generally are related to concentration rather than detection (presence or absence). In contrast, concerns about organic constituents are usually related to both detection and concentration. For inorganic constituents, a “<” (less than) symbol was assigned to low-concentration detections of constituents that may have been affected by contamination. The ≤ symbol means that the concentration of the constituent in the groundwater sample is less than or equal to the measured concentration (including the possibility that it may be less than the LT-MDL and therefore a nondetection). For trace elements, the concentration threshold for applying the < symbol was each constituent’s SRL (Olsen and Fram, 2010). Concentrations below their respective SRLs were reported with ≤ symbol to the left of their reported concentrations.

Replicates

Sequential replicate samples were collected to assess the precision of the water-quality data. Estimates of data precision are needed to assess whether differences between concentrations in samples are due to differences in groundwater quality or to variability that may result from collecting, processing, and analyzing the samples. Relative standard deviation (RSD) of the measured values was used in determining the variability between replicate pairs for each constituent (table A4). The RSD is defined as 100 times the standard deviation divided by the mean concentration for each replicate pair of samples, expressed as a percentage. If one value for a sample pair was reported as a nondetection and the other value was reported as an estimate below the LRL or MRL (that is, an E-coded value), the RSD was set to zero because the values are analytically identical. If one value in a sample pair was reported as a nondetection and the other value was greater than the LRL or MRL, the nondetection value was set equal to a quarter of the LRL and the RSD was calculated (Hamlin and others, 2002). Values of RSD less than 20 percent are considered acceptable in this study. An RSD value equaling 20 percent corresponds to a relative percent difference (RPD) value of 29 percent. High RSD values for a constituent may indicate analytical uncertainty at low concentrations, particularly for concentrations within an order of magnitude of the LT-MDL or the MDL. Sequential replicate samples were collected at 7 percent of the wells sampled.

Matrix Spikes

Adding a known concentration of a constituent (‘spike’) to a replicate environmental sample enables the analyzing laboratory to determine the effect of the matrix, in this case groundwater, on the analytical technique used to measure the constituent. The known constituent added in matrix spikes are the same as those being analyzed in the method. This enables matrix interferences to be analyzed on a constituent by constituent basis. Matrix spikes were added at the laboratory doing the analysis. A low matrix-spike recovery may indicate that the constituent was not be detected in some samples if it was present at very low concentrations. Low and high matrix-spike recoveries may be a potential concern if the concentration of a constituent in a groundwater sample is close to the MCL: a low recovery could falsely result in a measured concentration below the MCL, whereas a high recovery could falsely result in a measured concentration above the MCL. For COLOR, matrix-spike samples were collected at approximately 11 percent of the wells sampled.

Acceptable ranges for matrix-spike recoveries are based on the acceptable ranges established for laboratory “set” spike recoveries. Laboratory-set spikes are aliquots of laboratory blank water to which the same spike solution used for the matrix spikes has been added. One set spike is analyzed with each set of samples. Acceptable ranges for set spike recoveries are 70 to 130 percent for VOCs (Connor and others, 1998; Rose and Sandstrom, 2003), 60 to 120 percent for pesticides and pesticide degradates (Sandstrom and others, 2001), and 60 to 130 percent for Schedule 9003 (Kolpin and others, 2002). On the basis of these ranges, 70 to 130 percent was defined as the acceptable range for matrix-spike recoveries for organic constituents in this study.

Matrix spike recovery tests were done for VOCs, pesticides, pharmaceuticals (not reported in this document), 1,4-dioxane, and 1,2,3-TCP because the analytical methods for these constituents are chromatographic methods that may be susceptible to matrix interferences (tables A5A–C).

Surrogates

Surrogate compounds are added to environmental samples in the laboratory before analysis in order to evaluate the recovery of similar constituents. Surrogate compounds were added to all groundwater and quality-control samples that were analyzed for VOCs, pesticides, and pharmaceuticals (pharmaceutical data will be presented in a subsequent report). Most of the surrogate compounds are deuterated analogs of compounds being analyzed. For example, the surrogate toluene-*d*8 used for the VOC analytical method has the same chemical structure as toluene, except that the eight hydrogen-1 atoms on the molecule have been replaced by deuterium (hydrogen-2). Toluene-*d*8 and toluene behave very similarly in the analytical procedure, but the small mass difference between the two results in slightly different chromatographic retention times; thus, using a toluene-*d*8 surrogate does not interfere with analyzing toluene (Grob, 1995). Only 0.015 percent of hydrogen atoms are deuterium (Firestone and others, 1996). Thus, deuterated compounds like toluene-*d*8 do not exist naturally and are not found in environmental samples. Surrogates are used to identify general problems that may arise during sample analysis that could affect the analysis results for all compounds in that sample. Potential problems include matrix interferences (such as high levels of dissolved organic carbon) that produce a positive bias, or incomplete laboratory recovery (possibly as a result of improper maintenance and calibration of analytical equipment) that produces a negative bias. A 70 to 130 percent recovery of surrogates is generally considered acceptable; values outside this range indicate possible problems with processing and analyzing samples (Connor and others, 1998; Sandstrom and others, 2001).

Quality-Control Results

Detections of Constituents in Field and Source-Solution Blanks

Field blanks were collected at 3 of the 28 sites, equaling approximately 10 percent of the sites sampled in COLOR. Table A3 gives a summary of detections of constituents in field blanks. No organic constituents were detected in field blanks. The inorganic constituents boron and silica were detected in the field blanks. These constituents were known to be present in the inorganic blank water obtained from the NWQL. No groundwater samples had boron and silica concentrations less than their concentrations detected in the respective blank samples. Zinc was detected in one blank sample at a concentration of 1.7 µg/L which is less than the SRL of 4.8 µg/L. Groundwater samples containing zinc concentrations less than the SRL were therefore coded with the “≤” symbol (tables 10, A3). Radium-226 was detected in one blank sample at a concentration of 0.02 pCi/.L No environmental samples had activities equal to or less than this activity measured in the blank. Radium-228 was not detected in blank samples.

No constituents in the following analyte groups were detected in the field blanks: VOCs; pesticide and pesticide degradates; perchlorate; 1,4-dioxane; 1,2,3-TCP; major and minor ions; arsenic, chromium, and iron species; and nutrients.

Variability in Replicate Samples

Table A4 summarizes the results of replicate analyses of constituents detected in groundwater samples collected in for the COLOR. Most replicate analyses yielded RSD values less than 5 percent and only 12 replicate analyses yielded RSD values greater than the acceptable limit of 20 percent. However, the concentrations of constituents in all the replicate sample pairs, except the two mercury pairs, with RSD values greater than 20 percent were within a factor of five of the LT-MDLs for the respective analytes. At these low concentrations, small deviations in measured values result in large RSDs.

Matrix-Spike Recoveries

Tables A5A–C summarize matrix-spike recoveries for the COLOR. Three environmental samples were spiked with VOCs so that matrix-spike recoveries could be calculated (table A5A). Two of the 85 VOC spike compounds had median recoveries outside of the acceptable range of 70 to 130 percent. These two constituents were not detected in environmental samples. Low recoveries may indicate that these compounds might not have been detected in some samples if their concentrations were very low.

Thirteen of the 62 pesticide and pesticide degradate spike constituents had at least one median recovery below 70 percent, and one spike constituent had at least one recovery above 130 percent (table A5B). One of the constituents that had a low spike recovery, deethylatrazine, was detected in environmental samples. Two groundwater samples were spiked with 1,4-dioxane and 1,2,3-Trichlorporpane (1,2,3-TCP). The spike recoveries were within the acceptable range of 70 to 130 percent for 1,4-dioxane, but 1,2,3-TCP recoveries were below 70 percent (table A5C). 1,2,3-TCP was detected in one environmental sample. Low recoveries may indicate that these compounds might not have been detected in some samples if they were present at very low concentrations.

Surrogate Compound Recoveries

Surrogate compounds were added to environmental samples in the laboratory to help determine the precision and accuracy of analytical methods and equipment used to analyze the samples. Table A6 lists the surrogate, the analytical schedule on which it was applied, the number of analyses for blank and non-blank samples, the number of surrogate recoveries below 70 percent, and the number of surrogate recoveries above 130 percent for the blanks and groundwater samples. Blanks and groundwater samples were considered separately to assess whether the matrices present in the groundwater samples affect surrogate recoveries. No systematic differences between surrogate recoveries in the blanks and the groundwater samples were observed.

Table A1. Analytical methods used to measure organic and inorganic constituents by the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) and other laboratories.

[Laboratory entity codes in the USGS National Water Information System (NWIS) for laboratories other than the USGS National Water Quality Laboratory (NWQL) are given in parentheses after the laboratory names. VOC, volatile organic compound; HPLC, high-performance liquid chromatography; UV, ultraviolet]

Analyte	Analytical method	Laboratory and analytical schedule	Citation(s)
Water-quality indicators			
Field parameters (pH, specific conductance, temperature)	Calibrated field meters and test kits	USGS field measurement	U.S. Geological Survey, variously dated
Organic constituents			
VOCs	Purge and trap capillary gas chromatography/mass spectrometry	NWQL, Schedule 2020	Connor and others, 1998
Pesticides and degradates	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, Schedule 2003	Zaugg and others, 1995; Lindley and others, 1996; Madsen and others, 2003; Sandstrom and others, 2001
Pharmaceuticals	Solid-phase extraction and HPLC/mass spectrometry	NWQL, Schedule 9003	Kolpin and others, 2002; Furlong and others, 2008
Constituents of special interest			
Perchlorate	Ion chromatography/mass spectrometry	Weck Laboratories, Inc., standard operating procedure ORG099.R01	U.S. Environmental Protection Agency, 2005
1,2,3-Trichloropropane	Isotopic dilution purge and trap/gas chromatography/mass spectrometry	Weck Laboratories, Inc., standard operating procedure ORG083	Okamoto and others, 2002
1,4-Dioxane	Isotopic dilution gas chromatography/mass spectrometry (USEPA Method 8270C modified)	Weck Laboratories, Inc., standard operating procedure ORG043.R3	U.S. Environmental Protection Agency, 1996; Draper and others, 2000
Inorganic constituents			
Nutrients	Alkaline persulfate digestion, Kjedahl digestion	NWQL, Schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Major and minor ions, trace elements and nutrients	Atomic absorbance spectroscopy, colorimetry, ion-exchange chromatography, inductively-coupled plasma atomic emission spectrometry and mass spectrometry	NWQL, Schedule 1948	Fishman and Friedman, 1989; Faires, 1993; Fishman, 1993; McLain, 1993; American Public Health Association, 1998; Garbarino, 1999; Garbarino and Damrau, 2001; Garbarino and others, 2006
Chromium, arsenic and iron speciation	Various techniques of ultraviolet visible (UV-VIS) spectrophotometry and atomic absorbance spectroscopy	USGS Trace Metal Laboratory, Boulder, Colorado (USGSTMCO)	Stookey, 1970; To and others, 1998; Ball and McCleskey, 2003a,b; McCleskey and others, 2003
Stable isotopes			
Stable isotopes of hydrogen and oxygen in water	Gaseous hydrogen and carbon dioxide-water equilibration and stable-isotope mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA), NWQL Schedule 1142	Epstein and Mayeda, 1953; Coplen and others, 1991; Coplen, 1994
Carbon isotopes	Accelerator mass spectrometry	University of Waterloo, Environmental Isotope Laboratory (CAN-UWIL); University of Arizona Accelerator Mass Spectrometry Laboratory (AZ-UAMSL), NWQL Schedule 2015	Donahue and others, 1990; Jull and others, 2004

Table A1. Analytical methods used to measure organic and inorganic constituents by the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) and other laboratories.—Continued

[Laboratory entity codes in the USGS National Water Information System (NWIS) for laboratories other than the USGS National Water Quality Laboratory (NWQL) are given in parentheses after the laboratory names. VOC, volatile organic compound; HPLC, high-performance liquid chromatography; UV, ultraviolet]

Analyte	Analytical method	Laboratory and analytical schedule	Citation(s)
		Radioactivity and gases	
Tritium	Electrolytic enrichment-liquid scintillation	USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA)	Thatcher and others, 1977
Tritium and noble gases	Helium-3 in-growth and mass spectrometry	Lawrence Livermore National Laboratory (CA-LLNL)	Moran and others, 2002; Eaton and others, 2004
Radon-222	Liquid scintillation counting	NWQL, Schedule 1369	American Society for Testing and Materials, 1998
Radium isotopes	Alpha activity counting	Eberline Analytical Services (CA-EBERL), NWQL Schedule 1262	Kreiger and Whittaker, 1980 (USEPA methods 903 and 904)
Gross alpha and beta radioactivity	Alpha and beta activity counting	Eberline Analytical Services, NWQL Schedule 1792	Kreiger and Whittaker, 1980 (USEPA method 900.0)

Table A2. Preferred analytical schedules for constituents appearing on multiple schedules for samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[Of the methods used to analyze the compound in question, analytical schedules that are the most accurate and precise are preferred except when consistency with historic data analyzed using the same method is preferred. **Laboratory:** LLNL, Lawrence Livermore National Laboratory; MWH, Montgomery Watson Harza Laboratory; SITL, U.S. Geological Survey Stable Isotope and Tritium Laboratory; TML, U.S. Geological Survey Trace Metal Laboratory, Boulder, Colorado; WECK, Weck Laboratories, Inc. **Other abbreviations:** VOC, volatile organic compound; —, no preference]

Constituent	Primary constituent classification	Analytical schedules	Preferred analytical schedule
	Results from preferred method reported		
Acetone	Solvent	2020, 4024	2020
tert-Amyl methyl ether (TAME)	Gasoline oxygenate	2020, 4024	2020
Diisopropyl ether (DIPE)	Gasoline oxygenate	2020, 4024	2020
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	2020, 4024	2020
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	2020, 4024	2020
	Results from both methods reported		
Alkalinity	Water-quality indicator	1948, field	Field
Arsenic, total	Trace element	1948, TML	1948
Chromium, total	Trace element	1948, TML	1948
Iron, total	Trace element	1948, TML	1948
pH	Water-quality indicator	1948, field	Field
Specific conductance	Water-quality indicator	1948, field	Field
Perchlorate	Special interest	MWH, WECK	WECK
1,2,3-Trichloropropane (1,2,3-TCP)	VOC	2020, WECK	WECK
Tritium	Isotope tracer	LLNL, SITL	—

Table A3. Constituents detected in field blanks collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[mg/L, milligram per liter; µg/L, microgram per liter; pCi/L, picocurie per liter; na, not applicable; ≤, less than or equal to]

Constituent	Number of field blank detections/analyses	Concentrations detected in field blanks
	Organic constituents	
None	0/3	na
	Inorganic constitutents	
Boron (µg/L)	2/3	20.8; 25.2
Silica (mg/L)	2/3	0.03, 0.04
Zinc[1] (µg/L)	1/3	≤1.7
	Radioactive constituents (pCi/L)	
Radium-226	1/3	0.02

[1] Study reporting levels (SRL) for constituents were based on examinations of GAMA quality-control samples collected May 2004 through January (L.D. Olsen and M.S. Fram, U.S. Geological Survey, unpub. data, 2008).

Table A4. Quality-control summary of replicate analyses of constituents detected in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[E, estimated value; mg/L, milligram per liter; µg/L, microgram per liter; pCi/L, picocurie per liter; nv, no values in category; TU, tritium unit; <, less than]

Constituent	Number of relative standard deviations greater than 20 percent/ number of replicate pairs	Maximum relative standard deviation (percent)	Concentrations or activities for replicates with RSD greater than 20 percent (environmental sample; replicate)
Volatile organic compounds from schedule 2020			
1,2,4-Trimethylbenzene (µg/L)	1/2	53	(0.09; <0.04)
Pesticides and pesticide degradates from schedule 2003			
All constituents	0/2	<20	nv
Constituents of special interest [1]			
Perchlorate (µg/L)	1/2	53	(2.2; 1.0)
1,2,3-Trichloropropane and 1,4 dioxane (µg/L)	0/2	<20	nv
Major ions, minor ions, trace elements, and nutrients			
Mercury (µg/L)	2/2	56	(0.013; E0.006) (0.019; 0.012)
Zinc (µg/L)	1/2	47	(0.9; <1.8)
All additional major ions, minor ions, trace elements, and nutrients from schedules 1948 and 2755	0/2	<20	nv
Isotopes, radioactivity, and noble gases			
Radium-226 [2] (pCi/L)	1/2	55	(0.024; 0.055)
Radium-228 [2] (pCi/L)	0/2	<20	nv
Gross alpha radioactivity, 72-hour count [2] (pCi/L)	1/2	35	(57; 34)
Gross alpha radioactivity, 30-day count [2] (pCi/L)	2/2	141	(0; 3.8) (52.2; 26.2)
Gross beta radioactivity, 72-hour count [2] (pCi/L)	2/2	34	(6.4; 3.9) (7.5; 4.9)
Gross beta radioactivity, 30-day count [2] (pCi/L)	1/2	29	(12.8; 19.3)
Stable isotopes	0/2	<20	nv
Tritium (TU) [3]	0/2	<20	nv
Tritium (TU) and noble gases [4]	nv	nv	nv

[1] Analysed at Weck Laboratories, Inc., City of Industry, California.

[2] Analysed at the Eberline Analytical Services laboratory, Richmond, California.

[3] Analysed at the U.S. Geological Survey Stable Isotope and Tritium Laboratory, Menlo Park, California.

[4] Analysed at the Lawrence Livermore National Laboratory, Livermore, California.

Table A5A. Quality-control summary of matrix-spike recoveries of volatile organic compounds (VOC) in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetone	3	91	125	93
Acrylonitrile	3	95	112	96
tert-Amyl methyl ether (TAME)	3	88	105	101
Benzene	3	96	105	102
Bromobenzene	3	93	112	94
Bromochloromethane	3	100	110	97
Bromodichloromethane	3	94	104	104
Bromoethene	3	89	113	110
Bromoform (Tribromomethane)	3	96	103	100
Bromomethane (Methyl bromide)	3	102	110	109
tert-Butyl ethyl ether	3	76	100	97
n-Butylbenzene	3	71	95	90
sec-Butylbenzene	3	81	100	97
tert-Butylbenzene	3	84	107	103
Carbon disulfide	3	75	85	78
Carbon tetrachloride (Tetrachloromethane)	3	91	103	98
Chlorobenzene	3	85	102	97
Chloroethane	3	96	108	101
Chloroform (Trichloromethane)	3	105	113	108
Chloromethane	3	92	107	98
3-Chloropropene	3	96	115	108
2-Chlorotoluene	3	95	106	97
4-Chlorotoluene	3	93	104	100
Dichloromethane	3	99	103	100
Dibromochloromethane	3	97	102	101
1,2-Dibromo-3-chloropropane (DBCP)	3	87	100	95
1,2-Dibromoethane (EDB)	3	95	109	102
Dibromomethane	3	103	106	105
1,2-Dichlorobenzene (*o*-Dichlorobenzene)	3	98	112	99
1,3-Dichlorobenzene	3	93	106	94
1,4-Dichlorobenzene (*p*-Dichlorobenzene)	3	91	108	97
trans-1,4-Dichloro-2-butene	3	91	102	99
Dichlorodifluoromethane (CFC-12)	3	83	99	97
1,1-Dichloroethane (1,1-DCA)	3	102	107	104
1,2-Dichloroethane (1,2-DCA)	3	98	106	103
1,1-Dichloroethene (1,1-DCE)	3	82	100	94
cis-1,2-Dichloroethene (*cis*-1,2-DCE)	3	95	111	103
trans-1,2-Dichloroethene (*trans*-1,2-DCE)	3	100	111	101
1,3-Dichloropropane	3	100	108	106
1,2-Dichloropropane	3	97	106	103
2,2-Dichloropropane	3	77	87	81
1,1-Dichloropropene	3	83	99	92
cis-1,3-Dichloropropene	3	81	88	84
trans-1,3-Dichloropropene	3	84	94	85
Diethyl ether (DIPE)	3	96	115	109
Diisopropyl ether	3	96	114	96
Ethylbenzene	3	83	102	95
Ethyl methacrylate	3	94	100	99
Ethyl methyl ketone (2-Butanone)	3	92	116	95
2-Ethyltoluene	3	78	93	92
Hexachlorobutadiene	3	64	83	82

Table A5A. Quality-control summary of matrix-spike recoveries of volatile organic compounds (VOC) in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Hexachloroethane	3	87	100	98
2-hexanone (*n*-Butyl methyl ketone)	3	93	114	100
Isobutyl methyl ketone (4-Methyl-2-pentanone)	3	90	103	99
Iodomethane (Methyl iodide)	3	99	111	105
Isopropylbenzene (Cumene)	3	80	98	89
4-Isopropyltoluene (*p*-Isopropyltoluene)	3	70	95	93
Methyl acrylate (Methyl-2-propenoate)	3	101	113	105
Methyl acrylonitrile	3	113	114	114
Methyl methacrylate	3	86	98	96
Methyl *tert*-butyl ether (MTBE)	3	86	105	104
m-Xylene plus *p*-xylene	3	88	108	99
Naphthalene	3	75	92	89
n-Propylbenzene	3	82	95	88
o-Xylene	3	81	96	90
Styrene	3	87	100	90
Tetrachloroethene	3	93	100	100
Tetrahydrofuran	3	91	107	99
1,1,1,2-Tetrachloroethane	3	96	103	103
1,1,2,2-Tetrachloroethane	3	103	122	117
1,2,3,4-Tetramethylbenzene	3	69	93	88
1,2,3,5-Tetramethylbenzene	3	74	104	97
1,2,4-Trichlorobenzene	3	74	95	86
1,1,1-Trichloroethane (1,1,1-TCA)	3	90	104	99
1,1,2-Trichloroethane	3	97	108	103
Trichloroethylene	3	85	98	97
Trichlorofluoromethane (CFC-11)	3	85	106	104
1,2,3-Trichlorobenzene	3	87	101	93
1,2,3-Trichloropropane (1,2,3-TCP)	3	95	102	101
1,1,2-Trichloro-1,2,2-trifluoroethane	3	78	88	87
1,2,3-Trimethylbenzene	3	86	110	106
1,2,4-Trimethylbenzene	3	88	110	104
1,3,5-Trimethylbenzene	3	81	101	94
Toluene	3	93	100	99
Vinyl chloride (Chloroethene)	3	97	116	113

Table A5B. Quality-control summary of matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetochlor	3	111	114	113
Alachlor	3	109	110	109
Atrazine	3	97	110	97
Azinphos-methyl	3	81	120	111
Azinphos-methyl oxon	3	38	63	58
Benfluralin	3	71	76	75
Carbaryl	3	100	116	114
2-Chloro-2',6'-diethylacetanilide	3	105	113	109
4-Chloro-2-methylphenol	3	62	67	67
Chlorpyrifos	3	89	104	96
Chlorpyrifos oxon	3	11	25	11
Cyfluthrin	3	52	96	82
Cypermethrin	3	53	93	93
Dacthal (DCPA)	3	103	112	104
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-s-triazine; CIAT)	3	47	55	53
Desulfinylfipronil amide	3	96	109	104
Desulfinyl fipronil	3	87	97	94
Diazinon	3	95	107	99
3,4-Dichloroaniline	3	83	92	86
Dichlorvos	3	14	27	23
Dicrotophos	3	34	75	56
Dieldrin	3	95	127	96
2,6-Diethylaniline	3	93	104	103
Dimethoate	3	32	37	37
Ethion monoxon	3	104	121	112
Ethion	3	104	135	116
2-Ethyl-6-methylaniline	3	88	99	95
Fenamiphos sulfone	3	91	120	92
Fenamiphos sulfoxide	3	13	59	39
Fenamiphos	3	120	126	125
Fipronil	3	102	121	114
Fipronil sulfide	3	94	104	101
Fipronil sulfone	3	74	89	83
Fonofos	3	92	100	98
Hexazinone	3	87	89	87
Iprodione	3	43	60	59
Isofenphos	3	116	131	124
Malaoxon	3	76	99	82
Malathion	3	99	111	111
Metalaxyl	3	97	108	101

Table A5B. Quality-control summary of matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Methidathion	3	107	136	113
Metolachlor	3	103	108	103
Metribuzin	3	82	98	92
Myclobutanil	3	110	129	113
1-Naphthol	3	20	43	26
Paraoxon-methyl	3	51	61	58
Parathion-methyl	3	89	91	90
Pendimethalin	3	117	123	119
cis-Permethrin	3	74	103	81
Phorate	3	59	81	78
Phorate oxon	3	93	113	100
Phosmet	3	8	8	8
Phosmet oxon	2	49	50	49.5
Prometon	3	96	115	103
Prometryn	3	105	117	108
Pronamide (Propyzamide)	3	92	110	108
Simazine	3	95	111	103
Tebuthiuron	3	90	148	102
Terbufos	3	111	265	218
Terbufos oxygen oxon sulfone	3	79	97	82
Terbuthylazine	3	106	113	108
Trifluralin	3	81	87	85
Tribufos	3	81	116	97

Table A5C. Quality-control summary for matrix-spike recoveries of 1,4-dioxane and 1,2,3-trichloropropane (1,2,3-TCP) in groundwater samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)
1,4-Dioxane	2	109	111
1,2,3-Trichloropropane [1]	2	67	69

[1] Constituent detected in groundwater samples.

Table A6. Quality-control summary for surrogate recoveries of volatile organic compounds, pesticides and pesticide degradates, and constituents of special interest in samples collected for the Colorado River Groundwater Ambient Monitoring and Assessment (GAMA) study, California, autumn 2007.

[VOC, volatile organic compound; nv, no value]

Surrogate	Analytical schedule	Constituent class analyzed	Number of analyses	Median recovery (percent)	Number of surrogate recoveries below 70 percent	Number of surrogate recoveries above 130 percent
Blanks						
1-Bromo-4-fluorobenzene	2020	VOC	3	75	0	0
1,2-Dichloroethane-*d*4	2020	VOC	3	131	0	2
Toluene-*d*8	2020	VOC	3	93	0	0
Isobutyl alcohol-*d*6	4024	Gasoline oxygenate	0	nv	nv	nv
Diazinon-*d*10	2003	Pesticide	3	95	0	0
α-HCH-*d*6	2003	Pesticide	3	84	0	0
Groundwater, replicate, and matrix-spike test samples						
1-Bromo-4-fluorobenzene	2020	VOC	28	77	7	0
1,2-Dichloroethane-*d*4	2020	VOC	28	131	0	15
Toluene-*d*8	2020	VOC	28	95	0	0
Isobutyl alcohol-*d*6	4024	Gasoline oxygenate	2	89	0	0
Diazinon-*d*10	2003	Pesticide	28	99	0	0
α-HCH-*d*6	2003	Pesticide	28	83	0	0

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