



Streamflow and Water-Quality Trends of the Rio Chama and Rio Grande, Northern and Central New Mexico, Water Years 1985 to 2002

Prepared in cooperation with the
CITY OF ALBUQUERQUE

Scientific Investigations Report 2005-5118

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

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By Jeff B. Langman and Emma O. Nolan

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**U.S. Department of the Interior
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CONVERSION FACTORS

Inch/pound to SI

	Multiply	By	To obtain
		Length	
inch (in.)		2.54	centimeter (cm)
foot (ft)		0.3048	meter (m)
mile (mi)		1.609	kilometer (km)
		Area	
square mile (mi ²)		2.590	square kilometer (km ²)
		Volume	
ounce, fluid (fl. oz)		29.5735	milliliter (mL)
acre-foot (acre-ft)		1,233	cubic meter (m ³)
		Flow Rate	
cubic foot per second (ft ³ /s)		0.02832	cubic meter per second (m ³ /s)
		Radioactivity	
picocurie per liter (pCi/L)		0.037	becquerel per liter (Bq/L)

Degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = (1.8°C) +32

Degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C = (°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83).

Elevation, as used in this report, refers to distance above the vertical datum.

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

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L), micrograms per liter (µg/L), picocuries per liter (pCi/L), or milliequivalents per liter (meq/L).

Streamflow and Water-Quality Trends of the Rio Chama and Rio Grande, Northern and Central New Mexico, Water Years 1985 to 2002

By Jeff B. Langman and Emma O. Nolan

Abstract

The City of Albuquerque plans to divert San Juan-Chama Project water from the Rio Grande for potable water use. This report examines streamflow and water-quality trends in the Rio Chama and the Rio Grande for water years 1985 to 2002 following the implementation of reservoir storage agreements in northern and central New Mexico. Streamflow/water-quality stations used for this study include the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita.

Water years 1985 to 2002 were a period of larger than average precipitation and streamflow compared to the stations' historical averages. Annual precipitation and streamflow trended downward during the study period because of a drought during 1999 to 2002. Streamflow in the Rio Chama and Rio Grande was divided into three distinct seasonal periods that corresponded to natural and anthropogenic influences: fall/winter baseflow (November through February), snowmelt runoff (March through June), and the irrigation/monsoon (July through October) seasons.

A calcium bicarbonate water type was evident at all study area stations on the Rio Chama and Rio Grande. Specific conductance increased downstream, but alkalinity and pH did not substantially change in the downstream direction. Nearly all nitrogen and phosphorous concentrations were less than 1 milligram per liter for all stations. Median trace-element concentrations and maximum radionuclide concentrations did not exceed drinking-water standards. Anthropogenic compounds were infrequently detected in the Rio Chama and Rio Grande, and concentrations did not exceed drinking-water standards.

Water quality in the Rio Chama and Rio Grande varied spatially and temporally during water years 1985 to 2002. Specific conductance increased downstream in the Rio Grande during the fall/winter baseflow and snowmelt runoff seasons but was similar at the Taos, Otowi, and San Felipe stations during the irrigation/monsoon season. This similarity was a result of the release of stored water from Abiquiu Reservoir and Cochiti Lake, which masked the natural influences that increased specific conductance in the downstream direction during the other seasons. During all seasons, pH decreased and major ion concentrations remained stable at the Albuquerque station compared with the San Felipe station, but no single influence could be identified that caused these conditions. Manganese and uranium concentrations at the Otowi and San Felipe stations were largest during the fall/winter baseflow and smallest during the

snowmelt runoff, indicating that ground-water inflows likely influenced these concentrations.

Water-quality temporal trends were evaluated for selected constituents during the study period and during the individual seasons. Downward trends in major ion concentrations were similar in magnitude at the Taos and Otowi stations, indicating that an upstream influence and (or) the downward trend in annual precipitation was the main reason(s) for these trends. The stations most affected by reservoirs, Chamita and San Felipe, were the only stations at which downward trends in major ions were apparent for flow-adjusted concentrations but not for seasonally correlated flow-adjusted concentrations, which indicates fewer seasonal differences at these stations due to reservoir operations.

Introduction

Streamflow and water quality in northern and central New Mexico are important because of an increasing population and a semiarid climate. The City of Albuquerque implemented a strategy in the 1960's for future use of surface water to supplement ground water as a potable water supply by becoming a partner in the San-Juan Chama Project (SJC Project). The SJC Project diverts streamflow from three tributaries of the San Juan River in southwestern Colorado, transports the water under the Continental Divide, and releases the water into the Rio Grande Basin through Willow Creek (tributary of the Rio Chama).

The City of Albuquerque has proposed diverting their allotment of SJC Project water (48,200 acre-ft per year) from the Rio Grande starting in 2006 (City of Albuquerque, 2005). Because of the proposed diversion of SJC Project water from the Rio Grande, analysis of streamflow and water-quality trends in the Rio Chama and Rio Grande is useful for understanding spatial and temporal changes that may affect river water use. Storage agreements for northern and central New Mexico reservoirs were implemented in the mid-1980's and incorporated into the historical legislative directives that govern water management in the study area. The legislative directives form the reservoir operations framework, which influences streamflow in the Rio Chama and Rio Grande because of retention of natural riverflows and reservoir delivery obligations to downstream users according to various Federal, State, and local agreements.

The City of Albuquerque has implemented various initiatives under the Water Resources Management Strategy (City of Albuquerque, 1997) to ensure a sustainable water supply. In

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cooperation with the City of Albuquerque, the U.S. Geological Survey (USGS) analyzed streamflow and water-quality data in the Rio Chama and Rio Grande to provide streamflow and water-quality trends to water resource managers so they can better understand the variability of the resource.

Purpose and Scope

This report characterizes streamflow and water-quality trends (spatial and temporal variability) of the Rio Chama and the Rio Grande for the existing (2002) reservoir operations framework in northern and central New Mexico during water years (October 1 to September 30) 1985 to 2002. The study area included the Rio Chama and the Rio Grande in central and northern New Mexico (fig. 1). The scope of analysis included streamflow and water-quality data collected from October 1, 1984, to September 30, 2002. Water year 1985 represents the start of the existing (2002) framework for reservoir operations for Heron Lake, El Vado Reservoir, Abiquiu Reservoir, and Cochiti Lake and increased storage of native and non-native water in Abiquiu Reservoir (fig. 2). Water year 2002 was selected as an end point because it was the last full year of streamflow and water-quality data available at the time of analysis. Water-quality data were analyzed by defined categories: basic water chemistry and physical properties (specific conductance, alkalinity, pH, dissolved oxygen, chemical oxygen demand, and total dissolved solids); major ions; nutrients, organic carbon, and bacteria (nitrogen and phosphorous forms, total organic carbon (TOC), and fecal bacteria); trace elements; radionuclides; and anthropogenic compounds (pesticides and volatile and semivolatile organic compounds).

Description of the Study Area

The study area is defined as the Rio Chama and Rio Grande from the Colorado-New Mexico border to the City of Albuquerque (fig. 1). The station network for this study consisted of streamflow-gaging stations on the Rio Chama and Rio Grande within the study area (table 1; fig. 1).

Physiography

The study area is bordered by the Continental Divide to the west and the Sangre de Cristo and Sandia Mountains to the east (fig. 1). Elevations in the study area range from about 4,650 to greater than 13,000 feet above NAVD88. The Rio Grande is the main drainage in the study area, and the Rio Chama is its largest tributary in this area. The Rio Grande originates in the San Juan Mountains in south-central Colorado, bisects New Mexico, and exits the State near El Paso, Texas. The Rio Chama drains north-central New Mexico and discharges to the Rio Grande near Española, New Mexico (fig. 1).

Climate

Climate in the study area is mostly semiarid with substantial variation in precipitation from the lower valley areas to the mountains. Annual precipitation in the mountains can exceed 40 inches, whereas other areas in the watershed may receive less than 10 inches (Natural Resources Conservation Service, 1999). Most precipitation typically falls during the irrigation/monsoon season (Western Regional Climate Center, 2002), although the largest streamflows typically occur during the spring snowmelt runoff.

Streamflow of the Rio Chama and Rio Grande

Streamflow in the Rio Chama is highly variable; the largest recorded annual-mean streamflow is 1,317 ft³/s and the smallest is 145 ft³/s at the Chamita station (period of record 1913 to 2002). Rio Grande streamflow is similarly variable. The Rio Grande at the Taos station is upstream from the major reservoirs in the study area and provides an example of the variability of streamflow for this reach of the river. During the period of record (1926 to 2002), the largest annual-mean streamflow at the Taos station was 1,840 ft³/s and the smallest was 271 ft³/s.

Influences on Streamflow and Water Quality in the Study Area

The Rio Grande begins in the mountains of Colorado and is soon altered by the effects of dams, irrigation diversions, and channelization. The Rio Grande is fully appropriated; all of its annual streamflow volume is accounted for by various compacts, treaties, and individual water rights (Rio Grande Compact Commission, 1999). The streamflow of the Rio Grande between the United States and the Republic of Mexico is governed by the 1944 Water Treaty. The interstate flow of the river between Colorado, New Mexico, and Texas is governed by the 1937 Rio Grande Compact. Rio Grande streamflow within the study area is appropriated for municipal, agricultural, and recreational uses.

Reservoirs

Streamflow in the Rio Chama and Rio Grande in the study area is regulated with four large reservoirs: Heron Lake, El Vado Reservoir, Abiquiu Reservoir, and Cochiti Lake (fig. 1). The U.S. Army Corps of Engineers and the Bureau of Reclamation coordinate operation of the reservoirs in the study area to allocate available water supplies, provide for irrigation needs, maintain flood control, and provide for recreation. Operation of the reservoir system is complex because release volumes and dates are in continual flux depending on available SJC Project water, native Rio Grande water, and the needs of the users.

The Rio Grande Compact provides the legal framework for regulation of equitable apportionment of Rio Grande streamflow between States and permits each State to develop

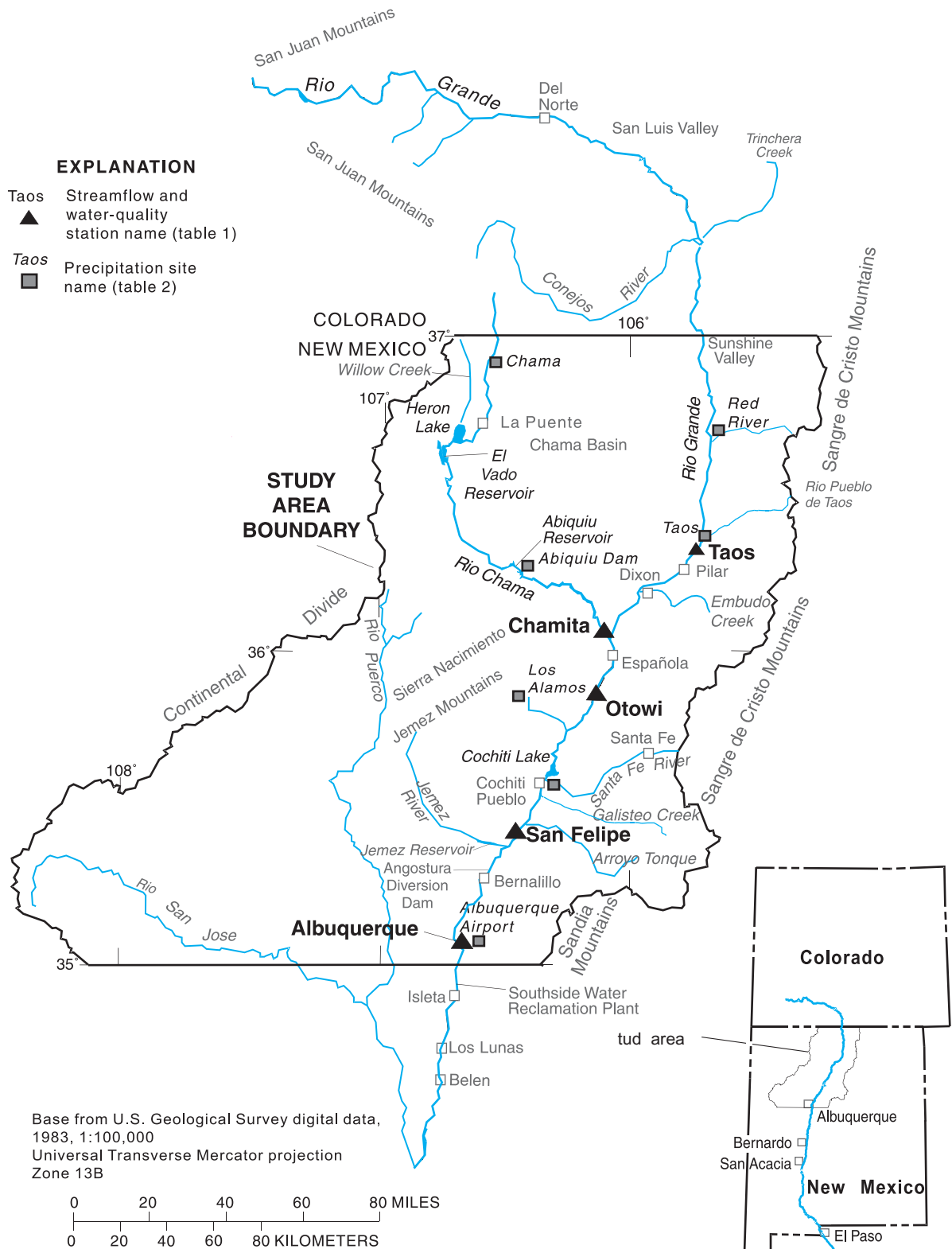


Figure 1. Selected streamflow and water-quality stations in the study area.

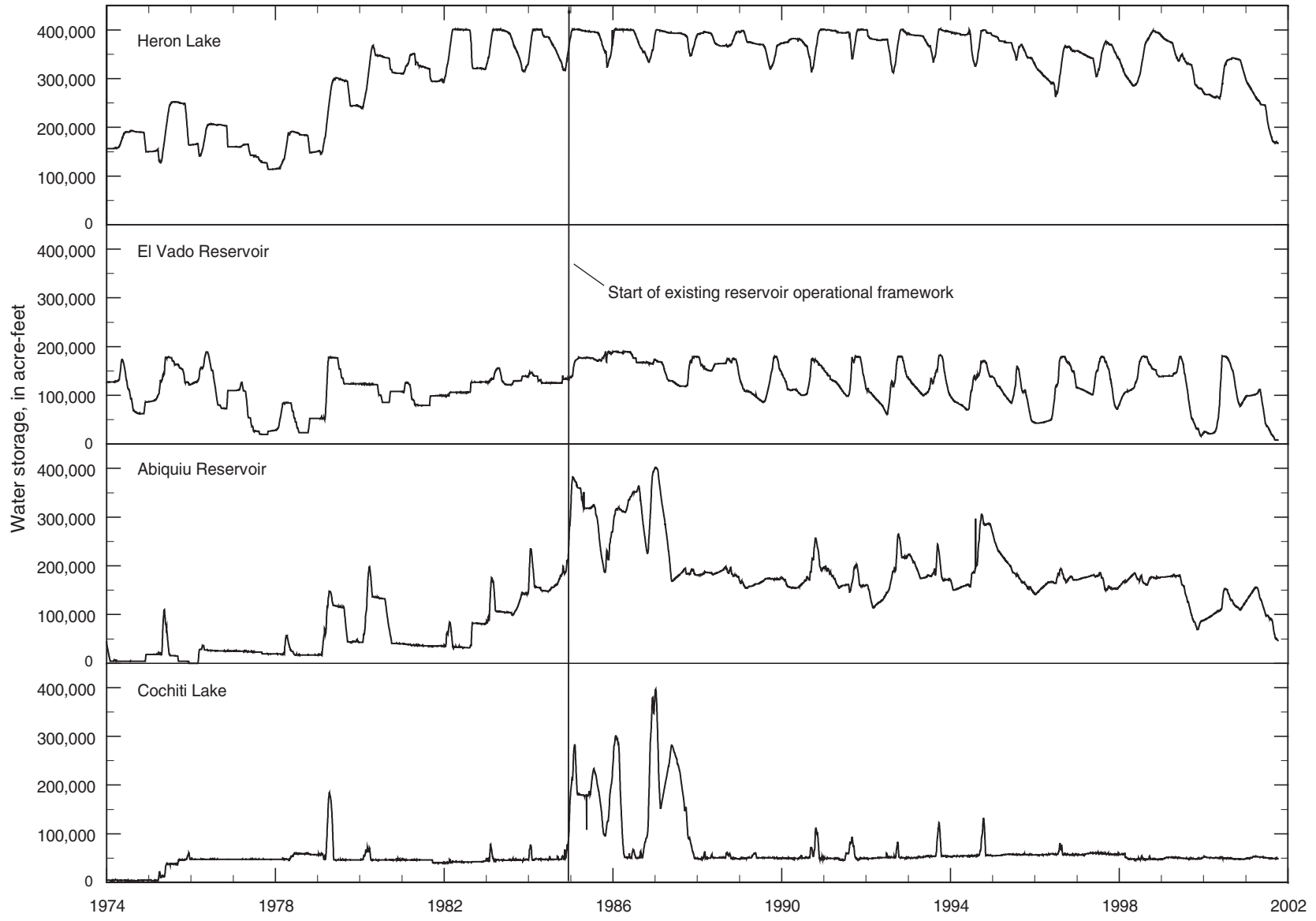


Figure 2. Water storage in Heron Lake, El Vado Reservoir, Abiquiu Reservoir, and Cochiti Lake, 1974 to 2002.

Table 1. Selected streamflow-gaging stations in the study area.[NAD83, North American Datum of 1983; HUC, hydrologic unit code; mi², square miles; ft, feet; NAVD88, North American Vertical Datum of 1988]

USGS station number	Streamflow-gaging station name	Report station name (fig. 1)	Latitude and longitude (NAD83)	Location (county, HUC)	Drainage area (mi ²) ¹	Elevation (ft above NAVD88)
08276500	Rio Grande below Taos Junction Bridge, near Taos	Taos	36°19'12" 105°45'16"	Taos, 13020101	6,790	6,053
08290000	Rio Chama near Chamita	Chamita	36°04'26" 106°06'42"	Rio Arriba, 13020102	3,044	5,657
08313000	Rio Grande at Otowi Bridge, near San Ildefonso	Otowi	35°52'29" 106°08'32"	Santa Fe, 13020101	11,360	5,491
08319000	Rio Grande at San Felipe	San Felipe	35°26'47" 106°26'26"	Sandoval, 13020201	13,160	5,119
08330000	Rio Grande at Albuquerque	Albuquerque	35°05'21" 106°40'50"	Bernalillo, 13020203	14,500	4,949

¹Drainage area does not include non-contributing areas, closed basins, or out-of-basin areas associated with interbasin transfers.

and use its water resources provided each State meets its delivery obligations (Rio Grande Compact Commission, 1999). In addition to the Rio Grande Compact, operational requirements of the reservoirs and diversions that control streamflow in the Rio Chama and Rio Grande have a long history of legislative directives. A major legislative influence was the approval of the SJC Project, which allows for the diversion of streamflow from three tributaries of the San Juan River in southwestern Colorado into the Rio Grande Basin through the Rio Chama (diversions began in 1973).

More recent legislative actions that influence streamflow regulation in the Rio Grande Basin include storage of as much as 200,000 acre-ft of SJC Project water in Abiquiu Reservoir (Public Law 97-140), which began in 1985, and storage of as much as 200,000 acre-ft of Rio Grande Basin water instead of SJC Project water in Abiquiu Reservoir (Public Law 100-522), which began in 1988. These two operational directives, along with prior compacts and treaties, provide the existing operational framework of surface-water regulation in the Rio Chama and Rio Grande. Additionally, existing Federal legislation, such as the Endangered Species Act, have required adjustments to reservoir operations to balance water user needs and environmental needs.

Tributaries

Within the study area, tributaries to the Rio Grande, other than the Rio Chama, contribute little to daily streamflow. Only Embudo Creek and the Jemez River (fig. 1) provide a mean annual streamflow greater than 50 ft³/s. Numerous intermittent and ephemeral drainages flow into the Rio Chama and Rio Grande in response to snowmelt or summer thunderstorms. The Jemez River drains an area that has geothermal activity and contains larger dissolved-solids concentrations and different mineral content than the Rio Grande (Trainer and others, 2000).

Ground-Water Inflows and Outflows

The Rio Grande is hydraulically connected with the surrounding basin-fill aquifer. The basin-fill aquifer is recharged along the mountain fronts, and ground water generally flows from the mountainous areas toward the Rio Grande (Ellis and others, 1993; Anderholm and others, 1995). Ground water in the Middle Rio Grande Basin (Cochiti Lake to Albuquerque in the study area) predominantly flows north to south but with greater east to west direction at the basin margins as a result of mountain-front recharge (Plummer and others, 2004).

Follansbee and Dean (1915) determined that the Rio Chama is likely a gaining stream from the town of Chama to its inflow to the Rio Grande because of ground-water inflows. Additional seepage studies between 1966 and 1968 confirmed these results and indicated overall gains from La Puente to its inflow to the Rio Grande (U.S. Geological Survey, 1968 and 1969).

From Taos to Cochiti Lake, the Rio Grande is likely a gaining stream overall. Moore and Anderholm (2002) found an increase in streamflow greater than what could be attributed to inflow from the Rio Chama, indicating other inflows in this area. The USGS did find a losing reach in this area during a seepage investigation in 2002 (Jack Veenhuis, U.S. Geological Survey, written commun., 2003), but also found that earlier seepage investigations in 1964 included this reach in a larger gaining reach (Jack Veenhuis, written commun., 2002).

From Cochiti Dam to Albuquerque, the interaction of surface water and ground water becomes more complex. In many areas of this reach the water table outside the river corridor is below the river bottom (Kernodle and Scott, 1986; Kernodle and others, 1994). Within the river corridor, the effects of irrigation, drains, river leakage, and evapotranspiration (ET) form complex interactions that make it difficult to determine ground-water inflows and outflows. The Rio Grande likely both gains and loses streamflow as a result of ground-water inflows and

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outflows through this reach. S.S. Papadopoulos and Associates (2000) determined that the Rio Grande from Cochiti Lake to the town of Bernardo typically loses water but does show a gain in winter months. The Rio Grande is likely a losing stream overall from Cochiti Lake to San Acacia as determined by model simulations (McAda and Barroll, 2002).

Evapotranspiration

Evapotranspiration (ET) from the Rio Chama and the Rio Grande corridors is substantial because of the arid climate, reservoirs, broad channel areas, and substantial riparian areas. S.S. Papadopoulos and Associates (2000) estimated that mean-annual riparian ET from 1985 to 1998 was about 155,000 acre-ft for the Rio Grande from Cochiti Dam to San Acacia. S.S. Papadopoulos and Associates (2000) also estimated that mean-annual agricultural ET from 1985 to 1998 was about 192,000 acre-ft in the Middle Rio Grande Valley from Cochiti Dam to San Acacia.

Irrigation Diversions and Inflows

Agricultural areas in the study area rely on diversions of Rio Chama and Rio Grande water for irrigation. The agricultural areas and irrigation systems along the Rio Chama and from Pilar to Otowi on the Rio Grande are small compared with the agricultural areas and irrigation system of the Middle Rio Grande Conservancy District (MRGCD), which are located in a narrow band of land from Cochiti Lake to Albuquerque in the study area. The MRGCD provides water for flood irrigation by diverting water from the Rio Grande through a system of canals while directing return flows to the Rio Grande through drainage ditches and interior and riverside drains. The riverside drains also collect water from the interior drains and canals and leakage from the Rio Grande to prevent waterlogging of agricultural areas (Kernodle and Scott, 1986).

Irrigation water applied to fields may return to the river as tail water (surface flow) or as ground water discharged to the canals and drains. Both pathways have been documented for Rio Grande agricultural areas outside the study area (Anderholm, 2002) and are assumed to be present in the study area. For this report, "irrigation return flow" indicates either or both of the possible pathway sources. Given the different pathways, irrigation return flow may occur throughout the year. Tail water may contribute return flow during the irrigation season, and captured shallow ground water may contribute during the irrigation season and also when diversions are not occurring (Anderholm, 2002). Possible influences from irrigation return flow and from ground-water inflows from the basin-fill aquifer in the Middle Rio Grande Basin are discussed separately.

Previous Studies

Installation of the study area's reservoirs and the SJC Project substantially altered streamflow in the Rio Chama and Rio Grande (Mussetter Engineering, Inc., 2002; Langman and Anderholm, 2004). Moore and Anderholm (2002) noted that

streamflow at stations in the study area during 1993 to 1995 was smallest during winter months, snowmelt runoff produced the largest flows through late spring and early summer, and summer thunderstorms produced large flows of short duration.

On a regional scale, the USGS has performed water-quality studies as part of the National Water-Quality Assessment (NAWQA) Program for the Rio Grande Valley study unit, which encompasses the Rio Grande watershed from its headwaters in Colorado to the New Mexico–Texas border. For data collected between 1972 and 1990, Anderholm and others (1995) stated that nutrient concentrations in the Rio Grande, with the exception of phosphorus, generally remained constant and that pesticides were detected infrequently in the study area. Healy (1997) noted that dissolved solids, major ions, boron, lithium, molybdenum, strontium, and uranium increased in the downstream direction and that pesticides were detected infrequently for data collected from 1993 to 1995. For data collected between 1992 and 1995, Levings and others (1998) indicated that pesticide detections did not exceed U.S. Environmental Protection Agency (USEPA) drinking-water standards or applicable Federal or State ambient criteria or guidelines, that median nitrogen and phosphorous values were less than 0.12 mg/L, and that dissolved solids increased in the downstream direction. For data collected between 1993 and 1995, Moore and Anderholm (2002) found that concentrations of dissolved solids, nutrients, and suspended sediment generally increased in the downstream direction but that concentrations decreased at the Otowi station because of Rio Chama inflow.

In addition to the NAWQA Program, other studies have examined Rio Grande water quality in the study area. Mills (2003) attributed most downstream increases in chloride concentration in the Rio Grande to ET and an effect on Rio Grande chloride loads by the Jemez River. Additionally, agricultural drain inflows did not appear to contribute substantial salt loads to the Rio Grande in the Albuquerque area, and chloride concentrations were similar or only slightly larger in drains than in river water for data collected in 2001 and 2002 (Mills, 2003). Passell and others (2004) described upward trends in flow-adjusted values/concentrations of specific conductance, dissolved solids, and certain major ions at stations in northern New Mexico and downward trends of specific conductance, dissolved solids, and certain major ions at stations in central New Mexico for data collected between 1975 and 1999. Langman and Anderholm (2004) described an effect on Rio Grande water quality due to importation of SJC Project water and seasonal effects on water quality due to reservoir releases.

Besides overall evaluation of water-quality trends, some studies have more closely examined possible influences on Rio Grande water quality in the study area. Anderholm (1987) indicated that agriculture in the Albuquerque area was likely responsible for larger specific-conductance values in shallow ground water compared to river values and that the shallow ground water might discharge to the river. Anderholm and others (1995) attributed the change in nutrient concentrations downstream from Albuquerque to irrigation return flows and the City's wastewater treatment plant. Anderholm (1997) attrib-

uted major ion concentrations in shallow ground water near the river in Albuquerque to the influence of agriculture and the system of canals and drains that recharge shallow ground water. Wilcox (1997) presented water-quality data for 1994 to 1996 for the Rio Grande and MRGCD drains in the Albuquerque area that indicated differences between Rio Grande water and drain water.

In addition to river water quality, reservoir water quality has been examined in the study area. In 1978-79, nitrogen, phosphorus, and iron, individually or combined, were algal-growth limiters during various seasonal periods in Abiquiu Reservoir and Cochiti Lake (Johnson and Barton, 1980). In 1989, the State of New Mexico analyzed water samples from Abiquiu Reservoir and said that phosphorus was the limiting nutrient for algal growth (Potter and Davis, 1989). In 1991, the State of New Mexico indicated that nitrogen and phosphorous concentrations in Heron Lake were co-limiting for algal growth and that no pesticides were detected in the reservoir (New Mexico Environment Department, 1992). Bolin and others (1987) tried to model phosphorous changes in Abiquiu Reservoir and Cochiti Lake and found that settling velocities and flushing rates were important for phosphorous removal. Johnson and Barton (1980) described dissolved-oxygen stratification near the dam at Cochiti Lake during summer months and downward pH values with depth.

Acknowledgments

The authors acknowledge the City of Albuquerque for providing the support to implement this study. In particular, the authors express their appreciation to John Stomp, City of Albuquerque Director of Water Resources, for his guidance and support of this study to better understand New Mexico's water resources.

Methods of Analysis

This study was based entirely on available data. Streamflow data consisted of daily-mean streamflow. Water-quality samples were discrete samples collected at Rio Chama and Rio Grande stations at different frequencies from October 1, 1984, to September 30, 2002. All data are stored in the USGS National Water Information System (NWIS) database; stations used for this investigation are presented in table 1. All statistical analyses were performed using the SPlus 6.1 statistical software package created by Insightful Corporation. The Seasonal Kendall test used in this study was applied using the USGS ESTREND module for SPlus 6.1.

Exploratory data analysis indicated non-normal data sets for streamflow and most water-quality constituents in the study

area. Because of these non-normal data sets, nonparametric statistics were used for streamflow and water-quality analysis.

Water-quality data were grouped into six categories: basic water chemistry and physical properties (specific conductance, alkalinity, pH, dissolved oxygen, chemical oxygen demand, and total dissolved solids); major ions; nutrients, organic carbon, and bacteria (nitrogen and phosphorous forms, total organic carbon (TOC), and fecal bacteria); trace elements; radionuclides; and anthropogenic compounds (pesticides and volatile and semivolatile organic compounds).

Water-Quality Spatial Trend Analysis

For all stations, summary statistics (minimum, 25th percentile, median, 75th percentile, and maximum values) were calculated for all water-quality constituents for which nine or more values were available (Supplemental information). Estimated values (values larger than the method detection level (MDL) but smaller than the laboratory reporting level (LRL)) were assumed to be actual concentrations. The MDL values were substituted for censored (non-detect) data to calculate the summary statistics. Because simple substitution of censored values with MDL values may result in larger estimates of statistical values (Helsel and Hirsch, 1991), all statistics less than or equal to the largest MDL value for that constituent are shown as censored data (Supplemental information).

An MDL is defined as the statistically calculated minimum concentration that can be measured with 99 percent confidence that the reported value is greater than zero; MDL's are determined from replicate analyses of small concentration standards in a typical representative matrix (Oblinger Childress and others, 1999). An MDL is used to control the reporting of false positives. An LRL is typically twice the MDL and is used to reduce reporting of false negatives (Oblinger Childress and others, 1999).

Summary statistics were used to evaluate spatial changes in water quality from upstream to downstream stations. Median values provided a central value for comparison of overall conditions during the study period, and minimum and maximum values and interquartile ranges (25th to 75th percentile) provided indicators of constituent variability during the study period.

Water-quality concentrations were compared to drinking-water standards established by the USEPA under the Safe Drinking Water Act (U.S. Environmental Protection Agency, 2004). These standards are not required for streamflow in the Rio Chama and Rio Grande, but the standards provide useful benchmarks for evaluating the quality of the water for its use as drinking water.

Streamflow and Water-Quality Seasonal Trend Analysis

Streamflow and water quality were evaluated for seasonal trends using box plots or annual fit lines. Box plots consist of the distribution's median, interquartile range, standard span whiskers (interquartile range multiplied by 1.5), and outliers. To develop an annual fit line, the concentrations of a constituent during the study period were plotted without respect to year, and a fit line was applied using the LOESS smooth technique. The LOESS smooth technique derives a locally weighted fit line that responds to the individual data point and a few neighboring data points. A variable fit window with locally linear fitting was used to create the LOESS fit lines.

Streamflow and Water-Quality Temporal Trend Analysis

Temporal trend analysis consisted of monotonic trend analysis using the Seasonal Kendall test or Mann-Kendall test to evaluate whether streamflow or flow-adjusted water-quality concentrations were increasing (upward trend), decreasing (downward trend), or showing no change during the study period. Water-quality concentrations were adjusted for streamflow to reduce the variability attributable to streamflow differences. Monotonic trend analysis for flow-adjusted water-quality concentrations during the study period was applied by season using the Seasonal Kendall test to reduce the variability attributable to seasonal differences. Reduction of the total variability increases the power of the trend analysis and increases the probability of detecting a trend that is a result of an influence other than seasonal or streamflow differences. Streamflow and flow-adjusted concentrations also were analyzed for individual seasonal temporal trends by using the Mann-Kendall test to evaluate whether the study period temporal trend was representative of trends within the individual seasonal periods.

Because of non-normal data sets, water-quality concentrations were adjusted for streamflow using the non-parametric LOESS smooth technique. The LOESS smooth technique was used to derive a locally weighted fit line for determination of residuals (differences between the predicted value and the actual value). The Seasonal Kendall test applies the Mann-Kendall test to the residual data from each selected seasonal period and combines the results for an evaluation of an increase or decrease over time. The Mann-Kendall test uses Kendall's tau correlation coefficient with the x-variable as time to test whether the y-variable (residuals in this study) tends to increase or decrease over time. Kendall's tau was used to present strength of correlation between individual constituents and time. Kendall's tau is a rank method (resistant to outliers) that measures the strength of the monotonic relation between two variables. The coefficient ranges from +1 (positive relation) to -1 (negative relation); values closer to ± 1 indicate a stronger relation. A value of zero indicates no correlation. Generally, a coefficient greater than or equal to +0.7 or less than or equal to

-0.7 indicates a strong correlation for Kendall's tau (Helsel and Hirsch, 1991).

Method detection level values were substituted for censored values for the Seasonal Kendall test provided that a single MDL existed for the constituent record. Additionally, the Seasonal Kendall test has certain requirements for the amount and distribution of data points based on the number of seasonal periods. Because of these requirements, the Seasonal Kendall test was applied only to data sets with a single MDL and with 50 or more data points of which at least 95 percent were larger than the MDL. The Mann-Kendall test for seasonal temporal trend analysis was applied to the same constituents as those selected for the Seasonal Kendall test.

A temporal trend in streamflow or water quality was based on a p-value ($1 - \alpha$) less than or equal to 0.10 (90 percent confidence level) for both the Seasonal Kendall and the Mann-Kendall tests. If the p-value was greater than 0.10, the comparison was considered to indicate no temporal trend. The trend direction was based on the positive (upward trend) or negative (downward trend) value of the Seasonal Kendall or Mann-Kendall test (Kendall's tau for both tests). The p-value indicates whether a trend was statistically significant and that the variability of the constituents could be explained by the relation between streamflow or concentration and time. Kendall's tau results (strength of relation) were used to evaluate the magnitude of trends for comparison of sites.

Streamflow Trends of the Rio Chama and Rio Grande, Water Years 1985 to 2002

Seasonal Trends in Streamflow

Because of many natural and anthropogenic influences on streamflow, seasonal variation of streamflow in the Rio Chama and Rio Grande was substantial, and streamflow in the Rio Chama and Rio Grande were similar in seasonal patterns (fig. 3). The annual streamflow pattern in the study area can be divided into three distinct seasons: fall/winter baseflow (November through February), snowmelt runoff (March through June), and the irrigation/monsoon (July through October) seasons (fig. 3).

Streamflow generally increased in the downstream direction because of surface- and ground-water inflows (fig. 3). However, reservoir operations can reduce downstream flows during certain periods of the year, such as when streamflow is retained in a reservoir for flood protection or snowmelt runoff retention. Reservoir operations at Cochiti Lake moderated streamflow during the snowmelt runoff, resulting in smaller streamflow at the San Felipe station than at the Otowi station during this season. Additionally, diversions for agriculture along with ET and losses to ground water can reduce instream flow at downstream stations, as is evident during the irrigation/monsoon season when streamflow decreased between San Felipe and Albuquerque.

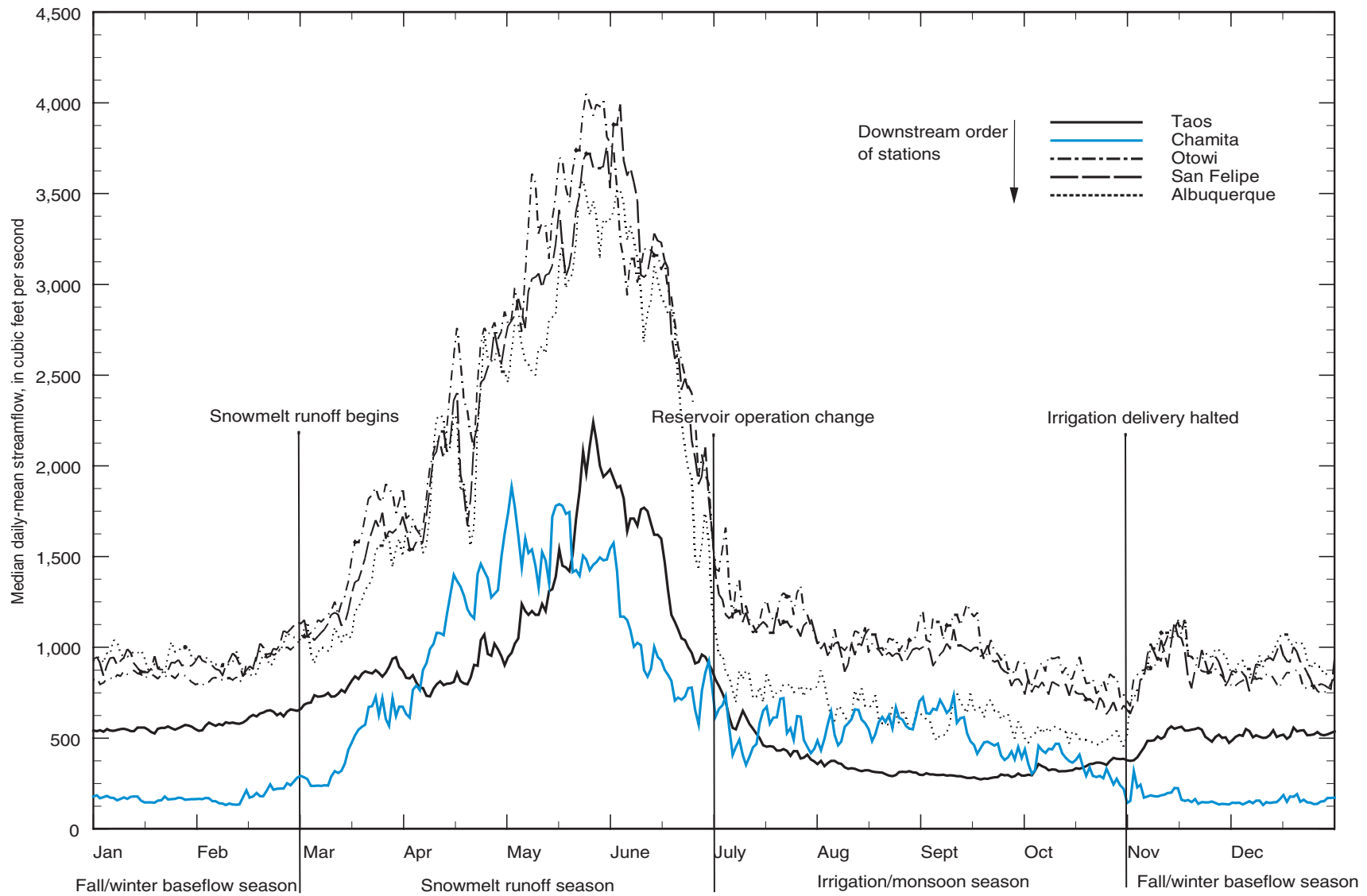


Figure 3. Seasonal trend of streamflow at the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

Temporal Trends in Climate and Streamflow

The climate during the study period ranged from periods of above-average rainfall to drought conditions. The period of 1978 to 1992 was an above-average rainfall period for New Mexico (Lewis and Hathaway, 2001). From 1999 to 2002, a drought resulted in below-average annual rainfall in New Mexico; water year 2002 was the second driest on record for the Southwest (Betancourt, 2003). Passell and others (2004) described an upward trend for Rio Grande streamflow from 1975 to 1999, primarily during January, February, March, September, and October.

Mean-annual precipitation and mean-annual streamflow during the study period were larger at all sites and stations than during the entire period of record (tables 2 and 3), indicating a wetter climate during the study period. Temporal trend analysis of mean-annual precipitation, 1985 to 2002 (table 2), indicated a downward trend in annual precipitation except for the Red River site. Analysis of streamflow trends (table 3) for the study period also indicated downward trends except during the irrigation/monsoon season for stations downstream from Taos. These downward trends are likely a result of the drought that occurred in New Mexico from 1999 to 2002 during the study period. The upward trend in streamflow at sites downstream from Taos during the irrigation/monsoon season was likely a result of SJC Project water that minimized the natural decrease in streamflow that would have occurred without the SJC Project. The drought did affect SJC Project water inflow to the Rio Grande Basin, as seen by smaller diversions during 2000 and 2002 (table 4), but release of multiyear stored water from Heron Lake allowed SJC Project water users to receive their full allotment each year (total allotment is 96,200 acre-ft). Decreased SJC Project inflows to Heron Lake and release of full allotments during the drought reduced the water stored in Heron Lake (fig. 2).

Water-Quality Trends of the Rio Chama and Rio Grande, Water Years 1985 to 2002

Spatial and temporal trends in water quality were evaluated for Rio Chama and Rio Grande stations for which sufficient water-quality data were available for analysis. The six water-quality groups evaluated were basic water chemistry and physical properties (specific conductance, alkalinity, pH, dissolved oxygen, chemical oxygen demand, and total dissolved solids); major ions; nutrients, organic carbon, and bacteria (nitrogen and phosphorous forms, total organic carbon (TOC), and fecal bacteria); trace elements; radionuclides; and anthropogenic compounds (pesticides and volatile and semivolatile organic compounds).

Water-Quality Spatial Trends

The six water-quality groups were evaluated for changes between stations from upstream to downstream in the Rio Grande. The effect of the Rio Chama is described by comparison with data from the Rio Grande station upstream from the Rio Chama inflow (Taos) and the downstream station (Otowi).

Basic Water Chemistry and Physical Properties

Of all water-quality groups, basic water chemistry and physical properties provided the best indication of influences on water quality in the Rio Chama and Rio Grande. Median specific conductance in the Rio Chama and Rio Grande ranged from 290 to 370 $\mu\text{S}/\text{cm}$ (tables I-1 to I-5, Supplemental information) and increased in the downstream direction, likely because of surface- and ground-water inflows and ET. Specific conductance in the Rio Chama (333- $\mu\text{S}/\text{cm}$ median at the Chamita station) was larger than that in the Rio Grande upstream from the Rio Chama inflow (290- $\mu\text{S}/\text{cm}$ median at the Taos station). Rio Chama inflow contributed to the increase in specific conductance in the Rio Grande (314- $\mu\text{S}/\text{cm}$ median at the Otowi station). The largest increase in specific conductance between Rio Grande stations was between the San Felipe and Albuquerque stations, possibly as a result of Jemez River inflow, ET, and irrigation return flows (Langman and Anderholm, 2004). Additionally, Plummer and others (2004) measured specific conductance in ground water between San Felipe and Albuquerque that ranged from 400 to greater than 1,000 $\mu\text{S}/\text{cm}$. However, Plummer and others presented geochemical evidence that the Rio Grande recharges the aquifer from about San Felipe through Albuquerque, indicating that ground water would not substantially contribute to the Rio Grande through this reach.

Median alkalinity in the study area ranged from 94 to 113 mg/L (tables I-1 to I-5, Supplemental information). Alkalinity did not substantially vary from site to site, and median alkalinity values increased or decreased only slightly from site to site: an 8-percent increase from Taos to Otowi, a 6-percent increase from Otowi to San Felipe, and a 1-percent decrease from San Felipe to Albuquerque. Given the pH ranges described in the following paragraph, alkalinity in the Rio Chama and Rio Grande is determined by the bicarbonate concentration.

Median pH in the study area ranged from 7.9 to 8.3 and decreased in the downstream direction (tables I-1 to I-5, Supplemental information). As with alkalinity, pH did not substantially vary from site to site and interquartile ranges were between 7.8 and 8.5 at all stations. The small ranges of pH and alkalinity indicate that natural and anthropogenic influences do not affect substantially pH and alkalinity substantially in the Rio Grande in the study area.

Streamflow in the Rio Chama and Rio Grande was well oxygenated; median dissolved oxygen concentrations ranged from 8.6 to 9.4 mg/L and minimum concentrations ranged from 5.9 to 7.0 mg/L (tables I-1 to I-5, Supplemental information). Because minimum dissolved oxygen values were 5.9 mg/L or larger at all stations, hypoxic conditions likely do not occur at the Rio Chama and Rio Grande stations.

Table 2. Mean-annual precipitation in the study area.

[in., inches; periods of record are calendar years; p-value significant if less than or equal to 0.10]

Precipitation sites ¹ in the study area (fig. 1)	Mean-annual precipitation (in.), period of record	Mean-annual precipitation (in.), 1984 to 2002	Precipitation site period of record	Temporal trend, 1984 to 2002	Mann-Kendall p-value	Kendall's tau
Chama	20.80	23.56	1914 - 2002	Downward	0.086	-0.286
Abiquiu Dam	9.79	10.30	1958 - 2002	Downward	0.054	-0.322
Red River	20.23	22.90	1918 - 2002	None	0.221	-0.205
Taos	12.24	13.12	1914 - 2002	Downward	0.103	-0.314
Los Alamos	18.25	19.54	1942 - 2002	Downward	0.002	-0.509
Cochiti Lake	12.17	13.16	1975 - 2002	Downward	0.031	-0.372
Albuquerque Airport	8.56	9.65	1914 - 2002	Downward	0.025	-0.374

¹Precipitation sites are National Weather Service Cooperative Network stations (New Mexico Climate Center, 2004). For analysis of precipitation during the study period and periods of record, annual precipitation values were removed when more than 1 month of data was missing.

Table 3. Mean-annual streamflow and streamflow temporal trends in the study area.

[ft³/s, cubic feet per second; p-value significant if less than or equal to 0.10; fall/winter baseflow, November through February; snowmelt runoff, March through June; irrigation/monsoon, July through October]

Station (fig. 1) and seasonal period	Mean-annual streamflow (ft ³ /s), period of record	Streamflow period of record	Mean-annual streamflow (ft ³ /s), water years 1985 to 2002	Streamflow temporal trend, water years 1985 to 2002	Mann-Kendall p-value	Kendall's tau
Taos	754	1926 - 2002	837	Downward	<0.001	-0.157
<i>Fall/winter baseflow</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.207</i>
<i>Snowmelt runoff</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.273</i>
<i>Irrigation/monsoon</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.166</i>
Chamita	538	1913 - 2002	634	Downward	0.009	-0.022
<i>Fall/winter baseflow</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.192</i>
<i>Snowmelt runoff</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.114</i>
<i>Irrigation/monsoon</i>				<i>Upward</i>	<i><0.001</i>	<i>0.184</i>
Otowi	1,501	1896 - 2002	1,623	Downward	<0.001	-0.124
<i>Fall/winter baseflow</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.282</i>
<i>Snowmelt runoff</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.264</i>
<i>Irrigation/monsoon</i>				<i>Upward</i>	<i>0.011</i>	<i>0.036</i>
San Felipe	1,422	1927 - 2002	1,574	Downward	<0.001	-0.140
<i>Fall/winter baseflow</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.285</i>
<i>Snowmelt runoff</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.246</i>
<i>Irrigation/monsoon</i>				<i>Upward</i>	<i>0.014</i>	<i>0.035</i>
Albuquerque	1,177	1943 - 2002	1,432	Downward	<0.001	-0.158
<i>Fall/winter baseflow</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.260</i>
<i>Snowmelt runoff</i>				<i>Downward</i>	<i><0.001</i>	<i>-0.244</i>
<i>Irrigation/monsoon</i>				<i>None</i>	<i>0.878</i>	<i>-0.002</i>

Table 4. Annual San Juan-Chama Project streamflow diversion from the Colorado River Basin into the Rio Grande Basin.

[acre-ft, acre feet]

Year	Diversion, acre-ft	Year	Diversion, acre-ft	Year	Diversion, acre-ft
1984	113,619	1991	113,389	1998	96,701
1985	91,780	1992	87,064	1999	118,904
1986	89,177	1993	98,812	2000	42,741
1987	83,047	1994	82,193	2001	110,575
1988	63,563	1995	86,268	2002	6,306
1989	50,126	1996	58,528		
1990	76,174	1997	142,256		

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Major Ions

Streamflow at all Rio Chama and Rio Grande stations was of the same calcium bicarbonate water type (fig. 4). Among stations, median concentrations of calcium and sulfate were the most variable of the major ions. Bicarbonate was the most prevalent major ion.

Nutrients, Organic Carbon, and Bacteria

All median nitrogen and phosphorous concentrations for the Rio Chama and Rio Grande stations were less than or equal to 0.40 mg/L, and all concentrations were less than 2 mg/L except for one total nitrite plus nitrate (12 mg/L) and one total phosphorous (2.8 mg/L) concentration (fig. 5; tables I-1 to I-5, Supplemental information). The 12-mg/L total nitrite plus nitrate concentration at the San Felipe station (January 1986) was the only nitrogen concentration to exceed the dissolved 10-mg/L drinking-water standard (U.S. Environmental Protection Agency, 2004), and the 2.8-mg/L dissolved total phosphorous concentration at the Otowi station (July 1991) was the only phosphorous concentration to exceed the 0.50-mg/L drinking-water standard.

Median TOC concentrations were similar at all stations, ranging from 3.6 to 5.0 mg/L; the largest median TOC concentration was at the Otowi station (tables I-1 to I-5, Supplemental information). Median fecal coliform and median fecal streptococci concentrations increased in the Rio Grande from Taos to Otowi. The median fecal coliform concentration at the Otowi

station (64 colonies per 100 mL) was similar to that at the Chamita station (60 colonies per 100 mL) (tables I-1 to I-5, Supplemental information). The increase in TOC, fecal coliform, and fecal streptococci concentrations from Taos to Otowi cannot be attributed only to Rio Chama inflow because the distribution of these concentrations at the Otowi station was larger than the distribution at the Chamita station (fig. 5).

Trace Elements

At all stations, median trace-element concentrations did not exceed drinking-water standards, and only individual aluminum, iron, and manganese concentrations exceeded standards. For each trace element and each station, the percentage of samples exceeding a drinking-water standard was no more than 4 percent (table 5). The aluminum drinking-water standard (200 µg/L) was exceeded at Otowi (4 percent of samples) and San Felipe (3 percent). The iron secondary standard (300 µg/L) was exceeded in 1 to 3 percent of samples at all stations except the Albuquerque station, at which no single sample exceeded the standard. The manganese secondary standard (50 µg/L) was exceeded at the Taos (4 percent), Otowi (2 percent), and San Felipe (3 percent) stations. Drinking-water standards generally were exceeded during the irrigation/monsoon season, and trace-element concentrations larger than drinking-water standards were detected only from April through October. Water-quality samples analyzed for aluminum, iron, and manganese were distributed nearly evenly across all seasonal periods (table 6).

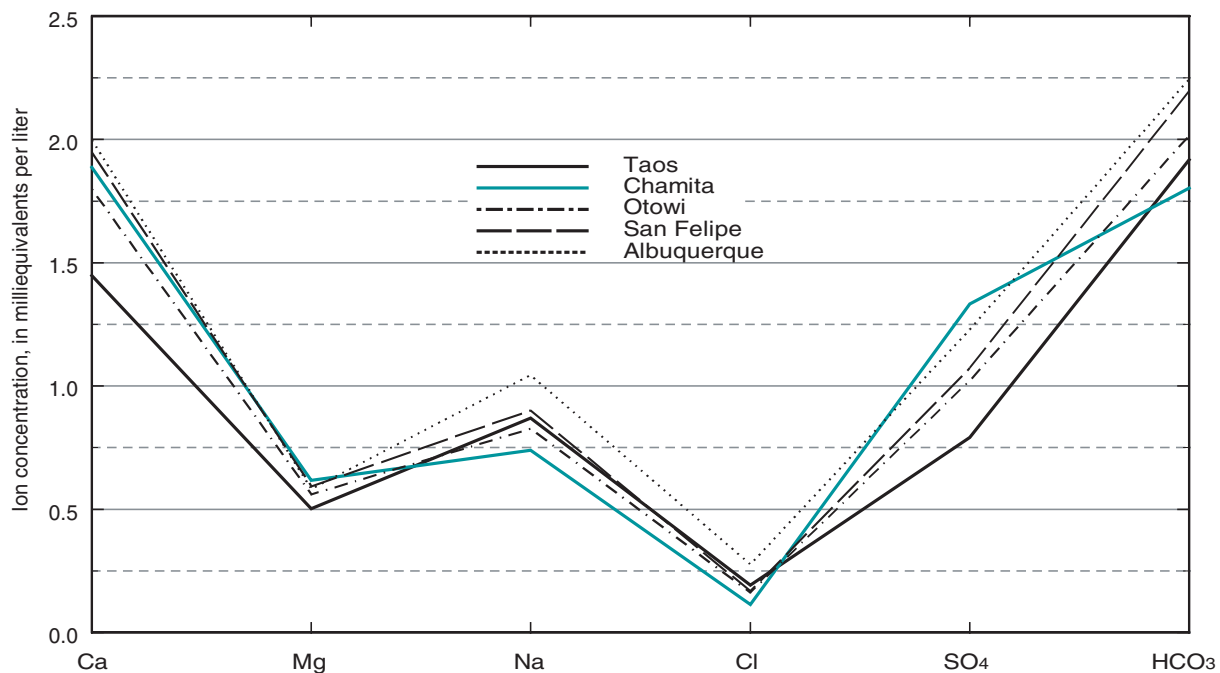


Figure 4. Median ion concentrations for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

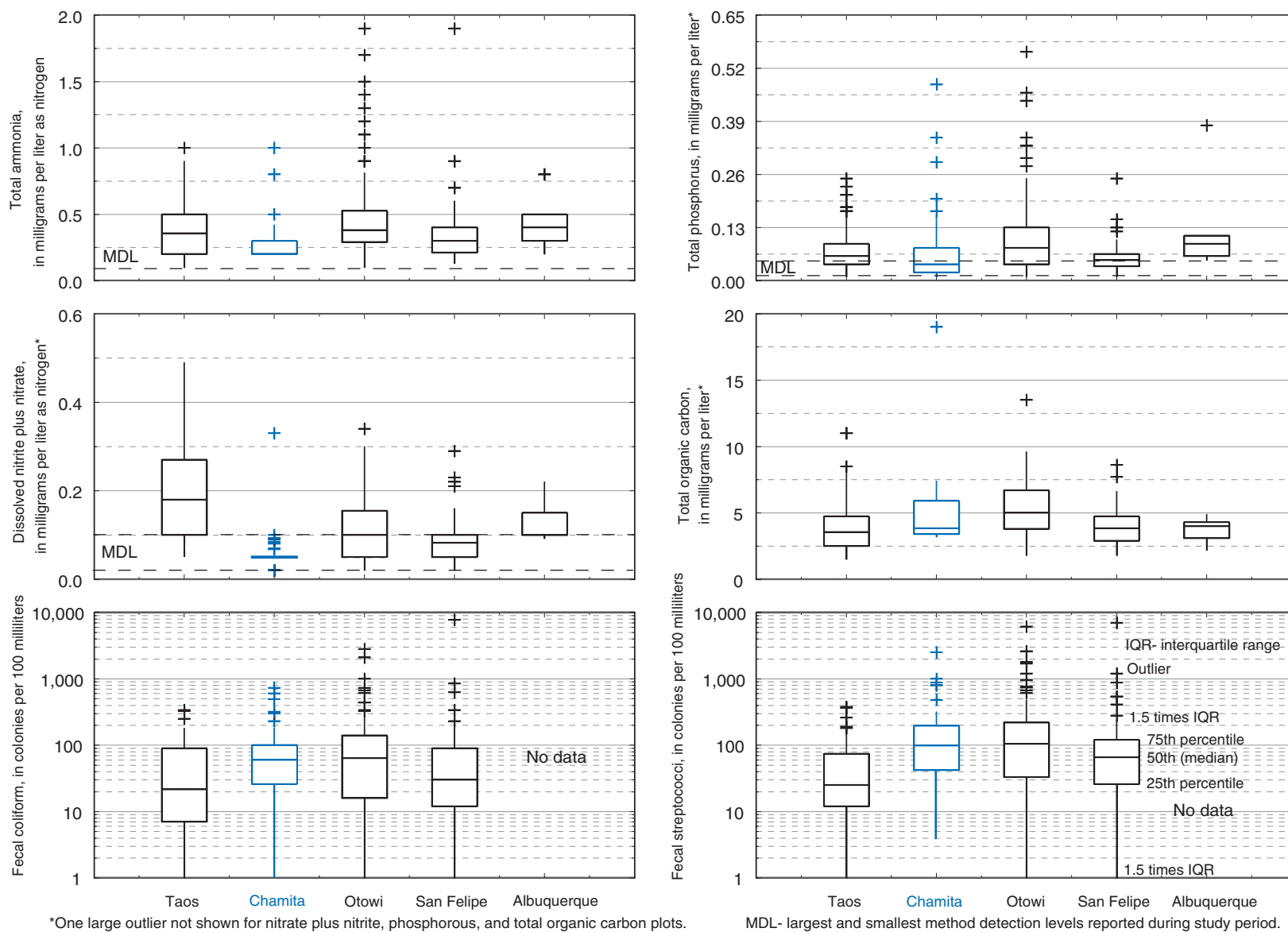


Figure 5. Total ammonia, total phosphorous, dissolved nitrite plus nitrate, total organic carbon, fecal coliform, and fecal streptococci concentrations for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

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Table 5. Median dissolved trace-element concentrations in the Rio Chama and Rio Grande during water years 1985 to 2002 and percentage exceedance of applicable drinking-water standards.

[%, percentage of samples that exceeded the drinking-water standard; µg/L, micrograms per liter; NA, none available; <, less than]

Station (fig. 1)		Taos		Chamita		Otowi		San Felipe		Albuquerque		Drinking-water standard ¹	Drinking-water standard type ²
Constituent	Unit	Median	%	Median	%	Median	%	Median	%	Median	%		
Aluminum	µg/L	13	0	4	0	11	4	5	3	NA	NA	200	Secondary
Arsenic	µg/L	2	0	2	0	2	0	2	0	3	0	10	Primary
Barium	µg/L	28	0	71	0	57	0	68	0	NA	NA	2,000	Primary
Boron	µg/L	40	NA	30	NA	40	NA	40	NA	60	NA	NA	NA
Chromium ³	µg/L	1	0	<1	0	<1	0	<1	0	<1	0	100	Total
Copper	µg/L	2.0	0	1.7	0	1.5	0	1.2	0	2.0	0	1,300	Action
Iron	µg/L	19	2	16	1	14	2	10	3	14	0	300	Secondary
Manganese	µg/L	8.1	4	5.7	0	5.0	2	9.3	3	NA	NA	50	Secondary
Molybdenum	µg/L	6	NA	1.2	NA	NA	NA	4.0	NA	NA	NA	NA	NA
Nickel	µg/L	1.0	NA	1.0	NA	1.00	NA	1.0	NA	NA	NA	NA	NA
Zinc	µg/L	<10	0	3	0	3	0	3	0	3	0	5,000	Secondary

¹Drinking-water standard maximum contaminant levels as issued by the U.S. Environmental Protection Agency for National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2004).

²Drinking-water standard type refers to the U.S. Environmental Protection Agency's designation for primary, secondary, or action level standard per the National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2004).

³Total and dissolved chromium concentrations were compared to the 100-µg/L total concentration drinking-water standard.

Table 6. Seasonal number of samples collected for aluminum, iron, and manganese analysis for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita during water years 1985 to 2002.

Constituent	Taos	Chamita	Otowi	San Felipe	Albuquerque
Aluminum total samples	13	16	110	33	4
<i>Fall/winter baseflow</i>	4	7	32	10	1
<i>Snowmelt runoff</i>	5	5	37	10	1
<i>Irrigation/monsoon</i>	4	4	41	13	2
Iron total samples	90	69	139	65	17
<i>Fall/winter baseflow</i>	25	22	43	17	5
<i>Snowmelt runoff</i>	36	27	46	27	8
<i>Irrigation/monsoon</i>	29	20	50	21	4
Manganese total samples	45	46	132	32	4
<i>Fall/winter baseflow</i>	12	15	36	10	1
<i>Snowmelt runoff</i>	18	17	45	10	1
<i>Irrigation/monsoon</i>	15	14	51	12	2

Radionuclides

Samples for radionuclide analysis were not frequently collected at the stations during the study period. Of the radionuclides analyzed, alpha particles, radium-226, and natural uranium were the most common, and maximum concentrations did not exceed drinking-water standards (table 7).

Anthropogenic Compounds

Anthropogenic compounds were rarely detected (table 8), and concentrations did not exceed 0.1 $\mu\text{g/L}$ or drinking-water standards (table 9). Anthropogenic compounds were analyzed only for samples collected between March and September for all stations except Chamita, where samples were collected during all months for anthropogenic compound analysis. Nearly all analyses were conducted for pesticide compounds only (table I-6, Supplemental information), and all detections listed in table 9 are pesticides.

Water-Quality Seasonal Trends

Five of the six water-quality groups were analyzed for changes by season. Data were insufficient for seasonal trend analysis of anthropogenic compounds.

Basic Water Chemistry and Physical Properties

Basic water chemistry and physical properties indicate that water quality in the study area varied spatially and temporally during the study period. Specific conductance increased downstream in the Rio Grande during the fall/winter baseflow and snowmelt runoff seasons, but the distribution of specific-conductance values at Taos, Otowi, and San Felipe stations were similar during the irrigation/monsoon season (fig. 6). This pattern indicates that influences that increase specific conductance in the downstream direction were masked or not present during the irrigation/monsoon season. Because of the release of stored water from the reservoirs, in particular Abiquiu Reservoir and Cochiti Lake, during the irrigation/monsoon season, this stored water released from the reservoirs likely was masking the natural influences that increased specific conductance in the downstream direction during the other seasons.

The inflow of the Rio Chama increases specific conductance between the Taos and Otowi stations during the fall/winter baseflow and snowmelt runoff seasons (fig. 6). During the irrigation/monsoon season, the specific conductance of Rio Chama inflow was similar to that at the Taos station and no increase in specific conductance was evident at the Otowi station. The effect of the Rio Chama on specific conductance in the Rio Grande was largest during the fall/winter baseflow season, when the largest specific conductance was measured at the Chamita station.

Specific conductance in the Rio Grande between the Otowi and San Felipe stations increased during the fall/winter baseflow and snowmelt runoff seasons (fig. 6). Release of

stored snowmelt runoff from Cochiti Lake during the irrigation/monsoon season has been shown to decrease specific conductance at the San Felipe station compared with the Otowi station during this seasonal period (Langman and Anderholm, 2004). Because natural inflows of ground and surface water were likely a greater percentage of total flow in the Rio Grande during the fall/winter baseflow and possibly the snowmelt runoff seasons, these inflows likely entered the Rio Grande between the Otowi and San Felipe stations and increased specific conductance during these seasons. Although evaporation at Cochiti Lake was possibly responsible for this increase, it does not seem likely because the increase in specific conductance between the stations was largest during the snowmelt runoff season and when water temperatures were lowest (fall/winter baseflow season). Plummer and others (2004) defined an area east of the Rio Grande from Galisteo Creek to Arroyo Tonque that likely discharges ground water to the Rio Grande upstream from the San Felipe station. Median specific conductance of ground water in this area was greater than 1,200 $\mu\text{S/cm}$. Water-quality samples from Galisteo Creek from 1968 to 1979 also indicated surface runoff from this area with relatively large specific conductance (five samples ranging from 465 to 1,710 $\mu\text{S/cm}$) (U.S. Geological Survey, 2004).

Specific conductance in the Rio Grande increased during each seasonal period from San Felipe to Albuquerque (fig. 6). This increase was likely the result of natural influences such as ET and surface inflows such as the Jemez River. The Jemez River median specific conductance for data collected during the study period was 888 $\mu\text{S/cm}$ (U.S. Geological Survey, 2004). Substantial ground-water inflows to the Rio Grande in this area are unlikely (Plummer and others, 2004).

The influence of irrigation return flows on specific conductance in the Rio Grande between San Felipe and Albuquerque is not discernible. Specific conductance increased between these stations during the fall/winter baseflow when irrigation return flows were likely minimal. Although many MRGCD canals carry no flow from November through February, they do carry flow beginning in March when the MRGCD begins diverting water to make irrigation water available to its customers (S.S. Papadopulos and Associates, 2002). Many of the drains along the river carry substantial flow throughout the year, but flow is likely composed of mostly river leakage instead of irrigation return flows during the winter.

Seasonal patterns of alkalinity in the Rio Chama and Rio Grande were similar to seasonal patterns of specific conductance (fig. 7). Alkalinity increased in the Rio Grande in the downstream direction during the fall/winter baseflow and snowmelt runoff seasons except from San Felipe to Albuquerque and did not increase between stations during the irrigation/monsoon season. The Rio Chama provided an increase in alkalinity to the Rio Grande only during the fall/winter baseflow season, and alkalinity in the Rio Chama was less than that in streamflow at the Taos station during the snowmelt runoff and irrigation/monsoon seasons. Alkalinity increased from the Otowi to San Felipe station during the fall/winter baseflow and snowmelt runoff seasons, but an increase is not as apparent during the irrigation/monsoon season.

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Table 7. Maximum dissolved radionuclide concentrations detected in the Rio Chama and Rio Grande during water years 1985 to 2002 and applicable drinking-water standards.

[pCi/L, picocuries per liter; µg/L, micrograms per liter; NA, none available]

Constituent	Unit	Taos	Chamita	Otowi	San Felipe	Albuquerque	Drinking-water standard ¹
Alpha particles	pCi/L	NA	NA	3.4	NA	NA	15
Radium-226	pCi/L	0.05	NA	0.67	0.57	0.37	² 5
Uranium	µg/L	3.0	4.48	4.90	3.64	3.6	30

¹Drinking-water standard maximum contaminant levels as issued by the U.S. Environmental Protection Agency for National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2004).

²Standard is for radium-226 and radium-228 combined.

Table 8. Percentage of anthropogenic compounds detected in samples collected from the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita during water years 1985 to 2002.

	Taos	Chamita	Otowi	San Felipe	Albuquerque
Total compounds analyzed	166	600	343	60	115
Percentage of compounds detected	0.6	0.5	1.5	1.7	1.7

Table 9. Anthropogenic compounds detected in samples from the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita during water years 1985 to 2002 and associated drinking-water standards.

[recoverable, compounds were partitioned from water sample by C-18 solid phase extraction cartridge; month of detection, month when sample was collected for each detection; total, unfiltered sample; dissolved, filtered sample; µg/L, micrograms per liter; ----, no detections; NA, not established; E, estimated value less than the laboratory reporting level]

Note: all detections are single detections that were produced from one sample

Compound, recoverable	Unit	Month of detection	Taos	Chamita	Otowi	San Felipe	Albuquerque	Drinking-water standard ¹
2,4-D, total	µg/L	March, March	----	----	----	0.01	0.01	70
Atrazine, dissolved	µg/L	July	----	E 0.003	----	----	----	3
DCPA, dissolved	µg/L	July	----	E 0.003	----	----	----	NA
Diazinon, dissolved	µg/L	May	----	----	0.008	----	----	NA
Diazinon, total	µg/L	September	----	----	----	----	0.01	NA
EPTC, dissolved	µg/L	June	----	----	0.004	----	----	NA
Malathion, dissolved	µg/L	July	----	----	0.007	----	----	NA
p,p'-ethyl-DDD, total	µg/L	September	0.1	----	----	----	----	NA
Simazine, dissolved	µg/L	July	----	----	E 0.003	----	----	4
Tebuthiuron, dissolved	µg/L	July, April	----	E 0.01	0.01	----	----	NA

¹Drinking-water standard maximum contaminant levels as issued by the U.S. Environmental Protection Agency for National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2004).

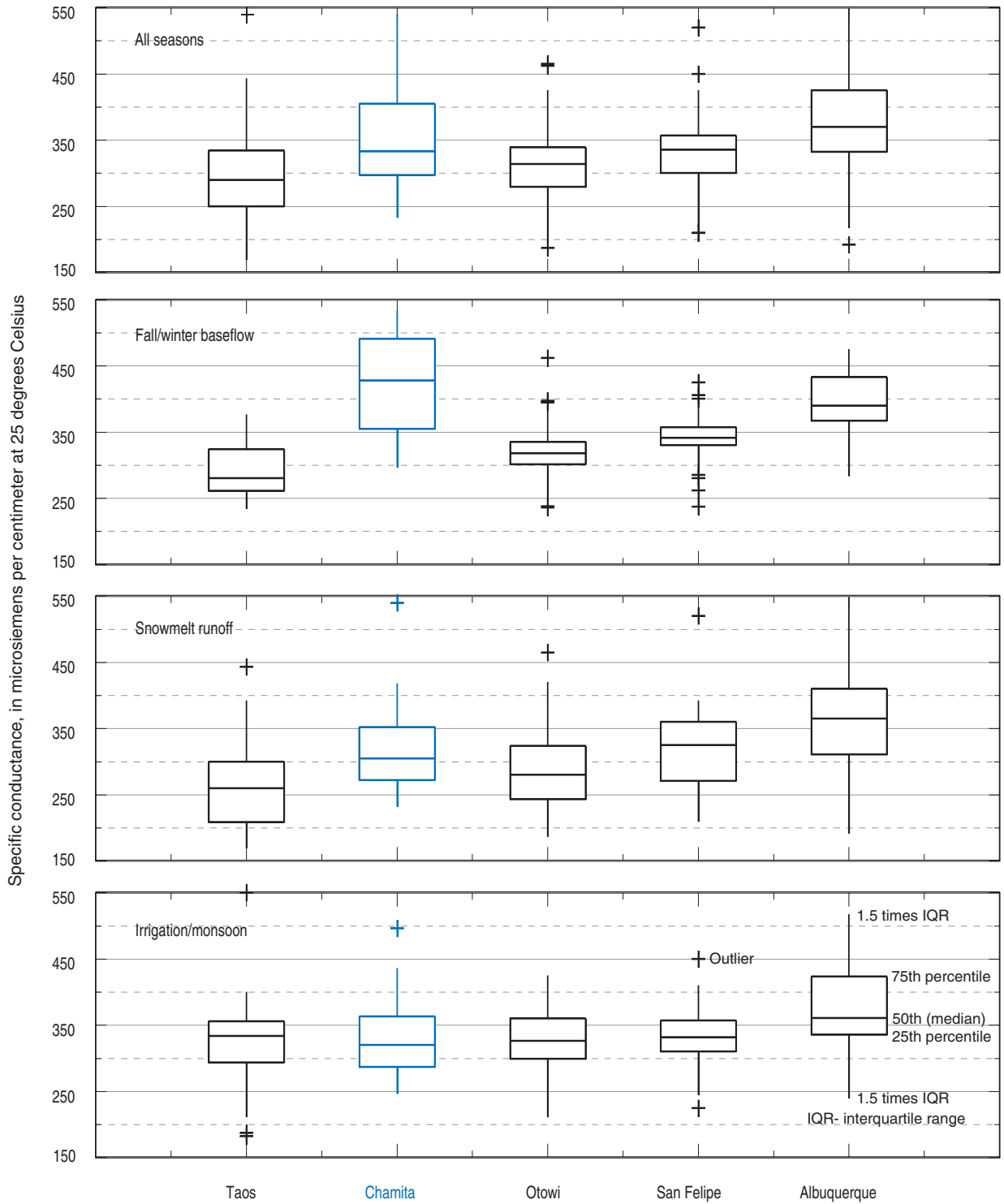


Figure 6. Specific conductance during seasonal periods for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

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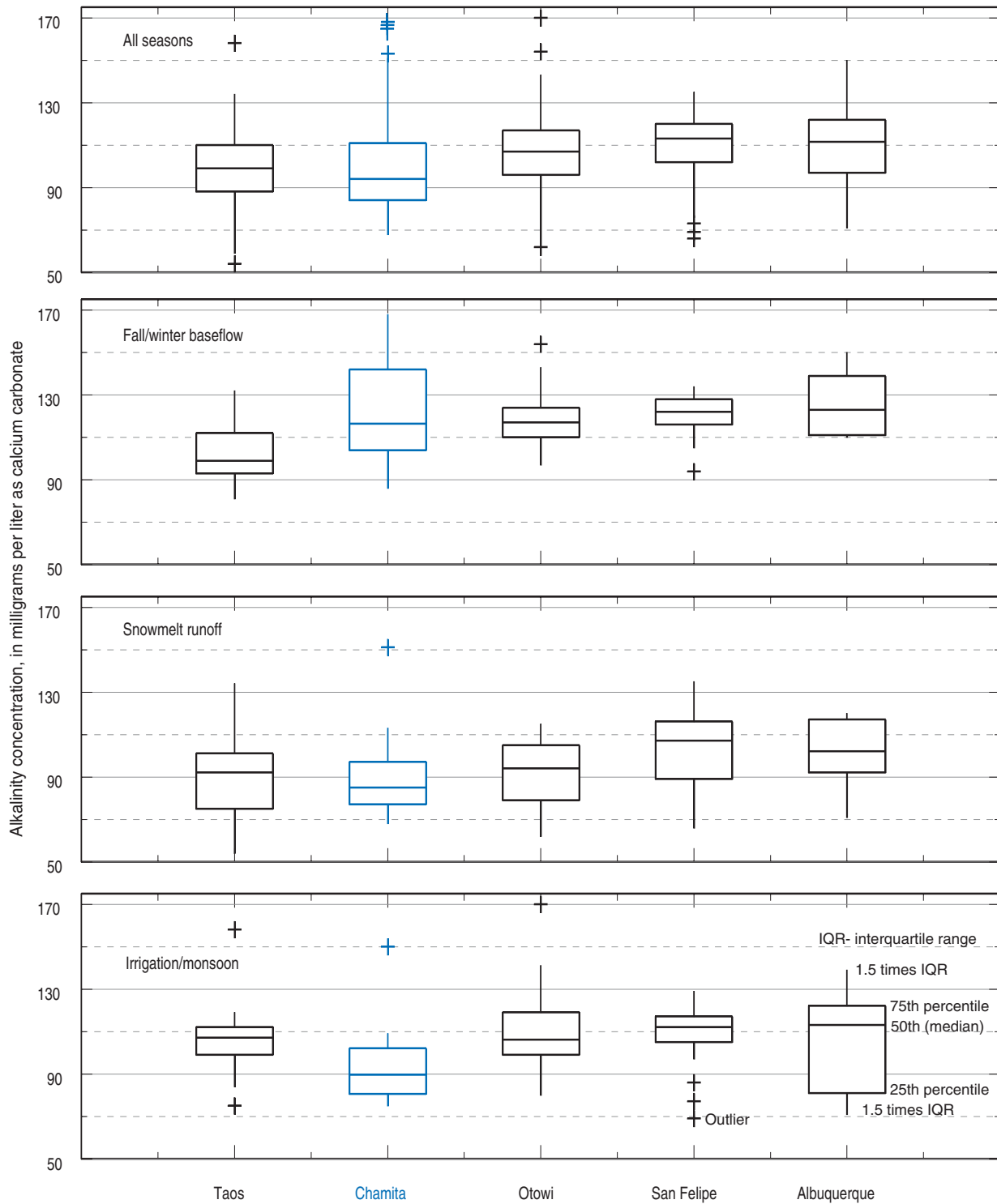


Figure 7. Alkalinity concentrations during seasonal periods for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

For all sites except Taos, alkalinity concentrations typically were largest during the fall/winter baseflow season (fig. 7). Because ground-water inflows likely provide a larger percentage of total streamflow during the fall/winter baseflow, these inflows influenced alkalinity in the Rio Chama and Rio Grande. Ground-water inflows were diluted during snowmelt runoff because of large surface-water inflows, which resulted in decreased alkalinity at each site during this season. During the irrigation/monsoon season, the effect on alkalinity from the release of stored snowmelt runoff from the reservoirs is apparent because alkalinity at Chamita, Otowi, and San Felipe was more similar to concentrations during the snowmelt runoff season than to concentrations during the fall/winter baseflow season.

During the snowmelt runoff and irrigation/monsoon seasons, Rio Chama inflow decreased pH in the Rio Grande (fig. 8). During the fall/winter baseflow season, pH in the Rio Chama was similar to or larger than pH in the Rio Grande and no change occurred between the Taos and Otowi sites. During the fall/winter baseflow and snowmelt runoff seasons, pH values in the Rio Grande at the Otowi and San Felipe stations were similar, but during the irrigation/monsoon season, pH decreased from Otowi to San Felipe, likely a result of releases from Cochiti Lake.

From San Felipe to Albuquerque, pH decreased during each season. Rio Grande pH did not decrease as a result of Jemez River inflow because the median pH at the USGS Jemez River below Jemez Canyon Dam station (08329000) during the study period was 8.2 (range of 7.5 to 9.1). A decrease in pH due to ground-water inflows also is unlikely because Plummer and others (2004) found evidence that ground water in this reach is highly influenced by water infiltrating from the Rio Grande. The decrease in pH may be a result of irrigation and drain return flow that is composed of shallow ground water captured by canals and drains along the river and returned to the river throughout the year.

Major Ions

The calcium bicarbonate water type for streamflow at all stations did not change between seasons, although major ion concentrations did vary from site to site and among seasons (fig. 9). Median concentrations that varied the most among sites were calcium and sulfate during the fall/winter baseflow and snowmelt runoff seasons, and sodium and bicarbonate during the irrigation monsoon season. The shift in variability of median concentrations was a result of similar concentrations at the Chamita site during the snowmelt runoff and irrigation/monsoon seasons. If median ion concentrations at the Chamita site are not considered, calcium, sodium, and bicarbonate were the most variable ions during the irrigation/monsoon season.

Median major ion concentrations at the Chamita station were similar to Rio Grande concentrations during the fall/winter baseflow and snowmelt runoff seasons (fig. 9). During the irrigation/monsoon season, median concentrations at the Rio Grande stations increased compared with snowmelt runoff concentrations, but median concentrations at the Chamita station

did not increase. The snowmelt runoff that was retained in Rio Chama reservoirs was released during the irrigation/monsoon season, and median concentrations at the Chamita station were similar during both seasons.

During the fall/winter baseflow season, median major ion concentrations were smallest at the Taos station and increased in the downstream direction due to Rio Chama inflow and other influences (fig. 9). During the snowmelt runoff season, Rio Chama inflow diluted sodium and chloride concentrations in the Rio Grande, resulting in smaller median concentrations at the Otowi station than those at the Taos station. During the irrigation/monsoon season, reservoir releases from Abiquiu Reservoir on the Rio Chama and from Cochiti Lake on the Rio Grande diluted ion concentrations, resulting in smaller magnesium, sodium, and chloride concentrations at the Otowi and San Felipe stations compared with those at the Taos station.

During all seasons, median major ion concentrations were the most stable at the Albuquerque station (fig. 9). Median concentrations at Albuquerque did not correspond to seasonal changes in concentrations at the San Felipe station. Plummer and others (2004) described ranges of major ion concentrations in ground water between San Felipe and Albuquerque near the river that were larger than those at the San Felipe and Albuquerque stations, but other geochemical data indicate that the Rio Grande primarily loses water to the aquifer through this reach. Likely a combination of factors such as ET, the Jemez River and other surface-water inflows, and irrigation return flows variably affect the Rio Grande throughout the year and result in similar major ion concentrations at the Albuquerque station during all seasons.

Nutrients, Organic Carbon, and Bacteria

Analysis of seasonal trends of nitrogen and phosphorous forms was not feasible because of small concentrations and the large number of samples with censored values. TOC and fecal streptococci provided sufficient data, however, for examination of seasonal trends in the Rio Chama and Rio Grande. For both constituents, concentrations were smallest during the fall/winter baseflow, increased during the snowmelt runoff, and were largest typically during the snowmelt runoff or irrigation/monsoon season (fig. 10). The Rio Chama appears to increase fecal streptococci, and Cochiti Lake likely decreases fecal streptococci in the Rio Grande.

Trace Elements

Of the trace elements that exceeded drinking-water standards (aluminum, iron, and manganese), only manganese indicates a seasonal pattern. Manganese concentrations decreased during the snowmelt runoff season, began to increase during the irrigation/monsoon season, and were largest during the fall/winter baseflow season (fig. 11). This pattern indicates that manganese concentrations in the Rio Grande were diluted during spring runoff and were influenced by ground-water inflows.

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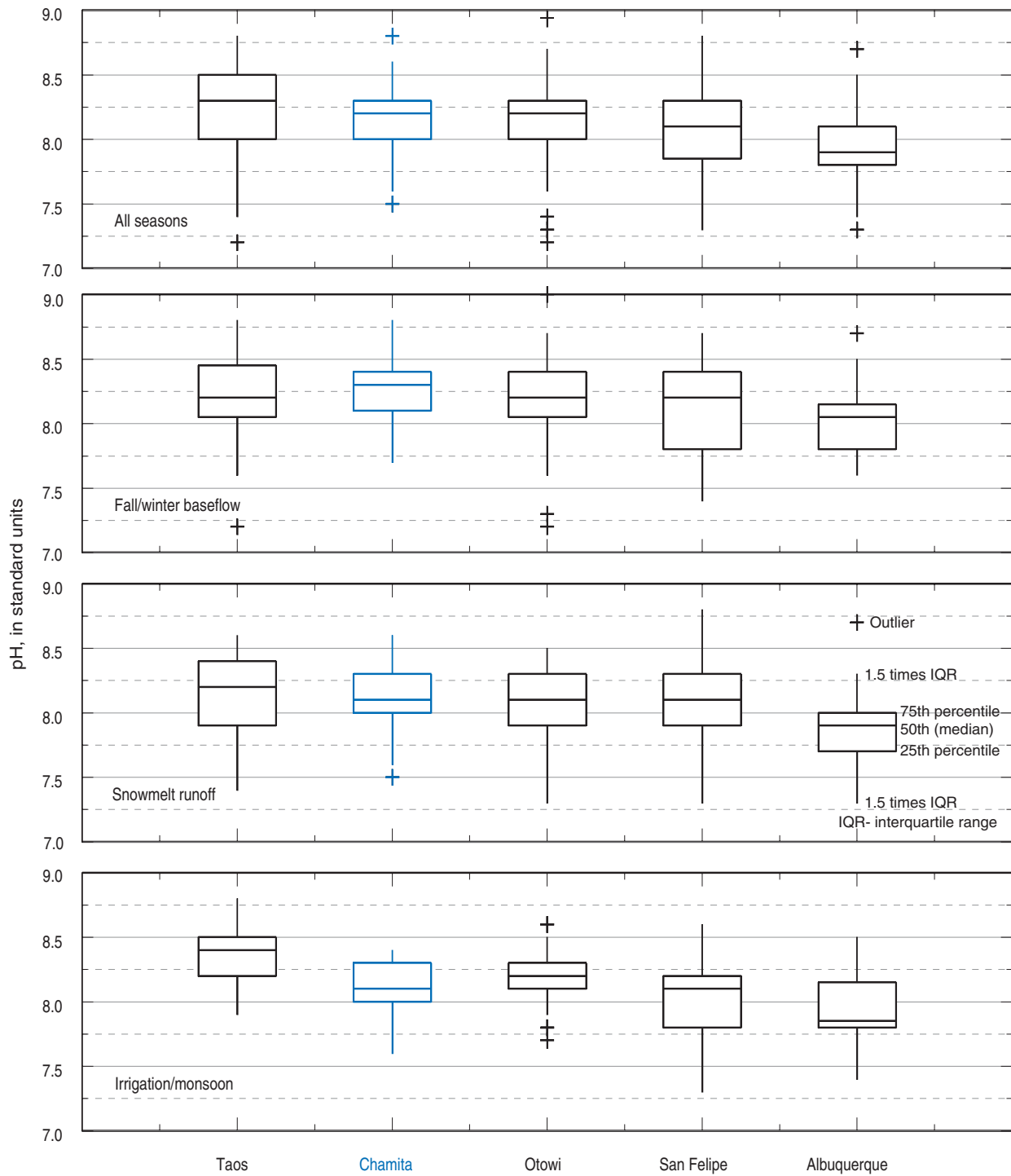


Figure 8. Seasonal period pH for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

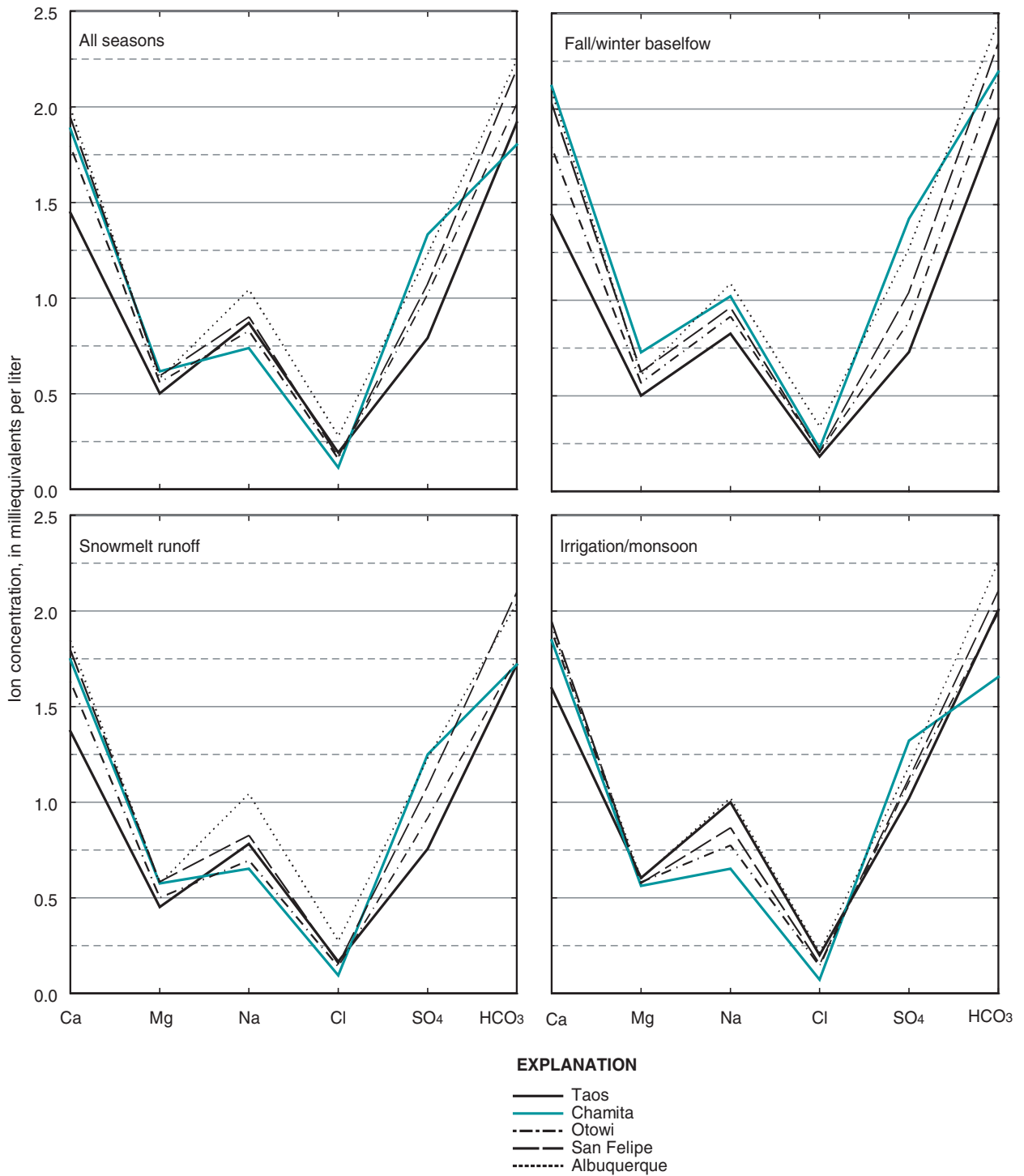


Figure 9 Median ion concentrations during seasonal periods for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

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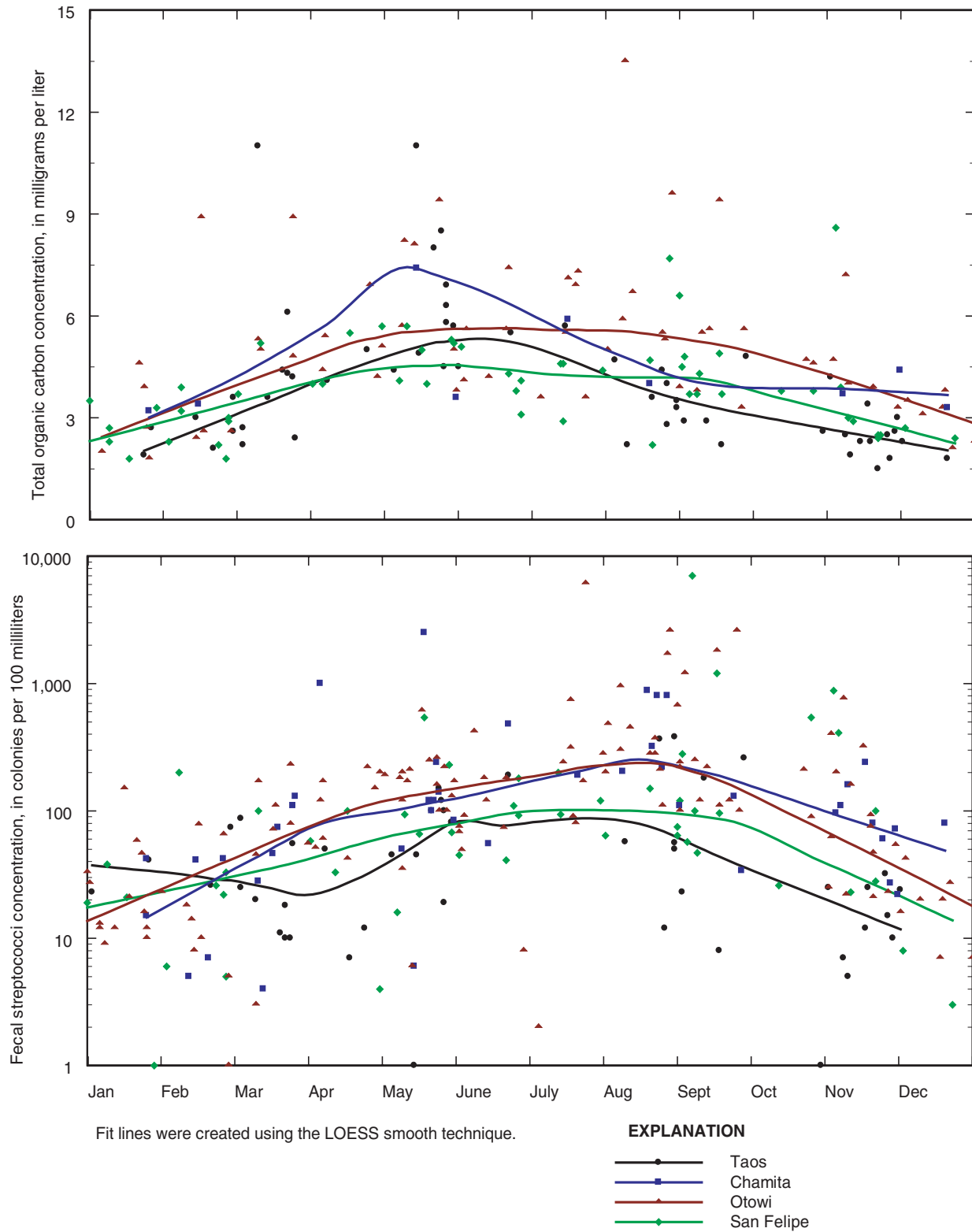


Figure 10. Seasonal trend of total organic carbon and fecal streptococci for the Rio Grande stations of Taos, Otowi, and San Felipe and the Rio Chama station of Chamita, water years 1985 to 2002.

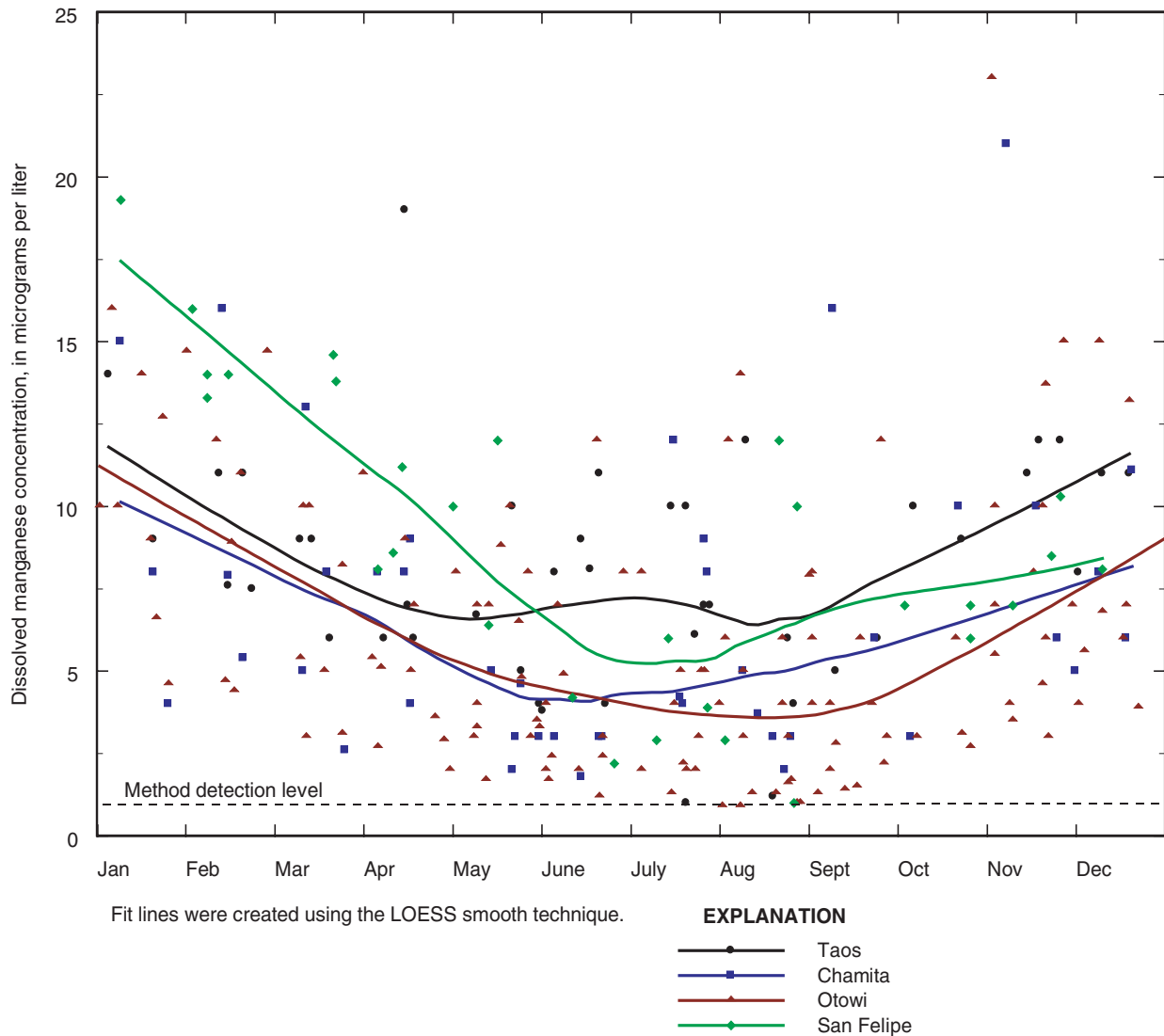


Figure 11. Seasonal trend of manganese concentrations for the Rio Grande stations of Taos, Otowi, and San Felipe and the Rio Chama station of Chamita, water years 1985 to 2002.

Radionuclides

Uranium is a relatively soluble radionuclide in its highly oxidized form (U^{6+}) and is generally present in natural waters ranging from 0.1 to 10 $\mu\text{g/L}$ (Hem, 1989). A seasonal trend plot of uranium indicates that concentrations fluctuate seasonally (fig. 12). Similar to manganese, uranium concentrations in the Rio Grande decreased with snowmelt runoff, then increased during the irrigation/monsoon season. The largest concentrations were detected during the winter months when streamflow was smallest and ground-water inflows were largest. Uranium concentrations at Otowi and San Felipe were similar, but the range of those at San Felipe was smaller, possibly due to sediment deposition or mixing in Cochiti Lake.

Water-Quality Temporal Trends

Temporal trend analysis was used to detect statistically significant increases or decreases in flow-adjusted concentrations during the study period (study period trends) and during individual seasons (seasonal trends) at each station. Samples for analysis of specific conductance, dissolved oxygen, pH, calcium, magnesium, sodium, sulfate, and chloride were of sufficient number and seasonal representation for analysis of study period trends and seasonal trends (table 10).

Study period trends were not significant for specific conductance, dissolved oxygen, and pH. Seasonal trends of these constituents were evident at certain stations during specific seasons (table 10), but there was no consistent pattern in seasonal

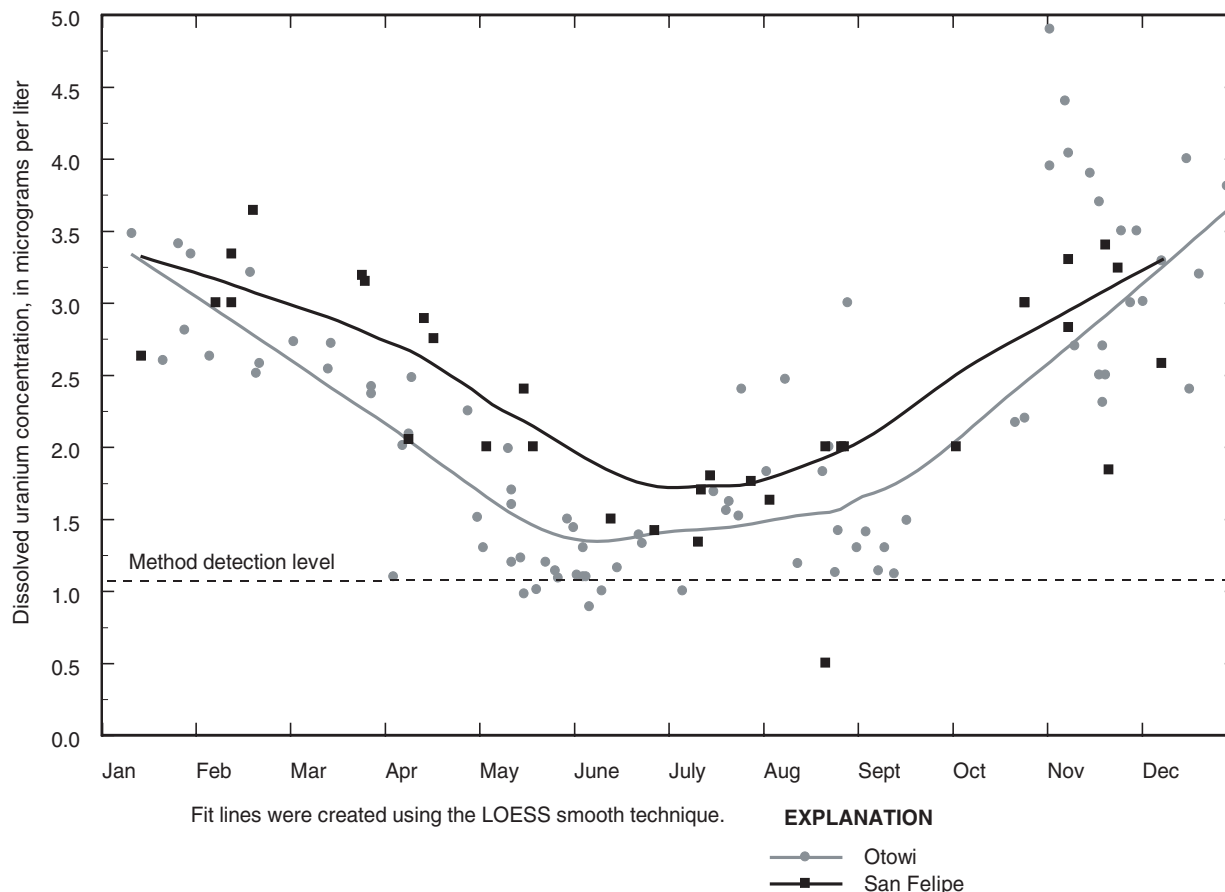


Figure 12. Seasonal trend of dissolved uranium concentrations for the Rio Grande stations of Otowi and San Felipe, water years 1985 to 2002.

trends among stations. Only at the San Felipe station were seasonal trends not detected for these constituents, likely an effect of Cochiti Lake. Langman and Anderholm (2004) determined that Cochiti Lake has a moderating effect on specific conductance between Otowi and San Felipe because of the retention and later release of snowmelt runoff from the reservoir.

Significant decreases in calcium, magnesium, sodium, sulfate, and chloride concentrations were detected for the study period and during most seasons at each station (table 10). Decreasing trends and similar trend magnitudes (Kendall's tau) for major ion concentrations at Taos and Otowi indicate that water-quality influences upstream from the study area and (or) the downward trend in annual precipitation (table 2) strongly affected major ion concentrations and were likely the main reason(s) for the downward trends in the study area.

The lack of major ion study period trends at the San Felipe station compared with the other stations indicates that the effect of either Cochiti Lake or ground-water inflows were masking the downward trend at the Taos and Otowi stations. Seasonal trends (decreases) at the San Felipe station were detected only for calcium, sodium, and sulfate concentrations during the fall/winter baseflow season. Ground-water inflows during the fall/

winter baseflow season likely diminished during the study period because of the downward trend in annual precipitation (table 2). Storage and mixing in Cochiti Lake likely minimized major ion concentration-trend decreases during the other two seasonal periods.

The stations most affected by reservoirs, Chamita and San Felipe, were the only ones at which downward trends in major ions were apparent for flow-adjusted concentrations (Mann-Kendall test) during the study period but not for flow-adjusted concentrations with seasonal correlation (Seasonal Kendall test) (table 10). Study period trends without seasonal correlation indicate that flow-adjusted concentrations at the Chamita and San Felipe stations were more similar among seasons than concentrations among seasons at the other stations. Although study period trends were still apparent at these stations, seasonal differences were reduced due to mixing of seasonal inflows and retained reservoir water.

Using multiple trend methods (linear regression, Mann-Kendall test, and Seasonal Kendall test), Passell and others (2004) described upward trends in calcium, sodium, magnesium, bicarbonate, and chloride at the Taos station for data collected from 1975 to 1999. The same study described downward

Table 10. Results of Seasonal Kendall test (study period) and Mann-Kendall test (seasonal period) for temporal trend analysis of flow-adjusted concentrations for the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

[Constituent presents results of Seasonal Kendall test for all seasons during the study period (study period trend), and subsequent seasons (italics) present the results of the Mann-Kendall test for each season (seasonal trend); p-value significant if less than or equal to 0.10; tau, Kendall's tau; ----, no descriptor or value shown because no significant trend; fall/winter baseflow, November through February; snowmelt runoff, March through June; irrigation/monsoon, July through October; NA, not available; <, less than]

Constituent and seasonal period	Taos			Chamita ¹			Otowi			San Felipe			Albuquerque		
	p-value	trend	tau	p-value	trend	tau	p-value	trend	tau	p-value	trend	tau	p-value	trend	tau
Specific conductance	0.460	----	----	0.838	----	----	0.522	----	----	0.646	----	----	0.947	----	----
<i>Fall/winter baseflow</i>	<i>0.235</i>	----	----	<i>0.418</i>	----	----	<i>0.357</i>	----	----	<i>0.185</i>	----	----	<i>0.219</i>	----	----
<i>Snowmelt runoff</i>	<i>0.809</i>	----	----	<i>0.158</i>	----	----	<i>0.099</i>	Downward	-0.145	<i>0.386</i>	----	----	<i>0.099</i>	Downward	-0.195
<i>Irrigation/monsoon</i>	<i>0.092</i>	Downward	-0.210	<i>0.005</i>	Upward	0.302	<i>0.045</i>	Downward	-0.179	<i>0.407</i>	----	----	<i>0.713</i>	----	----
Dissolved oxygen	0.276	----	----	0.543	----	----	0.516	----	----	0.648	----	----	0.513	----	----
<i>Fall/winter baseflow</i>	<i>0.859</i>	----	----	<i>0.003</i>	Downward	-0.342	<i>0.385</i>	----	----	<i>0.919</i>	----	----	<i>0.034</i>	Upward	0.325
<i>Snowmelt runoff</i>	<i>0.048</i>	Downward	-0.227	<i>0.197</i>	----	----	<i>0.001</i>	Downward	-0.304	<i>0.778</i>	----	----	<i>0.066</i>	Downward	-0.246
<i>Irrigation/monsoon</i>	<i>0.897</i>	----	----	<i>0.241</i>	----	----	<i>0.059</i>	Upward	0.177	<i>0.653</i>	----	----	<i>0.709</i>	----	----
pH	0.394	----	----	0.370	----	----	0.357	----	----	0.268	----	----	0.234	----	----
<i>Fall/winter baseflow</i>	<i>0.797</i>	----	----	<i>0.034</i>	Downward	-0.243	<i>0.925</i>	----	----	<i>0.144</i>	----	----	<i>0.197</i>	----	----
<i>Snowmelt runoff</i>	<i>0.773</i>	----	----	<i>0.459</i>	----	----	<i>0.334</i>	----	----	<i>0.241</i>	----	----	<i>0.008</i>	Downward	-0.357
<i>Irrigation/monsoon</i>	<i>0.897</i>	----	----	<i>0.179</i>	----	----	<i>0.065</i>	Downward	-0.171	<i>0.496</i>	----	----	<i>0.002</i>	Downward	-0.423
Calcium	0.047	Downward	-0.296	0.256	----	----	0.013	Downward	-0.291	0.053	Downward	-0.261	NA	NA	NA
<i>Fall/winter baseflow</i>	<i>0.023</i>	Downward	-0.323	<i>0.059</i>	Downward	-0.290	<i>0.682</i>	----	----	<i>0.032</i>	Downward	-0.347	NA	NA	NA
<i>Snowmelt runoff</i>	<i>0.050</i>	Downward	-0.229	<i>0.032</i>	Downward	-0.293	<i>0.004</i>	Downward	-0.348	<i>0.177</i>	----	----	NA	NA	NA
<i>Irrigation/monsoon</i>	<i>0.006</i>	Downward	-0.365	<i>0.173</i>	----	----	<i><0.001</i>	Downward	-0.429	<i>0.304</i>	----	----	NA	NA	NA
Magnesium	0.040	Downward	-0.289	² 0.050	Downward	-0.243	0.059	Downward	-0.235	0.573	----	----	NA	NA	NA
<i>Fall/winter baseflow</i>	<i>0.021</i>	Downward	-0.330	<i>0.052</i>	Downward	-0.299	<i>0.018</i>	Downward	-0.247	<i>0.218</i>	----	----	NA	NA	NA
<i>Snowmelt runoff</i>	<i>0.191</i>	----	----	<i>0.003</i>	Downward	-0.407	<i>0.021</i>	Downward	-0.235	<i>0.311</i>	----	----	NA	NA	NA
<i>Irrigation/monsoon</i>	<i>0.063</i>	Downward	-0.249	<i>0.052</i>	Downward	-0.316	<i>0.001</i>	Downward	-0.311	<i>0.926</i>	----	----	NA	NA	NA
Sodium	0.042	Downward	-0.223	0.148	----	----	0.052	Downward	-0.214	² 0.057	Downward	-0.212	NA	NA	NA
<i>Fall/winter baseflow</i>	<i>0.050</i>	Downward	-0.280	<i>0.150</i>	----	----	<i>0.479</i>	----	----	<i>0.080</i>	Downward	-0.284	NA	NA	NA
<i>Snowmelt runoff</i>	<i>0.182</i>	---	---	<i>0.204</i>	----	----	<i>0.010</i>	Downward	-0.262	<i>0.388</i>	----	----	NA	NA	NA
<i>Irrigation/monsoon</i>	<i>0.144</i>	---	---	<i>0.060</i>	Downward	-0.305	<i><0.001</i>	Downward	-0.393	<i>0.102</i>	----	----	NA	NA	NA
Sulfate	0.024	Downward	-0.282	² 0.050	Downward	-0.243	0.021	Downward	-0.268	² 0.073	Downward	-0.200	NA	NA	NA
<i>Fall/winter baseflow</i>	<i>0.020</i>	Downward	-0.333	<i>0.034</i>	Downward	-0.325	<i>0.045</i>	Downward	-0.209	<i>0.080</i>	Downward	-0.284	NA	NA	NA
<i>Snowmelt runoff</i>	<i>0.097</i>	Downward	-0.194	<i>0.017</i>	Downward	-0.328	<i>0.114</i>	----	----	<i>0.368</i>	----	----	NA	NA	NA
<i>Irrigation/monsoon</i>	<i>0.006</i>	Downward	-0.365	<i>0.069</i>	Downward	-0.295	<i>0.503</i>	----	----	<i>0.607</i>	----	----	NA	NA	NA
Chloride	0.017	Downward	-0.243	0.354	----	----	0.581	----	----	0.101	----	----	NA	NA	NA
<i>Fall/winter baseflow</i>	<i>0.191</i>	----	----	<i>0.382</i>	----	----	<i>0.430</i>	----	----	<i>0.218</i>	----	----	NA	NA	NA
<i>Snowmelt runoff</i>	<i>0.091</i>	Downward	-0.200	<i>0.466</i>	----	----	<i>0.012</i>	Downward	-0.256	<i>0.708</i>	----	----	NA	NA	NA
<i>Irrigation/monsoon</i>	<i>0.114</i>	----	----	<i>0.153</i>	----	----	<i>0.002</i>	Downward	-0.306	<i>0.510</i>	----	----	NA	NA	NA

¹Because of a limited number of data points during water years 1985 and 1986, the number of years for trend analysis of Chamita data was shortened to water years 1986 to 2002 for specific conductance and water years 1987 to 2002 for all other constituents.

²This constituent indicated a trend in flow-adjusted concentrations without seasonal correlation. The values presented for this constituent are uncorrected for seasonal correlation and represent the results of the Mann-Kendall test for the study period.

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trends in calcium, potassium, bicarbonate, and sulfate concentrations and upward trends in chloride and fluoride concentrations at the Otowi station and upward trends in calcium, potassium, bicarbonate, and sulfate concentrations at the San Felipe station. From 1975 to 1999, the Taos, Otowi, and San Felipe stations had an upward trend in streamflow (Passell and others, 2004). Given these trends and the differing trends detected during this study, precipitation conditions appear to strongly influence major ion concentrations in the Rio Grande. For this study, this effect was particularly apparent during the fall/winter baseflow season when ground-water inflows were the most dominant and likely diminished during the study period because of the downward trend in annual precipitation, which appears to have resulted in downward trends of most major ion concentrations.

Summary

The City of Albuquerque is planning to divert SJC Project water from the Rio Grande for potable water use. The Rio Grande is a fully appropriated river and operation of the reservoirs on the river and its tributaries has undergone various changes because of water users' needs, climate variations, and coordination of reservoir operations. This report examines streamflow and water-quality trends in the Rio Chama and the Rio Grande for water years 1985 to 2002 following the implementation of reservoir storage agreements in northern and central New Mexico. Storage agreements for northern and central New Mexico reservoirs were implemented in the mid-1980's and incorporated into the historical legislative directives that govern water management in the study area. Data for the streamflow/water-quality stations of Taos, Otowi, San Felipe, and Albuquerque on the Rio Grande and the Rio Chama station of Chamita were used for trend analysis. Water-quality constituents were separated into six groups for analysis: basic water chemistry and physical properties; major ions; nutrients, organic carbon, and bacteria; trace elements; radionuclides; and anthropogenic compounds.

Streamflow in the Rio Chama and Rio Grande were divided into three distinct seasonal periods that correspond to natural and anthropogenic influences: fall/winter baseflow (November through February), snowmelt runoff (March through June), and the irrigation/monsoon (July through October) seasons. Water years 1985 to 2002 were a period of larger than average annual precipitation and streamflow compared to the stations' periods of record. Downward trends in precipitation and streamflow during the study period reflect the drought during 1999 to 2002. The SJC Project and release of stored snowmelt runoff from the study area during the irrigation season resulted in an upward trend in streamflow during this season compared with downward trends during the remaining seasons.

Water-quality spatial trends indicated a downstream increase in specific conductance, and Rio Chama inflow contributed to this increase. Alkalinity and pH did not substantially change in the downstream direction. Streamflow at all stations

was of a calcium bicarbonate water type. Nearly all nitrogen and phosphorous concentrations were less than 2 mg/L for all stations. Median trace-element concentrations and maximum radionuclide concentrations did not exceed drinking-water standards. Anthropogenic compounds were rarely detected, and concentrations did not exceed 0.1 µg/L or drinking-water standards.

Analysis of seasonal differences indicated that water quality in the Rio Chama and Rio Grande varied temporally and spatially during the study period. Specific conductance increased downstream in the Rio Grande during the fall/winter baseflow and snowmelt runoff seasons, but was similar at the Taos, Otowi, and San Felipe stations during the irrigation/monsoon season. This similarity was a result of the release of stored water from Abiquiu Reservoir and Cochiti Lake, which masked the natural influences that increased specific conductance in the downstream direction during the other seasons. During all seasons, pH decreased and major ion concentrations remained stable at the Albuquerque station compared with the San Felipe station. Seasonal trends of TOC and fecal streptococci indicated smallest concentrations during the fall/winter baseflow season, increased concentrations during the snowmelt runoff season, and largest concentrations during the snowmelt runoff or irrigation/monsoon season. Manganese and uranium concentrations were largest during the fall/winter baseflow season and smallest during the snowmelt runoff season, indicating that ground-water inflows influenced concentrations.

Water-quality temporal trends were evaluated for selected constituents during the study period and during the individual seasons. Although study period trends were not apparent for specific conductance, dissolved oxygen, and pH, seasonal trends of these constituents were evident at certain stations during certain seasons. Major ion concentrations decreased during the study period and during most individual seasons. Downward trends in major ions were similar in magnitude at the Taos and Otowi stations, indicating that an upstream influence and (or) the downward trend in annual precipitation was likely the main reason(s) for these decreases. The stations most affected by reservoirs, Chamita and San Felipe, were the only ones at which downward trends in major ions were apparent for flow-adjusted concentrations but not for seasonally correlated flow-adjusted concentrations, which indicated fewer seasonal differences at these stations due to reservoir operations.

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Supplemental Information:

Summary Statistics and Listing of Analyzed Anthropogenic Compounds

30 Trends of the Rio Chama and Rio Grande, Water Years 1985 to 2002

Table I-1. Summary statistics of selected water-quality constituents for Rio Grande below Taos Junction Bridge, water years 1985 to 2002.

[$\mu\text{S/cm}$, microsiemens per centimeter at 25 degrees Celsius (deg C); mg/L, milligrams per liter; diss., dissolved; <, less than; mL, milliliters; $\mu\text{g/L}$, micrograms per liter]

Summary statistics	Mini- mum	25th percentile	Median	75th percentile	Maxi- mum	Number of samples	Percentage censored values
Basic water chemistry and physical properties:							
Specific conductance, field ($\mu\text{S/cm}$)	170	251	290	334	550	95	0
Alkalinity, total, titration to 4.5, lab (mg/L as CaCO_3)	54	88	99	110	158	88	1
pH, total, field (standard units)	7.2	8.0	8.3	8.5	8.8	98	0
Oxygen, diss. (mg/L)	6.8	8.4	9.4	10.4	18.0	97	0
Chemical oxygen demand, total (mg/L)	<10	<10	12	20	40	48	25
Total dissolved solids, 180 deg C (mg/L)	128	164	196	219	257	32	0
Major ions:							
Calcium, diss. (mg/L as Ca)	18.0	26.0	29.0	33.0	41.0	89	0
Magnesium, diss. (mg/L as Mg)	3.60	5.40	6.10	7.30	9.20	89	0
Potassium, diss. (mg/L as K)	1.80	2.80	3.10	3.50	8.00	89	0
Sodium, diss. (mg/L as Na)	8.5	16.6	20.0	25.0	72.0	89	0
Bicarbonate, field, diss. (mg/L as HCO_3)	55.0	101.5	117.0	125.5	166.0	75	0
Chloride, diss. (mg/L as Cl)	2.60	5.36	6.80	8.10	26.00	89	0
Fluoride, diss. (mg/L as F)	<0.10	0.40	0.50	0.70	1.40	89	1
Sulfate, diss. (mg/L as SO_4)	17.5	32.0	38.0	48.0	92.0	89	0
Silica, diss. (mg/L as SiO_2)	15.0	22.0	25.0	27.0	33.6	89	0
Nutrients, organic carbon, and bacteria:							
Nitrogen, ammonia + organic, diss. (mg/L as N)	<0.20	<0.20	<0.20	<0.20	0.38	58	76
Nitrogen, ammonia + organic, total (mg/L as N)	<0.20	0.20	0.36	0.50	1.00	92	24
Nitrogen, ammonia, diss. (mg/L as N)	<0.01	<0.01	0.01	0.02	0.04	67	43
Nitrogen, ammonia, total (mg/L as N)	<0.01	0.02	0.03	0.05	0.13	52	10
Nitrogen, $\text{NO}_2 + \text{NO}_3$, diss. (mg/L as N)	<0.05	0.10	0.18	0.27	1.90	93	10
Nitrogen, $\text{NO}_2 + \text{NO}_3$, total (mg/L as N)	<0.10	0.10	0.20	0.30	0.50	35	11
Phosphorus, diss. (mg/L as P)	<0.01	<0.01	0.02	0.03	0.19	58	36
Orthophosphate, diss. (mg/L as P)	<0.01	0.02	0.03	0.03	0.10	92	15
Phosphorus, total (mg/L as P)	<0.01	0.04	0.06	0.09	0.25	93	5
Organic carbon, total (mg/L as C)	1.5	2.5	3.6	4.7	11.0	56	0
Fecal coliform, 0.7 micron (colonies/100 mL)	1	7	22	84	340	44	7
Fecal streptococci, 0.7 micron (colonies/100 mL)	1	12	25	74	380	45	2
Trace elements¹:							
Aluminum, diss. ($\mu\text{g/L}$ as Al)	3	9	13	27	88	12	0
Arsenic, diss. ($\mu\text{g/L}$ as As)	<1	2	2	2	4	33	3
Arsenic, total ($\mu\text{g/L}$ as As)	<1	2	2	2	4	19	5
Barium, diss. ($\mu\text{g/L}$ as Ba)	23	26	28	34	37	13	0
Boron, diss. ($\mu\text{g/L}$ as B)	20	30	40	50	90	60	0
Chromium, diss. ($\mu\text{g/L}$ as Cr)	<1	<1	1	1	30	33	48
Copper, diss. ($\mu\text{g/L}$ as Cu)	<1	1.1	2.0	2.0	7.0	32	9
Iron, diss. ($\mu\text{g/L}$ as Fe)	<10	10	19	36	620	90	4
Manganese, diss. ($\mu\text{g/L}$ as Mn)	1	6	8.1	11	52	45	0
Molybdenum, diss. ($\mu\text{g/L}$ as Mo)	<1	4	6	9	89	48	2
Nickel, diss. ($\mu\text{g/L}$ as Ni)	<1.0	<1.0	1.0	2.0	2.1	13	46
Zinc, diss. ($\mu\text{g/L}$ as Zn)	<10	<10	<10	<10	46	34	79
Uranium (natural), diss. ($\mu\text{g/L}$ as U)	1.0	1.7	2.1	2.6	3.0	16	0

¹Each data set for antimony, beryllium, cadmium, cobalt, lead, mercury (dissolved and total), selenium, and silver contained less than nine samples greater than method detection level.

Table I-2. Summary statistics of selected water-quality constituents for Rio Chama near Chamita, water years 1985 to 2002.

[$\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius (deg C); mg/L, milligrams per liter; diss., dissolved; <, less than; mL, milliliters; $\mu\text{g}/\text{L}$, micrograms per liter]

Summary statistics	Mini- mum	25th percentile	Median	75th percentile	Maxi- mum	Number of samples	Percentage censored values
Basic water chemistry and physical properties:							
Specific conductance, lab ($\mu\text{S}/\text{cm}$)	233	297	333	398	540	119	0
Alkalinity, total, titration to 4.5, lab (mg/L as CaCO_3)	68	84	94	111	168	69	0
pH, total, field (standard units)	7.5	8.0	8.2	8.3	8.8	117	0
Oxygen, diss. (mg/L)	7	8.25	9.4	10.8	14.8	115	0
Chemical oxygen demand, total (mg/L)	NA	NA	NA	NA	NA	6	50
Total dissolved solids, 180 deg C (mg/L)	152	167	189	222	256	31	0
Major ions:							
Calcium, diss. (mg/L as Ca)	26.0	33.0	37.8	43.0	61.0	69	0
Magnesium, diss. (mg/L as Mg)	5.30	6.74	7.50	9.40	14.00	69	0
Potassium, diss. (mg/L as K)	1.30	1.80	2.00	2.40	3.60	68	0
Sodium, diss. (mg/L as Na)	10.0	13.4	17.0	22.0	45.0	69	0
Bicarbonate, field, diss. (mg/L as HCO_3)	75	98	110	133	206	64	0
Chloride, diss. (mg/L as Cl)	<0.10	2.60	4.04	7.00	50.00	69	1
Fluoride, diss. (mg/L as F)	<0.10	0.20	0.20	0.30	0.50	68	1
Sulfate, diss. (mg/L as SO_4)	41.0	54.0	65.0	82.0	110.0	69	0
Silica, diss. (mg/L as SiO_2)	12.0	13.7	14.0	16.0	21.0	69	0
Nutrients, organic carbon, and bacteria:							
Nitrogen, ammonia + organic, diss. (mg/L as N)	<0.2	<0.2	<0.2	0.2	0.4	47	70
Nitrogen, ammonia + organic, total (mg/L as N)	<0.2	<0.2	0.2	0.3	1.0	47	30
Nitrogen, ammonia, diss. (mg/L as N)	<0.01	<0.01	0.02	0.02	0.04	47	38
Nitrogen, ammonia, total (mg/L as N)	<0.01	0.01	0.02	0.04	0.06	9	22
Nitrogen, $\text{NO}_2 + \text{NO}_3$, diss. (mg/L as N)	<0.05	<0.05	<0.05	<0.05	0.33	47	87
Nitrogen, $\text{NO}_2 + \text{NO}_3$, total (mg/L as N)	NA	NA	NA	NA	NA	NA	NA
Phosphorus, diss. (mg/L as P)	<0.01	<0.01	0.02	0.02	0.05	47	45
Orthophosphate, diss. (mg/L as P)	<0.01	<0.01	<0.01	0.01	0.04	47	55
Phosphorus, total (mg/L as P)	<0.01	0.02	0.04	0.08	0.48	47	11
Organic carbon, total (mg/L as C)	3.2	3.5	3.9	5.5	19.0	10	0
Fecal coliform, 0.7 micron (colonies/100 mL)	0	26	60	100	730	45	7
Fecal streptococci, 0.7 micron (colonies/100 mL)	4	42	98	193.5	2500	44	0
Trace elements¹:							
Aluminum, diss. ($\mu\text{g}/\text{L}$ as Al)	1	3	4	6	72	16	0
Arsenic, diss. ($\mu\text{g}/\text{L}$ as As)	<1	1	2	2	3	26	8
Arsenic, total ($\mu\text{g}/\text{L}$ as As)	1	2	2	2	4	11	0
Barium, diss. ($\mu\text{g}/\text{L}$ as Ba)	52	63	71	81	119	16	0
Boron, diss. ($\mu\text{g}/\text{L}$ as B)	<10	20	30	45	80	43	5
Chromium, diss. ($\mu\text{g}/\text{L}$ as Cr)	<1	<1	<1	1	30	26	73
Copper, diss. ($\mu\text{g}/\text{L}$ as Cu)	<1	1.0	1.7	2.1	5	26	15
Iron, diss. ($\mu\text{g}/\text{L}$ as Fe)	<3	9	16	40	330	69	14
Manganese, diss. ($\mu\text{g}/\text{L}$ as Mn)	1.8	3.2	5.7	9.0	45.0	46	0
Molybdenum, diss. ($\mu\text{g}/\text{L}$ as Mo)	<1	<1	1.2	1.7	2.1	16	25
Nickel, diss. ($\mu\text{g}/\text{L}$ as Ni)	<1.0	1.0	1.0	1.2	2.0	16	19
Zinc, diss. ($\mu\text{g}/\text{L}$ as Zn)	<1	<1	3	5	16	26	31
Uranium (natural), diss. ($\mu\text{g}/\text{L}$ as U)	<1.00	<1.00	1.11	2.18	4.48	16	31

¹Each data set for antimony, beryllium, cadmium, cobalt, lead, mercury (dissolved and total), selenium, and silver contained less than nine samples greater than method detection level.

32 Trends of the Rio Chama and Rio Grande, Water Years 1985 to 2002

Table I-3. Summary statistics of selected water-quality constituents for Rio Grande at Otowi Bridge, near San Ildefonso, water years 1985 to 2002.

[$\mu\text{S/cm}$, microsiemens per centimeter at 25 degrees Celsius (deg C); mg/L, milligrams per liter; diss., dissolved; <, less than; mL, milliliters; $\mu\text{g/L}$, micrograms per liter]

Summary statistics	Mini- mum	25th percentile	Median	75th percentile	Maxi- mum	Number of samples	Percentage censored values
Basic water chemistry and physical properties:							
Specific conductance, lab ($\mu\text{S/cm}$)	187	279	314	339	465	172	0
Alkalinity, total, titration to 4.5, lab (mg/L as CaCO_3)	62	96	107	117	170	137	0
pH, total, field (standard units)	7.2	8.0	8.2	8.3	9.0	164	0
Oxygen, diss. (mg/L)	6.9	8.0	8.8	10.5	16.8	162	0
Chemical oxygen demand, total (mg/L)	NA	NA	NA	NA	NA	NA	NA
Total dissolved solids, 180 deg C (mg/L)	131	189	212	229	327	74	0
Major ions:							
Calcium, diss. (mg/L as Ca)	20.1	33.6	36.0	40.0	49.0	140	0
Magnesium, diss. (mg/L as Mg)	3.74	6.28	6.80	7.52	9.70	140	0
Potassium, diss. (mg/L as K)	1.60	2.28	2.60	2.88	3.90	140	0
Sodium, diss. (mg/L as Na)	9.6	16	19	22	30	140	0
Bicarbonate, field, diss. (mg/L as HCO_3)	76	108	123	133	173	100	0
Chloride, diss. (mg/L as Cl)	2.60	4.50	5.70	7.10	32	137	0
Fluoride, diss. (mg/L as F)	<0.10	0.30	0.32	0.40	0.90	137	1
Sulfate, diss. (mg/L as SO_4)	21.2	39.1	49.0	56.5	89.0	137	0
Silica, diss. (mg/L as SiO_2)	0.1	17.0	19.0	22.0	52.0	140	0
Nutrients, organic carbon, and bacteria:							
Nitrogen, ammonia + organic, diss. (mg/L as N)	<0.20	<0.20	<0.20	0.20	0.40	63	65
Nitrogen, ammonia + organic, total (mg/L as N)	<0.10	0.30	0.38	0.51	1.90	116	12
Nitrogen, ammonia, diss. (mg/L as N)	<0.01	<0.01	0.02	0.02	0.36	116	41
Nitrogen, ammonia, total (mg/L as N)	<0.01	0.02	0.03	0.04	0.15	70	19
Nitrogen, $\text{NO}_2 + \text{NO}_3$, diss. (mg/L as N)	<0.10	<0.10	0.10	0.15	0.34	116	39
Nitrogen, $\text{NO}_2 + \text{NO}_3$, total (mg/L as N)	NA	NA	NA	NA	NA	NA	NA
Phosphorus, diss. (mg/L as P)	<0.02	<0.02	0.02	0.03	0.16	116	32
Orthophosphate, diss. (mg/L as P)	<0.01	<0.01	0.02	0.03	0.1	116	28
Phosphorus, total (mg/L as P)	<0.01	0.04	0.08	0.13	2.8	116	3
Organic carbon, total (mg/L as C)	1.8	3.8	5.0	6.3	90.8	63	0
Fecal coliform, 0.7 micron (colonies/100 mL)	<10	16	64	140	2,800	123	2
Fecal streptococci, 0.7 micron (colonies/100 mL)	<1	34	105	220	6,100	122	1
Trace elements¹:							
Aluminum, diss. ($\mu\text{g/L}$ as Al)	<2	5	11	30	1,900	110	5
Arsenic, diss. ($\mu\text{g/L}$ as As)	<1	1	2	2	7	96	7
Arsenic, total ($\mu\text{g/L}$ as As)	NA	NA	NA	NA	NA	NA	NA
Barium, diss. ($\mu\text{g/L}$ as Ba)	29	46	57	71	110	110	0
Boron, diss. ($\mu\text{g/L}$ as B)	10	30	40	40	170	113	0
Chromium, diss. ($\mu\text{g/L}$ as Cr)	<1	<1	<1	1	3	94	64
Copper, diss. ($\mu\text{g/L}$ as Cu)	<1.0	1.1	1.5	3.0	33	94	8
Iron, diss. ($\mu\text{g/L}$ as Fe)	<10	10	14	28	1,300	139	23
Manganese, diss. ($\mu\text{g/L}$ as Mn)	<1.0	3.0	5.0	8.1	180	132	3
Molybdenum, diss. ($\mu\text{g/L}$ as Mo)	NA	NA	NA	NA	NA	NA	NA
Nickel, diss. ($\mu\text{g/L}$ as Ni)	<1.00	<1.00	1.00	1.17	13.0	109	44
Zinc, diss. ($\mu\text{g/L}$ as Zn)	<1	1	3	6	71	95	18
Uranium (natural), diss. ($\mu\text{g/L}$ as U)	<1.00	1.30	2.05	2.72	4.90	84	2

¹Each data set for antimony, beryllium, cadmium, cobalt, lead, mercury (dissolved and total), selenium, and silver contained less than nine samples greater than method detection level.

Table I-4. Summary statistics of selected water-quality constituents for Rio Grande at San Felipe, water years 1985 to 2002.

[$\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius (deg C); mg/L, milligrams per liter; diss., dissolved; <, less than; mL, milliliters; $\mu\text{g}/\text{L}$, micrograms per liter]

Summary statistics	Mini- mum	25th percentile	Median	75th percentile	Maxi- mum	Number of samples	Percentage censored values
Basic water chemistry and physical properties:							
Specific conductance, lab ($\mu\text{S}/\text{cm}$)	210	300	336	357	520	104	0
Alkalinity, total, titration to 4.5, lab (mg/L as CaCO_3)	66	102.25	113	120	135	74	0
pH, total, field (standard units)	7.3	7.9	8.1	8.3	8.8	104	0
Oxygen, diss. (mg/L)	6.5	8.0	9.4	11.2	14.4	101	0
Chemical oxygen demand, total (mg/L)	<10	10	10	20	1,800	50	24
Total dissolved solids, 180 deg C (mg/L)	187	210	219.5	225.5	252	10	0
Major ions:							
Calcium, diss. (mg/L as Ca)	24.0	34.7	39.0	41.3	49.0	74	0
Magnesium, diss. (mg/L as Mg)	4.60	6.36	7.20	7.70	9.20	74	0
Potassium, diss. (mg/L as K)	1.80	2.60	2.80	3.09	4.00	74	0
Sodium, diss. (mg/L as Na)	11.0	18.0	20.7	22.6	31.0	74	0
Bicarbonate, field, diss. (mg/L as HCO_3)	76	120	134	142	248	57	0
Chloride, diss. (mg/L as Cl)	1.80	4.84	5.95	6.93	9.70	74	0
Fluoride, diss. (mg/L as F)	0.20	0.30	0.40	0.40	0.90	66	0
Sulfate, diss. (mg/L as SO_4)	29.5	44.5	51.5	60.0	84.0	74	0
Silica, diss. (mg/L as SiO_2)	14.9	17.0	18.0	20.0	27.0	66	0
Nutrients, organic carbon, and bacteria:							
Nitrogen, ammonia + organic, diss. (mg/L as N)	<0.20	<0.20	<0.20	0.21	0.30	26	58
Nitrogen, ammonia + organic, total (mg/L as N)	<0.20	0.22	0.30	0.40	1.90	72	14
Nitrogen, ammonia, diss. (mg/L as N)	<0.01	<0.01	<0.01	0.02	0.06	46	50
Nitrogen, ammonia, total (mg/L as N)	<0.01	0.02	0.03	0.06	0.12	52	6
Nitrogen, $\text{NO}_2 + \text{NO}_3$, diss. (mg/L as N)	<0.05	<0.05	0.08	0.10	0.29	72	47
Nitrogen, $\text{NO}_2 + \text{NO}_3$, total (mg/L as N)	<0.10	<0.10	<0.10	0.10	12	35	54
Phosphorus, diss. (mg/L as P)	<0.02	<0.02	<0.02	0.03	0.05	26	69
Orthophosphate, diss. (mg/L as P)	<0.01	<0.01	0.02	0.03	0.06	72	29
Phosphorus, total (mg/L as P)	<0.01	0.04	0.05	0.06	0.25	72	6
Organic carbon, total (mg/L as C)	1.8	2.9	3.9	4.7	27	56	0
Fecal coliform, 0.7 micron (colonies/100 mL)	<10	12	30	85	7,700	51	2
Fecal streptococci, 0.7 micron (colonies/100 mL)	<1	26	66	120	7,000	51	2
Trace elements¹:							
Aluminum, diss. ($\mu\text{g}/\text{L}$ as Al)	<1	2	5	11	632	33	12
Arsenic, diss. ($\mu\text{g}/\text{L}$ as As)	<1	2	2	2	3	52	2
Arsenic, total ($\mu\text{g}/\text{L}$ as As)	1	2	2	2	3	28	0
Barium, diss. ($\mu\text{g}/\text{L}$ as Ba)	44	65	68	75	116	32	0
Boron, diss. ($\mu\text{g}/\text{L}$ as B)	20	30	40	40	60	67	0
Chromium, diss. ($\mu\text{g}/\text{L}$ as Cr)	<1	<1	<1	1	2	53	72
Copper, diss. ($\mu\text{g}/\text{L}$ as Cu)	<1.0	1.0	1.2	3.0	9.0	52	9
Iron, diss. ($\mu\text{g}/\text{L}$ as Fe)	<10	<10	10	18	550	65	25
Manganese, diss. ($\mu\text{g}/\text{L}$ as Mn)	<1.0	6.3	9.3	13.9	989	32	3
Molybdenum, diss. ($\mu\text{g}/\text{L}$ as Mo)	2.0	3.2	4.0	4.3	5.5	32	0
Nickel, diss. ($\mu\text{g}/\text{L}$ as Ni)	<1.00	<1.00	1.00	1.91	3.00	32	28
Zinc, diss. ($\mu\text{g}/\text{L}$ as Zn)	<3	<3	3	6	22	52	33
Uranium (natural), diss. ($\mu\text{g}/\text{L}$ as U)	0.50	1.84	2.40	3.00	3.64	33	0

¹Each data set for antimony, beryllium, cadmium, cobalt, lead, mercury (dissolved and total), selenium, and silver contained less than nine samples greater than method detection level.

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Table I-5. Summary statistics of selected water-quality constituents for Rio Grande at Albuquerque, water years 1985 to 2002.

[$\mu\text{S/cm}$, microsiemens per centimeter at 25 degrees Celsius (deg C); mg/L, milligrams per liter; diss., dissolved; <, less than; mL, milliliters; $\mu\text{g/L}$, micrograms per liter]

Summary statistics	Minimum	25th percentile	Median	75th percentile	Maximum	Number of samples	Percentage censored values
Basic water chemistry and physical properties:							
Specific conductance, lab ($\mu\text{S/cm}$)	192	334	370	425	548	98	0
Alkalinity, total, titration to 4.5, lab (mg/L as CaCO_3)	71	98	112	122	150	22	0
pH, total, field (standard units)	6.8	7.8	7.9	8.1	8.7	80	0
Oxygen, diss. (mg/L)	5.9	8.0	8.6	10.8	13.8	75	0
Chemical oxygen demand, total (mg/L)	<10	10	20	30	50	9	22
Total dissolved solids, 180 deg C (mg/L)	NA	NA	NA	NA	NA	NA	NA
Major ions:							
Calcium, diss. (mg/L as Ca)	27.0	35.5	40.0	42.8	53.0	22	0
Magnesium, diss. (mg/L as Mg)	4.80	6.75	7.05	8.10	9.70	22	0
Potassium, diss. (mg/L as K)	2.50	2.73	2.90	3.40	7.00	22	0
Sodium, diss. (mg/L as Na)	13.0	23.0	24.0	26.8	43.0	22	0
Bicarbonate, field, diss. (mg/L as HCO_3)	NA	NA	NA	NA	NA	NA	NA
Chloride, diss. (mg/L as Cl)	4.50	7.60	9.80	13.0	22.0	22	0
Fluoride, diss. (mg/L as F)	0.20	0.30	0.35	0.40	0.50	18	0
Sulfate, diss. (mg/L as SO_4)	36.0	55.0	59.0	69.8	84.0	22	0
Silica, diss. (mg/L as SiO_2)	16.0	17.0	18.5	20.8	22.0	18	0
Nutrients, organic carbon, and bacteria:							
Nitrogen, ammonia + organic, diss. (mg/L as N)	NA	NA	NA	NA	NA	NA	NA
Nitrogen, ammonia + organic, total (mg/L as N)	0.20	0.30	0.40	0.50	0.80	9	0
Nitrogen, ammonia, diss. (mg/L as N)	NA	NA	NA	NA	NA	NA	NA
Nitrogen, ammonia, total (mg/L as N)	<0.01	0.02	0.03	0.04	0.07	11	9
Nitrogen, $\text{NO}_2 + \text{NO}_3$, diss. (mg/L as N)	<0.10	<0.10	<0.10	0.13	0.22	11	55
Nitrogen, $\text{NO}_2 + \text{NO}_3$, total (mg/L as N)	<0.10	<0.10	<0.10	0.10	0.20	11	55
Phosphorus, diss. (mg/L as P)	NA	NA	NA	NA	NA	NA	NA
Orthophosphate, diss. (mg/L as P)	0.02	0.03	0.04	0.05	0.07	11	0
Phosphorus, total (mg/L as P)	0.05	0.06	0.09	0.11	0.38	9	0
Organic carbon, total (mg/L as C)	2.2	3.1	4	4.3	4.9	9	0
Fecal coliform, 0.7 micron (colonies/100 mL)	NA	NA	NA	NA	NA	NA	NA
Fecal streptococci, 0.7 micron (colonies/100 mL)	NA	NA	NA	NA	NA	NA	NA
Trace elements¹:							
Aluminum, diss. ($\mu\text{g/L}$ as Al)	NA	NA	NA	NA	NA	NA	NA
Arsenic, diss. ($\mu\text{g/L}$ as As)	<1	3	3	3	4	10	10
Arsenic, total ($\mu\text{g/L}$ as As)	<1	3	3	3	4	9	11
Barium, diss. ($\mu\text{g/L}$ as Ba)	NA	NA	NA	NA	NA	NA	NA
Boron, diss. ($\mu\text{g/L}$ as B)	20	35	60	78	130	18	0
Chromium, diss. ($\mu\text{g/L}$ as Cr)	<1	<1	<1	<10	<10	9	100
Copper, diss. ($\mu\text{g/L}$ as Cu)	<1.0	1.0	2.0	3.3	4.0	8	22
Iron, diss. ($\mu\text{g/L}$ as Fe)	9	10	14	28	76	17	0
Manganese, diss. ($\mu\text{g/L}$ as Mn)	NA	NA	NA	NA	NA	NA	NA
Molybdenum, diss. ($\mu\text{g/L}$ as Mo)	NA	NA	NA	NA	NA	NA	NA
Nickel, diss. ($\mu\text{g/L}$ as Ni)	NA	NA	NA	NA	NA	NA	NA
Zinc, diss. ($\mu\text{g/L}$ as Zn)	<1	<1	3	5	20	9	33
Uranium (natural), diss. ($\mu\text{g/L}$ as U)	NA	NA	NA	NA	NA	NA	NA

¹Each data set for antimony, beryllium, cadmium, cobalt, lead, mercury (dissolved and total), selenium, and silver contained less than nine samples greater than method detection level.

Table I-6. Anthropogenic compounds analyzed for in samples collected from the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002.

[MDL, method detection level; X, analysis performed; group: 1 = pesticides, 2 = total phenols, 3 = polychlorinated naphthalenes, 4 = polychlorinated biphenyls; diss., dissolved; µg/L, micrograms per liter; <, less than; --, no analysis performed]

Compound	Unit	MDL	Taos	Chamita	Otowi	San Felipe	Albuquerque	Group
Propachlor, diss.	µg/L	<0.007	X	X	X	--	--	1
Butylate, diss.	µg/L	<0.002	X	X	X	--	--	1
Simazine, diss.	µg/L	<0.005	X	X	X	--	--	1
Prometon, diss.	µg/L	<0.02	X	X	X	--	--	1
2-chloro-4-isopropylamino-6-amino-s-triazine, diss.	µg/L	<0.002	X	X	X	--	--	1
Cyanazine, diss.	µg/L	<0.004	X	X	X	--	--	1
Fonofos, diss.	µg/L	<0.003	X	X	X	--	--	1
Phenolic compounds, total	µg/L	<1	--	--	X	--	--	2
alpha-HCH, diss.	µg/L	<0.002	X	X	X	--	--	1
p,p'-DDE, diss.	µg/L	<0.006	X	X	X	--	--	1
Chlorpyrifos, total	µg/L	<0.01	X	X	X	X	--	1
Chlorpyrifos, diss.	µg/L	<0.004	X	X	X	--	--	1
Disulfoton, total	µg/L	<0.01	X	X	X	X	X	1
Phorate, total	µg/L	<0.01	X	X	X	X	X	1
p,p'-ethyl-DDD, total	µg/L	<0.1	X	X	X	X	X	1
Tribuphos, total	µg/L	<0.01	X	X	X	X	--	1
Polychlorinated naphthalenes, total	µg/L	<0.1	X	X	X	X	X	3
Aldrin, total	µg/L	<0.01	X	X	X	X	X	1
Lindane, total	µg/L	<0.010	X	X	X	X	X	1
Lindane, diss.	µg/L	<0.004	X	X	X	--	--	1
Chlordane (technical), total	µg/L	<0.1	X	X	X	X	X	1
p,p'-DDD, total	µg/L	<0.010	X	X	X	X	X	1
p,p'-DDE, total	µg/L	<0.010	X	X	X	X	X	1
p,p'-DDT, total	µg/L	<0.010	X	X	X	X	X	1
Dieldrin, total	µg/L	<0.010	X	X	X	X	X	1
Dieldrin, diss.	µg/L	<0.001	X	X	X	--	--	1
alpha-endosulfan, total	µg/L	<0.01	X	X	X	X	X	1
Endrin, total	µg/L	<0.01	X	X	X	X	X	1
Ethion, total	µg/L	<0.01	X	X	X	X	X	1
Toxaphene, total	µg/L	<1	X	X	X	X	X	1
Heptachlor, total	µg/L	<0.01	X	X	X	X	X	1
Metolachlor, diss.	µg/L	<0.002	X	X	X	--	--	1
Heptachlor epoxide, total	µg/L	<0.010	X	X	X	X	X	1
p,p'-methoxychlor, total	µg/L	<0.010	X	X	X	X	X	1
PCB's, total	µg/L	<0.1	X	X	X	X	X	4
Malathion, total	µg/L	<0.01	X	X	X	X	X	1
Malathion, diss.	µg/L	<0.005	X	X	X	--	--	1
Parathion, total	µg/L	<0.01	X	X	X	X	X	1
Parathion, diss.	µg/L	<0.004	X	X	X	--	--	1
Diazinon, total	µg/L	<0.01	X	X	X	X	X	1
Diazinon, diss.	µg/L	<0.002	X	X	X	--	--	1

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Table I-6. Anthropogenic compounds analyzed for in samples collected from the Rio Grande stations of Taos, Otowi, San Felipe, and Albuquerque and the Rio Chama station of Chamita, water years 1985 to 2002--Concluded.

Compound	Unit	MDL	Taos	Chamita	Otowi	San Felipe	Albuquerque	Group
Azinphos-methyl, total	µg/L	<0.1	--	--	--	--	X	1
Methyl parathion, total	µg/L	<0.01	X	X	X	X	X	1
Atrazine, diss.	µg/L	<0.001	X	X	X	--	--	1
2,4-D, total	µg/L	<0.01	X	X	X	X	X	1
2,4,5-T, total	µg/L	<0.01	X	X	X	X	X	1
Mirex, total	µg/L	<0.010	X	X	X	X	X	1
Silvex, total	µg/L	<0.01	X	X	X	X	X	1
Carbophenothion, total	µg/L	<0.01	X	X	X	X	X	1
Methyl trithion, total	µg/L	<0.01	X	X	X	X	X	1
Alachlor, diss.	µg/L	<0.002	X	X	X	--	--	1
Acetochlor, diss.	µg/L	<0.002	X	X	X	--	--	1
Dichlorprop, total	µg/L	<0.01	X	X	X	X	X	1
Fonofos, total	µg/L	<0.01	X	X	X	X	--	1
Metribuzin, diss.	µg/L	<0.004	X	X	X	--	--	1
2,6-diethylaniline, diss.	µg/L	<0.003	X	X	X	--	--	1
Trifluralin, diss.	µg/L	<0.002	X	X	X	--	--	1
Ethalfuralin, diss.	µg/L	<0.004	X	X	X	--	--	1
Phorate, diss.	µg/L	<0.002	X	X	X	--	--	1
Terbacil, diss.	µg/L	<0.007	X	X	X	--	--	1
Linuron, diss.	µg/L	<0.002	X	X	X	--	--	1
Methyl parathion, diss.	µg/L	<0.006	X	X	X	--	--	1
EPTC, diss.	µg/L	<0.002	X	X	X	--	--	1
Pebulate, diss.	µg/L	<0.004	X	X	X	--	--	1
Tebuthiuron, diss.	µg/L	<0.01	X	X	X	--	--	1
Molinate, diss.	µg/L	<0.004	X	X	X	--	--	1
Ethoprop, diss.	µg/L	<0.003	X	X	X	--	--	1
Benfluralin, diss.	µg/L	<0.002	X	X	X	--	--	1
Carbofuran, diss.	µg/L	<0.003	X	X	X	--	--	1
Terbufos, diss.	µg/L	<0.01	X	X	X	--	--	1
Propyzamide, diss.	µg/L	<0.003	X	X	X	--	--	1
Disulfoton, diss.	µg/L	<0.02	X	X	X	--	--	1
Triallate, diss.	µg/L	<0.001	X	X	X	--	--	1
Propanil, diss.	µg/L	<0.004	X	X	X	--	--	1
Carbaryl, diss.	µg/L	<0.003	X	X	X	--	--	1
Thiobencarb, diss.	µg/L	<0.002	X	X	X	--	--	1
DCPA, diss.	µg/L	<0.002	X	X	X	--	--	1
Pendimethalin, diss.	µg/L	<0.004	X	X	X	--	--	1
Napropamide, diss.	µg/L	<0.003	X	X	X	--	--	1
Propargite, diss.	µg/L	<0.01	X	X	X	--	--	1
Azinphos-methyl, diss.	µg/L	<0.001	X	X	X	--	--	1
cis-permethrin, diss.	µg/L	<0.005	X	X	X	--	--	1