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Streamflow Gains and Losses and Selected Water-Quality Observations in Five Subreaches of the Rio Grande/Rio Bravo del Norte from near Presidio to Langtry, Texas, Big Bend Area, United States and Mexico, 2006

Scientific Investigations Report 2012–5125

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

Front cover:

Top, Rio Grande/Rio Bravo Del Norte in the Lower Canyons (background), with inflow from Hot Springs in Mexico (foreground) near site 22 in Texas, March 2006 (photograph by Michael B. Nyman, U.S. Geological Survey).

Lower left, U.S. Geological Survey, National Parks Service personnel evaluating possible measurement locations on the Rio Grande/Rio Bravo Del Norte, February 2006 (photograph by Cory Horan, Texas Commission on Environmental Quality).

Lower right, U.S. Geological Survey hydrologic technician making a discharge measurement (Acoustic Doppler Current Profiler) on the Rio Grande/Rio Bravo Del Norte, February 2006 (photograph by Christine M. Kolbe, Texas Commission on Environmental Quality).

Back cover:

Top, Close-up photograph depicting part of a historical map of the Rio Grande/Rio Bravo Del Norte near Big Bend National Park from the 1950s (photograph by Brian L. Petri, U.S. Geological Survey).

Bottom, U.S. Geological Survey hydrologic technician making a discharge measurement (Acoustic Velocity Meter) on the Rio Grande/Rio Bravo Del Norte, February 2006 (photograph by Mark A. Warzecha, U.S. Geological Survey).

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Conversion Factors, Datum, and Water-Quality Units

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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

$$°F=(1.8×°C)+32$$

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Water-Quality Units

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

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

Streamflow Gains and Losses and Selected Water-Quality Observations in Five Subreaches of the Rio Grande/Rio Bravo del Norte from near Presidio to Langtry, Texas, Big Bend Area, United States and Mexico, 2006

By Timothy H. Raines,[1] Michael J. Turco,[1] Patrick J. Connor,[2] and Jeffery B. Bennett[3]

Abstract

Few historical streamflow and water-quality data are available to characterize the segment of the Rio Grande/Rio Bravo del Norte (hereinafter Rio Grande) extending from near Presidio to near Langtry, Texas. The U.S. Geological Survey, in cooperation with the National Park Service and the Texas Commission on Environmental Quality, collected water-quality and streamflow data from the Rio Grande from near Presidio to near Langtry, Texas, to characterize the streamflow gain and loss and selected constituent concentrations in a 336.3-mile reach of the Rio Grande from near Presidio to near Langtry, Texas. Streamflow was measured at 38 sites and water-quality samples were collected at 20 sites along the Rio Grande in February, March, and June 2006. Streamflow gains and losses over the course of the stream were measured indirectly by computing the differences in measured streamflow between sites along the stream. Water-quality data were collected and analyzed for salinity, dissolved solids, major ions, nutrients, trace elements, and stable isotopes. Selected properties and constituents were compared to available Texas Commission on Environmental Quality general use protection criteria or screening levels. Summary statistics of selected water-quality data were computed for each of the five designated subreaches. Streamflow gain and loss and water-quality constituent concentration were compared for each subreach, rather than the entire segment because of the temporal variation in sample collection caused by controlled releases upstream. Subreach A was determined to be a losing reach, and subreaches B, C, D, and E were determined to be gaining reaches. Compared to concentrations measured in upstream subreaches, downstream subreaches exhibited evidence of dilution of selected constituent concentrations. Subreaches A and B had measured total dissolved solids, chloride, and sulfate exceeding the Texas Commission on Environmental Quality general use protection criteria. Subreaches C, D, and E did not exceed the general use protection criteria for any constituent concentration criteria, but dissolved oxygen concentrations did not meet the general use criteria in these subreaches.

Introduction

Few historical streamflow and water-quality data are available to characterize the segment of the Rio Grande/Rio Bravo del Norte (hereinafter Rio Grande) extending from near Presidio to near Langtry, Tex. The Rio Grande forms the boundary between Texas in the United States and the States of Chihuahua and Coahuila in Mexico. About 3.5 million acres of protected lands exist on both sides of the Rio Grande, and more than 250 miles (mi) of the river are under some form of conservation protection between Presidio and Langtry. Parks and protected areas along this part of the Rio Grande include the Big Bend Ranch State Park, Big Bend National Park, Black Gap State Wildlife Management Area, and Rio Grande Wild and Scenic River in the United States, and the Áreas de Protección de Flora y Fauna Cañón de Santa Elena, Ocampo, and Maderas del Carmen in Mexico (fig. 1). All of these parks and protected areas are downstream from the confluence of the Rio Conchos and the Rio Grande. In 2006, the U.S. Geological Survey (USGS), in cooperation with the National Park Service and the Texas Commission on Environmental Quality (TCEQ), did a study to characterize streamflow gain and loss and the quality of water in five subreaches of the Rio Grande from near Presidio to near Langtry.

Purpose and Scope

The purpose of this report is to provide an initial characterization of streamflow gain and loss and water quality in five

[1]U.S. Geological Survey.

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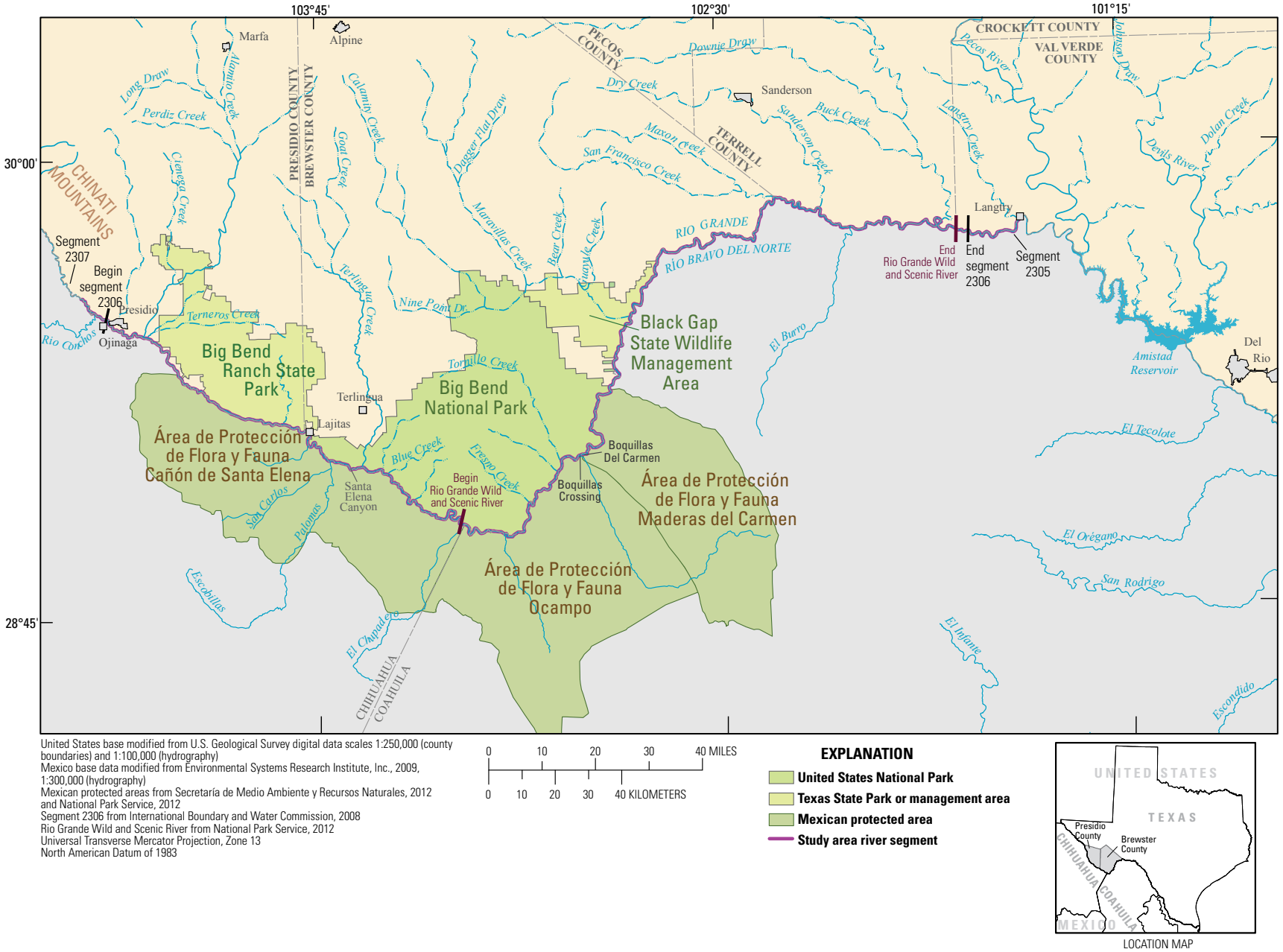


Figure 1. Rio Grande/Rio Bravo del Norte (Rio Grande) in the Big Bend area, United States and Mexico, 2006.

subreaches of the Rio Grande extending from near Presidio to near Langtry. Streamflow gains and losses and water-quality properties were measured in the five subreaches during three synoptic surveys done between February and June 2006 and at one site upstream from the five subreaches during June 2006. Water-quality data were compared to available Texas Surface Water Quality Standards or to screening levels in the absence of State standards.

Description of Study Area

Streamflow and water-quality data were obtained from a 336.3-mi reach of the Rio Grande from near Presidio to near Langtry along the U.S.–Mexico border (fig. 1). The study reach includes parts of Presidio, Brewster, Terrell, and Val Verde Counties in Texas. Segment 2306 represents most of the Rio Grande in the study area; the segment begins about 1 mi downstream from the confluence of the Rio Grande and Rio Conchos near Presidio and ends about 313 mi downstream where the river is first affected by backwater from Amistad Reservoir, near the Terrell and Val Verde County line (International Boundary and Water Commission, 2005) (fig. 2). Designated uses in segment 2306 include aquatic life, contact recreation, general use, fish consumption, and public water supply. Listed concerns for this segment include excessive algal growth (caused by elevated nutrient concentrations) and elevated total dissolved-solids and sulfate concentrations (Texas Commission on Environmental Quality, 2002).

The Rio Grande hydrology is noted for long periods (months) of base flow punctuated by flashy high flows (Schmandt and others, 2000). The greatest precipitation occurs during July, August, and September during the annual North American monsoon (National Climatic Data Center, 2011). North American monsoon-associated precipitation is noted for broad variation in time (interseasonal to interannual) and space. Part of this variability is attributed to surges of moisture from the Gulf of California and to changes in latitudinal position of the subtropical ridge over Mexico and the Southwestern United States (Adams and Comrie, 1997). During 1968–2005, the highest monthly mean discharge (as measured in the Rio Grande downstream from the Rio Conchos near Presidio) was measured in September; the second and third highest monthly mean discharges were in October and August, respectively (International Boundary and Water Commission, 2003).

Rio Grande tributaries (streams and arroyos) in the study area are typically intermittent dry washes. The duration of flow (typically, hours to days) in these streams is tied to the intensity and duration of precipitation and runoff. Some small streams in the Big Bend area receive flow from springs and seeps that are typically perennial but generally do not add sufficiently to the Rio Grande to discern their contribution to flow. Much of the flow in the Rio Grande near Presidio consists of inflow from the Rio Conchos (Patrick, 2003).

The Rio Grande is hydraulically connected to alluvial deposits in the stream channel. The alluvium is composed of silty sand, clay, and gravel (Berry and Williams, 2008). In addition to agricultural uses near Presidio, some of the flow in the Rio Grande is also likely lost by seepage and recharge to the alluvium (U.S. Army Corps of Engineers, 2008). Irrigated fields near Presidio are in direct connection to the alluvium, which may be a source of return flow to the Rio Grande (Reeves and Small, 1973). Groundwater recharge occurs in alluvial fans, along faults, and along stream channels; groundwater discharges from springs to the Rio Grande are common in some parts of the Rio Grande between Presidio and Langtry (Dr. Shirley Wade, Texas Water Development Board, written commun., 2006).

The Edwards-Trinity aquifer is the major aquifer in the study area. Minor aquifers in the study area include the Igneous, Marathon, and West Texas Bolsons (Ashworth and Hopkins, 1995) (fig. 3). Faulting occurs throughout the study area and can alter or impede local groundwater flow paths (Baker and Buszka, 1993; Bartolino and Cole, 2002; Gray and Page, 2008).

Methods of Investigation

Streamflow measurements were made and water-quality samples collected in five subreaches of the Rio Grande to measure streamflow gains and losses during February–June 2006 (an additional streamflow measurement and water-quality sampling site was upstream from the most upstream subreach). At 20 of the 38 streamflow-measurement sites, water-quality samples were collected at the time streamflow measurements were made (table 1 at end of report). Streamflow gain and loss and water-quality constituent concentrations were compared for each subreach. Subreaches were labeled A through E in consecutive downstream order. Subreach A is the most upstream reach in the study area; beginning near Presidio, it spans 48.1 mi. Subreach B is the longest reach in the study area, spanning 79.7 mi of the Rio Grande. Subreach C is the shortest reach in the study area and spans 23.7 mi of the river. Subreach D spans 60.7 mi of the Rio Grande, and Subreach E spans 55.0 mi of the Rio Grande, ending near Langtry (fig. 2; table 1).

At each water-quality sampling site, selected physical properties (dissolved oxygen, pH, specific conductance, water temperature, and alkalinity) and water-quality constituents (salinity, total dissolved solids, major ions, nutrients, and trace elements) were measured. Ratios of the stable isotopes of oxygen (oxygen-18 to oxygen-16) and nitrogen (nitrogen-15 to nitrogen-14) also were measured. Water-quality data were compared (table 2 at end of report) to available Texas Surface Water Quality Standards (Texas Commission on Environmental Quality, 2010) or to screening levels (Lambert and others, 2008, table 3 at end of report) for selected water-quality constituents.

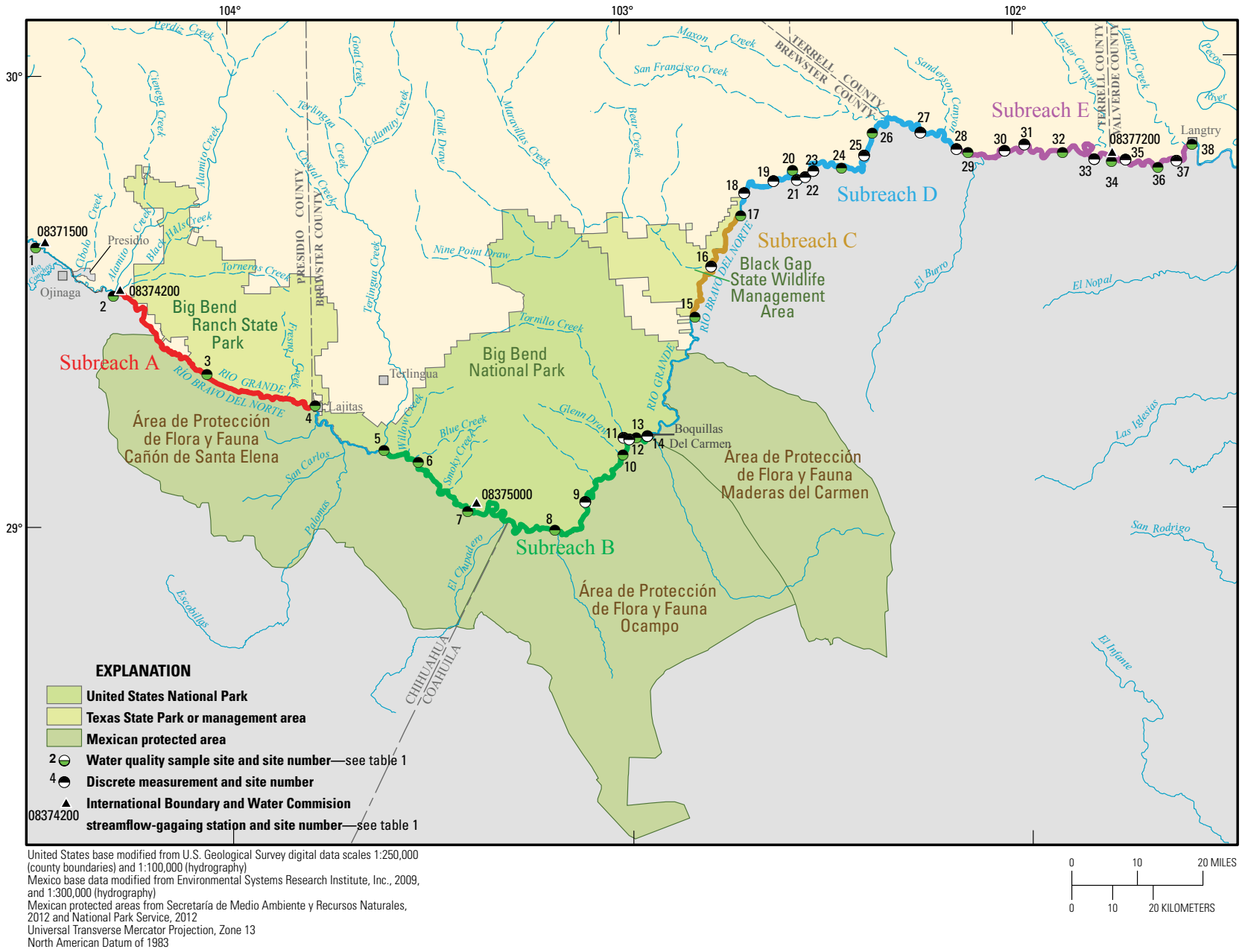
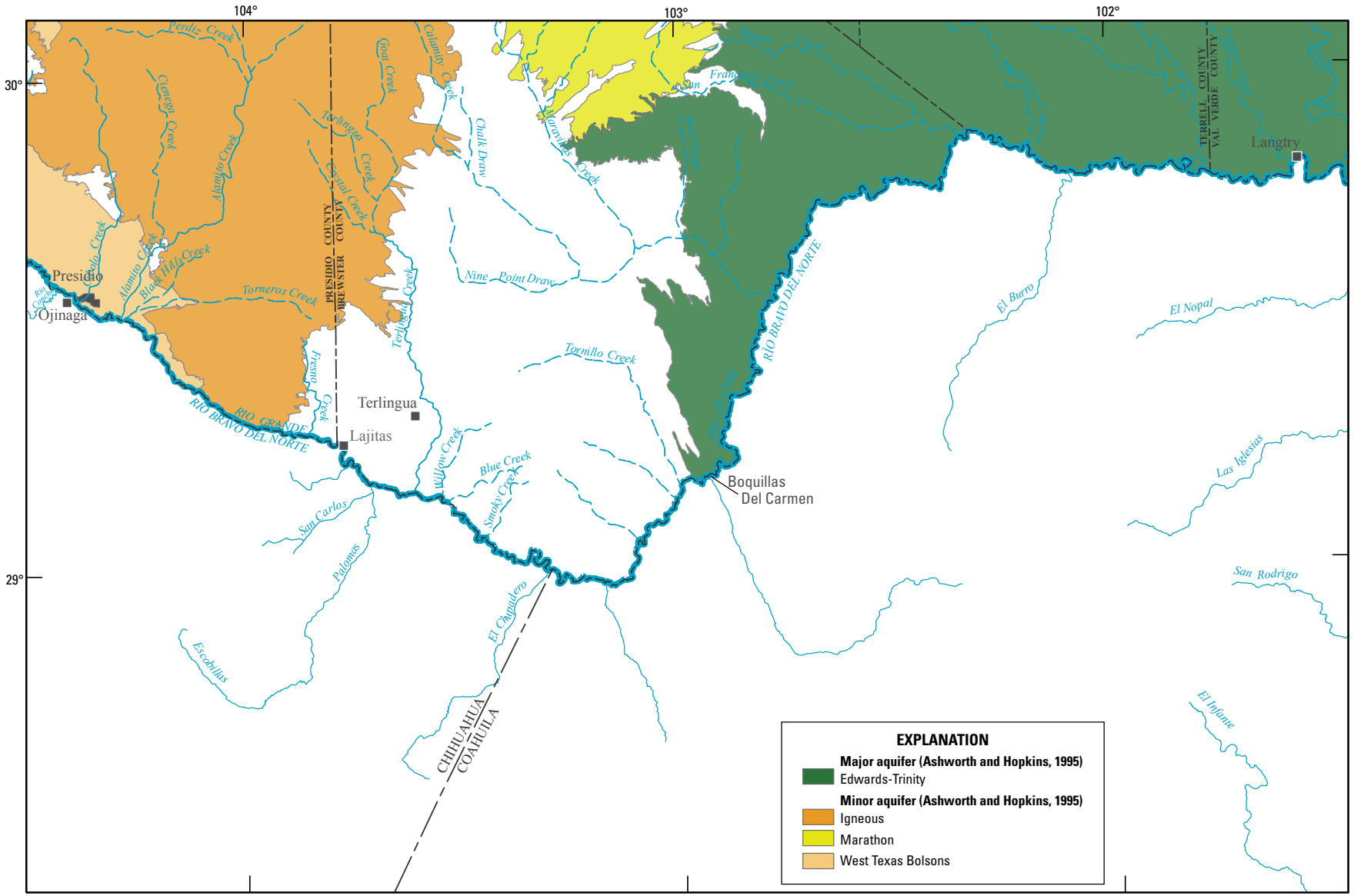


Figure 2. Location of data-collection sites and subreaches A–E along the Rio Grande, Big Bend area, United States and Mexico, 2006.



United States base modified from U.S. Geological Survey digital data
Scales 1:250,000 (county boundaries) and 1:100,000 (hydrography)
Mexico base data modified from Environmental Systems Research Institute, Inc., 2009, 1:300,000 (hydrography)
Universal Transverse Mercator Projection, Zone 13
North American Datum of 1983

Figure 3. Major and minor aquifers in the Big Bend area, United States and Mexico.

Streamflow Data Collection

Streamflow data were collected at 37 sites on the Rio Grande and 1 tributary site adjacent to the Rio Grande during February 5–June 29, 2006. At three sites (sites 2, 7, and 34) streamflow was obtained from the nearest International Boundary and Water Commission streamflow-gaging station (fig. 2; table 1). At all other sites, discrete measurements of streamflow were made in each subreach using USGS methods (Rantz and others, 1982; Turnipseed and Sauer, 2010). Streams were waded and velocity measurements were made using rod-mounted acoustic meters (Turnipseed and Sauer, 2010) where conditions allowed (water depths generally less than 3 feet). In all other instances, boat-mounted acoustic Doppler current profilers were used to measure streamflow (Oberg and others, 2005). USGS protocols describing the operation and maintenance of streamflow measuring equipment were followed (Turnipseed and Sauer, 2010).

Computation of Streamflow Gains and Losses

Streamflow gains and losses over the length of a subreach were measured indirectly by computing the differences in streamflow between consecutive sites in each subreach and for the overall length of the subreach based on an approach described by Turco and others (2007). Sources of gains or losses between sites, in addition to groundwater inflow or outflow through the streambed, might include tributary inflow, diversions, return flows, and evaporation. Using these factors, streamflow gain or loss in the reach is computed as

$$G = Q_d - Q_u - I + D - R + E + ET, \quad (1)$$

where

G is streamflow gain or loss (groundwater inflow or outflow), in cubic feet per second;

Q_d is measured streamflow at the downstream site, in cubic feet per second;

Q_u is measured streamflow at the upstream site, in cubic feet per second;

I is measured inflows from tributaries, in cubic feet per second;

D is measured outflows, in cubic feet per second;

R is return flows to the reach, in cubic feet per second;

E is evaporation, in cubic feet per second; and

ET is evapotranspiration, in cubic feet per second.

Tributaries were checked for any inflows at their confluence with the Rio Grande at the time of Rio Grande measurements. The Rio Conchos is upstream from the subreaches where gains and losses were calculated. In subreaches A–E, all tributaries that were observed appeared to be dry streambeds that did not appear to contribute flow to the Rio Grande except for one site where less than 1 cubic foot per second (ft^3/s) was measured (site 12). Most of the irrigation withdrawals and return flows occur upstream from subreach A; those affecting subreach A would likely vary considerably day to day and would be difficult to quantify during the study period and were therefore not accounted for in the gain-loss calculations. No wastewater-treatment plants are known to discharge to the Rio Grande in subreaches A through E. There may have been an unknown amount of subsurface flow in the alluvium of the dry streambeds. For this study, upstream (Q_u) and downstream (Q_d) measured streamflow were the only components used in the calculation of gain and loss over a reach, defined as the main-stem length between adjacent sites. The magnitude of error associated with the exclusions of other gain and loss components was believed to be minor when compared to potential errors associated with the streamflow measurements.

Individual streamflow measurement error must be considered when evaluating the streamflow gain and loss determined solely by individual discharge measurements. Measurement error was based on a qualitative rating (excellent, good, fair, and poor) of the streamflow measurement by the hydrographer (Sauer and Meyer, 1992). The rating is based on factors such as cross-section condition, velocity homogeneity, streambed conditions, and other factors that affect the accuracy of the measurement. Measurements rated "excellent" are believed to be within 2 percent of the actual flow, "good" measurements are believed to be within 5 percent, "fair" measurements are believed to be within 8 percent, and "poor" measurements are believed to differ from the actual flow by greater than 8 percent. The potential errors associated with each pair of streamflow measurements within a reach were summed to obtain the composite potential error for comparison with the computed gain or loss. Differences between streamflow measured at sites in each subreach were computed and compared to the composite potential error associated with each discharge measurement. For this report, apparent gains (or losses) are described when the difference between streamflow at the upstream and downstream measuring sites that define the reach was greater than (or less than) the composite potential error associated with the streamflow measurements. For example, two fair measurements of 100 and 120 ft^3/s would have a composite potential error of 100*0.08 + 120*0.08 = 17.6 ft^3/s, which is less than the difference in measurements, 120 – 100 = 20 ft^3/s.

Water-Quality Data Collection and Analysis

Water-quality data were collected from selected sites in each subreach in conjunction with streamflow measurements (table 1). Water-quality samples were collected, processed, and

preserved using standard USGS protocols as described in the "National Field Manual for the Collection of Water-Quality Data" (U.S. Geological Survey, variously dated). Selected physical properties and constituents (including dissolved oxygen, pH, salinity, specific conductance, water temperature, and alkalinity) were measured in the field in accordance with standard USGS methods (U.S. Geological Survey, variously dated). Salinity, in parts per thousand, was estimated from a 30-point rating table in Wagner and others (2000) using specific conductance values measured at each site. Major-ion and trace-element concentrations were measured using filtered samples; these samples were filtered through a 0.45-micrometer membrane filter and acidified with ultrapure nitric acid to pH less than 2 standard units (Garbarino and Taylor, 1996). The concentrations of total dissolved solids, major ions, nutrients, and trace elements in the water samples were determined by the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., using approved methods (Fishman and Friedman, 1989; Patton and Truitt, 1992, 2000; Fishman, 1993; Garbarino and Struzeski, 1998; Garbarino, 1999; Garbarino and others, 2006). Stable environmental isotopes are measured as the ratio of the two most abundant isotopes of a given element (Clark and Fritz, 1997). The ratios of naturally occurring, stable isotopes of oxygen and nitrogen of water were measured by the USGS Stable Isotope Laboratory in Reston, Va., using approved methods (Epstein and Mayeda, 1953; Coplen and others, 1991). Results for stable isotope analysis of the ratio of oxygen-18 to oxygen-16 and nitrogen-15 to nitrogen-14 are reported as delta oxygen-18 ($\delta^{18}O$) and delta nitrogen-15 ($\delta^{15}N$), respectively, which represent the relative difference in parts per thousand (per mil) between the sample isotope ratio and the isotope ratio of a known standard (Kendall and McDonnell, 1998).

As explained by Oden and others (2011, p. 9) "the analytical quantification procedure used by the NWQL for reporting results is based on the long-term method detection level (LT–MDL) and laboratory reporting level (LRL). The LT–MDL concentrations are defined as a censoring limit for most analytical methods at the NWQL, and its purpose is to limit the false positive rate to less than or equal to 1 percent. An LT–MDL is a modification of the USEPA 40 Code of Federal Regulations Part 136 definition of the method detection limit (MDL). The LRL is defined as twice the LT–MDL and is established to limit the occurrence of false negative detections to less than or equal to 1 percent (Childress and others, 1999). A constituent concentration is considered estimated by the laboratory when results are greater than the LT–MDL and less than the LRL; that is, a detection is considered likely, but quantification is considered questionable. The remark code of "E" (estimated) is assigned by the laboratory for these results."

The Texas Surface Water Quality Standards (TSWQS), Title 30, Chapter 307 of the Texas Administrative Code, was written by the TCEQ with the authority of Section 303(c) of the Clean Water Act and Section 26.023 of the Texas Administrative Code (Texas Commission on Environmental Quality, 2010). The standards established specific water-quality goals for specific stream segments, lakes, and reservoirs throughout Texas. The TSWQS include specific numerical criteria for 30 toxic contaminants, maximum allowable in-stream concentrations for specific constituents, and criteria needed to protect aquatic life. Water-quality data for selected constituents were compared to applicable TSWQS criteria (Texas Commission on Environmental Quality, 2010) or to screening levels (Lambert and others, 2008, table 3) in the absence of State standards (table 2).

Quality Assurance

Quality-assurance and quality-control information was collected as part of this study to provide a measure of uncertainty in the streamflow and water-quality measurements. Replicate streamflow measurements were made at 15 selected sites on the same day representing 16 pairs of measurements; the differences between replicate streamflow measurements computed as the relative percent difference were less than 5 percent (table 1). For sites where two streamflow measurements were made on the same day, the average of the replicate measurements was used for gain-loss calculations. A water-quality field-blank sample was collected in February 2006 at International Boundary and Water Commission station 08377200 Rio Grande at Foster Ranch near Langtry, Tex. (site 34); a sequential-replicate water-quality sample also was collected in February 2006 at USGS station 290855103002800 Rio Grande at La Clocha Campground, Big Bend National Park, Tex. (site 10). Quality-control water samples were collected as described in the "National Field Manual for the Collection of Water-Quality Data" (U.S. Geological Survey, variously dated) and analyzed by the same laboratory following the same methods used to analyze the environmental samples. Quality-assurance data for water-quality constituents are listed in table 3, including the results from the sequential-replicate water-quality samples.

No target analytes were detected in the field blank sample. The sequential-replicate samples were analyzed to determine the variability of the results for target analytes. The relative percent difference (RPD) was determined for each pair of replicate analyses as a measure of variability. The RPD for each constituent was computed using the equation

$$RPD = |C_1 - C_2|/((C_1 + C_2)/2) \times 100, \quad (2)$$

where

C_1 is the concentration from the first sample in the replicate pair; and

C_2 is the concentration from the second sample in the replicate pair.

The RPDs for water-quality constituents were generally 10 percent or smaller, indicating good analytical precision (table 3).

Streamflow Gains and Losses

During the study, discharge in the Rio Grande ranged from 4.06 ft^3/s at site 1 upstream from where the Rio Conchos flows into the Rio Grande (upstream from subreach A) to 450 ft^3/s at site 38, the most downstream site of the study (table 1). Using measurements made in February, March, and June 2006, streamflow gains and losses were computed in subreaches A–E. Tributary inflow from one site (site 12 in subreach B) of 0.64 ft^3/s was also measured during February 2006.

To analyze streamflow gains and losses, differences between streamflow measured at sites on the main-stem Rio Grande in subreaches A–E were computed for consecutive sites and for the most upstream and downstream sites in a given subreach and then compared to the potential error associated with each discharge measurement (table 4 at end of report). Only 7 of the 31 differences in streamflow between consecutive upstream and downstream sites were greater than the sum of the measurement error associated with each measurement, indicating an apparent gain or loss between the individual sites within each subreach.

Streamflow measurements for the sites on the Rio Grande within each subreach are plotted against location as represented in river miles downstream from site 1 (fig. 4). Subreach A is the most upstream reach in the study area, spanning 48.1 mi of the Rio Grande between sites 2 and 4 (fig. 2; table 1). Streamflow was measured in subreach A during June 20–29, 2006, and decreased from 41.2 ft^3/s at the upstream end to 15.0 ft^3/s at the downstream end of the subreach. An apparent loss in streamflow in subreach A was quantified (table 4). Streamflow at the most downstream site in subreach B (173 ft^3/s at site 14) was much larger compared to streamflow at the most upstream site in subreach C (55.4 ft^3/s at site 15). Site 17 was the most downstream site in subreach C during June when 92.6 ft^3/s was measured and also the most upstream site in subreach D during March when 162 ft^3/s was measured. The large apparent loss shown in figure 4 between subreaches B and C and the large apparent gain between subreaches C and D results from seasonal differences in base flow; there was less flow in Rio Grande in the study area in June compared to February and March. Streamflow measurements were made during February or March in subreaches B, D and E, whereas they were made during June in subreaches A and C.

Subreach B, the longest reach on the Rio Grande within the study area, spans 79.7 mi of the Rio Grande between sites 5 and site 14 (fig. 2; table 1). Streamflow in subreach B ranged from 109 to 173 ft^3/s during February 6–10, 2006 (table 4). For consecutive streamflow measurements made in this reach, no change in streamflow was determined where the difference in streamflow exceeded the measurement error. Between the most upstream to most downstream sites in subreach B, an apparent gain in streamflow was quantified.

Subreach C is the shortest reach on the Rio Grande within the study area, spanning 23.7 mi between sites 15 and 17 (fig. 2; table 1). Streamflow ranged from 49.0 to 92.6 to ft^3/s on June 22, 2006; an apparent gain in streamflow was quantified for this reach (table 4).

Subreach D spans 60.7 mi between sites 17 and 28. Streamflow was measured during March 13–19, 2006. Streamflow increased from 162 ft^3/s at site 17 to 278 ft^3/s at site 26 (measurements from sites 27 and 28 were not used because they were affected by releases from reservoirs in Mexico thus affecting the amount of inflow from the Rio Conchos). For most consecutive streamflow measurements in subreach D, no change in streamflow was determined where the difference in streamflow exceeded the measurement error. An apparent gain in streamflow was quantified for Subreach D between the most upstream and most downstream sites with useable streamflow values.

Subreach E extends along 55.0 mi of the Rio Grande between sites 28 and 38. Streamflow was measured during February 5–11, 2006. Streamflow increased along the reach from 292 ft^3/s at site 28 to 450 ft^3/s at site 38. Gains in streamflow were measured for two pairs of consecutive measurement sites, and on an overall basis, Subreach E was quantified as a gaining reach.

Selected Water-Quality Observations

Water-quality data were collected from 20 of the 38 streamflow measurement sites. In addition to collection of water-quality samples at sites in subreaches A–E, water-quality samples were collected upstream from subreach A.

Salinity, Dissolved Solids, and Major Ions

High concentrations of salinity in parts of the Rio Grande Basin have been noted for almost 100 years (Stabler, 1911). Salinity values measured in samples collected from subreaches A and B were fairly consistent; at sites 2–10 in subreaches A and B, salinity ranged from 1.66 to 1.82 parts per thousand (ppt) (table 5 at end of report). Beginning at site 13 in subreach B and continuing downstream to site 38 in subreach E, salinity generally decreases; between sites 13 and 38, salinity ranged from 0.67 ppt at site 38 to 1.17 ppt at site 13 (table 5). Upstream from site 15 in subreach C, salinity values exceeded 1.00 ppt; downstream from site 15 salinity values were all less than 1.00 ppt.

Similar patterns of generally higher dissolved-solids and major-ion concentrations upstream from site 15 compared to downstream from site 15 were observed. Dissolved solids increase naturally in water through two processes: (1) salt concentration through evaporation and evapotranspiration, and (2) salt pickup, which occurs when surface water or groundwater acquires dissolved solids through dissolution (Anning and others, 2007). Conversely, dissolved-solids concentrations can decrease as a result of dilution from groundwater inflows,

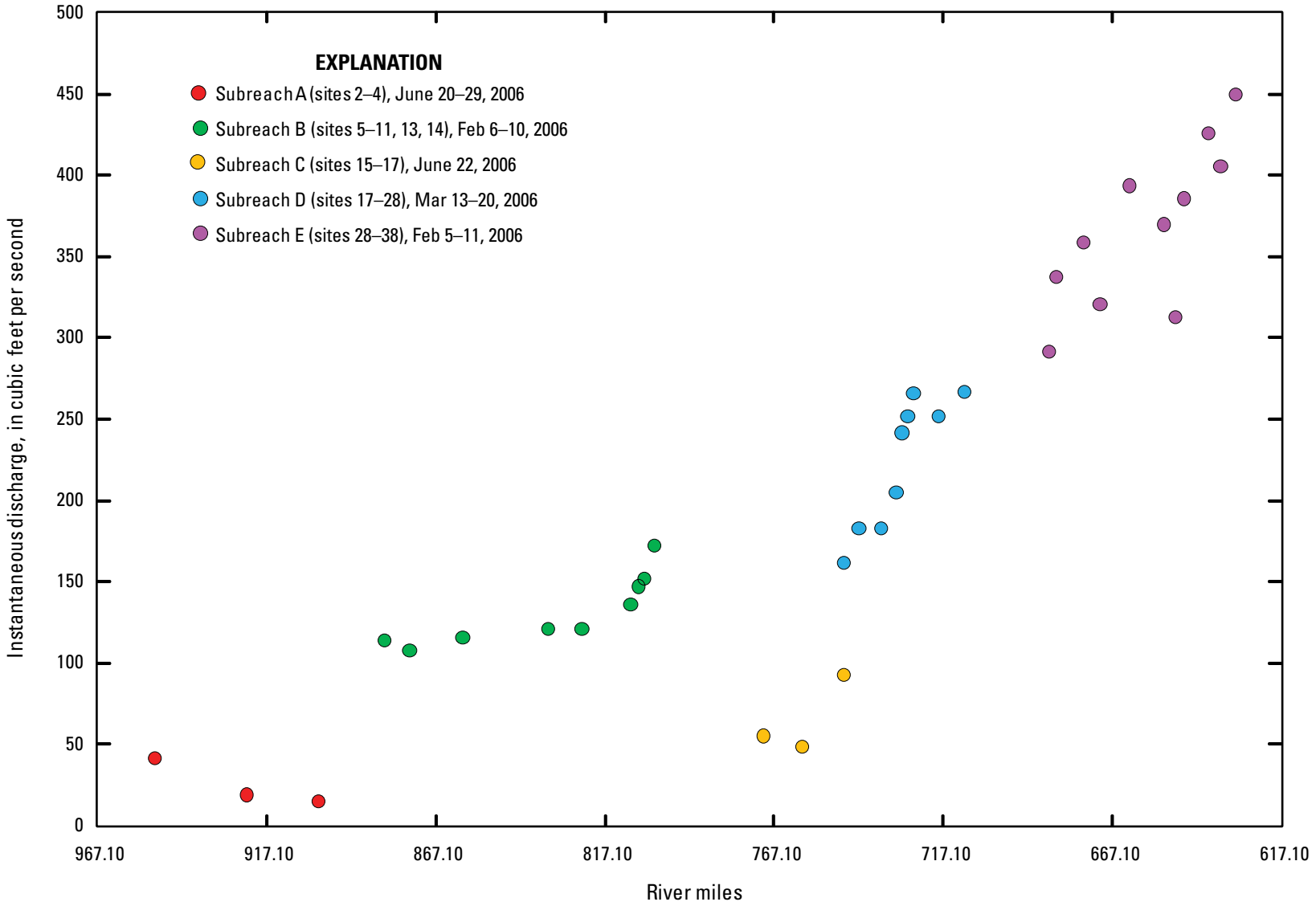


Figure 4. Instantaneous discharge for data-collection sites on the Rio Grande in subreaches A–E, Big Bend area, United States and Mexico, February–June 2006.

which can have lower dissolved-solids concentrations compared to surface water depending on the bedrock the groundwater flows through (U.S. Environmental Protection Agency, 2012). Water with dissolved-solids concentrations exceeding 1,000 milligrams per liter (mg/L) generally is considered unsuitable for many purposes (Heath, 1983; Hem, 1985). Total dissolved-solid concentrations ranged from 2,560 mg/L at site 3 in subreach A to 886 mg/L at site 38 in downstream subreach E.

In subreaches A and B, chloride and sulfate concentrations exceeded the TCEQ general use protection criteria (table 2). Chloride and sulfate concentrations decreased in the downstream direction in subreach D. Chloride concentration in water-quality samples from subreaches A and B exceeded the TCEQ general use protection criteria of 300 mg/L (table 2), whereas, the maximum concentration from subreaches C, D, and E was 236 mg/L (table 3) at site 17 in subreach D (table 5). Sulfate concentrations generally decreased from site 2 in subreach A to site 38 in subreach E. Sulfate concentrations measured in samples collected from subreaches A and B consistently exceeded the 570 mg/L TCEQ general use protection criteria (table 2), whereas, the maximum concentration measured in samples collected from subreaches C, D, and E was 454 mg/L at site 15 in subreach C (table 5). Compared to subreaches A and B, few water-quality data collected in subreaches C–E exceeded the TCEQ general use protection criteria (table 2); dissolved-solids, chloride, and sulfate concentrations were generally at their lowest levels in subreach E at site 38 (table 5).

Nutrients

Nitrogen and phosphorus are major nutrients affecting water quality. The most common forms of nitrogen include: (1) ammonia nitrogen (NH_4^+), (2) nitrate (NO_3^-), (3) nitrite (NO_2^-), and (4) a variety of organic nitrogen compounds (Wetzel, 1983). The primary source of soluble inorganic phosphorus is orthophosphate (PO_4^{-3}). Orthophosphate typically is lower in concentration than other nutrients.

The screening level for nitrate plus nitrite (reported as nitrogen) is 2.0 mg/L (table 2), and the nitrate plus nitrite concentrations measured in all samples were less than 0.9 mg/L (table 6 at end of report). All subreaches except subreach B had sites with detectable concentrations of nitrate plus nitrite. In contrast with many constituent concentrations that generally decreased in the downstream direction, nitrate plus nitrite values increased in the downstream direction. For example, nitrate plus nitrite concentrations increased from 0.331 mg/L at site 20 in subreach D to 0.642 mg/L at site 26 in subreach D. The screening levels for orthophosphate and phosphorous are 0.37 and 0.69 mg/L, respectively (table 2). Measured concentrations of orthophosphate and phosphorous were less than the screening levels at all sites (table 6).

Trace Elements

Trace elements are inorganic chemicals usually found in small concentrations (typically less than 1.0 mg/L) in water. Some trace elements have been linked to certain geologic formations and land uses, including mining and agriculture (Lambert and others, 2008). Trace-element concentrations in water samples were determined for arsenic, boron, iron, lithium, selenium, strontium, and vanadium. Arsenic and selenium concentrations in all samples were less than the TCEQ aquatic life use protection and human health criteria (table 2). Among the trace elements shown in table 7 (at end of report), the decrease in concentration downstream within each reach was most pronounced for strontium and boron. Strontium concentrations generally decreased in downstream direction, ranging from a maximum of 3,690 micrograms per liter (µg/L) at site 2 to a minimum of 2,010 µg/L at site 38. Boron concentrations also generally decreased in downstream direction, ranging from a maximum of 607 µg/L at site 2 to a minimum of 220 µg/L at site 38. For other trace elements, a pattern between downstream site order and concentration was not evident (table 7).

Stable Isotopes

Oxygen has three stable isotopes: oxygen-16, oxygen-17, and oxygen-18 (^{16}O, ^{17}O, and ^{18}O) (Faure, 1986); nitrogen has two stable isotopes: nitrogen-14 (^{14}N) and nitrogen-15 (^{15}N) (Kendall and Aravena, 2000). Stable isotope concentrations are reported in per mil, the ratio of stable-isotope abundances of an element in a sample to those of a standard material. For example, nitrogen isotopes are reported relative to the nitrogen gas (N_2) concentration in atmospheric air (Kendall and Aravena, 2000). Stable isotope results from sites 17, 26, 29, 32, 36, and 38 collected from subreaches D and E were generally similar, and markedly different compared to the stable isotope results obtained from site 3 in subreach A (appendix 1). Differences in groundwater inflows in subreach A compared to subreaches D and E might be causing the different isotope results observed during this study.

Summary

The Rio Grande/Rio Bravo del Norte (hereinafter Rio Grande) forms the boundary between Texas in the United States and Chihuahua and Coahuila in Mexico. The study area encompasses a 336.3-mile reach of the Rio Grande from near Presidio to near Langtry, Texas, in the Big Bend area along the United States–Mexico border. Few historical streamflow and water-quality data are available to characterize this reach of the Rio Grande. The U.S. Geological Survey (USGS), in cooperation with the National Park Service and the Texas Commission on Environmental Quality (TCEQ), collected streamflow

data from near Presidio to near Langtry, Texas, to characterize streamflow gains and losses. Streamflow gains and losses and water-quality properties were measured in five subreaches of the Rio Grande during three synoptic surveys done between February and June 2006 and at one site upstream from the five subreaches. Water-quality data were compared to available TCEQ or screening levels in the absence of State standards.

Streamflow was measured at 38 sites and water-quality samples were collected at 20 sites in February, March, and June 2006. Water-quality data were analyzed for selected physical properties and constituents including salinity, dissolved solids, major ions, nutrients, trace elements, and stable isotopes. Streamflow gains and losses over the course of the Rio Grande from near Presidio to near Langtry were measured indirectly by computing the differences in measured streamflow between sites in five subreaches of the Rio Grande. The potential errors associated with each streamflow measurement for a given site were compared to estimate streamflow gain or loss within each subreach.

Water-quality data were collected from 20 of the 38 sites in the study area. Water-quality samples were analyzed by the USGS National Water Quality Laboratory for salinity, dissolved solids, major ions, nutrients, and trace elements; samples were analyzed by the USGS Stable Isotope Laboratory for stable isotopes.

Streamflow gain and loss and water-quality constituent concentrations were evaluated for each subreach. Dissolved solids, chloride, and sulfate, concentrations measured in subreach A, which was predominately losing reach, exceeded the TCEQ general use protection criteria. Subreach B is the longest reach within the study area, and small downstream increases in streamflow were measured in this gaining reach. Dissolved-solids, chloride, and sulfate concentrations decreased along the reach, however, concentrations of these constituents exceeded the TCEQ general use protection criteria at all sites within subreach B. Subreaches C, D, and E were gaining reaches in the lower part of the study area. Salinity values measured in samples collected from subreaches A and B were fairly consistent; at sites 2–10 in subreaches A and B, salinity ranged from 1.66 to 1.82 parts per thousand (ppt). Beginning at site 13 in subreach B and continuing downstream to site 38 in subreach E, salinity generally decreases; between sites 13 and 38, salinity ranged from 0.67 ppt at site 38 to 1.17 ppt at site 13. Upstream from site 15 in subreach C, salinity values exceeded 1.00 ppt; downstream from site 15, salinity values were all less than 1.00 ppt. Chloride, sulfate, and dissolved-solids concentrations decreased downstream along each of the subreaches. None of the constituents measured in subreaches C, D, and E exceeded applicable TCEQ water-quality criteria. Chloride, sulfate, and dissolved-solids concentrations were at their lowest levels in subreach E at site 38. Concentrations of arsenic and selenium were below the TCEQ criteria and screening levels for all samples.

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Table 1. Sites at which measurements for streamflow gain and loss computation were made on the Rio Grande and one tributary, from near Presidio to near Langtry, Texas, Big Bend area, United States and Mexico, February–June 2006.

[USGS, U.S. Geological Survey; IBWC, International Boundary and Water Commission; ft^3/s, cubic feet per second; Q, instantaneous discharge measurement; RPD, relative percent difference; --, not applicable; Q^e, discharge estimated from continous streamflow records from nearest IBWC streamflow-gaging station (fig. 2); QW, water-quality sample; QA, water-quality quality-assurance sample; Fair, Q uncertainty 8 percent; BBNP, Big Bend National Park; Poor, Q uncertainty greater than 8 percent; Good, Q uncertainty 5 percent]

Site number (fig. 2)	Site name	USGS or IBWC[1] streamflow-gaging station number	Sub-reach[2] (fig. 2)	Sample date	River mile	Discharge (ft^3/s)		Discharge measurement qualifier		RPD[3]	Mean discharge (ft^3/s)	Type of data collected	Latitude (decimal degrees)	Longitude (decimal degrees)	Segment (fig. 2)
						Q_1	Q_2	Q_1	Q_2						
1	Rio Grande above Rio Conchos near Presidio, Tex.	[1]08371500	U[4]	6/29/2006	967.1	4.06	--	--	--	--	--	Q^e, QW	29.6237	104.4742	2307
2	Rio Grande below Rio Conchos near Presidio, Tex.	[1]08374200	A	6/29/2006	950.1	41.2	--	--	--	--	--	Q^e, QW	29.5196	104.2866	2306
3	Rio Grande at Rancherias Rapids near Redford, Tex.	[1]08374325	A	6/20/2006	923.2	19.1	18.2	Fair	Fair	1.2	18.7	Q, QW	29.3371	104.0553	2306
4	Rio Grande above Lajitas, Tex.	291555103465900	A	6/20/2006	902.0	15.5	14.4	Fair	Fair	1.8	15.0	Q, QW	29.2653	103.7833	2306
5	Rio Grande at Santa Elena Canyon, BBNP, Tex.	290956103363600	B	2/6/2006	882.4	114	--	Fair	--	--	--	Q, QW	29.1655	103.6101	2306
6	Rio Grande near Castolon, BBNP, Tex.	08374550	B	2/6/2006	875.1	109	108	Fair	Fair	0.2	109	Q, QW	29.1380	103.5249	2306
7	Rio Grande at Johnson Ranch near Castolon, Tex.	[1]08375000	B	2/7/2006	859.2	114	117	Fair	Fair	0.6	116	Q, QW	29.0349	103.3921	2306
8	Rio Grande at Talley Campground, BBNP, Tex.	285858103110000	B	2/8/2006	834.1	120	122	Fair	Fair	0.4	121	Q, QW	28.9829	103.1833	2306
9	Rio Grande at Solis Campground, BBNP, Tex.	290239103061900	B	2/8/2006	824.1	117	125	Fair	Fair	1.7	121	Q	29.0442	103.1053	2306
10	Rio Grande at La Clocha Campground, BBNP, Tex.	290855103002800	B	2/9/2006	809.7	139	132	Fair	Fair	1.3	136	Q, QW, QA	29.1486	103.0078	2306
11	Rio Grande upstream from Hot Springs, BBNP, Tex.	291039102595000	B	2/10/2006	807.4	146	148	Fair	Fair	0.3	147	Q	29.1774	102.9972	2306
12	Hot Springs tributary near Rio Grande Village, BBNP, Tex.	291055102593100	B	2/10/2006	806.9	0.64	--	Fair	--	--	--	Q	29.1819	102.9919	2306
13	Rio Grande at Rio Grande Village, Tex.	08375300	B	2/9/2006	805.6	150	155	Fair	Fair	0.8	153	Q, QW	29.1855	102.9731	2306
14	Rio Grande at Boquillas Crossing, BBNP, Tex.	291119102564400	B	2/10/2006	802.7	172	173	Fair	Fair	0.1	173	Q	29.1886	102.9456	2306
15	Rio Grande at La Linda, Mexico	292658102492300	C	6/22/2006	770.2	56.1	54.7	Fair	Fair	0.6	55.4	Q, QW	29.4493	102.8230	2306
16	Rio Grande at Maravillas Creek near Sanderson, Tex.	293340102463700	C	6/22/2006	758.7	49.0	--	Fair	--	--	--	Q	29.5611	102.7769	2306
17	Rio Grande at Taylor's Farm near Sanderson, Tex.	294020102415900	C	6/22/2006	746.5	94.0	91.3	Fair	Fair	0.7	92.6	Q, QW	29.6724	102.6996	2306

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Site number (fig. 2)	Site name	USGS or IBWC[1] streamflow-gaging station number	Sub-reach[2] (fig. 2)	Sample date	River mile	Discharge (ft³/s)		Discharge measurement qualifier		RPD[3]	Mean discharge (ft³/s)	Type of data collected	Latitude (decimal degrees)	Longitude (decimal degrees)	Segment (fig. 2)
						Q_1	Q_2	Q_1	Q_2						
17	Rio Grande at Taylor's Farm near Sanderson, Tex.	294020102415900	D	3/13/2006	746.5	166	157	Fair	Fair	1.4	162	Q, QW	29.6724	102.6996	2306
18	Rio Grande above Big Canyon, Tex.	294319102412100	D	3/14/2006	742.2	183	--	Fair	--	--	--	Q	29.7219	102.6892	2306
19	Rio Grande above Bear Canyon, Tex.	294449102365300	D	3/14/2006	735.6	183	--	Fair	--	--	--	Q	29.7469	102.6147	2306
20	Rio Grande above Silber Canyon near Sanderson, Tex.	294613102335500	D	3/15/2006	731.1	205	206	Fair	Fair	0.1	206	Q, QW	29.7703	102.5653	2306
21	Rio Grande below Silber Canyon, Tex.	294457102331600	D	3/15/2006	729.4	242	--	Fair	Fair	--	--	Q	29.7492	102.5544	2306
22	Rio Grande below Hot Springs, Tex.	294517102320200	D	3/15/2006	727.8	239	264	Fair	Fair	2.5	252	Q	29.7547	102.5339	2306
23	Rio Grande at Caballo Blanco, Tex.	294604102304600	D	3/16/2006	726.1	266	--	Fair	--	--	--	Q	29.7678	102.5128	2306
24	Rio Grande below Rodeo Rapids near Sanderson, Tex.	294625102262700	D	3/16/2006	718.6	252	--	Fair	--	--	--	Q, QW	29.7736	102.4407	2306
25	Rio Grande below Lower Madison Canyon, Tex.	294759102223800	D	3/17/2006	711.2	267	--	Fair	Fair	--	--	Q	29.7997	102.3772	2306
26	Rio Grande below Panther Gulch near Sanderson, Tex.	295057102214000	D	3/18/2006	707.4	271	285	Fair	Fair	1.3	278	Q, QW	29.8491	102.3611	2306
27	Rio Grande below Middle Watering Hole, Tex.	295053102142200	D	3/19/2006	694.5	[5]445	--	Poor	--	--	--	Q	29.8481	102.2394	2306
28	Rio Grande at Dryden Crossing, Tex.	294833102085400	D	3/20/2006	685.8	[5]393	--	Fair	--	--	--	Q	29.8092	102.1483	2306
28	Rio Grande at Dryden Crossing, Tex.	294833102085400	E	2/5/2006	685.8	292	--	Fair	--	--	--	Q	29.8092	102.1483	2306
29	Rio Grande above Shafter Crossing near Dryden, Tex.	294808102071000	E	2/5/2006	683.7	338	--	Fair	--	--	--	Q, QW	29.8023	102.1195	2306
30	Rio Grande at Martin's Canyon, Tex.	294808102013400	E	2/6/2006	675.6	359	--	Fair	--	--	--	Q	29.8022	102.0262	2306
31	Rio Grande above Indian Creek near Dryden, Tex.	294857101583300	E	2/7/2006	670.8	321	--	Fair	--	--	--	Q	29.8160	101.9759	2306
32	Rio Grande above Lozier Canyon near Dryden, Tex.	294743101524500	E	2/8/2006	662.0	394	--	Fair	--	--	--	Q, QW	29.7952	101.8791	2306
33	Rio Grande below Lozier Canyon near Dryden, Tex.	294646101475800	E	2/9/2006	652.0	370	--	Fair	--	--	--	Q	29.7795	101.7996	2306
34	Rio Grande at Foster Ranch near Langtry, Tex.	[1]08377200	E	2/8/2006	648.7	313	--	--	--	--	--	Q[e], QW, QA	29.7808	101.7560	2305

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Site number (fig. 2)	Site name	USGS or IBWC[1] streamflow-gaging station number	Sub-reach[2] (fig. 2)	Sample date	River mile	Discharge (ft^3/s)		Discharge measurement qualifier		RPD[3]	Mean discharge (ft^3/s)	Type of data collected	Latitude (decimal degrees)	Longitude (decimal degrees)	Segment (fig. 2)
						Q_1	Q_2	Q_1	Q_2						
35	Rio Grande below Foster's Ranch near Langtry, Tex.	294634101431500	E	2/10/2006	646.0	386	--	Good	--	--	--	Q	29.7761	101.7208	2305
36	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	294527101381700	E	2/10/2006	638.7	426	--	Fair	--	--	--	Q, QW	29.7574	101.6379	2305
37	Rio Grande below Rattlesnake Canyon near Langtry, Tex.	294615101352800	E	2/11/2006	635.2	406	--	Fair	--	--	--	Q	29.7709	101.5910	2305
38	Rio Grande at take-out near Langtry, Tex.	294821101330400	E	2/11/2006	630.8	450	--	Fair	--	--	--	Q, QW	29.8058	101.5511	2305

[1]IBWC streamflow-gaging station with continous streamflow records; continuous records for streamflow used to determine streamflow for sites 1, 2, and 34 (discharge measurements made at site 7) (U.S. Geological Survey, 2012); USGS stations are discrete measurement sites.

[2]Subreaches A–E; site 12 is spring site about 0.2 mile upstream from Rio Grande near subreach B.

[3]RPD = $|Q_1 - Q_2|/((Q_1 + Q_2)/2) \times 100$, where Q_1 is the first discharge measurement in replicate pair and Q_2 is the second discharge measurement in replicate pair.

[4]Site upstream from Rio Conchos and subreach A.

[5]Q not used in gain/loss analysis because flow affected by releases from upstream reservoirs.

Table 2. Criteria and screening levels used to assess surface-water quality in Texas.

[--, not applicable; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; TSWQS, Texas Surface Water Quality Standards (Texas Commission on Environmental Quality, 2010)]

Constituent (units)	Aquatic life use protection[1]		Human health criteria[2]		General use protection criteria[3]	Screening levels[4]
	Acute criteria	Chronic criteria	Fish consumption use	Public water supply use		
pH (standard units)	--	--	--	--	6.5–9.0	--
Temperature (°C)	--	--	--	--	32.2	--
Dissloved oxygen (mg/L)	--	--	--	--	5	--
Chloride (mg/L)	--	--	--	--	300	--
Sulfate (mg/L)	--	--	--	--	570	--
Total dissolved solids (mg/L)	--	--	--	--	1,500	--
Ammonia (NH_4) (mg/L)	--	--	--	--	--	0.33
Nitrite (NO_2) + nitrate (NO_3) (mg/L)	--	--	--	--	--	2.00
Orthophosphate[5] (PO_4) (mg/L)	--	--	--	--	--	0.37
Phosphorus (P) (mg/L)	--	--	--	--	--	0.69
Arsenic (µg/L)	360	190	--	50	--	--
Selenium (µg/L)	20	5	50	--	--	--

[1]Aquatic life use protection established in the TSWQS includes acute and chronic criteria for metals and organics in water, dissolved oxygen, toxicity in water and sediment, sediment contaminants, biological communities, and in-stream habitat.

[2]Criteria established in the TSWQS designed to prevent contamination of drinking water, fish, and other aquatic life to ensure they are safe for human consumption.

[3]Water-quality criteria established in the TSWQS for segment 2306 to safeguard general water quality, rather than protection of a specific use, except for dissolved-oxygen criterion, which is related to aquatic life use protection.

[4]Statistically derived from 10 years of surface-water-quality monitoring data using the 85th percentile (Lambert and others, 2008, table 3); screening levels used in the absence of established criteria are not criteria but are levels used to denote a concern.

[5]Equivalent to orthophosphorus of TSWQS.

Table 3. Quality-assurance data for physical properties, major ions, nutrients, and trace elements measured in samples collected from the main-stem Rio Grande, Big Bend area, United States and Mexico, 2006.

[BBNP, Big Bend National Park; WS, surface water; WSQ, quality-control (QC) sample–surface water; OAQ, QC sample–deionized water; --, no data; <, less than; E, estimated]

Site number (fig. 2; table 1)	Site name	Subreach (fig. 2)	Date	Sample start time	Medium code	Sample type code	Discharge, instantaneous (cubic feet per second)	Dissolved oxygen, water, unfiltered (milligrams per liter)	pH, water, unfiltered, field (standard units)	Salinity, water, unfiltered (parts per thousand)
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	1100	WS	Environmental	136	8.5	8.1	1.66
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	1101	WSQ	Replicate	136	8.5	8.1	1.66
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	1230	WS	Environmental	313	10.3	8.2	0.75
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	1238	OAQ	Field Blank	--	--	--	--

Site number (fig. 2; table 1)	Site name	Subreach (fig. 2)	Date	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 degrees Celsius)	Temperature, water (degrees Celsius)	Dissolved solids dried at 180 degrees Celsius, water, filtered (milligrams per liter)	Hardness, water (milligrams per liter as calcium carbonate)	Calcium, water, filtered (milligrams per liter)	Magnesium, water, filtered (milligrams per liter)	Potassium, water, filtered (milligrams per liter)
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	3,210	14.5	2,190	667	192	44.6	10.7
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	3,210	14.5	2,190	646	184	44.2	10.4
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	1,530	15.1	1,010	383	103	29.9	6.45
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	--	--	--	<0.08	<0.02	<0.008	<0.010

Table 3. Quality-assurance data for physical properties, major ions, nutrients, and trace elements measured in samples collected from the main-stem Rio Grande, Big Bend area, United States and Mexico, 2006.—Continued

[BBNP, Big Bend National Park; WS, surface water; WSQ, quality-control (QC) sample–surface water; OAQ, QC sample–deionized water; --, no data; <, less than; E, estimated]

Site number (fig. 2; table 1)	Site name	Sub-reach (fig. 2)	Date	Sodium, water, filtered (milligrams per liter)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter as calcium carbonate)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter)	Bromide, water, filtered (milligrams per liter)	Carbonate, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter)	Chloride, water, filtered (milligrams per liter)	Fluoride, water, filtered (milligrams per liter)
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	438	179	216	0.82	1	507	1.29
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	427	--	--	0.69	--	507	1.30
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	183	174	209	--	1	183	1.19
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	<0.20	--	--	--	--	<0.01	<0.01

Site number (fig. 2; table 1)	Site name	Sub-reach (fig. 2)	Date	Silica, water, filtered (milligrams per liter as silicon dioxide)	Sulfate, water, filtered (milligrams per liter)	Ammonia plus organic nitrogen, water, unfiltered (milligrams per liter as nitrogen)	Nitrate plus nitrite, water, filtered (milligrams per liter as nitrogen)	Nitrite, water, filtered (milligrams per liter as nitrogen)	Orthophosphate, water, filtered (milligrams per liter)	Orthophosphate, water, filtered (milligrams per liter as phosphorus)
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	14.0	746	--	<0.016	<0.002	<0.092	<0.030
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	13.8	748	--	<0.016	E0.001	<0.092	<0.030
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	13.5	331	0.21	0.650	0.003	<0.018	<0.006
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	<0.04	<0.01	--	<0.016	<0.002	<0.018	<0.006

Table 3. Quality-assurance data for physical properties, major ions, nutrients, and trace elements measured in samples collected from the main-stem Rio Grande, Big Bend area, United States and Mexico, 2006.—Continued

[BBNP, Big Bend National Park; WS, surface water; WSQ, quality-control (QC) sample–surface water; OAQ, QC sample–deionized water; --, no data; <, less than; E, estimated]

Site number (fig. 2; table 1)	Site name	Sub-reach (fig. 2)	Date	Phosphorus, water, unfiltered (milligrams per liter as phosphorus)	Iron, water, filtered (micro-grams per liter)	Lithium, water, filtered (micro-grams per liter)	Strontium, water, filtered (micro-grams per liter)	Vanadium, water, (filtered micro-grams per liter	Arsenic, water, filtered (micro-grams per liter)	Boron, water, filtered (micro-grams per liter)	Selenium, water, filtered (micro-grams per liter)
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	--	E12	188	3,410	2.0	3.1	469	0.62
10	Rio Grande at La Clocha Campground, BBNP, Tex.	B	2/9/2006	--	<18	167	3,380	2.0	3.0	497	0.61
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	0.035	E5	96.2	2,170	3.5	2.6	256	0.96
34	Rio Grande at Foster Ranch near Langtry, Tex.	E	2/8/2006	--	<6	<0.6	<0.40	<0.10	<0.12	<8	<0.08

Table 4. Streamflow gains and losses computed for sites on the Rio Grande, Big Bend area, United States and Mexico, 2006.

[ft^3/s, cubic feet per second; --, not calculated; Fair, measured discharge uncertainty 8 percent; Good, measured discharge uncertainty 5 percent]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Segment	Date	Discharge[1] (ft^3/s)	Uncertainty qualifier	Difference in streamflow between consecutive downstream and upstream sites within subreach (ft^3/s)	Potential measurement error between consecutive downstream and upstream sites (ft^3/s)	Gain, loss, or no change in streamflow (based on consecutive downstream order discharge measurements)	Difference in streamflow between most downstream and upstream sites in subreach (ft^3/s)	Potential measurement error between most downstream and upstream sites in subreach (ft^3/s)	Subreach gain or loss designation (based on most upstream and downstream discharge measurements in subreach)
1	U[2]	2307	6/29/2006	4.06	Fair	--	--	--	--	--	--
2	A	2306	6/29/2006	41.2	Fair	--	--	--	--	--	--
3	A	2306	6/20/2006	18.7	Fair	-22.6	4.8	loss	--	--	--
4	A	2306	6/20/2006	15.0	Fair	-3.7	2.7	loss	-26.2	4.5	loss
5	B	2306	2/6/2006	114	Fair	--	--	--	--	--	--
6	B	2306	2/6/2006	109	Fair	-5.0	17.8	no change	--	--	--
7	B	2306	2/7/2006	116	Fair	6.5	18.0	no change	--	--	--
8	B	2306	2/8/2006	121	Fair	5.5	18.9	no change	--	--	--
9	B	2306	2/8/2006	121	Fair	0	19.4	no change	--	--	--
10	B	2306	2/9/2006	136	Fair	15.0	20.6	no change	--	--	--
11	B	2306	2/10/2006	147	Fair	11.0	22.6	no change	--	--	--
13	B	2306	2/9/2006	153	Fair	5.5	24.0	no change	--	--	--
14	B	2306	2/10/2006	173	Fair	20.5	26.0	no change	59.0	23.0	gain
15	C	2306	6/22/2006	55.4	Fair	--	--	--	--	--	--
16	C	2306	6/22/2006	49.0	Fair	-6.4	8.4	no change	--	--	--
17	C	2306	6/22/2006	92.6	Fair	43.6	11.3	gain	37	11.8	gain
17	D	2306	3/13/2006	162	Fair	--	--	--	--	--	--
18	D	2306	3/14/2006	183	Fair	21.5	27.6	no change	--	--	--
19	D	2306	3/14/2006	183	Fair	0	29.3	no change	--	--	--
20	D	2306	3/15/2006	206	Fair	23.0	31.1	no change	--	--	--
21	D	2306	3/15/2006	242	Fair	36.0	35.8	gain	--	--	--
22	D	2306	3/15/2006	252	Fair	10.0	39.5	no change	--	--	--
23	D	2306	3/16/2006	266	Fair	14.0	41.4	no change	--	--	--
24	D	2306	3/16/2006	252	Fair	-14.0	41.4	no change	--	--	--
25	D	2306	3/17/2006	267	Fair	15.0	41.5	no change	--	--	--
26	D	2306	3/18/2006	278	Fair	11.0	43.6	no change	--	--	--
27	D	2306	3/19/2006	[3]445	Fair	--	--	--	--	--	--
28	D	2306	3/20/2006	[3]393	Fair	--	--	--	116	31.5	gain

Table 4. Streamflow gains and losses computed for sites on the Rio Grande, Big Bend area, United States and Mexico, 2006.—Continued

[ft^3/s, cubic feet per second; --, not calculated; Fair, measured discharge uncertainty 8 percent; Good, measured discharge uncertainty 5 percent]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Seg-ment	Date	Dis-charge[1] (ft^3/s)	Uncertainty qualifier	Difference in streamflow between consecutive downstream and upstream sites within subreach (ft^3/s)	Potential measurement error between consecutive downstream and upstream sites (ft^3/s)	Gain, loss, or no change in streamflow (based on consecutive downstream order discharge measurements)	Difference in streamflow between most downstream and upstream sites in subreach (ft^3/s)	Potential measurement error between most downstream and upstream sites in subreach (ft^3/s)	Subreach gain or loss designation (based on most upstream and downstream discharge measurements in subreach)
28	E	2306	2/5/2006	292	Fair	--	--	--	--	--	--
29	E	2306	2/5/2006	338	Fair	46.0	50.4	no change	--	--	--
30	E	2306	2/6/2006	359	Fair	21.0	55.8	no change	--	--	--
31	E	2306	2/7/2006	321	Fair	-38.0	54.4	no change	--	--	--
32	E	2306	2/8/2006	394	Fair	73.0	57.2	gain	--	--	--
33	E	2306	2/9/2006	370	Fair	-24.0	61.1	no change	--	--	--
34	E	2306	2/8/2006	313	Fair	-57.0	54.6	loss	--	--	--
35	E	2306	2/10/2006	386	Good	73.0	44.3	gain	--	--	--
36	E	2306	2/10/2006	426	Fair	40.0	53.4	no change	--	--	--
37	E	2306	2/11/2006	406	Fair	-20.0	66.6	no change	--	--	--
38	E	2306	2/11/2006	450	Fair	44.0	68.5	no change	158	59.4	gain

[1]Mean discharge value used for sites where replicate measurements (table 1) made.

[2]Site upstream from Rio Conchos and subreach A.

[3]Values not used because flow affected by releases from upstream reservoirs.

Table 5. Selected physical properties and water-quality constituents, including salinity, dissolved solids, and major ions, measured in samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.

[--, no data; E, estimated; <, less than; SIO_2, silicon dioxide]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Site name	Date	Sample start time	Dissolved oxygen, water, unfiltered (milligrams per liter)	pH, water, unfiltered, field (standard units)	Salinity, water, unfiltered (parts per thousand[1])	Specific conductance, water, unfiltered (microsiemens per centimeter at 25 degrees Celsius)	Temperature, water (degrees Celsius)	Dissolved solids dried at 180 degrees Celsius, water, filtered (milligrams per liter)
1	U[2]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	0930	6.8	8.0	1.01	2,020	22.9	1,460
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	1430	8.4	7.9	1.71	3,300	28.8	2,460
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	1200	7.7	7.9	1.76	3,400	28.5	2560
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	1500	8.1	8.0	1.68	3,250	33.0	2,420
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	1200	10.2	8.3	1.78	3,430	12.1	2,320
6	B	Rio Grande near Castolon, Tex.	2/6/2006	1530	11.3	8.4	1.78	3,420	15.4	2,290
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	1430	10.5	8.3	1.80	3,470	13.0	2,340
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	1130	7.4	8.2	1.82	3,510	12.9	2,390
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	1100	8.5	8.1	1.66	3,210	14.5	2,190
13	B	Rio Grande at Rio Grande Village, BBNP, Tex.	2/9/2006	1400	7.5	7.9	1.17	2,930	19.6	1,990
15	C	Rio Grande at La Linda, Mexico	6/22/2006	1115	8.1	8.3	0.70	1,440	30.0	1,020
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	1500	9.9	8.0	0.98	1,970	21.3	1,280
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	1030	9.0	8.1	0.88	1,770	18.9	1,160
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	1630	9.8	8.2	0.76	1,550	23.7	993
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	1100	8.5	8.1	0.70	1,430	23.0	932
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	1815	9.6	8.2	0.82	1,660	17.0	1,080
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	1145	10.0	8.3	0.77	1,560	15.1	1,020
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	1230	10.3	8.2	0.75	1,530	15.1	1,010
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	1700	10.3	8.3	0.69	1,420	15.3	917
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	1730	10.5	8.3	0.67	1,380	15.6	886

Table 5. Selected physical properties and water-quality constituents, including salinity, dissolved solids, and major ions, measured in samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.—Continued

[--, no data; E, estimated; <, less than; SIO_2, silicon dioxide]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Site name	Date	Hardness, water (milli-grams per liter as calcium carbonate)	Calcium, water, filtered (milligrams per liter)	Mag-nesium, water, filtered (milligrams per liter)	Potassium, water, filtered (milligrams per liter)	Sodium, water, filtered (milligrams per liter)	Alkalinity, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter as calcium carbonate)	Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter)
1	U[2]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	452	144	22.1	8.70	244	--	--
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	809	256	39.9	10.3	411	249	299
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	664	203	37.1	9.51	473	--	--
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	722	216	43.1	12.6	470	--	--
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	678	196	44.7	11.5	501	201	240
6	B	Rio Grande near Castolon, Tex.	2/6/2006	664	190	45.3	11.5	507	184	E220
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	678	194	46.0	11.0	489	190	225
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	694	199	46.6	11.5	492	172	208
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	667	192	44.6	10.7	438	179	216
13	B	Rio Grande at Rio Grande Village, BBNP, Tex.	2/9/2006	617	175	43.0	9.73	378	183	220
15	C	Rio Grande at La Linda, Mexico	6/22/2006	415	110	33.0	7.29	153	--	--
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	458	126	34.0	7.87	239	176	212
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	413	111	32.2	7.49	210	158	191
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	376	101	29.6	6.63	174	168	201
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	356	94.2	28.5	6.20	162	163	195
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	372	99.9	29.0	6.43	190	170	203
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	365	98.5	28.1	6.06	178	174	208
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	383	103	29.9	6.45	183	174	209
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	351	94.3	27.4	5.75	161	167	199
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	336	90.4	26.3	5.38	151	174	208

Table 5. Selected physical properties and water-quality constituents, including salinity, dissolved solids, and major ions, measured in samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.—Continued

[--, no data; E, estimated; <, less than; SIO_2, silicon dioxide]

Site number (fig. 2; table 1)	Subreach (fig. 2)	Site name	Date	Bromide, water, filtered (milligrams per liter)	Carbonate, water, filtered, inflection-point titration method (incremental titration method), field (milligrams per liter)	Chloride, water, filtered (milligrams per liter)	Fluoride, water, filtered (milligrams per liter)	Silica, water, filtered (milligrams per liter as SiO_2)	Sulfate, water, filtered (milligrams per liter)
1	U[2]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	0.51	--	153	2.00	21.6	661
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	0.75	2	320	1.65	26.1	1,060
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	0.83	--	424	1.60	22.8	1050
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	0.83	--	391	1.71	26.8	1,030
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	0.84	2	580	1.20	11.8	754
6	B	Rio Grande near Castolon, Tex.	2/6/2006	0.87	E2	574	1.22	12.0	752
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	0.82	3	582	1.22	12.7	761
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	0.79	1	592	1.19	12.9	783
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	0.82	1	507	1.29	14.0	746
13	B	Rio Grande at Rio Grande Village, BBNP, Tex.	2/9/2006	0.81	1	441	1.41	15.7	689
15	C	Rio Grande at La Linda, Mexico	6/22/2006	0.39	--	117	1.84	24.4	454
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	0.45	<1	236	1.48	20.1	448
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	0.43	1	205	1.46	19.9	396
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	0.36	2	170	1.47	19.2	331
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	0.33	2	157	1.38	18.6	307
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	0.40	2	203	1.27	13.5	368
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	0.37	2	188	1.21	13.7	335
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	--	1	183	1.19	13.5	331
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	0.34	2	167	1.13	14.6	296
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	0.33	2	161	1.11	15.1	282

[1]Estimated from 30-point rating table (Wagner and others, 2000) using specific conductance measured at site.

[2]Site upstream from Rio Conchos and subreach A.

Table 6. Nutrient data in water-quality samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.

[WS, surface water; --, no data; <, less than; BBNP, Big Bend National Park; E, estimated]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Site name	Date	Sample start time	Medium code	Ammonia plus organic nitrogen, water, unfiltered (milligrams per liter as nitrogen)	Nitrate plus nitrite, water, filtered (milligrams per liter as nitrogen)	Nitrite, water, filtered (milligrams per liter as nitrogen)	Ortho-phosphate, water, filtered (milligrams per liter)	Ortho-phosphate, water, filtered (milligrams per liter as phos-phorus)	Phospho-rus, water, unfiltered (milligrams per liter as phosphorus)
1	U[1]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	0930	WS	--	0.283	0.011	0.024	0.008	--
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	1430	WS	0.60	0.41	0.013	0.03	0.01	0.12
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	1200	WS	--	0.028	0.002	0.026	0.009	--
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	1500	WS	--	<0.016	<0.002	0.029	0.009	--
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	1200	WS	--	<0.016	<0.002	<0.092	<0.030	--
6	B	Rio Grande near Castolon, Tex.	2/6/2006	1530	WS	--	<0.016	<0.002	<0.092	<0.030	--
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	1430	WS	--	<0.016	<0.002	<0.092	<0.030	--
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	1130	WS	--	<0.016	<0.002	<0.092	<0.030	--
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	1100	WS	--	<0.016	<0.002	<0.092	<0.030	--
13	B	Rio Grande at Rio Grande Village, BBNP, Tex.	2/9/2006	1400	WS	--	<0.016	E0.001	<0.092	<0.030	--
15	C	Rio Grande at La Linda, Mexico	6/22/2006	1115	WS	--	E0.011	<0.002	0.023	0.008	--
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	1500	WS	--	0.293	0.004	<0.055	<0.02	--
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	1030	WS	--	0.331	0.004	<0.055	<0.02	--
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	1630	WS	--	0.541	0.004	<0.055	<0.02	--
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	1100	WS	--	0.642	0.004	<0.055	<0.02	--
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	1815	WS	--	0.593	0.003	<0.018	<0.006	--
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	1145	WS	--	0.66	0.003	<0.092	<0.030	--
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	1230	WS	0.21	0.65	0.003	<0.018	<0.006	0.035
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	1700	WS	--	0.748	0.003	<0.092	<0.030	--
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	1730	WS	--	0.818	0.004	<0.092	<0.030	--

[1]Site upstream from Rio Conchos and subreach A.

Table 7. Trace-element data in water-quality samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.

[WS, surface water; <, less than; BBNP, Big Bend National Park; E, estimated]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Site name	Date	Sample start time	Medium code	Iron, water, filtered micrograms per liter)	Arsenic, water, filtered (micrograms per liter)	Boron, water, filtered (micrograms per liter)	Lithium, water, filtered (micrograms per liter)	Selenium, water, filtered (micrograms per liter)	Strontium, water, filtered (micrograms per liter)	Vanadium, water, filtered (micrograms per liter)
1	U[1]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	0930	WS	<6	4.5	438	117	1.2	2,710	4.2
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	1430	WS	<18	2.8	607	150	1.6	3,690	3.4
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	1200	WS	<18	2.2	501	74.3	0.66	3,540	1.8
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	1500	WS	<18	2.8	508	77.9	0.50	3,530	2.5
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	1200	WS	E17	3.4	476	201	0.61	3,240	2.1
6	B	Rio Grande near Castolon, Tex.	2/6/2006	1530	WS	<18	3.3	522	186	0.62	3,120	2.0
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	1430	WS	E13	3.1	511	178	0.60	3,200	1.8
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	1130	WS	E16	3.0	480	200	0.52	3,360	1.9
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	1100	WS	E12	3.1	469	188	0.62	3,410	2.0
13	B	Rio Grande at Rio Grande Village, BBNP, Tex.	2/9/2006	1400	WS	E18	3.4	462	160	0.67	3,450	2.1
15	C	Rio Grande at La Linda, Mexico	6/22/2006	1115	WS	<6	4.3	325	118	1.4	3,400	4.4
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	1500	WS	<6	3.5	366	116	1.0	2,890	3.8
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	1030	WS	<6	3.4	343	113	1.0	2,700	3.8
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	1630	WS	<6	3.3	252	99.6	1.2	2,330	4.1
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	1100	WS	<6	3.2	314	132	1.1	2,340	4.3
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	1815	WS	<6	2.6	273	101	1.0	2,430	3.3
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	1145	WS	<6	2.4	256	96.2	1.0	2,320	3.5
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	1230	WS	E5	2.6	256	96.2	0.96	2,170	3.5
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	1700	WS	<6	2.4	229	84.8	1.0	2,040	3.8
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	1730	WS	<6	2.2	220	79.4	1.0	2,010	3.9

[1]Site upstream from Rio Conchos and subreach A.

Appendix 1. Oxygen and nitrogen isotope data in water-quality samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006

Appendix 1. Oxygen and nitrogen isotope data in water-quality samples from the main-stem Rio Grande, Big Bend area, United States and Mexico, February 5–June 29, 2006.

[0^{18}, oxygen-18; O^{16}, oxygen-16; δ, delta; ^{15}N, nitrogen-15; --, not analyzed for or not calculated; BBNP, Big Bend National Park]

Site number (fig. 2; table 1)	Sub-reach (fig. 2)	Site name	Date	Deuterium/ protium ratio, water, unfiltered (per mil)	O^{18}/O^{16} ratio, water, unfiltered (per mil)	$\delta^{18}O$, water, filtered (per mil)	$\delta^{15}N$, water, filtered (per mil)
1	U[1]	Rio Grande above Rio Conchos near Presidio, Tex.	6/29/2006	--	--	--	--
2	A	Rio Grande below Rio Conchos near Presidio, Tex.	6/29/2006	--	--	--	--
3	A	Rio Grande at Rancherias Rapids near Redford, Tex.	6/20/2006	-31.9	-2.82	4.03	9.75
4	A	Rio Grande above Lajitas, Tex.	6/20/2006	-24.6	-1.02	--	--
5	B	Rio Grande at Santa Elena Canyon, BBNP, Tex.	2/6/2006	-47.7	-5.42	--	--
6	B	Rio Grande near Castolon, BBNP, Tex.	2/6/2006	-49.0	-5.37	--	--
7	B	Rio Grande at Johnson Ranch near Castolon, Tex.	2/7/2006	-48.0	-5.30	--	--
8	B	Rio Grande at Talley Campground, BBNP, Tex.	2/8/2006	-45.9	-5.00	--	--
10	B	Rio Grande at La Clocha Campground, BBNP, Tex.	2/9/2006	-45.6	-5.03	--	--
13	B	Rio Grande at Rio Grande Village, Tex.	2/9/2006	-46.3	-5.44	--	--
15	C	Rio Grande at La Linda, Mexico	6/22/2006	-36.7	-4.32	--	--
17	D	Rio Grande at Taylor's Farm near Sanderson, Tex.	3/13/2006	-43.7	-5.32	4.77	9.07
20	D	Rio Grande above Silber Canyon near Sanderson, Tex.	3/15/2006	-44.3	-5.54	6.61	10.30
24	D	Rio Grande below Rodeo Rapids near Sanderson, Tex.	3/16/2006	-45.3	-5.90	6.96	9.38
26	D	Rio Grande below Panther Gulch near Sanderson, Tex.	3/18/2006	-44.8	-5.84	5.93	8.78
29	E	Rio Grande above Shafter Crossing near Dryden, Tex.	2/5/2006	-47.1	-6.05	5.68	8.79
32	E	Rio Grande above Lozier Canyon near Dryden, Tex.	2/8/2006	-45.6	-6.09	4.57	8.58
34	E	Rio Grande at Foster Ranch near Langtry, Tex.	2/8/2006	--	--	--	--
36	E	Rio Grande above Rattlesnake Canyon near Langtry, Tex.	2/10/2006	-44.3	-5.98	4.47	8.33
38	E	Rio Grande at take-out near Langtry, Tex.	2/11/2006	-44.3	-6.01	4.81	8.66

[1]Site upstream from Rio Conchos and subreach A.

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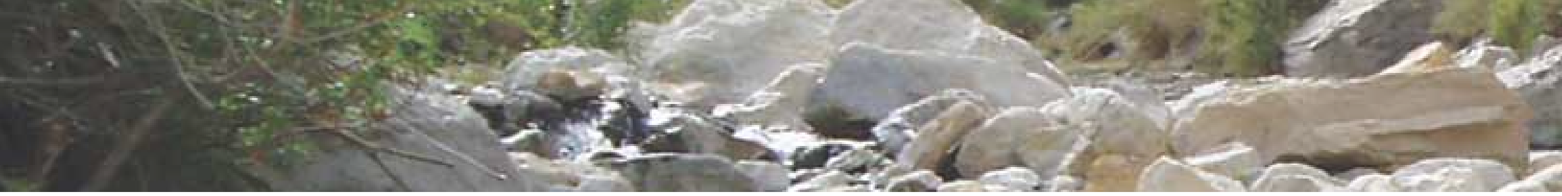

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