



Water Quality Monitoring for the Rito de los Frijoles and Capulin Creek in Bandelier National Monument

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/344



ON THE COVER

Rito de los Frijoles in Bandelier National Monument
Photograph courtesy of Southern Colorado Plateau Network

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1 Introduction and background

The National Park Service (NPS) Inventory and Monitoring (I&M) Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a strong scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. As part of the effort to create a comprehensive picture of aquatic ecosystem health, the Southern Colorado Plateau Network (SCPN) identified water quality as a core “vital sign” (Thomas et al. 2006).

Specific objectives of stream water quality monitoring for the SCPN parks are

1. determine status and trends in selected core water quality parameters (water temperature, pH, conductivity, dissolved oxygen, and discharge) under base flow conditions at selected sites in priority streams within SCPN parks as a function of flow, season and climatic conditions
2. determine status and trends of water quality constituents including bacteria, nutrients, major elements, and trace metals at selected sites in priority streams within SCPN parks
3. compare water quality data against state standards to identify chronic exceedances. multiple exceedances in a year typically indicate non-compliance

1.1 Selecting potential water quality monitoring sites

We targeted SCPN streams and springs with potential for water quality monitoring by reviewing (1) water quality data inventory and analysis reports prepared by the Water Resources Division (WRD) of the NPS (National Park Service (NPS) 1997), (2) a USGS summary and review of available water quality data from streams in SCPN parks (Brown 2008), (3) data collected during a Level 1 water quality inventory of streams in SCPN parks (Macy and Monroe 2006), and (4) results of water quality planning meetings with park staff.

SCPN water bodies targeted for water quality monitoring were selected based on the following criteria:

- 303(d) listed waters¹ - where previous sampling indicates one or more parameters regularly approach or exceed established water quality standards or recommended levels
- waters with demonstrated threat levels – where an analysis of existing data indicate that measured conditions regularly approach or exceed standards or recommended levels, but where the frequency of exceedances or the quality of the database do not support a 303(d) listing
- pristine waters – where there is no direct impact of human activities; provides baseline data
- ecological significance – presence of unique species or species of concern
- waters of management concern – where past sampling may not indicate constituent values of concern, but where anthropogenic activities indicate that contamination is a significant threat
- historic data – waters identified as important, for which substantial historic water quality data is available
- data gaps – waters identified as important, but where little or no water quality information exists

Water quality monitoring sites are generally located where there is a history of water quality data collection, or co-located with aquatic macroinvertebrate monitoring sites. NPS core water quality data and water quality samples are collected six to eight times per year. Water quality samples are analyzed by SCPN staff and by a qualified contract laboratory.

1.2 Water quality monitoring at Bandelier National Monument

The Rito de los Frijoles is a perennial stream flowing eastward from the Sierra de los Valles of the Jemez Mountains into the Rio Grande. The entire length of this stream lies within park boundaries and much of its watershed is designated wilderness. The watershed is bordered by lands administered by Los Alamos National Laboratory, Valles Caldera National Preserve, and Santa Fe National Forest. The BAND visitor

¹ Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters— waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes (EPA 2011).

center and numerous archeological sites are located near the stream in the lower portion of the watershed, resulting in high levels of visitor use for the stream. In recent years several large fires have impacted this watershed. In 1977 the La Mesa Fire burned about 58% of the Frijoles watershed (Allen 1996); in 2000, the Cerro Grande fire ignited in the upper portion of the watershed; and the 2011 Las Conchas Fire also burned this area. Water quality concerns for this stream include DDT, fecal coliform bacteria, elevated temperature, radium, aluminum, and turbidity, which has caused the Rito de los Frijoles to be included on New Mexico's 303(d) lists of impaired surface waters since 1998 (Surface Water Quality Board, New Mexico Environment Department(NMED SWQB)).

Capulin Creek is a perennial stream in the southwestern portion of the park, and joins the Rio Grande approximately 8 km south of the Rito de los Frijoles. The upper portion of its watershed lies within the Santa Fe National Forest, while the remainder lies within BAND. Most of the watershed is a designated wilderness area, managed for recreational use within park boundaries. The U.S. Forest Service manages land in the upper reaches of the watershed for recreation and timber harvest. In 1996 the Dome Fire burned approximately 90% of the Capulin watershed (Vieira et al. 2004), and the 2011 Las Conchas Fire also burned large portions of the watershed. Previous water quality data from Capulin Creek as well as the Rito de los Frijoles are summarized in Brown 2008. Water quality concerns in Capulin Creek are mainly due to fire-effects and silvicultural issues. The stream was included on New Mexico's 303(d) list because of sediment deposition and elevated turbidity levels from 1998 to 2004 (NMED SWQB).

In 2010, SCPN implemented water quality monitoring on the Rito de los Frijoles and Capulin Creek at the following locations (fig. 1):

- Rito de los Frijoles near Visitor Center (BANDRIT01), identified in this report as RIT01, is located adjacent to a streamflow gaging station (Los Alamos National Laboratory LANL-E350, USGS #08313350, Rito de los Frijoles in Bandelier Nat Mon, NM) and is co-located with a SCPN aquatic macroinvertebrate monitoring site. During 2010 the streamflow gaging station was maintained by Los Alamos National Laboratory.
- Rito de los Frijoles at Upper Crossing (BANDRIT02), identified in this report as RIT02, is located at the Upper Crossing Trail intersection, upstream from RIT01.
- Capulin Creek at Base Camp Gaging Station (BANDCAP01), identified in this report as CAP01, is located less than 0.3 km upstream from the backcountry ranger cabin at a discontinued U.S. Geological Survey streamflow gaging station (Capulin Canyon at Ranger Cabin, station #083133655). This site is co-located with a SCPN aquatic macroinvertebrate monitoring site.

During 2010, SCPN staff completed eight water quality monitoring site visits to RIT01, RIT02, and CAP01 at approximately six week intervals. This report documents the monitoring activities that occurred at each of the three sites and summarizes the data collected.

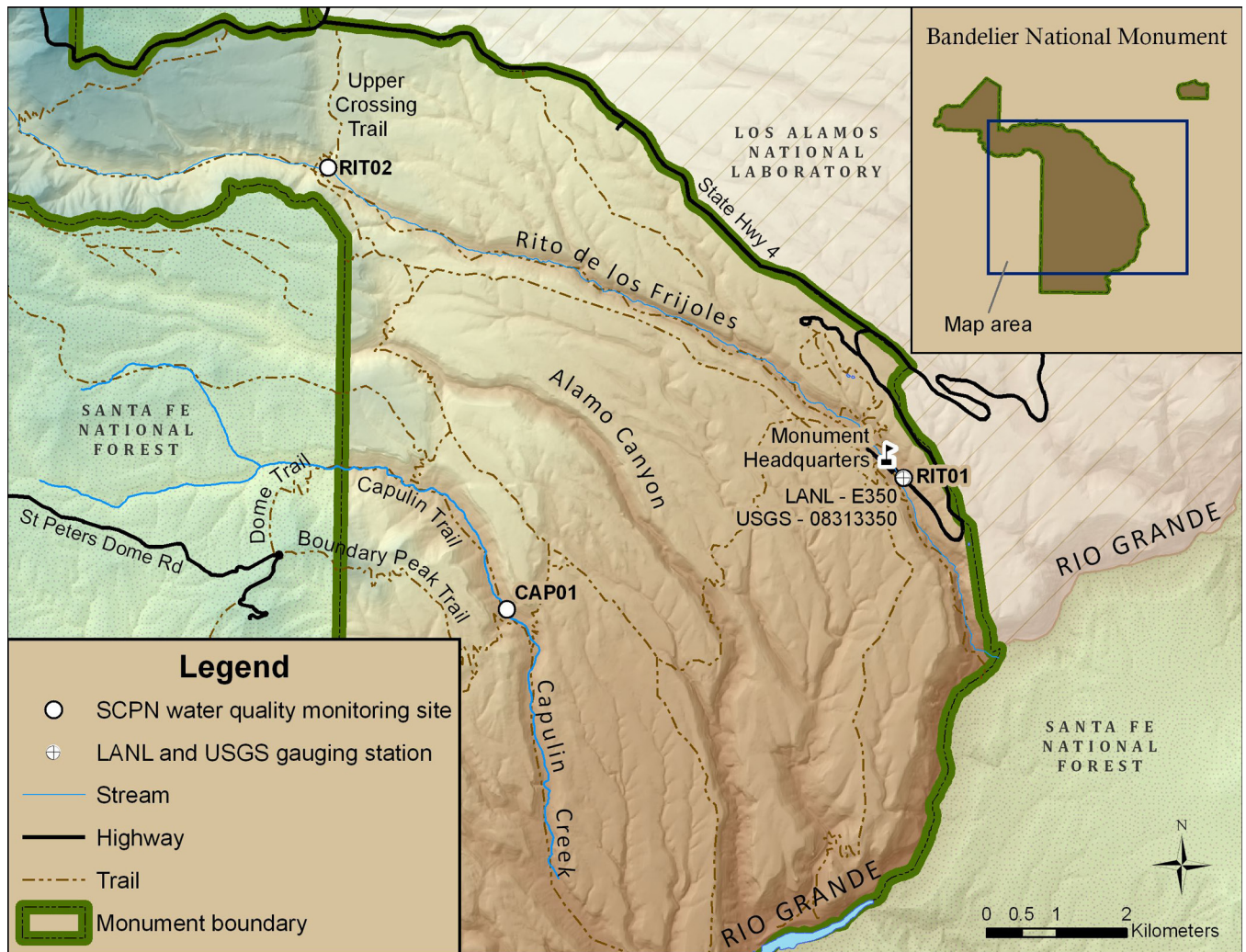


Figure 1. Map of water quality sites RIT01, RIT02, and CAP01 on the Rito de los Frijoles and Capulin Creek in Bandelier N.M.

2 Methods

Following is a brief outline of water quality data collection and processing methodologies followed by SCPN at BAND during 2010. Please refer to SCPN's draft water quality monitoring protocol (Monroe and Bliss in preparation) for further details.

2.1 Water quality core parameters

National Park Service core water quality parameters include water temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge. During each site visit, we noted the hydrologic conditions and collected water quality core parameter data using the following methods:

- Water and air temperatures were recorded at 15-minute intervals by a HOBO Pendant and HOBO TidbiT (Onset Computer Corporation) deployed at the monitoring site. The sensors were downloaded and maintenance was performed during each site visit. Sensor accuracy was confirmed using a NIST-certified thermometer during each download.
- As soon as possible after arriving at the site, a multi-parameter sonde (Hydrolab-MS5; Hach Inc.) was calibrated and deployed in a well-mixed part of the stream channel, where it logged temperature, pH, specific conductivity, and dissolved oxygen data at 5- to 15-second intervals. The sonde was left stationary in the stream for the entire site visit.
- Turbidity samples were collected in triplicate, kept on ice for less than 24 hours, and analyzed with a Hach 2100P Portable Turbidimeter (Hach Inc.). Turbidity samples that exceeded the turbidimeter detection limit of 1,000 NTU (Nephelometric Turbidity Units) were diluted; then turbidities were estimated using linear regression equations. Samples were diluted by at least three dilution factors in order to cover the detection range of the turbidimeter—low-range, medium-range, and high-range dilutions.
- Discharge was measured using either a FlowTracker Acoustic Doppler Velocimeter (SonTek Inc.), a Pygmy Meter and AquaCalc Pro (Rickly Inc. and JBS Instruments), or a Marsh McBirney Flo-Mate 2000 (Hach Inc.). Discharge was recorded by the LANL gage #E350 at 5-minute intervals throughout the year (Los Alamos National Laboratory, A. White, email to Stephen Monroe, National Park Service, 9 August 2011).

In addition to the regular site visits, which were generally less than two hours in length, we collected water quality core parameter data at RIT01 at 5-minute intervals from March 11-13 to characterize temporal variability.

2.2 Water quality samples

During each site visit, we collected a sample for bacterial analysis by dipping a sample bottle into the center of flow. The sample was then analyzed by SCPN staff for total coliforms and *E. coli* using the Quanti-Tray® 2000 system (Idexx Inc.). We collected samples for other analytes in a similar manner and sample water was filtered and/or acid-treated (as required), kept on ice, and shipped to the contract laboratory. For 2010, SCPN contracted with the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analyses of water samples for selected water quality constituents. These analyses fall into three categories: nutrients, major elements, and trace metals (table 1). Information documenting NWQL methods is included in the SCPN water quality monitoring protocol (Monroe and Bliss, in preparation).

2.3 Data handling, analysis, and quality assurance/quality control (QA/QC)

All SCPN water quality data is entered into NPSTORET, v.1.83, a Microsoft Access database created by the Water Resources Division of the National Park Service. All multiparameter sonde data files are stored on the SCPN server.

In this report, we only include the median values of a subset of seven consecutive multiparameter sonde measurements, with the exception of data presented in Section 3.4: *Temporal variability of core parameter data along the Rito de los Frijoles*. Similarly, only the median values for each set of turbidity triplicate samples

Table 1. National Water Quality Laboratory and Test America Lab sample analytes

Analytical group	Analytes
Nutrients	ammonia, nitrite, nitrite + nitrate, orthophosphate
Major elements	calcium, chloride, fluoride, magnesium, potassium, silica, sodium, sulfate, acid neutralizing capacity (ANC; as CaCO_3), total dissolved solids
Trace metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc

are presented herein. For total coliforms and *E. coli* samples, most-probable numbers (MPN/100 mL) are reported. MPN results are a statistical estimate of the number of bacteria per 100 mL of stream water and were determined by using a lookup table provided by the manufacturer (Idexx Inc.). New Mexico water quality criteria are expressed as the number of colony forming units (cfu) per 100 mL and do not assume an estimation. Although the units are different, they are still comparable.

Where applicable, we compared our water quality results against New Mexico's 2011 acute and chronic aquatic life standards (NMED SWQB 2011a). Acute standards require only a single sample, while chronic standards apply to either the arithmetic mean of consecutive-day samples or the results of individual grab samples taken during hydrologically stable conditions (NMED SWQB 2011b).

The QA/QC procedures described in Monroe and Bliss (in preparation) were followed.

3 Results

3.1 Rito de los Frijoles

This section presents data collected by SCPN staff from RIT01 and RIT02 on the Rito de los Frijoles at BAND in 2010. All data are included in Appendix B. NPS water quality core parameter data and bacteria samples were collected at both sites during every visit.

3.1.1 Water quality core parameter data

Summary statistics for water quality core parameter data collected at RIT01 and RIT02 during 2010 are presented in Table 2. Our data do not show exceedances of New Mexico state water quality standards (NMED SWQB 2011a).

Table 2. Summary of water quality core parameter data, with standard deviations (std. dev.) from all site visits to RIT01 and RIT02 on the Rito de los Frijoles in Bandelier N.M., 2010

Core parameter	Units	Site	Observations	Minimum	Maximum	Median	Std. dev.	NM state criteria
Water temperature	°C	RIT01	8	1.7	18.5	7.8	6.3	Max. temp <23°, 4T3 = 20 ^{0a}
		RIT02	8	1.6	17.2	7	5.8	
pH		RIT01	8	7.6	8.0	7.7	0.1	>6.6 and <8.8
		RIT02	8	7.7	8.1	8.1	0.2	
Specific conductivity	µS/cm	RIT01	8	98	122	109	10	<300
		RIT02	8	94	117	106	8	
Dissolved oxygen	mg/L	RIT01	8	7.0	10.6	9.2	1.4	>6
		RIT02	8	7.3	10.5	9.0	1.2	
Turbidity	NTU	RIT01	8	1.9	44	3.0	14	--- ^b
		RIT02	8	1.4	26	2.4	9	
Discharge	cfs	RIT01	8	0.2	8.4	0.7	2.7	---
		RIT02	8	0.9	6.6	1.3	1.9	

^a "4T3 temperature" means the temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days.

^b ---indicates that no criteria exist for RIT01 and RIT02

Water and air temperatures were recorded at 15-minute intervals at RIT01 and RIT02 throughout 2010, though accurate air and water logger data are unavailable for parts of the year at RIT01. The water temperature logger became exposed to air due to dropping water levels between early June and July 15, when the error was discovered and the logger was repositioned. One week after the logger was repositioned, it was buried by sediment until it was discovered during the next site visit on August 31. In addition, the air temperature logger was likely exposed to sun between June 1 and July 15, at which time the logger was relocated to a more sheltered location. The Rito de los Frijoles is designated a high-quality coldwater fishery, and the New Mexico Water Quality standards (NMED SWQB 2011a) specify these streams cannot exceed 23°C at any time, and also cannot exceed 20°C for four or more consecutive hours during three consecutive days (4T3). The highest water temperature recorded at RIT01 during 2010 was 22.8°C on July 20, slightly below the 23°C maximum temperature criterion for a high quality coldwater fishery (fig. 2).

Air and water temperatures at RIT02 are displayed below in Figure 3. Water temperatures at RIT02 were cool throughout the year and ranged between 0.0 °C on 12/31 and 18.7°C on July 17—well below the water temperature criteria for this stream. Air temperatures between April 27 and May 29 are missing. Excluding this time period, extreme air temperatures ranged from -18.9 °C on December 31 to 34.9°C on June 5.

Across all eight sampling events, pH was slightly lower at RIT01 than at RIT02; values ranged

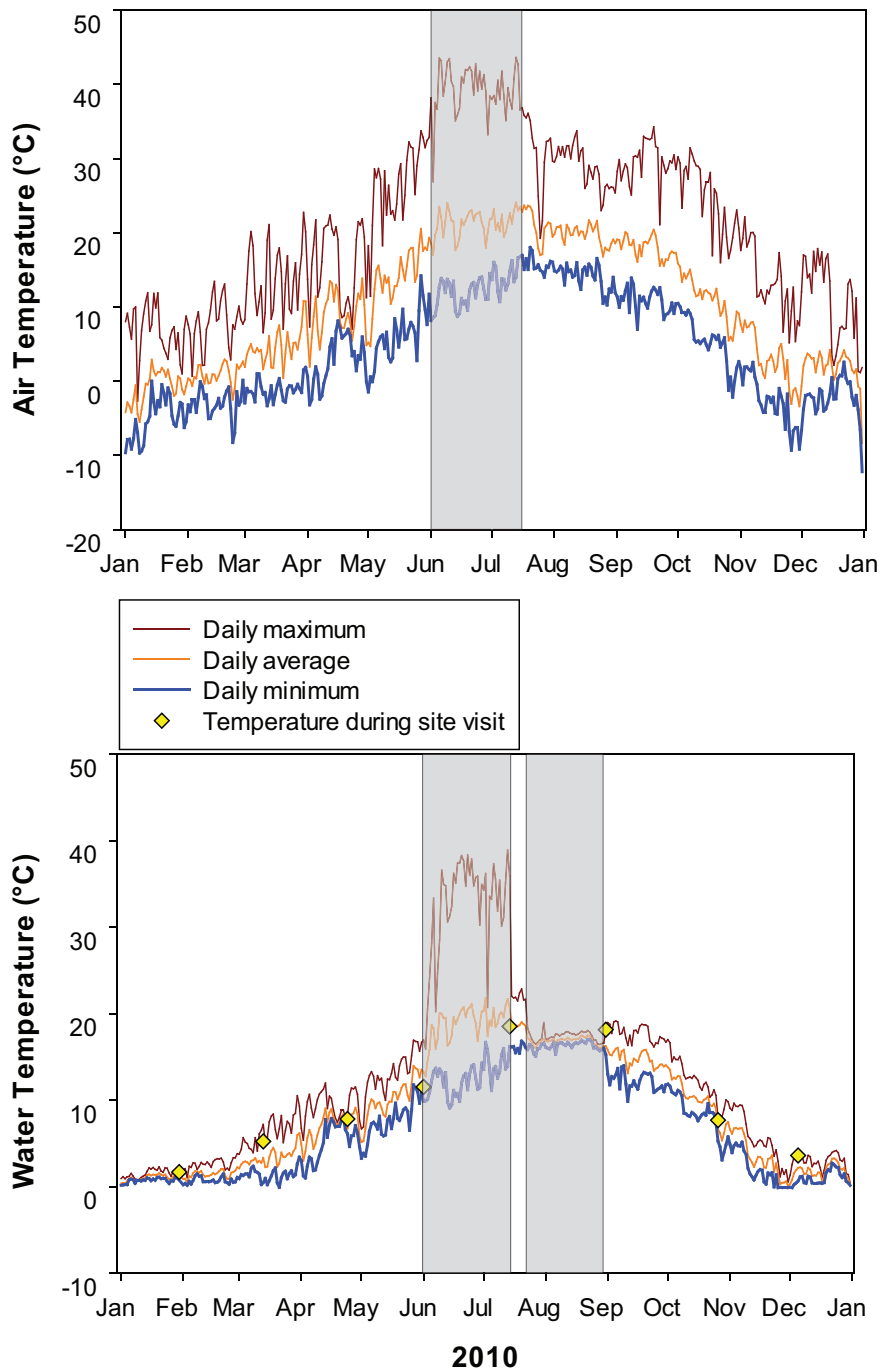


Figure 2. Air temperature data (top) and water temperature data (bottom) from RIT01 at Rito de los Frijoles in Bandelier N.M., 2010. Grey shaded areas represent periods of time when data was not accurate.

from 7.6 to 8.0 at RIT01 and 7.7 to 8.1 at RIT02. All pH measurements fell within the established State of New Mexico water quality criterion of between 6.6 and 8.8 NMED SWQB 2011a).

Specific conductivity did not vary at either site in 2010, and was similar for the two sites. Results were well below the water quality criterion of 300 $\mu\text{S}/\text{cm}$, which is specific to streams in BAND (NMED SWQB 2011a). Specific conductivity ranged from 98 to 122 $\mu\text{S}/\text{cm}$ at RIT01 and 94 to 117 $\mu\text{S}/\text{cm}$ at RIT02. Median results were 109 $\mu\text{S}/\text{cm}$ at RIT01 and 106 $\mu\text{S}/\text{cm}$ at RIT02. Specific conductivity was slightly lower at RIT02 in all but one visit. Measurements were lower at both sites during the months of January, March, April, and December than the summer and fall months.

Dissolved oxygen was high at both sites throughout the year, and all measurements were well above the State of New Mexico water quality criterion of 6 mg/L (NMED SWQB 2011a). Median results were 9.2 mg/L at RIT01 and 9.0 mg/L at RIT02. The lowest dissolved oxygen measurement at RIT01 was 7.0 mg/L, on August 31. The highest was 10.6 mg/L on January 30. The lowest measurement of dissolved oxygen at RIT02 was

7.3 mg/L and occurred on July 16. The highest measurement was 10.5 mg/L recorded on February 1.

Most water quality sampling events at RIT01 and RIT02 in 2010 occurred during base-flow conditions. As a result, discharge and turbidity were generally low, except for samples collected during a snowmelt period in April (fig. 4). In general, discharge was higher and turbidity was lower at RIT02 than at RIT01. Measured discharges at RIT01 ranged between 0.2 and 8.4 cfs. Turbidity ranged between 1.9 and 44 NTU; the median was 3.0 NTU. Discharges at RIT02 ranged between 0.9 and 6.6 cfs. Turbidity was lower at RIT02 in all eight samples, ranging between 1.4 and 26 NTU with a median of 2.4 NTU.

3.1.2 Temporal variability of water quality core parameter data from the Rito de los Frijoles

To document core parameter temporal variability at RIT01, SCPN deployed a multi-parameter water quality sonde from 18:00 on March 11 until 07:00 March 13. Data were recorded at 5-minute intervals and are summarized in Table 3. During this period discharge reported for streamflow gaging station LANL E350 was nearly constant at 1.3 cfs.

Water temperature ranged between 2.1 and 6.6°C. Dissolved oxygen varied inversely with the water temperature, ranging between 10.5 and 11.1 mg/L. Values for pH and specific conductivity were almost constant during the deployment, with pH ranging from 7.8 to 8.0 and specific conductivity ranging from 100 to 102. Median pH was 7.8 and the median specific conductivity was 101 μ S/cm.

3.1.3 *E. coli* and total coliforms

Bacteria data collected by SCPN at RIT01 and RIT02 in 2010 are presented in Figure 5. There are two *E. coli*

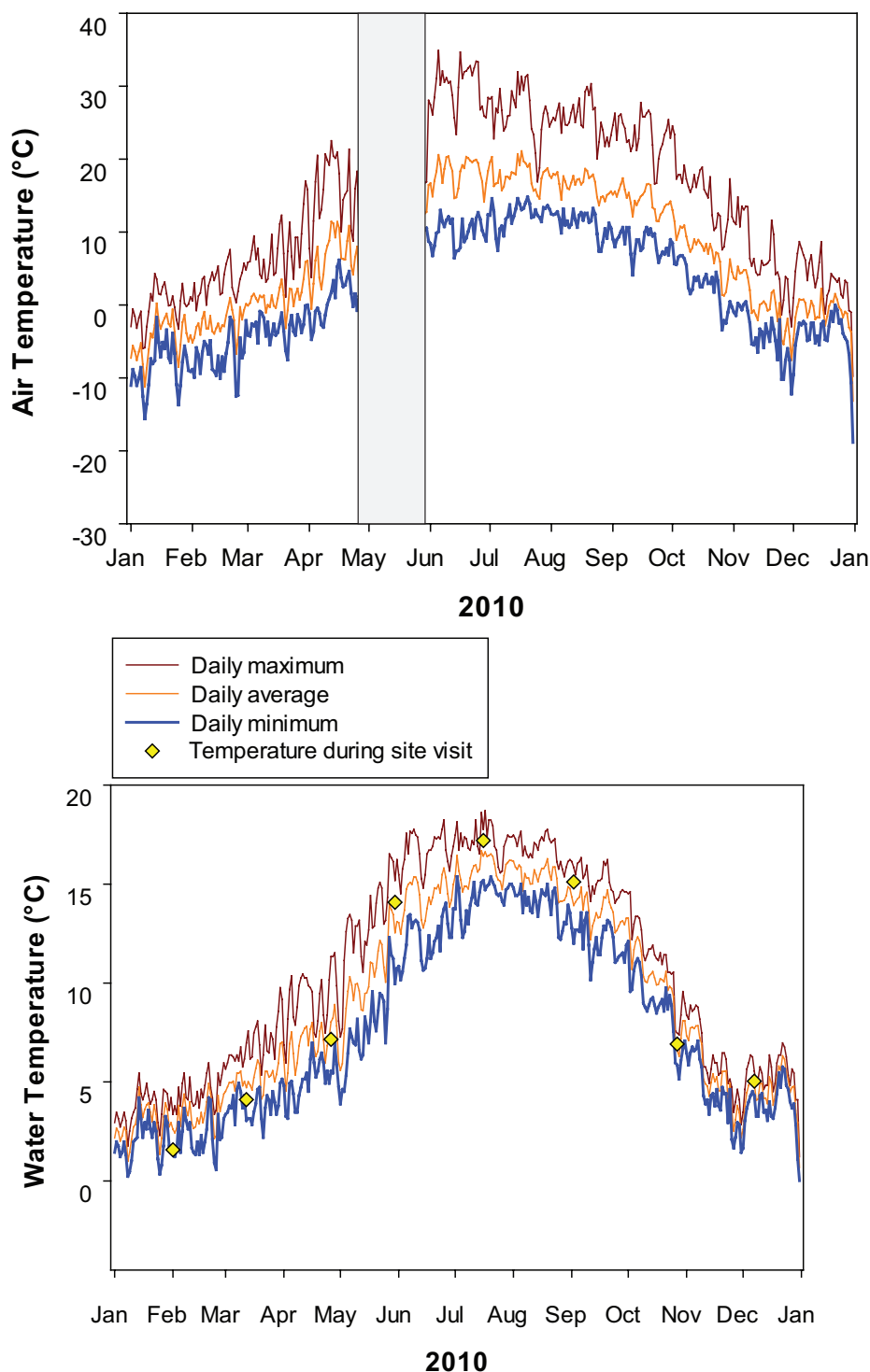


Figure 3. Air temperature data (top) and water temperature data (bottom) from RIT02 at Rito de los Frijoles in Bandelier N.M., 2010. Grey shaded area in air temperature graph represents missing data.

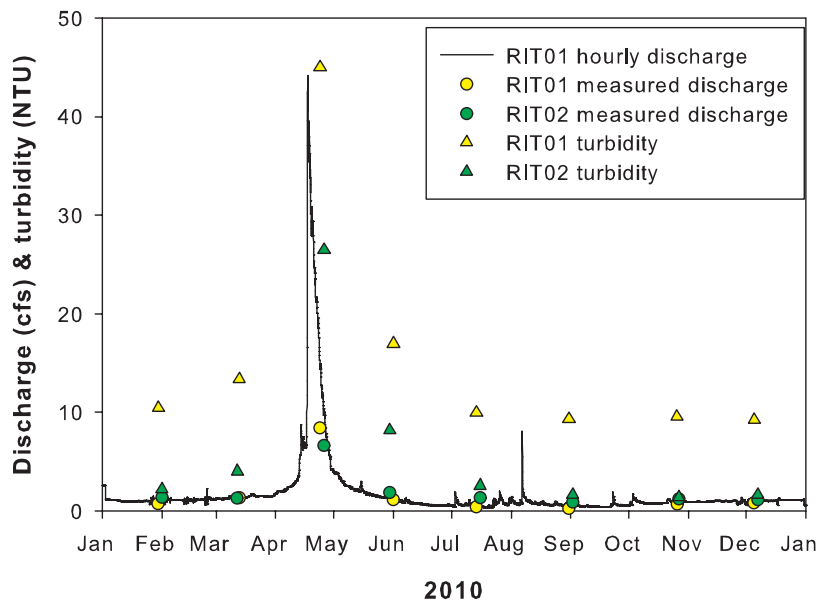


Figure 4. Hydrograph showing hourly discharge data from streamflow gauging station LANL-E350 on the Rito de los Frijoles in Bandelier N.M. and turbidity measurements at RIT01 and RIT02, 2010

Table 3. Summary of water quality core parameter data collected from RIT01 at 5-minute intervals from 18:00 on March 11 to 07:00 on March 13 on the Rito de los Frijoles in Bandelier N.M., 2010

Core parameter	Minimum	Maximum	Median	Range
Water temperature (°C)	0.4	6.6	1.9	6.2
pH	7.8	8.0	7.8	0.2
Specific conductivity (µS/cm)	100	102	101	2
Dissolved oxygen (mg/L)	9.3	11.2	10.5	1.9

criteria for perennial streams in BAND: a single-sample maximum of 235 cfu/100 mL and a geometric mean of 126 cfu/100 mL. The geometric mean must be calculated from at least five samples taken during a 30-day period (NMED SWQB 2011a).

Total coliform bacteria are considered indicators of potential pathogenic bacteria in water, however, there are no water quality criteria for these bacteria in New Mexico. Total coliforms were generally low at both sites in the winter months but were above the detection level during the summer months. At RIT01, total coliforms ranged from 31 MPN/100 mL on January 30 to >2400 MPN/100 mL on July 14 and August 31. At RIT02, total coliforms ranged from 79 MPN/100 mL on February 1 to >2400 MPN/100 mL on July 16 and September 2.

E. coli levels were low in all samples collected at RIT02 during 2010, varying from 1 MPN/100 mL to 22 MPN/100 mL (fig. 6). *E. coli* levels were higher in samples collected during the summer at RIT01 and reached a maximum of 550 MPN/100 mL in a sample collected on July 14. This value is well above the State of New Mexico water quality criteria of 235 cfu/100 mL (single-sample maximum) and 126 cfu/100 mL (geometric mean, NMED SWQB 2011a). There were no water quality exceedances for *E. coli* at RIT02.

3.1.4 Water quality laboratory data

Results from the NWQL for seven water quality samples collected from RIT01 and RIT02 in 2010 are summarized in Tables 4-6. Analytes fell into the following categories: nutrients, major elements and trace metals. Analyses were performed on samples from each site visit, with the exception of those from March 12 and 13 when trace metals, calcium, magnesium, potassium, silica, and sodium were not analyzed.

Nutrients analyzed included ammonia, nitrite and nitrate, nitrite, and orthophosphate. For both RIT01 and RIT02, ammonia and nitrite were not detected at concentrations above the laboratory reporting levels,

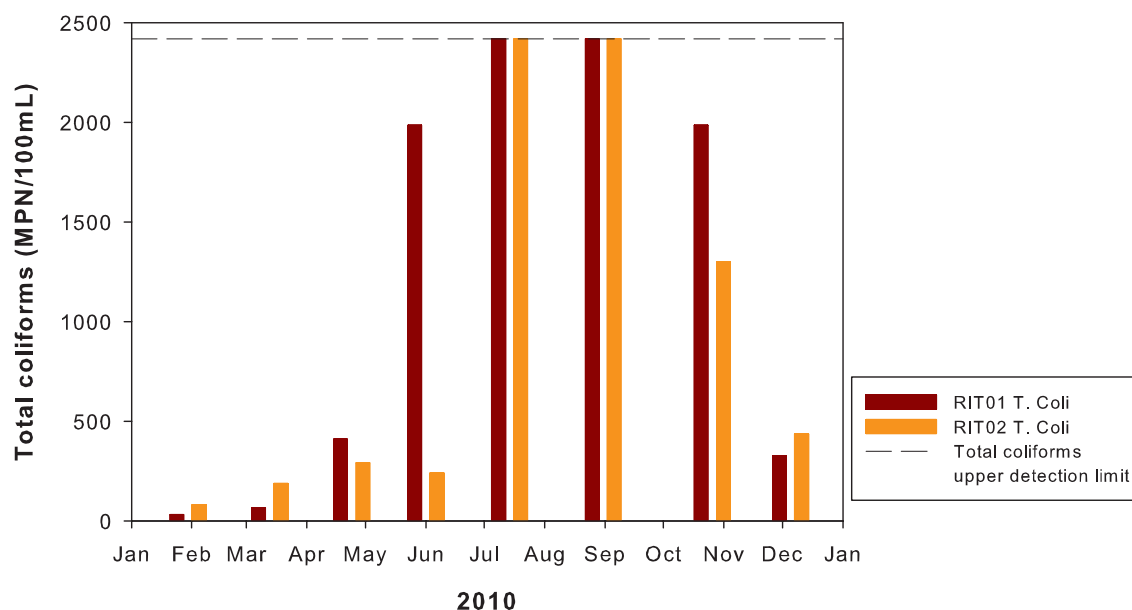


Figure 5. Total coliform data from RIT01 and RIT02 at Rito de los Frijoles in Bandelier N.M., 2010.

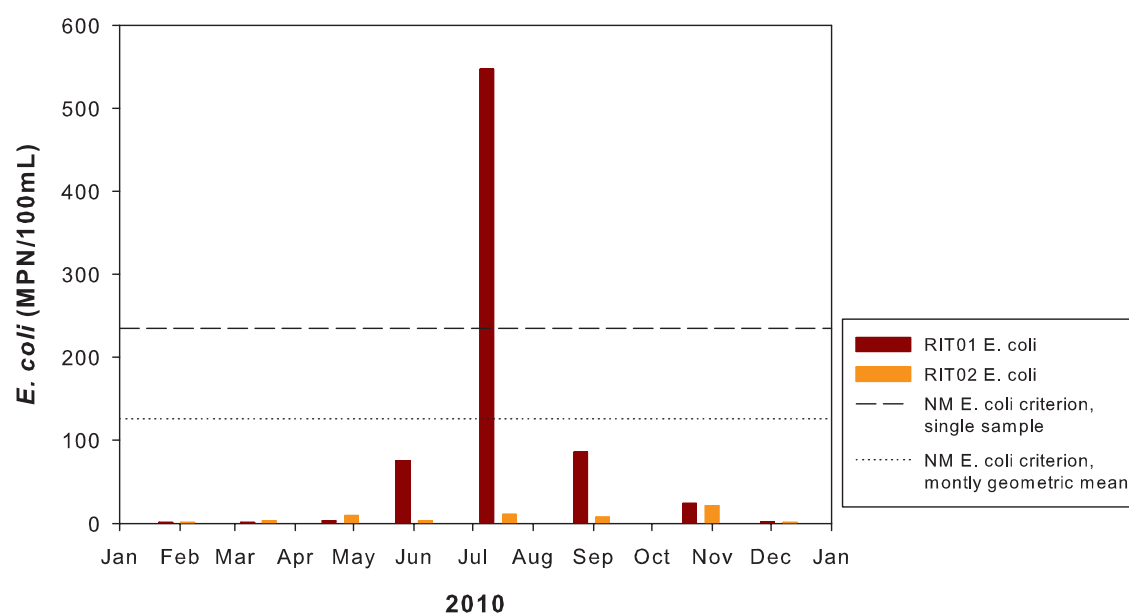


Figure 6. *E. coli* data from RIT01 and RIT02 at Rito de los Frijoles in Bandelier N.M., 2010

which ranged from 0.010 to 0.020 mg/L for ammonia, and 0.0010 to 0.0020 mg/L for nitrite, depending upon the month (table 4). Low concentrations of nitrite+nitrate were detected in two instances, but these nutrients were below the 0.020–0.040 mg/L reporting levels in the remaining six samples. Orthophosphate was reported in all eight samples, with levels ranging from 0.031–0.066 mg/L.

Ammonia was not detected above the reporting level at RIT02. However nitrite+nitrate were above the reporting level in all but one of the samples; results ranged from <0.0010 to 0.0030 mg/L. Nitrite was detected twice but at low levels—0.001 and 0.003 mg/L. Orthophosphate was also detected in all eight samples and ranged between 0.006–0.062 mg/L.

Major element data from RIT01 and RIT02 include major ions, silica, acid neutralizing capacity, and total

Table 4. Summary of nutrient data collected from RIT01 and RIT02 at the Rito de los Frijoles in Bandelier N.M., 2010^a

Nutrient (mg/L, dissolved)	Number of samples	Site	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Ammonia as N	8	RIT01	<0.010	<0.020	- ^b	-	0
	8	RIT02	<0.010	<0.020	-	-	0
Nitrite + nitrate as N	8	RIT01	<0.020	0.08	<0.040	-	---- ^c
		RIT02	<0.020	0.19	0.13	0.06	----
Nitrite as N	8	RIT01	<0.0010	<0.0020	-	-	----
		RIT02	<0.0010	0.0030	<0.0020	0.0008	----
Orthophosphate as P	8	RIT01	0.031	0.066	0.044	0.012	----
		RIT02	0.006	0.062	0.048	0.017	----

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Reporting levels changed to match the long-term method detection level starting October 1, 2010; therefore some samples have two different reporting levels displayed.

^b"-" means values not calculated because >70% of results were below the laboratory reporting level

^c"----" means no water quality standard for this analyte.

dissolved solids, and are described in Table 5. The concentration of the total dissolved solids at RIT01 ranged between 118 and 146 mg/L. Overall, the dissolved solids were comprised of silica (45%), sodium (8%), calcium (6%), chloride (5%), and 2% or less each of sulfate, magnesium, potassium, and fluoride.

Results at RIT02 were very similar to those at RIT01—total dissolved solids ranged between 118 and 137

Table 5. Summary of major element data collected from RIT01 and RIT02 at the Rito de los Frijoles in Bandelier N.M., 2010

Major element (mg/L, dissolved)	Number of samples	Site	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	7	RIT01	6.34	8.85	8.52	1.01
		RIT02	6.32	8.44	7.79	0.77
Chloride	8	RIT01	2.57	8.73	4.86	2.30
		RIT02	2.23	9.17	4.00	2.63
Fluoride	8	RIT01	0.13	0.22	0.18	0.03
		RIT02	0.11	0.17	0.16	0.02
Magnesium	7	RIT01	2.19	3.08	2.90	0.34
		RIT02	2.23	3.00	2.84	0.28
Potassium	7	RIT01	1.33	2.05	1.97	0.28
		RIT02	1.30	2.04	1.71	0.25
Silica	7	RIT01	41.4	63.2	61.2	7.8
		RIT02	40.7	66.3	64.3	9.3
Sodium	7	RIT01	8.6	11.5	10.8	1.0
		RIT02	7.98	11.4	10.4	1.1
Sulfate	8	RIT01	1.61	5.09	1.89	1.19
		RIT02	1.48	4.96	1.76	1.19
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	8	RIT01	30.7	54.9	49.8	7.9
		RIT02	28.1	53.0	50.2	8.3
Total dissolved solids	8	RIT01	118	146	133	11
		RIT02	118	137	131	6

mg/L in 2010. Dissolved solids contained, on average, silica (46%), sodium (8%), calcium (6%), chloride (4%), and 2% or less each of magnesium, sulfate, potassium, and fluoride. Acid neutralizing capacity was also similar between the two streams—median results were 49.8 mg/L for RIT01 and 50.2 for RIT02.

Figure 7 summarizes the major ion composition at RIT01 and RIT02, expressed as milliequivalents per liter, for all 2010 water sampling events. Anions varied throughout the year but overall were dominated by bicarbonate with smaller amounts of chloride and sulfate. Chloride and sulfate comprised a higher proportion relative to bicarbonate in the samples collected during April and June. Cation composition was more evenly mixed than the anions, but the proportion of sodium and potassium was greater than calcium and magnesium. Also, RIT01 had a higher proportion of calcium, and RIT02 had a higher proportion of magnesium. Cation composition remained consistent in all of the 2010 samples.

None of the samples from RIT01 exceeded established aquatic life standards for trace metals (table 6). Five metals were not detected above the laboratory reporting levels for samples collected in 2010—cadmium, copper, mercury, silver, and zinc. Two other metals, antimony and beryllium, were present at low levels in some samples but these levels were very close to the laboratory reporting limits. All other metals were

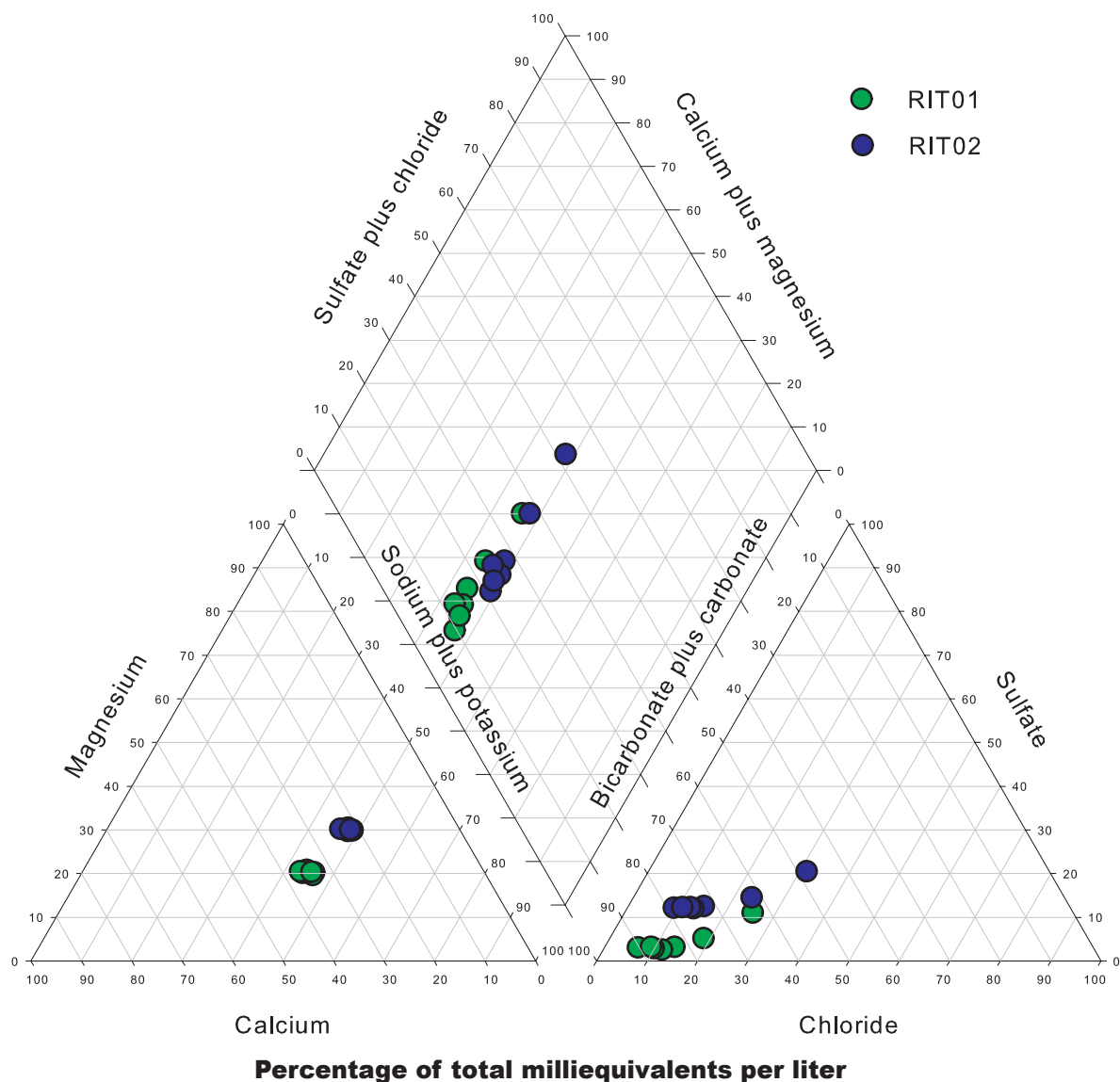


Figure 7. Major ion composition from RIT01 and RIT02 at the Rito de los Frijoles in Bandelier N.M., 2010

detected but were well below both the chronic and acute aquatic life criteria, except aluminum. In a sample collected on April 24, aluminum was 188 mg/L, approaching the chronic criterion of 203 mg/L (NMED SWQB 2011a). None of the samples for RIT02 exceeded the acute aquatic life criteria for trace metals (table 6). However, two constituents exceeded the chronic criteria values in the sample collected on April 26. The lead concentration was 0.95 µg/L, while the criterion for this sample was 0.54 µg/L. The aluminum concentration was 577 µg/L, more than double the criterion of 244 µg/L.

3.2 Capulin Creek

This section presents data collected by SCPN staff from Capulin Creek at BAND in 2010. All data, including

Table 6. Summary of trace metal data collected from RIT01 and RIT02 at the Rito de los Frijoles in Bandelier N.M., 2010^a

Trace metal (µg/L, dissolved)	Number of samples	Site	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	# of exceedances
Aluminum	7	RIT01	12.2	188	28.1	78	0
		RIT02	11.2	577	26.8	212	1 (potential)
Antimony	7	RIT01	0.031	0.139	<0.054	0.044	---- ^b
		RIT02	0.037	0.118	0.057	0.027	----
Arsenic	7	RIT01	0.488	0.937	0.684	0.159	0
		RIT02	0.369	0.708	0.691	0.124	0
Barium	7	RIT01	10.5	17.2	11.9	2.7	----
		RIT02	9.3	34.7	12.8	9.0	----
Beryllium	7	RIT01	0.007	0.048	0.012	0.017	----
		RIT02	<0.006	0.202	<0.012	0.078	----
Boron	7	RIT01	6.2	9.3	7.2	1.0	----
		RIT02	5.5	7.5	6.71	0.7	----
Cadmium	7	RIT01	<0.016	<0.020	- ^c	-	0
		RIT02	<0.016	<0.02	-	-	0
Chromium	7	RIT01	0.14	0.30	0.23	0.06	0
		RIT02	0.49	0.84	0.70	0.10	0
Cobalt	7	RIT01	0.03	0.91	0.04	0.33	----
		RIT02	<0.01	1.55	0.03	0.59	----
Copper	7	RIT01	<0.5	<1.0	-	-	0
		RIT02	<0.5	1.5	<1.0	0.4	0
Iron	7	RIT01	54.3	179	122	44	----
		RIT02	8.6	465	23.4	165	----
Lead	7	RIT01	0.04	0.20	0.06	0.06	0
		RIT02	0.02	0.95	0.05	0.34	1 (potential)
Manganese	7	RIT01	8.44	21.2	12.0	5.4	0
		RIT02	0.39	12.9	0.79	4.5	0
Mercury	7	RIT01	<0.005	<0.010	-	-	0
		RIT02	<0.005	<0.010	-	-	0
Molybdenum	7	RIT01	0.644	1.40	1.05	0.24	0
		RIT02	0.333	0.997	0.923	0.238	0
Nickel	7	RIT01	0.13	0.59	0.20	0.18	0
		RIT02	<0.09	0.76	0.13	0.25	0
Selenium	7	RIT01	0.05	0.21	0.07	0.07	0
		RIT02	0.12	0.45	0.18	0.11	0
Silver	7	RIT01	<0.005	<0.01	-	-	0

Table 6. *continued*

Trace metal (µg/L, dissolved)	Number of samples	Site	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	# of exceedances
Uranium	7	RIT02	<0.005	0.018	<0.01	0.01	0
		RIT01	0.035	0.089	0.044	0.020	----
Vanadium	7	RIT02	0.116	0.244	0.138	0.044	----
		RIT01	2.79	4.09	3.30	0.44	----
Zinc	7	RIT02	3.41	6.20	5.23	0.91	----
		RIT01	<1.4	<2.8	-	-	0
		RIT02	<1.4	2.84	<2.8	0.6	0

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Reporting levels changed to match the long-term method detection level starting October 1, 2010; therefore some samples have two different reporting levels displayed.

- " means no water quality standard for this analyte.

^c"-" means values not calculated because >70% of results were below the laboratory reporting level.

dates and sample times, are included in Appendix B. NPS water quality core parameter data and bacteria samples were collected during every visit.

3.2.1 Water quality core parameter data

Summary tables for water quality core parameter data collected during the eight site visits to CAP01 are presented in Table 7. Our data show no exceedances of New Mexico state water quality standards for CAP01.

Air and water temperature for CAP01 in 2010 are shown in Figure 8. Water temperatures were cool throughout the year, ranging between a low of 0.1 °C on January 8 to a high of 20.3 °C on July 20. The state of New Mexico has designated Capulin Creek is designated a High Quality Coldwater stream. Water quality criteria of a 23°C maximum temperature, which cannot be exceeded at any time, and a 20°C temperature which cannot be exceeded for more than four consecutive hours over three consecutive days, apply to streams with this designation (NMED SWQB 2011a). Temperatures at CAP01 in 2010 did not exceed these criteria. In 2010 recorded air temperatures were more variable, and ranged between -16.8°C on December 31 and 35.1°C on July 17.

Values for pH did not change significantly throughout the year, ranging between 7.8 and 8.2. Specific conductivity ranged between 107 and 145 µS/cm, with the lowest value occurring during the higher flows in April. Measured dissolved oxygen levels ranged between 7.1 and 11.3 mg/L. The highest levels were recorded in January and the lowest were in July; levels in April, May, and September were all similar. Turbidity increased with increasing discharge, and ranged between 0.63 and 25 NTU, with the highest values

Table 7. Summary of water quality core parameter data, with standard deviations (std. dev.) from CAP01 on Capulin Creek in Bandelier N.M., 2010

Core parameter	Units	Observations	Minimum	Maximum	Median	Std. dev.	NM state criteria
Water temperature	°C	8	0.5	19.5	8.3	7.3	Max. temp <23°, 4T3 ^a = 20°
pH		8	7.8	8.2	8.1	0.1	>6.6 and <8.8
Specific conductivity	µS/cm	8	107	145	131	12	<300
Dissolved oxygen	mg/L	8	7.1	11.3	9	1.6	>6
Turbidity	NTU	8	0.63	25	2.7	8	---- ^b
Discharge	cfs	8	0.2	2.1	0.4	0.6	----

^a "4T3 temperature" means the temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days.

^b---- indicates no criteria exist for BANDCAP01

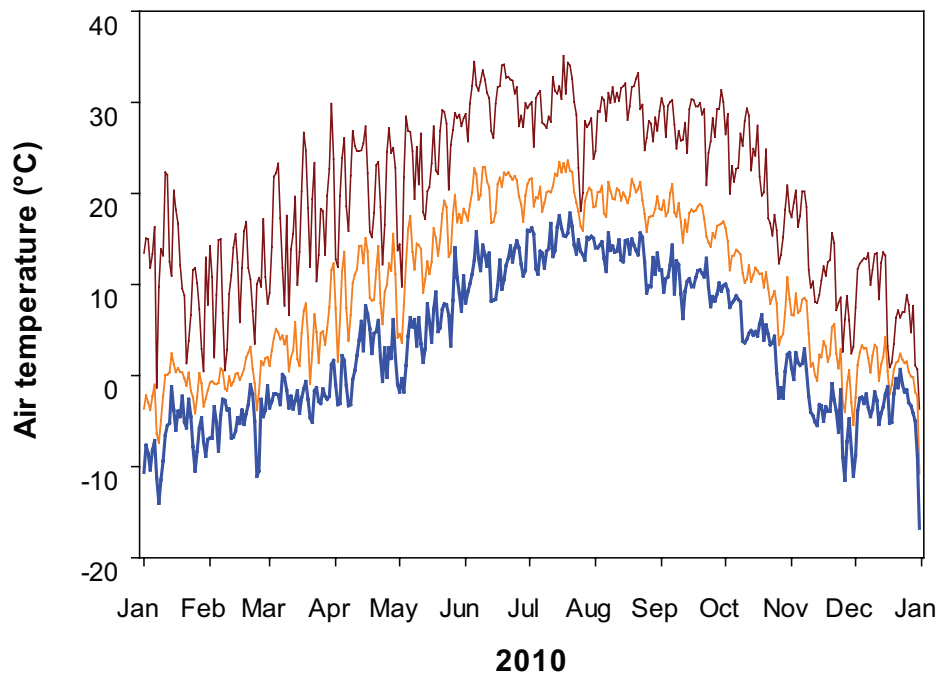
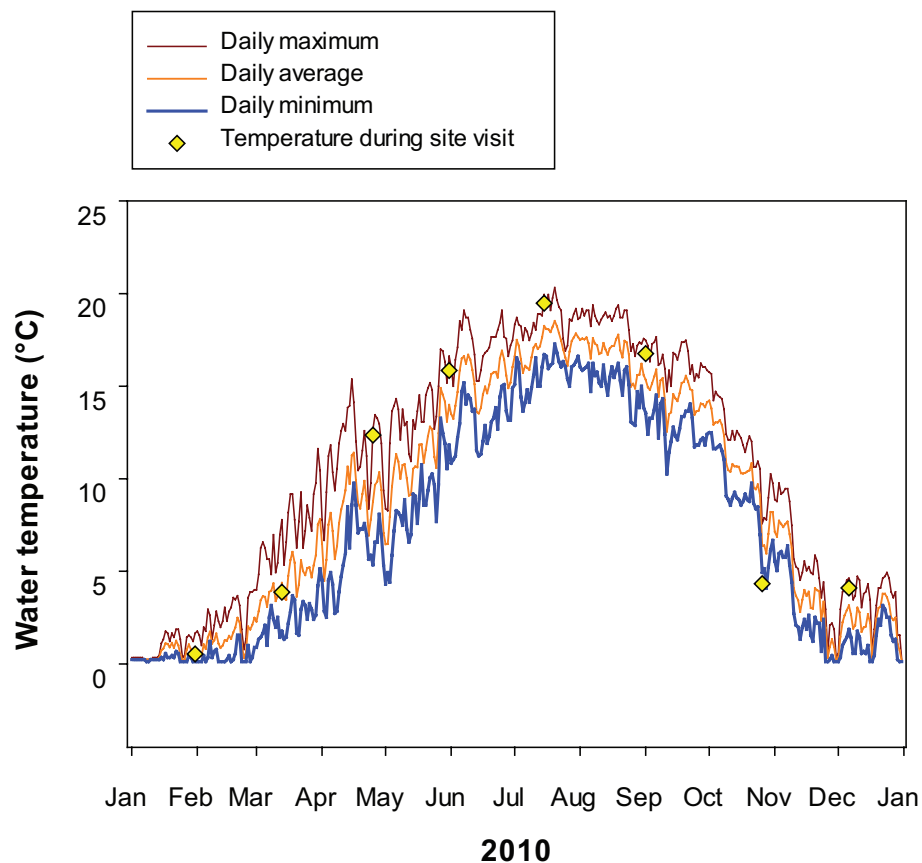


Figure 8. Air temperature data (top) and water temperature data (bottom) from CAP01 at Capulin Creek in Bandelier N.M., 2010



occurring in January, March, and April. Discharge ranged from 0.2 to 2.1 cfs.

3.2.2 *E. coli* and total coliforms

Bacteria data collected by SCPN at CAP01 during 2010 are shown in Figure 9. Total coliforms were measureable throughout the year but were highly variable. The lowest levels occurred in March at 300 MPN/100 mL. The highest levels occurred during June and September, and exceeded the maximum detection of 2400 MPN/100 mL. *E. coli* levels were not detected in January and December, and remained low throughout the year, even during the summer when total coliforms were high. Results were always well

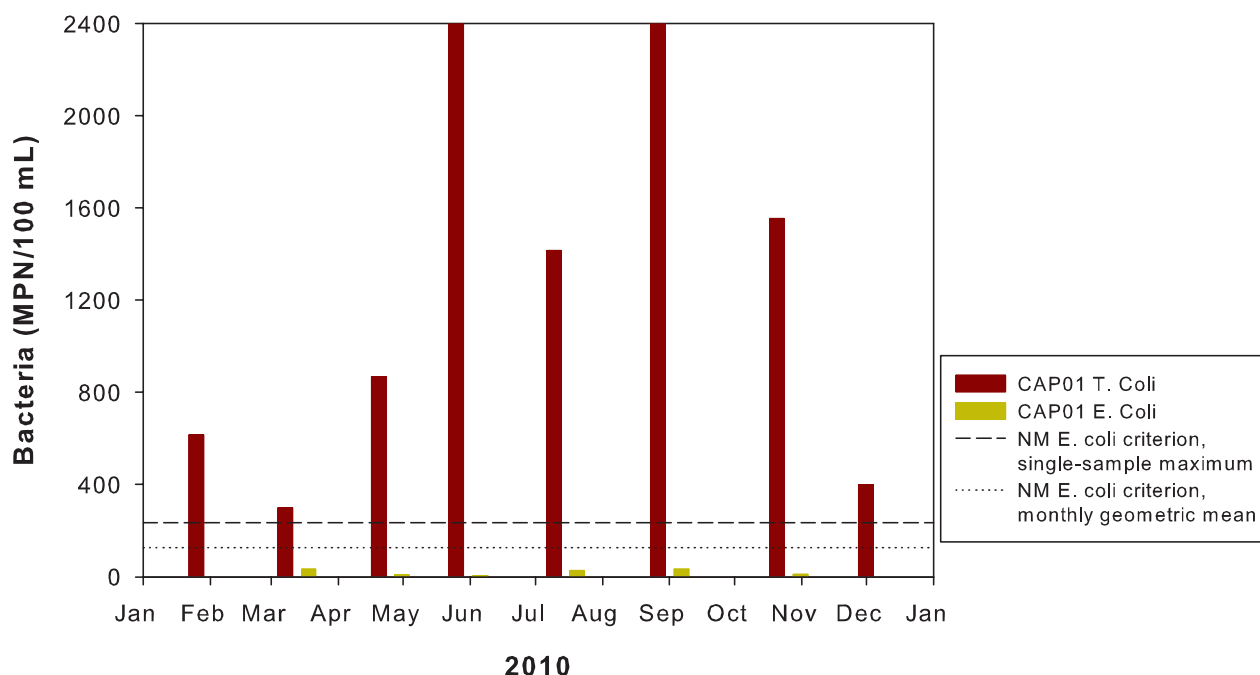


Figure 9. Total coliform and *E. coli* data from CAP01 at Capulin Creek in Bandelier N.M., 2010

below the water quality criteria and ranged between <1 and 31 MPN/100 mL.

3.2.3 Water quality laboratory data

Water quality sample results from the NWQL for samples collected from CAP01 are summarized in Tables 8–10. Analyses were performed on samples from each site visit, with the exception of those from March 12, when trace metals, calcium, magnesium, potassium, silica, and sodium were not analyzed.

Eight samples were analyzed in 2010 for the following nutrients: ammonia, nitrite+nitrate, nitrite, and orthophosphate (table 8). Ammonia was not detected above the reporting levels in any of the samples; nitrate+nitrite and nitrite were detected at low levels twice. Orthophosphate was always present, ranging between 0.036 and 0.068 mg/L.

Major element data from CAP01 for 2010 is reported in Table 9 and includes major ions, silica, acid neutralizing capacity, and total dissolved solids. The concentration of total dissolved solids was relatively constant, ranging between 137 to 162 mg/L. Overall, dissolved solids were dominated by silica, which averaged 41% of the total. This was followed by calcium (9%), sodium (6%), sulfate (3%), and 2% or less each of magnesium, potassium, chloride, and fluoride.

Table 8. Summary of nutrient data collected from CAP01 at Capulin Creek in Bandelier N.M., 2010^a

Nutrient (mg/L, dissolved)	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Ammonia as N	8	<0.010	<0.020	– ^b	–	0
Nitrite + nitrate as N	8	<0.020	0.061	0.030	0.018	– ^c
Nitrite as N	8	0.0011	<0.0020	–	–	–
Orthophosphate as P	8	0.036	0.068	0.051	0.011	–

^aResults that were lower than the NWQL reporting levels are noted as “<[reporting level]”. Reporting levels changed to match the long-term method detection level starting October 1, 2010; therefore some samples have two different reporting levels displayed.

^b“–” means that values were not calculated because >70% of results were below the laboratory reporting level.

^c“–” means there is no water quality standard for this analyte.

Table 9. Summary of major element data collected from CAP01 at Capulin Creek in BAND, 2010

Major element (mg/L, dissolved)	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	7	11.0	14.3	13.0	1.1
Chloride	8	1.90	2.95	2.68	0.39
Fluoride	8	0.20	0.24	0.21	0.01
Magnesium	7	2.88	3.99	3.62	0.36
Potassium	7	1.81	2.90	2.64	0.42
Silica	7	47.7	65.9	64.9	6.49
Sodium	7	7.30	10.5	10.2	1.14
Sulfate	8	3.00	6.88	3.71	1.34
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	8	44.9	72.4	65.2	8.6
Total dissolved solids	8	137	162	153	8

Figure 10 summarizes the major ion composition, expressed as milliequivalents per liter, at CAP01 in 2010. Anions were dominated by bicarbonate, with smaller amounts of chloride and sulfate. Cation composition was more evenly mixed than the anions and consisted of calcium, then sodium and potassium, and of lesser amounts of magnesium. Cation composition was very consistent in all of the 2010 samples.

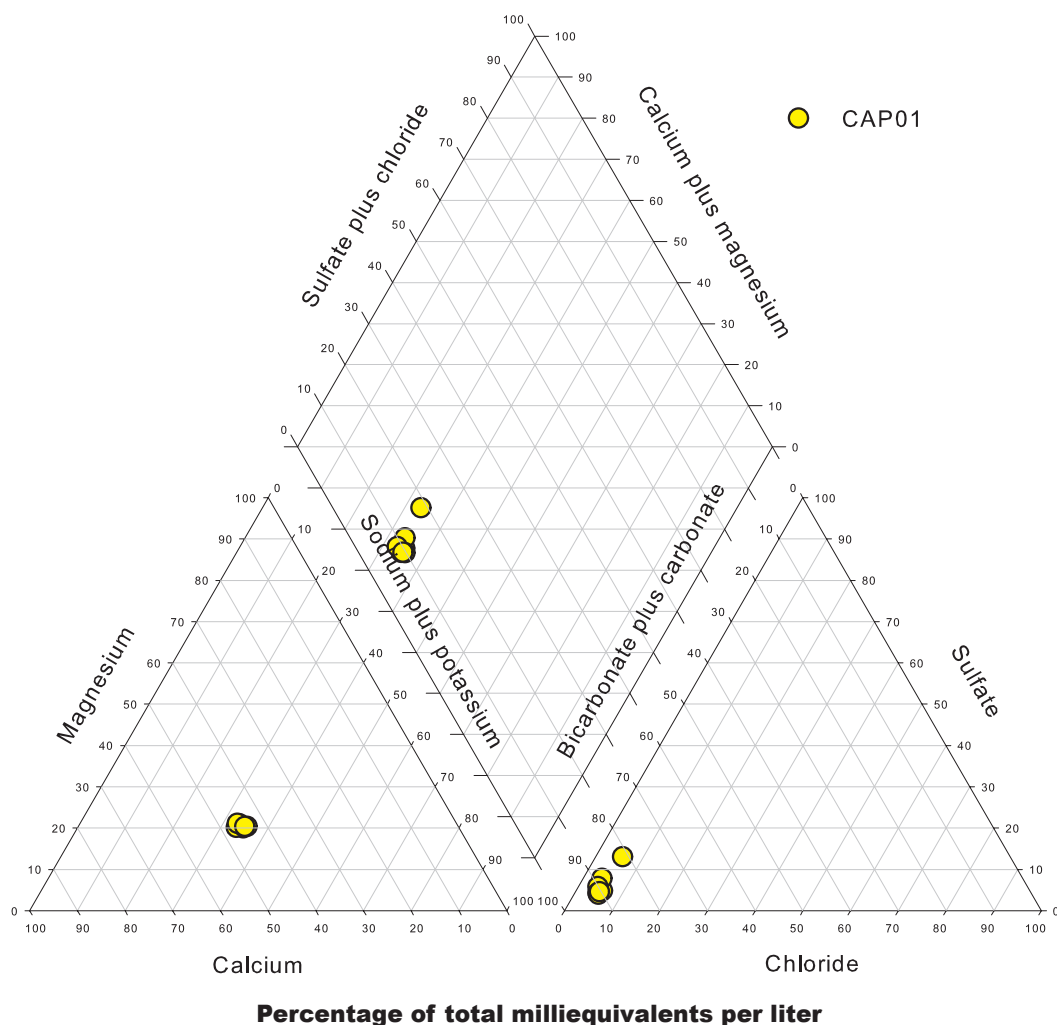
**Figure 10.** Major ion composition from CAP01 at Capulin Creek in Bandelier N.M., 2010

Table 10. Summary of trace metal data collected from CAP01 at Capulin Creek in Bandelier N.M., 2010

Trace metal (µg/L, dissolved)	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Aluminum	7	<3.4	384	11.8	147	1 (potential)
Antimony	7	<0.027	0.115	0.051	0.039	----b
Arsenic	7	1.04	1.41	1.18	0.14	0
Barium	7	33.4	40.4	36.4	2.7	----
Beryllium	7	<0.006	0.129	<0.012	0.049	----
Boron	7	8.27	12.4	9.75	1.5	----
Cadmium	7	<0.016	<0.02	-c	-	0
Chromium	7	0.15	0.32	0.22	0.07	0
Cobalt	7	0.020	0.86	0.03	0.31	----
Copper	7	<0.5	<1.0	-	-	0
Iron	7	10.7	229	35.1	88.4	----
Lead	7	0.020	0.593	0.040	0.220	0
Manganese	7	3.05	9.05	4.39	2.18	0
Mercury	7	<0.005	<0.010	-	-	0
Molybdenum	7	0.566	0.890	0.802	0.111	0
Nickel	7	0.16	0.74	0.21	0.24	0
Selenium	7	0.11	0.43	0.19	0.13	0
Silver	7	<0.005	0.017	<0.01	0.004	0
Uranium	7	0.026	0.150	0.041	0.043	----
Vanadium	7	2.05	4.94	3.84	1.10	----
Zinc	7	<1.4	<2.8	-	-	0

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Reporting levels changed to match the long-term method detection level starting October 1, 2010; therefore some samples have two different reporting levels displayed.

^b"----" means no water quality standard for this analyte.

^c"-" means values not calculated because >70% of results were below the laboratory reporting level.

Seven samples from CAP01 were analyzed for trace metals in 2010 (table 10). Thirteen of these metals have aquatic life standards assigned to them. On April 25th, the aluminum chronic criterion was exceeded. Based upon the water hardness in this sample, the criterion was 381 mg/L and the result was slightly higher than this at 384 mg/L. This should not be interpreted as a water quality exceedance because the New Mexico standards require that samples collected to evaluate chronic criteria compliance must be taken during representative flow conditions and more than one sample would have to exceed the criterion value (NMED SWQB 2011b). This sample was collected during period of high flows due to spring snowmelt and is not representative of typical base flow conditions at Capulin Creek.

Cadmium, copper, mercury, and zinc did not exceed laboratory reporting levels in any of the samples collected. Additionally, median results for beryllium and silver were below the reporting levels. All other metals were usually detected, but at levels well below the acute and chronic aquatic life criteria.

4 Summary

In 2010, SCPN implemented long-term water-quality monitoring in Bandelier National Monument at two sites on the Rito de los Frijoles—RIT01 and RIT02—and at one site on Capulin Creek—CAP01. This report summarizes data collected during eight site visits to RIT01, RIT02, and CAP01 during 2010, and compares these results against the relevant aquatic life standards (NMED SWQB 2011a).

Water temperature, recorded at 15-intervals at all sites in 2010, did not exceed the temperature criteria at RIT02 or CAP01. Temperature criteria compliance could not be determined at RIT01 due to fluctuating water and sediment levels (appendix B2, B4, B6).

Dissolved oxygen at the three BAND sites ranged between 7.0 and 11.3 mg/L. pH measurements ranged from 7.6 and 8.2. Specific conductivity ranged from 94 to 145 $\mu\text{S}/\text{cm}$. None of these results exceeded the water quality criteria. Turbidity was generally low at the three sites except during periods of higher discharge, measurements ranged from 0.63 to 44 NTU. Discharge ranged from 0.2 to 8.4 cfs. The highest discharge occurred during April, a time of snowmelt runoff.

Total coliform results ranged from 31 to >2400 MPN/100 mL (fig. 5, p. 8; fig. 9, p. 15). The lowest result was from RIT01 and all three sites exceeded the maximum detection limit of 2400 MPN/100 mL twice. The highest *E. coli* result was 550 MPN/100 mL (fig. 6, p. 9; fig. 9, p. 15). This result was from RIT01 and was the only sample to exceed the water quality criteria.

Nutrient results for the nitrogen species were low and often were below the laboratory reporting levels at all sites (appendix B1, B3, B5). Orthophosphate was always detected at the three sites and ranged from 0.006 to 0.068 mg/L.

Trace metal concentrations were generally well below the water quality criteria; cadmium, copper, mercury, silver, and zinc were rarely or never present at levels above laboratory reporting levels. Two sites, RIT02 and CAP01, contained aluminum concentrations above the chronic water quality criteria, but only one sample each. In samples collected during April the aluminum concentration at RIT02 and at CAP01 exceeded the chronic aquatic life criteria values, though these samples were collected during a period of high stream flow that did not represent typical flow conditions.

Major ion analyses at RIT01, RIT02, and CAP01 indicate that anions in these waters were dominated by bicarbonate (fig. 7, p.11; fig. 10, p.16). Sodium and potassium comprised the majority of cations at RIT01 and RIT02, and calcium was the most prevalent cation in CAP01. Results for acid neutralizing capacity at the three sites ranged from 28.1–72.4 mg/L, and results for total dissolved solids ranged from 118–162 mg/L.

The data in this report should be viewed as a snapshot of water quality conditions existing at the time that the data was collected. Data and analyses in this report are provisional and are subject to change. When sufficient data are available, SCPN plans to produce an interpretive report that will include trend analysis of water quality data for the Rito de los Frijoles and Capulin Creek in Bandelier National Monument.

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Appendix A: Southern Colorado Plateau Network water quality monitoring sites at Bandelier National Monument

Site code	Common name	Report name	UTM (NAD 83, Zone 13)		Elevation (m)
			X	Y	
BANDRIT01	Rito de los Frijoles near Visitor Center	RIT01	385363	3959889	1840
BANDRIT02	Rito de los Frijoles at Upper Crossing	RIT02	377110	3964317	2151
BANDCAP01	Capulin Creek at Base Camp Gaging Station	CAP01	379713	3958026	1904

Appendix B: 2010 Water quality results for Bandelier National Monument

Table B1. Results of laboratory analyses for BANDRIT01, as reported by the U.S. Geological Survey National Water Quality Laboratory^a

Analyte ^a	Sample collection date and time							
	1/30/10	3/13/10	4/24/10	6/1/10	7/14/10	8/31/10	10/26/10	12/5/10
	14:00	15:58	19:15	10:45	22:10	18:09	14:37	17:15
Nutrients (mg/L)								
Ammonia as N	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010
Nitrite + nitrate as N	0.083	<0.040	0.043	<0.040	<0.040	<0.040	<0.020	<0.020
Nitrite as N	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0011	<0.0010
Orthophosphate as P	0.046	0.042	0.031	0.042	0.066	0.064	0.056	0.041
Major elements (mg/L)								
Calcium	6.69	----	6.34	8.52	8.54	8.66	8.85	7.91
Chloride	2.57	2.84	8.73	8.05	6.41	5.29	4.43	3.80
Fluoride	0.20	0.19	0.13	0.16	0.21	0.22	0.16	0.17
Magnesium	2.43	----	2.19	3.08	2.90	3.04	3.02	2.85
Potassium	1.33	----	1.93	1.97	1.97	2.02	2.05	1.56
Silica	61.2	----	41.4	58.3	60.5	62.9	62.8	63.2
Sodium	9.68	----	8.60	11.2	10.7	11.5	10.8	11.1
Sulfate	1.61	2.35	5.09	3.03	2.00	1.62	1.74	1.78
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	48.9	48.5	30.7	46.5	54.2	54.9	54.7	50.7
Total dissolved solids	125	146	118	131	135	146	121	136
Trace metals (µg/L)								
Aluminum	25.8	----	188	179	31.7	28.1	27.1	12.2

Table B-1 *continued*

Analyte ^b	Sample collection date and time							
	1/30/10	3/13/10	4/24/10	6/1/10	7/14/10	8/31/10	10/26/10	12/5/10
	14:38	17:58	19:15	10:45	22:10	18:09	14:37	17:13
Antimony	<0.054	----	0.058	0.139	<0.054	<0.054	0.030	0.078
Arsenic	0.637	----	0.488	0.788	0.882	0.937	0.684	0.611
Barium	11.2	----	17.2	16.8	11.9	12.2	11.9	10.5
Beryllium	<0.012	----	0.048	0.040	0.012	0.013	0.011	0.007
Boron	6.88	----	6.53	7.59	9.26	7.38	7.24	6.22
Cadmium	<0.020	----	<0.020	<0.020	<0.020	<0.020	<0.016	<0.016
Chromium	0.23	----	0.28	0.30	0.14	0.15	0.23	0.27
Cobalt	0.044	----	0.084	0.913	0.055	0.037	0.040	0.027
Copper	<1.0	----	<1.0	<1.0	<1.0	<1.0	<0.5	<0.5
Iron	58.0	----	110	179	124	138	122	54.3
Lead	0.06	----	0.14	0.20	0.09	0.06	0.05	0.04
Manganese	9.27	----	8.44	20.9	12.0	9.98	21.2	15.0
Mercury	<0.010	----	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Molybdenum	0.987	----	0.644	0.956	1.23	1.40	1.14	1.05
Nickel	0.16	----	0.46	0.59	0.21	0.20	0.13	0.14
Selenium	0.21	----	0.20	0.08	0.07	0.07	0.05	0.06
Silver	<0.010	----	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Uranium	0.047	----	0.089	0.073	0.040	0.040	0.044	0.035
Vanadium	3.30	----	3.10	4.09	3.57	3.76	2.79	3.15
Zinc	<2.8	----	<2.8	<2.8	<2.8	<2.8	<1.4	<1.4
Total coliforms and <i>E. coli</i> (MPN/100 mL)								
Total coliforms	31	66	410	2000	>2400 ^c	>2400	2000	330
<i>E. coli</i>	≤1	≤1	3	75	550	86	24	2

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Note that reporting levels changed starting October, 2010.

^bParameters are dissolved unless otherwise specified.

^cThe maximum detection level for bacteria is 2400 MPN/100 mL.

Table B-2. NPS water quality core parameter field data for BANDRIT01

Core parameter	Unit	Sample collection date and time							
		1/30/10	3/13/10	4/24/10	6/1/10	7/14/10	8/31/10	10/26/10	12/5/10
		14:38	17:58	19:15	10:45	22:10	18:09	14:37	17:15
Water temperature	°C	1.7	5.2	7.8	11.5	18.5	18.2	7.7	3.6
pH	none	7.7	7.7	7.6	7.7	8.0	8.0	7.7	7.8
Specific conductivity	µS/cm	100	102	98	118	122	121	115	103
Dissolved oxygen	mg/L	10.6	9.6	8.8	8.3	7.10	7.0	9.5	10.4
Turbidity	NTU	3.3 ^a	6.7	44	11 ^a	2.7	2.0 ^a	2.3 ^a	1.9
Discharge	cfs	0.7	1.3	8.4	1.1	0.4	0.2	0.7	0.8

^aThe three turbidity samples for this visit were not within +/-10% of one another

Table B3. Results of laboratory analyses for BANDRIT02, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL)^a

	Sample collection date and time							
	2/1/10	3/12/10	4/26/10	5/30/10	7/16/10	9/2/10	10/27/10	12/7/10
Analyte ^b	08:15	10:15	11:30	19:35	14:52	14:15	17:13	11:37
Nutrients (mg/L)								
Ammonia as N	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010
Nitrite + nitrate as N	0.193	0.163	0.054	0.062	0.133	0.104	<0.020	0.147
Nitrite as N	<0.0020	<0.0020	0.0030	<0.0020	<0.0020	<0.0020	0.0010	<0.0010
Orthophosphate as P	0.049	0.047	0.036	0.053	0.062	0.053	0.006	0.046
Major elements (mg/L)								
Calcium	6.86	----	6.32	8.12	7.79	8.16	8.44	7.76
Chloride	2.23	2.38	9.17	8.33	4.96	4.15	3.85	3.00
Fluoride	0.17	0.16	0.11	0.13	0.17	0.17	0.16	0.16
Magnesium	2.53	----	2.23	3.00	2.77	2.97	2.94	2.84
Potassium	1.30	----	2.04	1.94	1.71	1.76	1.69	1.47
Silica	66.1	----	40.7	57.5	63.3	64.3	66.2	66.3
Sodium	9.72	----	7.98	10.7	10.4	11.4	10.4	10.7
Sulfate	1.48	1.78	4.96	2.93	1.84	1.58	1.74	1.62
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	49.5	48.9	28.1	43.9	51.3	52.8	53.0	50.9
Total dissolved solids	118	130	137	131	125	137	131	132
Trace metals (µg/L)								
Aluminum	16.3	----	577	259	67.5	26.8	17.1	11.2
Antimony	0.057	----	0.118	0.069	0.089	<0.054	0.037	0.057
Arsenic	0.705	----	0.369	0.676	0.708	0.702	0.595	0.691
Barium	9.30	----	34.7	20.6	14.4	12.8	11.6	10.1
Beryllium	<0.012	----	0.202	0.037	<0.012	<0.012	0.006	<0.006
Boron	6.9	----	5.5	6.9	7.5	6.3	6.71	6.03
Cadmium	<0.02	----	<0.02	<0.02	<0.02	<0.02	<0.016	<0.016
Chromium	0.70	----	0.49	0.71	0.70	0.70	0.73	0.84
Cobalt	0.03	----	1.55	0.07	0.399	<0.01	<0.02	<0.02
Copper	1.5	----	1.1	1.1	<1.0	<1.0	<0.5	<0.5
Iron	15.2	----	465	99.5	46.4	23.4	17.4	8.60
Lead	<0.03	----	0.95	0.15	0.07	<0.03	0.02	0.05
Manganese	0.48	----	12.9	2.35	1.49	0.66	0.79	0.39
Mercury	<0.010	----	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Molybdenum	0.997	----	0.333	0.759	0.919	0.963	0.923	0.992
Nickel	0.13	----	0.76	0.37	0.16	<0.12	<0.09	<0.09
Selenium	0.45	----	0.20	0.18	0.14	0.16	0.12	0.19
Silver	<0.010	----	<0.010	0.018	<0.010	<0.010	<0.005	<0.005
Uranium	0.180	----	0.244	0.131	0.116	0.142	0.138	0.128
Vanadium	5.23	----	3.41	5.19	6.20	5.94	4.78	5.40
Zinc	<2.8	----	2.84	<2.8	<2.8	<2.8	<1.4	<1.4
Total coliforms and <i>E. coli</i> (MPN/100 mL)								
Total coliforms	79	190	290	240	>2400 ^c	>2400	1300	440
<i>E. coli</i>	≤1	3	10	3	11	7	22	1

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Note that reporting levels changed starting October, 2010.

^bParameters are dissolved unless otherwise specified.

^cThe maximum detection level for bacteria is 2400 MPN/100 mL.

Table B-4. NPS water quality core parameter field data for BANDRIT02

Core parameter	Unit	Sample collection date and time							
		2/1/10	3/12/10	4/26/10	5/30/10	7/16/10	9/2/10	10/27/10	12/7/10
		09:15	10:15	11:30	19:35	14:52	14:15	17:13	11:37
Water temperature	°C	1.6	4.1	7.2	14.1	17.2	15.1	6.9	5.0
pH	none	8.1	8.1	7.7	8.1	8.1	8.1	7.8	7.9
Specific conductivity	µS/cm	98	99	94	117	114	112	109	103
Dissolved oxygen	mg/L	10.5	10.0	8.8	7.6	7.3	7.7	9.1	9.8
Turbidity	NTU	2.2	4.0	26	8.2	2.6	1.6	1.4	1.6 ^a
Discharge	cfs	1.4	1.3	6.6	1.8	1.3	0.9	1.2	1.1

^a The three turbidity samples for this visit were not within +/-10% of one another

Table B5. Results of laboratory analyses for BANDCAP01, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL)^a

Analyte ^b	Sample collection date and time							
	1/31/10	3/13/10	4/25/10	5/31/10	7/15/10	9/1/10	10/26/10	12/6/10
	10:45	10:40	16:20	16:00	16:50	14:50	8:27	13:04
Nutrients (mg/L)								
Ammonia as N	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010
Nitrite + nitrate as N	0.061	<0.040	<0.040	<0.040	<0.040	<0.040	<0.020	0.031
Nitrite as N	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0011	0.0011
Orthophosphate as P	0.044	0.041	0.055	0.054	0.068	0.062	0.047	0.036
Major elements (mg/L)								
Calcium	12.2	----	11.0	12.7	13.0	13.8	14.3	13.1
Chloride	2.85	2.95	2.25	1.90	2.17	2.69	2.91	2.67
Fluoride	0.21	0.21	0.20	0.20	0.20	0.24	0.21	0.20
Magnesium	3.29	----	2.88	3.56	3.63	3.80	3.99	3.62
Potassium	1.81	----	2.84	2.51	2.90	2.78	2.64	2.06
Silica	61.6	----	47.7	60.7	65.7	65.1	65.9	64.9
Sodium	9.68	----	7.30	9.24	10.2	10.5	10.2	10.5
Sulfate	3.29	4.92	6.88	5.03	4.13	3.20	3.00	3.20
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	63.6	59.5	44.9	59.5	66.7	70.0	72.4	66.7
Total dissolved solids	147	162	158	137	153	152	155	148
Trace metals (µg/L)								
Aluminum	<3.4	----	384	202	27.4	9.69	11.8	4.13
Antimony	<0.054	----	0.115	0.091	<0.054	<0.054	<0.027	0.051
Arsenic	1.18	----	1.10	1.41	1.29	1.29	1.04	1.04
Barium	33.4	----	36.3	36.4	36.7	40.4	40.1	34.3
Beryllium	<0.012	----	0.129	0.035	<0.012	<0.012	0.006	<0.006
Boron	8.27	----	11.0	10.8	12.4	9.75	9.02	8.34
Chromium	<0.02	----	<0.02	<0.02	<0.02	<0.02	<0.016	<0.016
Cadmium	0.18	----	0.32	0.29	0.15	0.17	0.22	0.29
Cobalt	0.03	----	0.18	0.86	0.04	0.02	0.03	0.02
Copper	<1.0	----	<1.0	<1.0	<1.0	<1.0	<0.5	0.6
Iron	10.7	----	229	181	35.1	31.0	47.6	15.1

Table B5 *continued*

Analyte ^b	Sample collection date and time							
	1/31/10	3/13/10	4/25/10	5/31/10	7/15/10	9/1/10	10/26/10	12/6/10
	10:45	10:40	16:20	16:00	16:50	14:50	8:27	13:04
Lead	<0.030	----	0.593	0.261	0.043	<0.030	0.020	0.109
Manganese	3.05	----	7.12	6.21	3.42	4.39	9.05	4.34
Mercury	<0.010	----	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Molybdenum	0.890	----	0.566	0.754	0.846	0.871	0.731	0.802
Nickel	0.18	----	0.63	0.74	0.29	0.21	0.16	0.20
Selenium	0.37	----	0.43	0.23	0.12	0.12	0.11	0.19
Silver	<0.01	----	0.017	<0.01	<0.01	<0.01	<0.005	<0.005
Uranium	0.066	----	0.150	0.068	0.041	0.038	0.032	0.026
Vanadium	3.47	----	4.94	4.91	4.54	3.84	2.05	2.78
Zinc	<2.8	----	<2.8	<2.8	<2.8	<2.8	<1.4	<1.4
Total coliforms and <i>E. coli</i> (MPN/100 mL)								
Total coliforms	610	300	870	>2400 ^c	1400	>2400	1600	400
<i>E. coli</i>	<1	31	6	4	25	31	10	<1

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Note that reporting levels changed starting October, 2010.

^bParameters are dissolved unless otherwise specified.

^cThe maximum detection level for bacteria is 2400 MPN/100 mL.

Table B-6. NPS water quality core parameter field data for BANDCAP01

Core parameter	Unit	Sample collection date and time							
		1/31/10	3/13/10	4/25/10	5/31/10	7/15/10	9/1/10	10/26/10	12/6/10
		12:00	10:40	16:20	16:00	16:50	14:50	08:27	13:04
Water temperature	°C	0.5	3.9	12.4	15.9	19.5	16.8	4.3	4.1
pH	none	7.9	8.1	8.2	8.1	8.0	8.1	7.8	7.9
Specific conductivity	µS/cm	128	129	107	128	139	145	143	132
Dissolved oxygen	mg/L	11.3	10.4	7.9	7.5	7.1	7.8	10.3	10.1
Turbidity	NTU	2.6 ^a	7.1	25	7.5	2.7 ^a	1.1	0.9 ^a	0.6
Discharge	cfs	0.6	1.0	2.1	0.4	0.2	0.2	0.4	0.4

^a The three turbidity samples for this visit were not within +/-10% of one another

Appendix C: Abbreviations and terms

Term	Definition
4T3	4T3 temperature - the temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days
ANC	acid neutralizing capacity of solutes plus particulates in an unfiltered water sample
CaCO ₃	chemical formula for calcium carbonate
cfs	cubic feet per second
cfu/100 ml	colony forming units, for bacteria sampling, a measure of the number of viable bacteria per 100 mL
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25°C, a measure of specific conductivity
mg/L	milligrams per liter
Milliequivalents per liter	an expression of the concentration of substances that is chemically equivalent in terms atomic weight and electrical charge
MPN/100 mL	most probable number, for sampling bacteria, a statistical estimation of the number of bacteria per 100 mL of sample water
N	chemical symbol for the element nitrogen
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for the element phosphorous