



Water Quality Monitoring for the Mancos River in Mesa Verde National Park

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/351



ON THE COVER

Mancos River in Mesa Verde National Park
Photograph by Clay Bliss

Water Quality Monitoring for the Mancos River in Mesa Verde National Park

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/351

Stephen A. Monroe, Clay Bliss, Melissa Dyer, and Kelly Lawrence

National Park Service
Southern Colorado Plateau Network
Northern Arizona University
P.O. Box 5765
Flagstaff, AZ 86011-5765

July 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

Funding for the SCPN water resources field crew was provided to Northern Arizona University by the National Park Service through Colorado Plateau CESU Agreement H1200090005 (Tasks NAU-331). Funding for water quality sample analysis was provided by the National Park Service to the United States Geological Survey through Interagency Agreement # F2121090111.

This report is available from the Southern Colorado Plateau Network (<http://science.nature.nps.gov/im/units/scpn/>), and the Natural Resource Publications Management Web site (<http://www.nature.nps.gov/publications/nrpm/>) on the Internet.

The corresponding author and project manager for this project is Stephen Monroe (stephen_monroe@nps.gov). Melissa Dyer is the Water Resources Crew Leader for the project. The 2010 crew consisted of Clayton Bliss, Kelly Lawrence, and Stacy Stumpf. SCPN staff provided support for the project.

Please cite this publication as:

Monroe, S. A., C. Bliss, M. Dyer, and K. Lawrence. 2012. Water quality monitoring for the Mancos River in Mesa Verde National Park: 2010 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2012/351. National Park Service, Fort Collins, Colorado.

Contents

Figures iv

Tables iv

1 Introduction and background 1

 1.1 Selecting potential water quality monitoring sites 1

 1.2 Water quality monitoring at Mesa Verde National Park 1

2 Methods 4

 2.1 Water quality core parameters 4

 2.2 Water quality samples 4

 2.3 Data handling, analysis, and quality assurance and quality control (QA/QC) 4

3 Results 6

 3.1 Water quality core parameter data 6

 3.2 Precipitation 7

 3.3 Temporal variability of water quality core parameter data from the Mancos River in MEVE 8

 3.4 Total coliforms and *E. coli* 8

 3.5 Water quality laboratory data 10

4 Summary 14

5 Literature cited 15

Appendix A: Southern Colorado Plateau Network water quality monitoring site at Mesa Verde National Park, 2010...... 16

Appendix B: 2010 Water quality monitoring results for the Mancos River at Mesa Verde National Park 16

Appendix C: Abbreviations and terms 18

Figures

Figure 1. Map of Mancos River, Mesa Verde National Park, Colorado, with the location of Southern Colorado Plateau Network water quality monitoring site MAN01 on the Mancos River, visited in 2010.	2
Figure 2. Daily maximum, average, and minimum air temperatures (top) and water temperatures (bottom) at MAN01 at the Mancos River in Mesa Verde NP, 2010. Water temperatures recorded during SCPN site visits are also shown.	7
Figure 3. Hourly gage discharge readings from the streamflow gaging station <i>Mancos River at Anitas Flat below Mancos, CO</i> (09370600) from MAN01 on the Mancos River in Mesa Verde NP, 2010. Turbidity data is in red; SCPN measured discharge is in yellow.	8
Figure 4. Daily precipitation from the NOAA/NCDC weather station (055327) at Mancos, Colorado, 2010.	8
Figure 5. Multi-parameter sonde data measured during a 18-day period, July 18–August 4, from MAN01 at the Mancos River in Mesa Verde NP, 2010, with grab sample yearly minima/maxima and stream discharge also shown. Water temperature (a), dissolved oxygen (b), pH (c), and specific conductivity (d).	9
Figure 6. Monthly data for <i>E. coli</i> and total coliforms from MAN01 at the Mancos River in Mesa Verde NP, 2010.	10
Figure 7. Major ion composition from MAN01 at Mancos River in Mesa Verde NP, 2010.	12

Tables

Table 1. National Water Quality Laboratory sample analytes	4
Table 2. Summary of water quality core parameter data, with standard deviations (std. dev.) from MAN01 on the Mancos River in Mesa Verde NP, 2010.....	6
Table 3. Summary of water quality core parameter temporal variability at MAN01 on the Manco River in Mesa Verde NP, July 18-19 and September 10-11, 2010.....	10
Table 4. Summary of nutrient data collected from MAN01 at the Mancos River in Mesa Verde NP, 2010.....	11
Table 5. Summary of major element data, acid neutralizing capacity, and total dissolved solids from MAN01 on the Mancos River in Mesa Verde NP, 2010.....	11
Table 6. Summary of trace metal data from MAN01 on the Mancos River in Mesa Verde NP, 2010. Number of exceedances of the State of Colorado acute and chronic water quality standards are given.....	13

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 condition
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 for 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, (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. Diurnal variation in NPS core water quality parameters during base flow conditions are characterized by deploying a multi-parameter sonde to collect data at 15-minute intervals for a period of two days to three weeks. Water quality samples are analyzed by SCPN staff and by a qualified contract laboratory.

1.2 Water quality monitoring at Mesa Verde National Park

The Mancos River is a perennial stream flowing from Colorado’s La Plata Mountains to its confluence with the San Juan River in northwestern New Mexico. Approximately four miles of the river flow along the eastern boundary of Mesa Verde National Park (MEVE). Upstream from the park, Jackson Gulch Dam diverts water from the Mancos River; both the dam and numerous diversions in the Mancos Valley reduce the amount of Mancos River flow that reaches MEVE (Colorado Water Trust 2011). In August of 2000 the NPS, in cooperation

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).

with the United States Geological Survey (USGS), installed a streamflow gaging station on the Mancos River within MEVE (fig. 1).

Water quality concerns within the park include insecticide, algicide, and herbicide applications (Brown 2008). Adjacent agriculture and sewage-treatment facilities have been sources of nutrient and bacterial contamination (Thomas et al. 2006). Irrigation practices along the Mancos River and its tributaries are suspected to have contributed to elevated salinity levels (Yochum 2004). Drought and wildfire have also affected the river. In 2000, a high-intensity fire burned portions of the watershed in MEVE; fire retardant drops during the fire resulted in fish kills (San Miguel, G., Natural Resource Manager, Mesa Verde N.P., personal communication, 28 July 2011). Data documenting water quality conditions in the Mancos River are sparse. The most recent samples collected in the park were part of a Level 1 water quality inventory of water bodies in SCPN parks completed by USGS in 2005 and 2006 (Macy and Monroe 2006). A ‘Rapid Assessment of the Functional Condition of the Mancos River,’ conducted in 2006, found high concentrations of algal blooms, and high solar exposure, combined with a wide shallow channel near MAN01, all indicators of poor water quality (Stacey 2007).

In 2010, SCPN implemented water quality monitoring on the Mancos River in MEVE. SCPN’s primary water quality monitoring site on the river is *Mancos River at Gage* (MEVEMAN01), identified in this report as MAN01

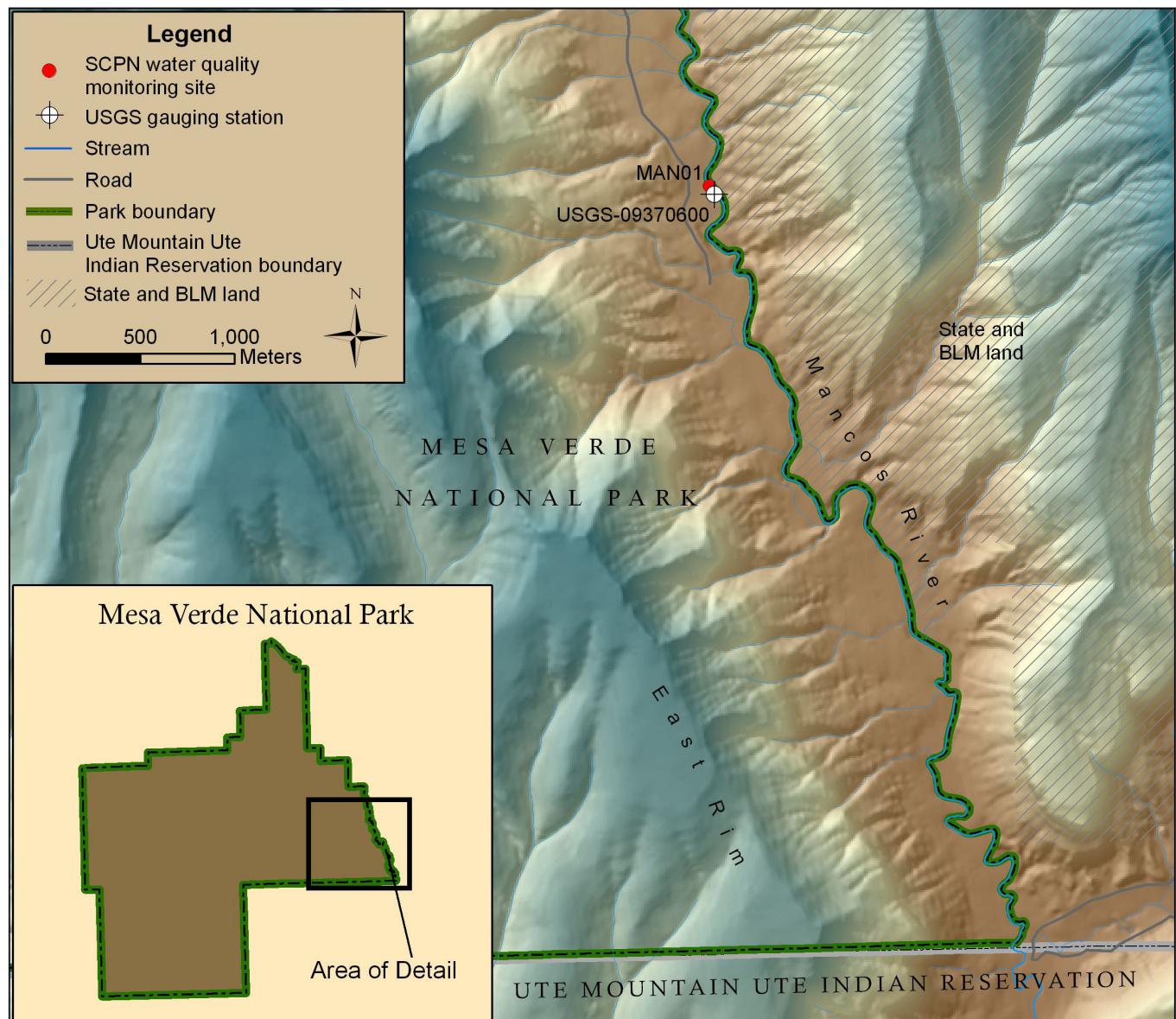


Figure 1. Map of Mancos River, Mesa Verde National Park, Colorado, with the location of Southern Colorado Plateau Network water quality monitoring site MAN01 on the Mancos River, visited in 2010.

(appendix A). The site is co-located with a SCPN aquatic macroinvertebrate monitoring site and the USGS streamflow gaging station *Mancos River at Anitas Flat below Mancos, CO* (USGS 09370600).

During 2010, SCPN staff completed a total of eight water quality sampling visits to MEVE at approximately six week intervals. This report documents SCPN water quality monitoring activities at MEVE in 2010, and summarizes the data collected.

2 Methods

Following is a brief outline of water quality data collection and processing methodologies followed by SCPN staff at MEVE during 2010. For further details please refer to SCPN’s water quality monitoring protocol (Monroe and Bliss, in preparation).

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 arrival at the site a multi-parameter sonde (Hydrolab-MS5; Hach Inc.) was calibrated and deployed in a well-mixed part of the stream channel, logging 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 a maximum of 24 hours, and analyzed with a HACH 2100P Portable Turbidimeter (Hach Inc.).
- 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 at 15-minute intervals during the entire year by the USGS gaging station.

During each site visit, we attempted to obtain all measurements and samples as close in time to one another as possible. Streamflow data from the USGS gaging station documented flow variation during site visits and throughout the year.

2.2 Water quality samples

During each site visit, we collected a sample for bacterial analysis by dipping a sample bottle at 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 analysis 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 are included in the SCPN water quality monitoring protocol (Monroe and Bliss, in preparation).

Table 1. National Water Quality Laboratory 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

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

All SCPN water quality data is entered to NPSTORET, v.1.83, a Microsoft Access database created by the Water Resources Division of the National Park Service. All multiparameter sonde electronic 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 the data presented in section 3.3: *Temporal variability of core parameter data from the Mancos River in MEVE*. Similarly, only the median values for each set of turbidity triplicate samples are presented herein. For total coliforms and *E. coli* samples, most-probable numbers (MPN/100 mL) are reported; these were determined using a lookup table provided by the manufacturer (Idexx Inc.).

Where applicable, we compared our results against the State of Colorado's 2011 acute and chronic aquatic life standards (Colorado Department of Public Health and Environment [CDPHE] 2011). Acute standards require only a single sample, while chronic standards require either a representative sample or an average of samples collected within a 30-day period.

We followed the QA/QC procedures described in Monroe and Bliss (in preparation).

3 Results

This section presents data collected by SCPN staff during eight water quality monitoring site visits to the Mancos River in MEVE during 2010. Data from the USGS streamflow gaging station on the Mancos River in MEVE (USGS 2011) and a National Oceanic and Atmospheric Administration (NOAA)/National Climatic data Center (NCDC) weather station in the town of Mancos are included.

3.1 Water quality core parameter data

Summary statistics for water quality core parameter data collected at MAN01 during 2010 are presented in Table 2 and complete results are displayed in Appendix B. These data exhibited considerable within-year variability for all parameters; however, there were no exceedances of Colorado state water quality standards during the year (CDPHE 2011).

Table 2. Summary of water quality core parameter data, with standard deviations (std. dev.) from MAN01 on the Mancos River in Mesa Verde NP, 2010

Core parameter	Observations	Minimum	Maximum	Median	Std. dev.	Colorado state criteria
Water temperature (°C)	8	0.4	25.2	8.5	8.8	--- ^a
pH	8	7.9	8.6	8.3	0.2	>6.5 or <9
Specific conductivity (µS/cm)	8	345	2210	1230	640	---
Dissolved oxygen (mg/L)	8	7.2	11.4	9.3	1.6	≥5
Turbidity (NTU)	8	7.2	120	12	42	---
Discharge (cfs)	8	4.6	269	18	89	---

^a--- indicates that no criteria exists for MEVEMAN01

Water and air temperature data from MAN01 for 2010 are summarized below and shown in Figure 2. The Mancos River was frozen for the month of January, after which the daily maximum water temperature increased to a maximum of 29.5°C on July 19. The average water temperature for the year was 9.1°C. Recorded air temperatures were well below corresponding water temperatures for the first two months of 2010. Water and air temperatures followed a similar pattern from late spring until early winter, though diurnal variations in the water temperature were moderate in comparison to diurnal variations in air temperature. A high of 39.4°C was recorded on July 16 and a low of -25.4°C on December 31. The average air temperature for the year was 7.7°C.

This section of the Mancos River is designated by the State of Colorado as a Class 2–Warm Water Biota stream (CDPHE 2010). There are three “tiers” of temperature standards, depending on the assemblage of fish species expected to occur. The Tier III Warm Water stream standards are the least stringent and should be applied where thermally sensitive species are not expected to occur. Our data show that the Mancos River temperatures did not exceed these criteria for 2010. However, because of the historic presence of razorback sucker (*Xyrauchen texanus*) within this river reach (San Miguel, G., Natural Resource Manager, Mesa Verde N.P., personal communication, 28 July 2011), we also evaluated the temperature against the Tier II Warm Water stream standards. The chronic water temperature criterion is a 27.5°C average over a seven-day period. In 2010 water temperatures did not exceed this limit. During the warmest seven-day period of the year, water temperatures averaged 22.1°C. However, the acute water temperature standard was exceeded on three consecutive days in July. This criterion is a 28.6°C daily maximum temperature, evaluated as the highest two-hour average water temperature on a given day. Average water temperatures during July 17-19 were 29.5, 29.1, and 29.5°C, respectively.

Measured pH ranged from 7.9 to 8.6, with highest values occurring during the spring runoff period. During the spring, pH exhibited a pattern similar to that of specific conductivity—both were highest in March and lowest in April. Specific conductivity ranged between 345 and 2210 µS/cm, with the highest values observed in January and March. There was a noticeable drop in specific conductivity in April and June, corresponding with the highest discharges measured during 2010.

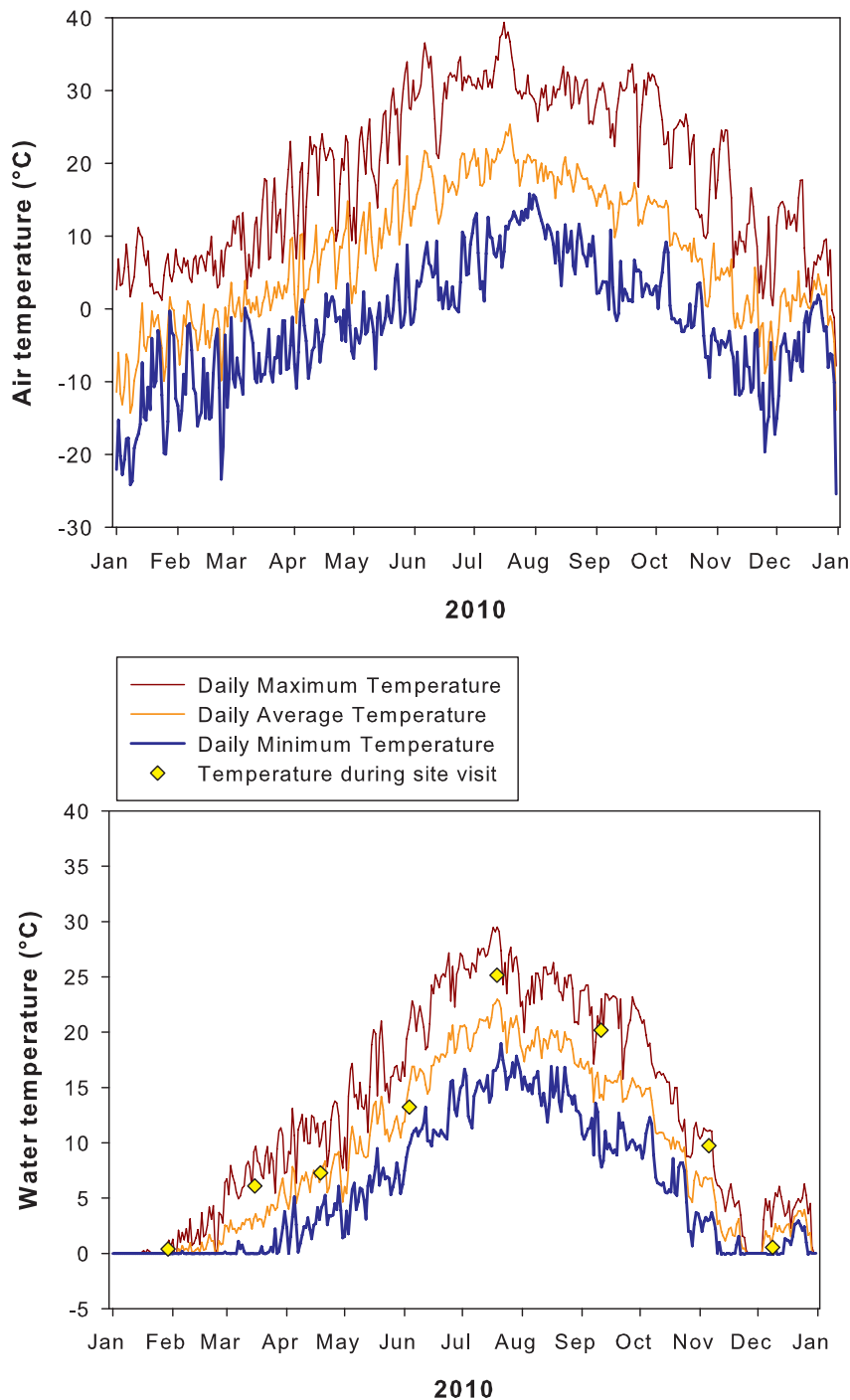


Figure 2. Daily maximum, average, and minimum air temperatures (top) and water temperatures (bottom) at MAN01 at the Mancos River in Mesa Verde NP, 2010. Water temperatures recorded during SCPN site visits are also shown.

An inverse relationship between water temperature and dissolved oxygen was observed at MAN01—warmer water temperatures coincided with lower dissolved oxygen levels. Dissolved oxygen ranged between 7.2 and 11.4 mg/L, with the lowest values observed in September and the highest in December. These values were well above the State of Colorado water quality standard applicable to MAN01 (5 mg/L, CDPHE 2011).

We measured the discharge of the Mancos River during each water quality sampling visit, except on April 18 when flow was too high to be measured safely. Measured flows ranged from 4.6 to 57 cfs. These data are provided to the USGS to fulfill the NPS part of an interagency agreement intended to collect and process data from the streamflow gaging station Mancos River at Anitas Flat below Mancos, CO (09370600) (USGS 2011). The hydrograph from the gaging station for the period February 2 through December 31, 2010 shows large peaks and sustained high flows during the snow melt period from March to June. Several smaller peaks occurred during the monsoon months of July to September (fig. 3).

A time-series plot of hourly discharge from USGS streamflow gaging station #09370600 and turbidity for MAN01 in 2010 (fig. 3) shows the relationship between these two parameters, with high turbidity values corresponding to high springtime flows. Turbidity levels ranged between 7.2 and 120 NTU; the two highest values for turbidity were associated with the two highest discharges, which occurred in March and April. Turbidity values were lower during our sampling events at other times of the year.

3.2 Precipitation

The Western Regional Climate Center collects weather data in the town of Mancos, Colorado (station 055327), approximately 12.5 km upstream of MAN01 (Western Regional Climate Center 2010). During 2010 the station recorded a total of 41 cm of precipitation (fig. 4). Precipitation was distributed relatively evenly throughout the year, with the exception of May and June, which were the driest months. The largest precipitation event during

the year was 1.8 cm, which occurred on January 22, 2010.

3.3 Temporal variability of water quality core parameter data from the Mancos River in MEVE

To assess temporal variability in core water quality parameters at MAN01, we deployed a multi-parameter sonde to record data at 1-hour intervals from July 18 to August 4. Figure 5 shows water quality core parameter data recorded during this period. For comparison, the minima/maxima from our regular “grab sample” monitoring data are displayed along with the stream gage data. This deployment occurred during a fairly active monsoon period; therefore a variety of stream flows were captured.

Table 3 summarizes diurnal variation in core parameter data during a 24-hour period in July when the river was at base flow. A clear inverse relationship existed between dissolved oxygen and temperature—the highest dissolved oxygen levels occurred in the morning and the lowest during the evening, while temperatures were lowest between 08:00 and 09:00 a.m. and highest during the early evening hours. The diurnal range was approximately 2 mg/L.

The pH varied, but the diurnal range was only 0.1. Measured pH was highest midday and lowest late at night during both months. Specific conductivity varied throughout the day, with an observed 200 $\mu\text{S}/\text{cm}$ range, but was higher midday than in the evening. This range was much smaller than the range observed during our sampling events for the entire year.

3.4 Total coliforms and *E. coli*

Bacteria data collected by SCPN at MAN01 in 2010 are graphed in Figure 6 and presented in Appendix B. SCPN’s data are expressed as a most probable number (MPN), a statistical estimate of the number of bacteria per 100 mL of stream water. Water quality criteria are expressed as colony forming units (cfu) per 100 mL and

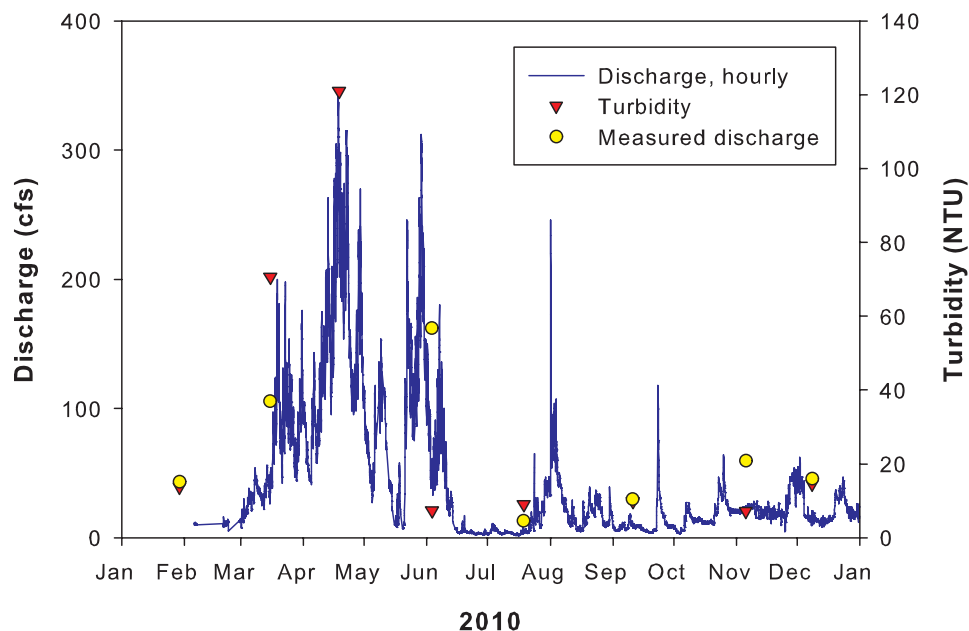


Figure 3. Hourly gage discharge readings from the streamflow gaging station *Mancos River at Anitas Flat below Mancos, CO (09370600)* from MAN01 on the Mancos River in Mesa Verde NP, 2010. Turbidity data is in red; SCPN measured discharge is in yellow.

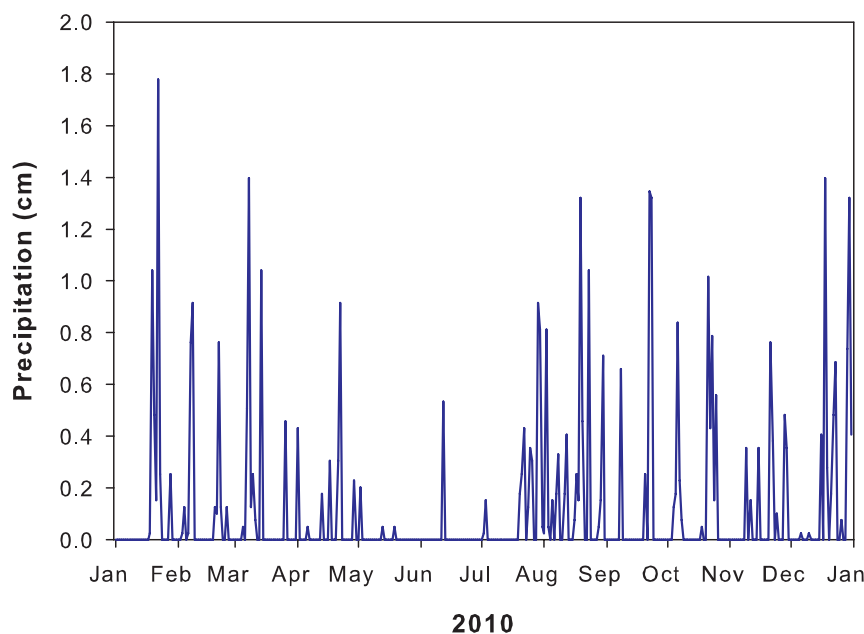
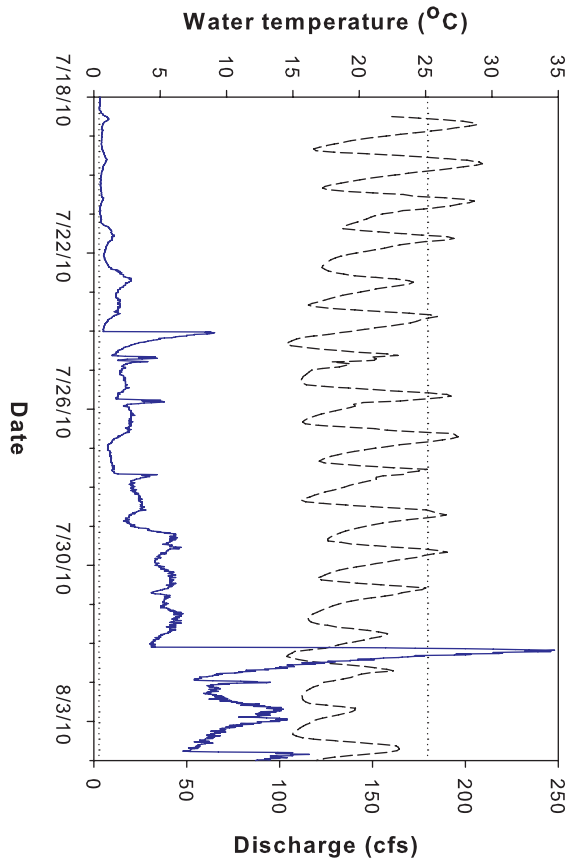
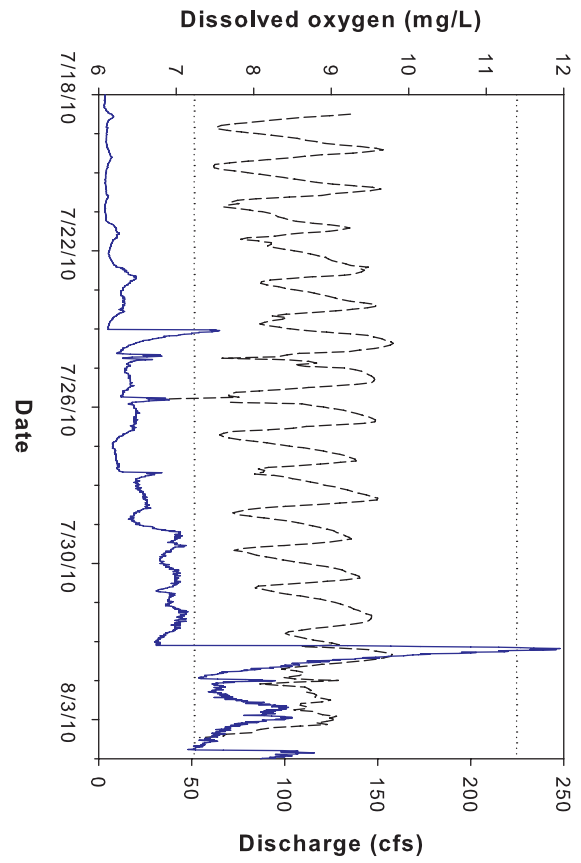


Figure 4. Daily precipitation from the NOAA/NCDC weather station (055327) at Mancos, Colorado, 2010.

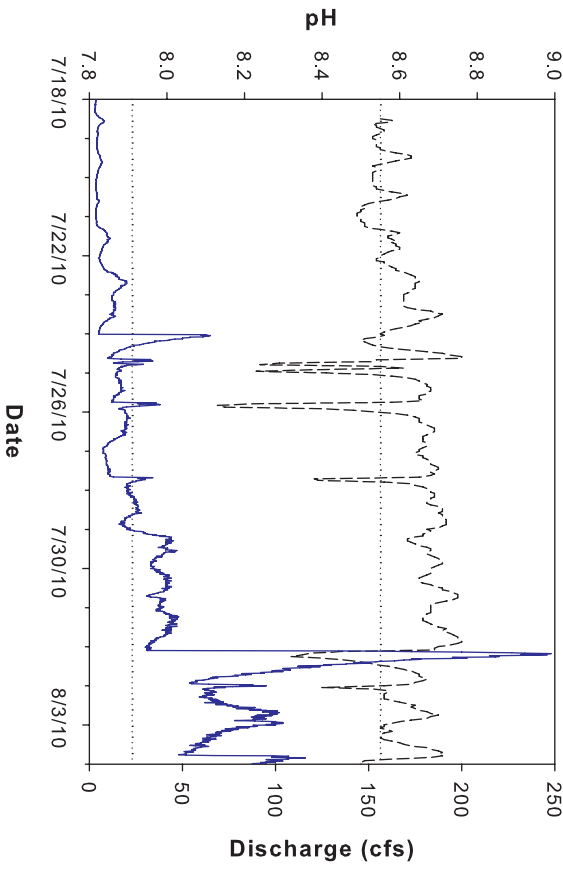
a.



b.



c.



d.

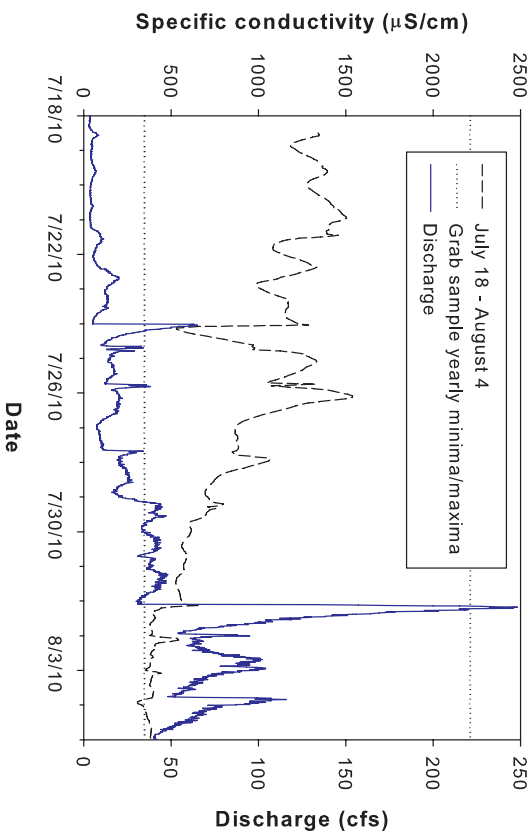


Figure 5. Multi-parameter sonde data measured during a 18-day period, July 18–August 4, from MAN01 at the Mancos River in Mesa Verde NP, 2010, with grab sample yearly minima/maxima and stream discharge also shown. Water temperature (a), dissolved oxygen (b), pH (c), and specific conductivity (d)

do not assume an estimation, but the two units are comparable. The Colorado state criterion value for *E. coli* is based on the geometric mean of at least four evenly-distributed samples taken over a 60-day period. The criterion applicable at MAN01 is 126 cfu/100 mL. We analyze our samples for total coliforms because theoretically they are indicators of the presence of all coliform groups of bacteria, both vegetative and fecal in origin. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source. There are no water quality criteria for total coliforms.

E. coli levels were highest in samples collected in April, at 210 MPN/100 mL, corresponding to a high flow event; whereas the highest total coliform count was in a sample collected in July during a low flow period, exceeding the maximum detection level of 2400 MPN/100 mL. Levels of both were discernibly lower in the late fall and winter relative to the rest of the year; *E. coli* below the minimum detection level of 100 MPN/100 mL in the sample collected in March. The *E. coli* counts in our April sample indicate that exceedances may occasionally occur in the Mancos River for this parameter, but more detailed sampling would be required to adequately document this condition.

3.5 Water quality laboratory data

Water samples collected at MEVE by SCPN during 2010 were sent to NWQL to be analyzed for a suite of analytes (table 1), with the exception of the samples collected on March 15, which were not analyzed for trace metals or calcium, magnesium, potassium, silica, and sodium. Laboratory results for water samples are summarized in Tables 4-6. Complete results are presented in Appendix B. Samples collected during 2010 did not exceed State of Colorado acute water quality standards, but potentially exceeded the chronic standard in two instances. These results should not be interpreted as exceedances because more samples would be needed to confirm that; rather, they should be interpreted as an indicator of the potential need for further sampling.

Table 3. Summary of water quality core parameter temporal variability at MAN01 on the Manco River in Mesa Verde NP, July 18-19 and September 10-11, 2010.

Core parameter	July 18-19
Water temperature (°C)	
Median	23.1
Minimum	16.6
Maximum	28.9
Range	12.3
Dissolved oxygen (mg/L)	
Median	8.6
Minimum	7.5
Maximum	9.7
Range	2.2
pH	
Median	8.6
Minimum	8.5
Maximum	8.6
Range	0.1
Specific conductivity (µS/cm)	
Median	1280
Minimum	1180
Maximum	1380
Range	200

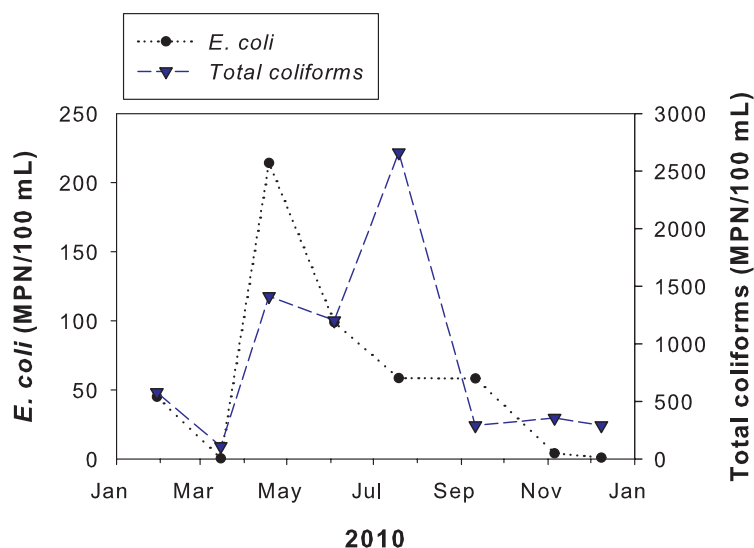


Figure 6. Monthly data for *E. coli* and total coliforms from MAN01 at the Mancos River in Mesa Verde N.P., 2010.

Nutrient concentrations (table 4) were very low and, for ammonia and nitrite, never approached the water quality standards. Among the eight samples analyzed in 2010, the nitrogen species tended to measure at or near the laboratory reporting levels (which ranged between 0.002 and 0.040, depending on the nitrogen species and the time of year), except during the winter months, when nitrate+nitrite and ammonia levels rose slightly above the reporting level. Orthophosphate levels remained relatively constant throughout the year, ranging between <0.008 and 0.045 mg/L.

Major element data, which includes major ions, silica, acid neutralizing capacity, and total dissolved solids, are summarized in Table 5. The concentration of total dissolved solids varied over the year from 244 mg/L to 1870 mg/L, with a median concentration of 923 mg/L. Dissolved solids were dominated by sulfate, which amounted to 51% of the total. This was followed by calcium (15%), magnesium (6%), sodium (6%), and 1% or less each of silica, chloride, potassium, and fluoride.

Figure 7 depicts the major ion composition found during all 2010 water sampling events. Anions mostly consisted of sulfate and, to a lesser extent, bicarbonate. Cation composition was more evenly mixed, with calcium comprising the highest proportion, followed by magnesium, then sodium and potassium. While cation and anion composition varied throughout the year, these relationships remained fairly consistent.

Seven samples collected from the MAN01 in 2010 were analyzed for a selected suite of dissolved trace metals (table 6). For the trace elements included in this suite that have aquatic life water quality standards assigned to them by the State of Colorado eight consistently measured far below the aquatic life criteria. The water quality criteria based on hardness and, because this varied between samples, the numeric criteria are omitted. Two elements exceeded the aquatic life chronic criteria in single samples, each during one sampling event. In

Table 4. Summary of nutrient data collected from MAN01 at the Mancos River in Mesa Verde NP, 2010

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 ^a	0.19	<0.020	0.07	0
Nitrite + nitrate as N	8	<0.020	0.26	0.040	0.09	---- ^b
Nitrite as N	8	0.001	0.006	0.001	0.002	0
Orthophosphate as P	8	0.007	0.045	0.009	0.014	----

^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 parameter

Table 5. Summary of major element data, acid neutralizing capacity, and total dissolved solids from MAN01 on the Mancos River in Mesa Verde NP, 2010

Major element (mg/L, dissolved)	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	7	38.8	197	138	52.4
Chloride	8	2.85	26.1	8.33	8.62
Fluoride	8	0.13	0.28	0.20	0.050
Magnesium	7	12.8	116	52.4	33.8
Potassium	7	1.75	4.37	2.57	0.955
Silica	7	7.07	10.1	8.90	1.08
Sodium	7	12.3	121	48.1	36.4
Sulfate	8	101	1100	470	354
Acid neutralizing capacity, as CaCO ₃ , unfiltered	8	65.1	254	192	63.2
Total dissolved solids	8	244	1870	923	580

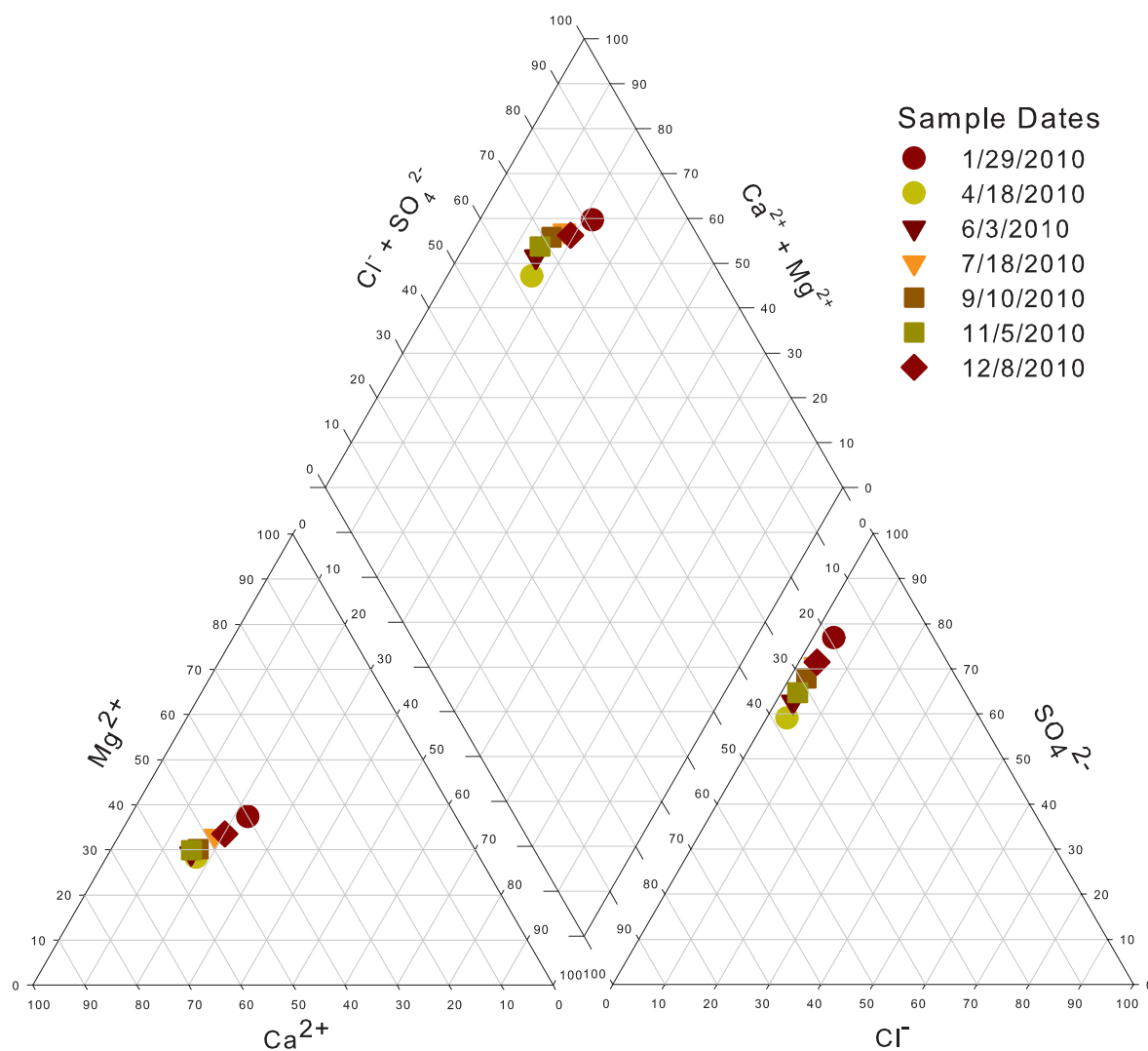


Figure 7. Major ion composition from MAN01 at Mancos River in Mesa Verde NP, 2010.

April, the laboratory-measured aluminum concentration was 128 $\mu\text{g/L}$. The chronic criterion for aluminum varies depending on the hardness of the stream water, but should not exceed 87 $\mu\text{g/L}$. In January, the selenium concentration was 5.51 $\mu\text{g/L}$; the chronic criterion value was 4.6 $\mu\text{g/L}$.

Mercury and zinc were not detected above the reporting level in any of the samples collected at MAN01 in 2010. Beryllium and silver exceeded the minimum laboratory reporting level twice and once, respectively.

Table 6. Summary of trace metal data from MAN01 on the Mancos River in Mesa Verde NP, 2010. Number of exceedances of the State of Colorado acute and chronic water quality standards are given.

Trace metal (µg/L, dissolved)	Number of samples	Minimum (µg/L)	Maximum (µg/L)	Median (µg/L)	Standard deviation	Number of exceedances
Aluminum	7	<1.7	128	2.9	49	1 (potential) ^a
Antimony	7	0.091	0.161	0.107	0.028	---- ^b
Arsenic	7	0.334	0.768	0.471	0.146	0
Barium	7	33.0	47.9	44.0	5.7	----
Beryllium	7	<0.006	0.015	0.009	0.004	----
Boron	7	14.9	77.8	45.8	22.9	----
Cadmium	7	<0.016 ^c	0.040	<0.020	0.010	0
Chromium	7	<0.06	0.16	— ^d	—	----
Cobalt	7	0.26	0.91	0.53	0.22	----
Copper	7	1.1	5.8	1.7	2.0	0
Iron	7	6.6	130	22.8	44	----
Lead	7	<0.015	0.19	0.02	0.07	0
Manganese	7	8.32	154	29.7	51	0
Mercury	7	<0.005	<0.010	—	—	----
Molybdenum	7	0.748	2.63	1.87	0.72	----
Nickel	7	0.93	5.01	1.58	1.5	----
Selenium	7	0.52	5.51	1.02	1.8	1 (potential)
Silver	7	<0.005	<0.01	—	—	0
Uranium	7	0.752	8.90	3.16	2.65	0
Vanadium	7	0.13	0.47	0.34	0.12	----
Zinc	7	<1.4	<2.8	—	—	0

^a Additional sampling is needed to confirm exceedance of the chronic water quality standard

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

^c Results 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.

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

4 Summary

In 2010, SCPN implemented long-term water-quality monitoring at MAN01 on the Mancos River in MEVE. Data collected during eight site visits to MAN01 in 2010 is summarized here and compared against Colorado aquatic life standards (CDPHE 2011).

Water quality core parameter data varied across the eight site visits. Discharge ranged from 4.6 to 269 cfs, and turbidity varied with discharge, ranging from 7.2 to 120 NTU. Specific conductance ranged from 345 to 2210 $\mu\text{S}/\text{cm}$. Dissolved oxygen measurements were well above the water quality criterion for a warm-water stream, and ranged from 7.2 to 11.4 mg/L. Measured pH was between 7.9 and 8.6, also within the water quality criteria. Water temperatures, which were collected at 15-minute intervals year-round, exceeded the acute Tier II Warm Water criterion of 28.6°C during three days in July. Temperatures did not exceed the chronic criterion in 2010. A long-term sonde deployment at MAN01 showed regular diurnal patterns in water temperature, dissolved oxygen, and pH; but specific conductivity varied greatly with changes in streamflow during the 18-day deployment period.

Total coliform results varied between 110 MPN/100 mL to >2400 MPN/100 mL. The highest count occurred in July, while the lowest occurred in March. *E. coli* results were generally low, but the count in samples collected in April was 210 MPN/100 mL, above the chronic criterion of 126 MPN/100 mL applicable at MAN01. However, more samples would need to be collected to adequately assess the compliance with this standard.

Laboratory-measured results for nutrients were low and were usually at or near the laboratory reporting levels and well below the water quality criteria, where applicable. Trace metal concentrations were also low in nearly all cases. Mercury and zinc were never present above the reporting levels. The acute aquatic life criteria for these analytes were not exceeded in our samples. Aluminum and selenium both exceeded the chronic criterion values once, though additional samples are needed to confirm that these are chronic exceedances. Major ion analyses show that the water at MAN01 is dominated by sulfate and calcium. Total dissolved solids were high and also variable, ranging from 244 to 1870 mg/L with a median of 923 mg/L. Acid neutralizing capacity was also variable and ranged from 65.1 to 254 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 which will include trend analysis of water quality data for the Mancos River in Mesa Verde National Park.

5 Literature cited

- Brown, J. B. 2008. Review of available water-quality data for the Southern Colorado Plateau Network and characterization of water quality in five selected park units in Arizona, Colorado, New Mexico, and Utah, 1925 to 2004: U.S. Geological Survey Scientific Investigations Report 2008–5130.
- Colorado Department of Public Health and Environment. 2010. Integrated water quality monitoring and assessment report. Water Quality Control Division, Denver, Colorado.
- Colorado Department of Public Health and Environment. 2011. The basic standards and methodologies for surface water (5 CCR 1002-31). Regulation No. 31. Water Quality Control Commission, Denver, Colorado.
- Colorado Water Trust. 2011. Mancos River basin instream flow report – Preliminary evaluation of flow restoration options. Report prepared for The Mancos Conservation District. Denver, Colorado.
- Macy, J. P., and Monroe, S. A. 2006. Water-quality data for selected National Park units in the Southern Colorado Plateau Network, Arizona, Utah, Colorado, and New Mexico, water years 2005 and 2006: U.S. Geological Survey Open-File Report 2006–1300, 84 p.
- Monroe, S. A., and C. A. Bliss. (In preparation). Water quality monitoring protocol for the Southern Colorado Plateau Network. National Park Service, Fort Collins, Colorado.
- National Oceanic and Atmospheric Administration/National Climatic Data Center (NOAA/NCDC). 2011. Period of record monthly climate summary page. NOAA/NCDC, Asheville, North Carolina. Available at <http://cdo.ncdc.noaa.gov/dly/DLY?stnid=20003389> (accessed November 2011).
- Stacey P. 2007. Functional assessment of the Mancos River watershed: Mancos Valley and adjacent areas. Mancos Conservation District, Mancos, Colorado.
- Thomas, L. P., M. N. Hendrie, editor, C. L. Lauver, S. A. Monroe, N. J. Tancreto, S. L. Garman, and M. E. Miller. 2006. Vital signs monitoring plan for the Southern Colorado Plateau Network: Natural Resources Report NPS/SCPN/NRR-2006/002, National Park Service, Fort Collins, Colorado. Available at <http://science.nature.nps.gov/im/monitor/MonitoringPlans.cfm> (accessed 8 August 2011).
- United States Geological Survey (USGS). 2011. National Water Information System: Web Interface. USGS, Denver, Colorado. Available at <http://waterdata.usgs.gov/nwis/uv?09370600> (accessed 28 November 2011).
- United States Environmental Protection Agency (EPA). 2011. Impaired waters and total maximum daily loads. Available at <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl> (accessed 22 November 2011).
- Yochum, Steven E. 2004. Mancos Valley Salinity: Hydrologic Study Report. Natural Resources Conservation Service, Northern Plains Engineering Team. Lakewood, Colorado.

Appendix A: Southern Colorado Plateau Network water quality monitoring site at Mesa Verde National Park, 2010

Site code	Common name	Report name	UTM (NAD 83, Zone 12)		Elevation (m)
			X	Y	
MEVEMAN01	Mancos River at Gage	MAN01	734375	4126163	1933

Appendix B: 2010 Water quality monitoring results for the Mancos River at Mesa Verde National Park

Table B1. Results of laboratory analyses for samples collected from MEVEMAN01. Analytes were analyzed by the U.S. Geological Survey National Water Quality Laboratory, except for total coliforms and *E. coli*, which were analyzed by SCPN.

Analyte ^a	Sample collection date and time							
	1/29/10	3/15/10	4/18/10	6/3/10	7/18/10	9/10/10	11/5/10	12/8/10
	13:00	13:55	13:10	11:35	21:15	18:18	15:00	12:15
Nutrients (mg/L)								
Ammonia as N	0.190	<0.020 ^b	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010
Nitrite + nitrate as N	0.26	0.13	0.040	<0.040	<0.040	<0.040	0.060	<0.020
Nitrite as N	0.006	0.004	<0.002	<0.002	<0.002	<0.002	0.0012	0.001
Orthophosphate as P	0.011	<0.008	<0.008	<0.008	0.009	0.010	0.045	0.007
Major elements (mg/L)								
Calcium	197	----	38.8	75.4	138	146	104	147
Chloride	22.5	26.1	2.85	4.12	8.69	7.96	5.37	11.0
Fluoride	0.23	0.28	0.13	0.15	0.20	0.24	0.17	0.19
Magnesium	116	----	12.8	25.4	59.2	52.4	36.1	67.2
Potassium	4.37	----	1.75	1.95	3.50	3.08	2.04	2.57
Silica	9.83	----	8.43	7.07	9.06	10.1	8.90	7.78
Sodium	121	----	12.3	22.4	55.4	48.1	30.9	68.9
Sulfate	981	1100	101	210	492	448	304	563
Acid neutralizing capacity, as CaCO ₃ (unfiltered) (mg/L)	254	243	65.1	118	185	198	157	205
Total dissolved solids (mg/L)	1750	1870	244	437	946	899	638	1080
Trace metals (µg/L)								
Aluminum	6.17	---- ^c	128	52.1	<3.4	<3.4	2.92	<1.7
Antimony	0.099	----	0.156	0.105	0.161	0.123	0.107	0.091
Analyte ^a	13:00	13:55	13:10	11:35	21:15	18:18	15:00	12:15
Total coliforms and <i>E. coli</i> (MPN/100 mL)								
Cadmium	0.040	----	<0.02	0.025	<0.02	<0.02	<0.016	0.021

Table B-1 *continued*

Analyte ^a	Sample collection date and time							
	1/29/10	3/15/10	4/18/10	6/3/10	7/18/10	9/10/10	11/5/10	12/8/10
	13:00	13:55	13:10	11:35	21:15	18:18	15:00	12:15
Chromium	<0.12	----	<0.12	<0.12	<0.12	<0.12	<0.06	0.16
Cobalt	0.91	----	0.74	0.39	0.61	0.42	0.26	0.53
Copper	1.4	----	5.8	5.2	2.3	1.4	1.7	1.1
Iron	38.1	----	130	46.5	8.3	8.8	22.8	6.6
Lead	<0.03	----	0.19	0.04	<0.03	<0.03	<0.015	0.020
Manganese	154	----	26.2	18.1	8.32	29.7	34.6	73.6
Mercury	<0.010	----	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Molybdenum	2.63	----	0.748	1.24	2.40	2.50	1.47	1.87
Nickel	5.01	----	1.21	3.23	1.53	1.74	0.93	1.58
Selenium	5.51	----	0.52	0.71	1.38	1.02	0.76	1.39
Silver	<0.01	----	<0.01	<0.01	<0.01	<0.01	<0.005	0.009
Total coliforms	580	110	1400	1200	>2400 ^c	290	360	290
<i>E. coli</i>	45	<1 ^d	210	99	59	58	4	1

^a All analytes are dissolved, except for acid neutralizing capacity, total coliforms and *E. coli*.

^b Results that were lower than the National Water Quality Laboratory reporting levels are noted as "<[reporting level]". However, reporting levels changed to match the long-term method detection level starting October 1, 2010, therefore some samples have two different reporting levels displayed.

^c This result exceeded the maximum detection level of 2400 MPN/100 mL.

^d This result was less than the minimum detection level of 1 MPN/100 mL.

Table B-2. NPS water quality core parameter 2010 data from MEVEMAN01

Core parameter	Unit	Sample collection date and time							
		1/29/10	3/15/10	4/18/10	6/3/10	7/18/10	9/10/10	11/5/10	12/8/10
		13:00	13:55	13:10	11:35	21:15	18:18	15:00	12:15
Water temperature	°C	0.4	6.1	7.3	13.2	25.2	20.2	9.7	0.5
pH	none	8.1	8.6	7.9	8.6	8.3	8.4	8.3	8.3
Specific conductivity	µS/cm	2020	2210	345	625	1220	1230	862	1270
Dissolved oxygen	mg/L	11.1	10.6	9.4	8.4	7.3	7.2	9.1	11.4
Turbidity	NTU	14 ^a	71	120	7.4	8.9	9.8	7.2	15
Discharge	cfs	15	37	---- ^b	57	4.6	12	21	16

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

^b On this date, flow was too high to be measured safely.

Appendix C: Abbreviations and terms

Term	Definition
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 probably number, for sampling bacteria, a statistical estimation of the number of coliform that would give the results shown by the laboratory examination
N	chemical symbol for the element nitrogen
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for the element phosphorous