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Status and Trends in Water Quality at Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014

Natural Resource Report NPS/NCPN/NRR—2019/1858



ON THE COVER

Ice recedes on Blue Mesa Reservoir as summer approaches, Curecanti National Recreation Area. NPS/Paul Santellan.

Status and Trends in Water Quality at Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014

Natural Resource Report NPS/NCPN/NRR—2019/1858

Prepared by
Rebecca Weissinger
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

Nicole Gibney
Curecanti National Recreation Area
102 Elk Creek
Gunnison, CO 81230

Editing and Design
Alice Wondrak Biel
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

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Glossary

Akaike Information Criterion (AIC) – A method of comparing two or more statistical models to determine which model better fits the data relative to the other models.

Censored data – Data for which a cut-off, rather than a true value, is known, such as for samples with concentrations below an analytical reporting limit (e.g., <0.02 mg/L).

Flow-adjusted concentration (FAC) – The residuals from modelling the relationship of concentration and flow, used as a method of removing the influence of flow when looking for trends in water quality.

Generalized additive model (GAM) – A non-parametric method for estimating smooth relationships between variables that can be linear or nonlinear.

Kjeldahl nitrogen – A combined concentration of organic nitrogen, ammonia, and ammonium. When combined with nitrite and nitrate concentrations, Kjeldahl nitrogen can be used to calculate total nitrogen.

Monotonic trend – A trend that always goes in one direction, for example, always increasing or always decreasing.

Non-parametric – Mathematical procedures for statistical hypothesis testing which, unlike parametric statistics, make no assumptions about the probability distributions of the variables being assessed.

p-value – Statistical probability that the observed data would occur if there were no trend over time. Setting this value to a low number, such as $p = 0.05$, reduces the chance of falsely reporting a trend that does not exist.

Relative Percent Difference (RPD) – A method for comparing two samples taken from the same water at the same time. A low RPD indicates low variability between samples and corresponding confidence in sample handling, analytical calibrations, and other processes that can introduce variability in samples. A high RPD indicates unexpected variability.

Seasonal Kendall test – A non-parametric test that analyzes seasonal data for monotonic trends.

Secchi disk – A black-and-white disk used to measure the transparency of water by measuring the depth at which it is no longer visible.

Sen slope – Also known as a Theil–Sen slope, it is a non-parametric alternative to the parametric ordinary least squares regression line.

Serial correlation – The relationship between a given variable and itself over time, such that one measurement of the variable is highly related to the adjacent measurement.

Executive Summary

From 2001 to 2014, the National Park Service supported monthly water-quality sampling in May–October at 23 fixed water-quality sites in Curecanti National Recreation Area (CURE) and Black Canyon of the Gunnison National Park (BLCA) (Figure i). Sites included streams and reservoirs protected within or upstream of the parks. This report analyzes the data to look for trends over time (Figure i, Tables i–iv) prior to re-evaluating the parks' water-quality monitoring program. Concentrations are also compared to water-quality standards for aquatic life and recreation established by the State of Colorado.

Key findings

- Trends in concentrations mostly indicated improving water quality, including decreases in nutrients, chloride, and metals at several sites.
- Improvements in water quality in Red Rock Canyon included decreases in total phosphorus, nitrite plus nitrate, and copper concentrations (see Tables iii, iv). These changes may be linked to a change in irrigation practices from 2006 to 2008, from flood irrigation to a sprinkler system that reduced overland flow. However, these improvements were not sufficient to bring water quality in Red Rock Canyon within state standards. The interim value for total phosphorus and the standard for fecal indicator bacteria (*Escherichia coli*) were still regularly exceeded at the upstream site in Red Rock Canyon. Selenium concentrations still exceeded the state aquatic-life standard at both the upstream and downstream sites on almost all visits. Continued management action is needed to bring irrigation return flows in Red Rock Canyon into compliance with state water-quality standards. A state plan for reducing selenium loading, the recent purchase of private land inholdings upstream of the canyon by the National Park Service, and a phase-out of livestock grazing upstream of the canyon may assist in bringing these waters into compliance.
- In Pine Creek, water-quality changes were a mixture of improving and degrading trends. Decreases in flow-adjusted concentrations of several ions and specific conductance may be linked to better targeting of dust suppressants on roads over time, with less spillover of suppressants into the creek. Increases in nitrite plus nitrate and selenium (see Tables iii, iv) were concerning but still at low concentrations. Residential septic systems or park pit toilets could contribute to increases in nitrite plus nitrate concentrations and could be checked for leaks to rule out these point sources.
- Total phosphorus regularly exceeded the state's interim water-quality standard at many tributary sites (see Figure i). While human activities that increase erosion, such as livestock grazing, roads, and agricultural activity, can contribute phosphorus to water bodies, volcanic rock common in the region can also be high in phosphorus. High phosphorus concentrations in tributaries have not caused algal blooms or other indicators of eutrophication at CURE or BLCA. Historically, Rocky Mountain streams have been more sensitive to increases in nitrogen species than to phosphorus concentrations.
- Evidence of eutrophication has been noted in Blue Mesa Reservoir in low water years, even when phosphorus concentrations have remained acceptable. Several localized fish kills were observed in the middle of the reservoir in 2013, and the most upstream site in the reservoir occasionally exceeded the interim chlorophyll-*a* standard for cold-water reservoirs. Park monitoring has been updated to include sampling dissolved oxygen and water temperature at multiple depths for better comparison with state water-quality standards. NPS personnel are also coordinating with the state to increase nutrient sampling in the reservoir. Investigations into sources of nutrients in watersheds in this area, particularly nitrogen species, may help land managers to develop a plan for improving water quality in Blue Mesa Reservoir.

- Continued exceedances of fecal coliforms in Blue Creek and the Cimarron River support the need for management action to improve public health and safety in these streams.

Key for the following tables:

- Arrows indicate trend analysis of raw concentrations:
  - no arrow = insufficient data for analysis
  - ⇔ =no trend
  - ⇧ =increasing trend
  - ⇩ = decreasing trend
  - CENS = data >50% censored
- Arrow color indicates comparisons to State of Colorado aquatic-life and recreation water-quality standards or interim values:
  - black (e.g., ↔) = no standard
  - green (e.g., ↔) = <10% exceedances
  - yellow (e.g., ↔) = 10–14% exceedances
  - red (e.g., ↔) = 15% or more exceedances.

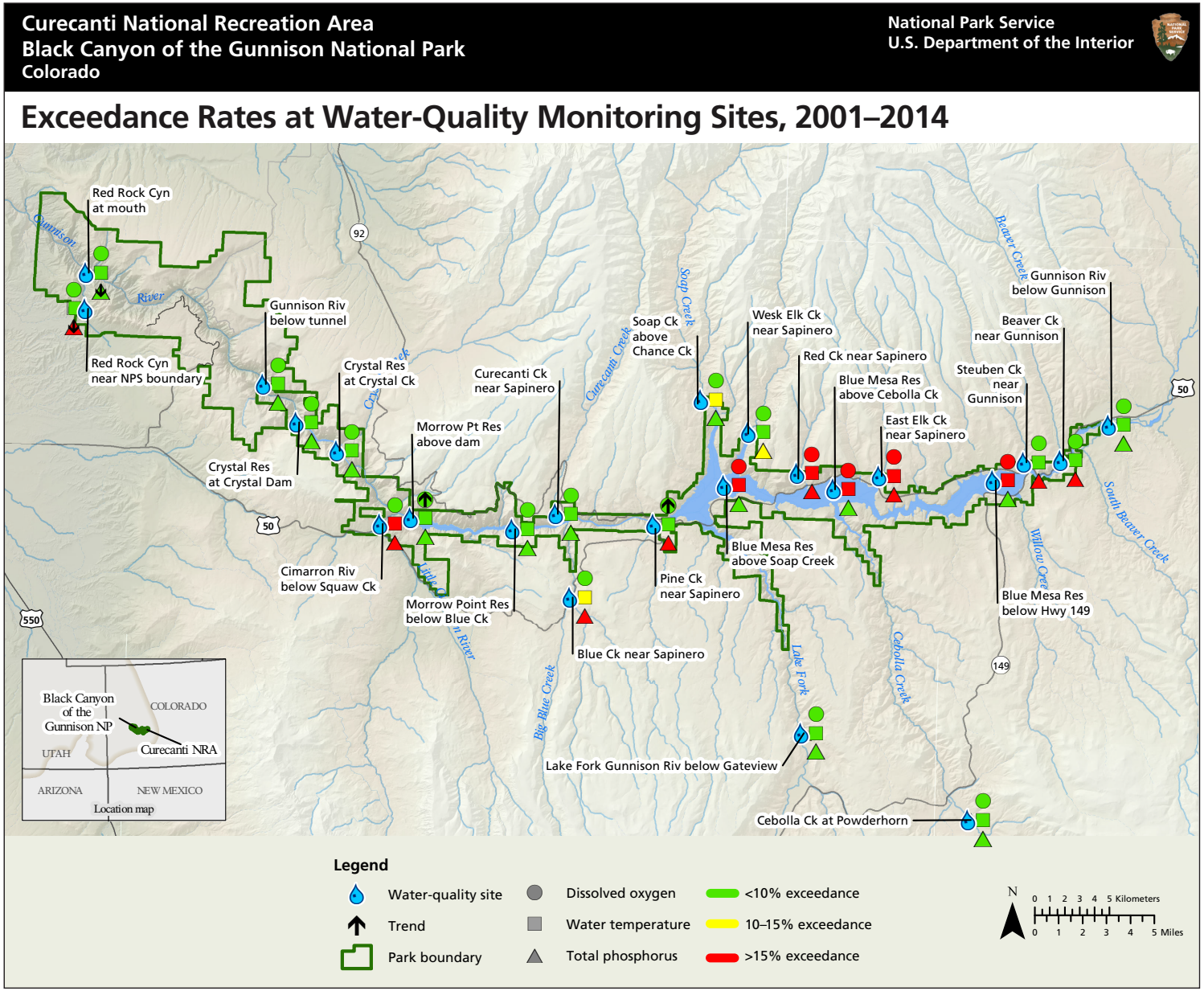


Figure i. Trends in total phosphorus, water temperature, and dissolved oxygen, and comparisons to state aquatic life water-quality standards at water-quality sites in Curecanti National Recreation Area and Black Canyon of the Gunnison National Park. Upwards arrow indicates an increasing trend, downwards arrow a decreasing trend, and no arrow indicates no trend. Total phosphorus is an interim value. Water-temperature and dissolved-oxygen comparisons are made using discrete data rather than the continuous or lake-profile data required by current standards.

Table i. Trends in core water-quality parameters, Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014.†

Site	Chlorophyll-a††	DO[2]	*E. coli*	Flow	pH	Secchi disk depth (m)	Specific conductance	Temperature†††
Gunnison River at Cty Rd 32 below Gunnison, CO	–	↔	↔	↔	↔	–	↔	↔
Beaver Creek at Highway 50 near Gunnison, CO	–	↔	↔	↔	↔	–	↔	↔
Steuben Creek near mouth near Gunnison, CO	–	↔	↔	↔	↓	–	↔	↔
East Elk Creek near mouth near Sapinero, CO	–	↔	↔	↔	↑	–	↔	↔
Red Creek near mouth near Sapinero, CO	–	↔	↔	↔	↔	–	↔	↔
West Elk Creek below forest boundary near Sapinero, CO	–	↔	↔	↔	↓	–	↔	↔
Soap Creek above Chance Creek near Sapinero, CO	–	↔	↔	↔	↔	–	↔	↔
Cebolla Creek at Powderhorn, CO	–	↔	↔	↔	↔	–	↔	↔
Lake Fork Gunnison River below Gateview, CO	–	↔	↔	↔	↔	–	↔	↔
Blue Mesa Reservoir below Highway 149 near Gunnison, CO	↔	↔	↔	–	↔	↔	↔	↔
Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	↔	↔	CENS	–	↔	↔	↔	↔
Blue Mesa Reservoir above Soap Creek near Sapinero, CO	↔	↔	CENS	–	↔	↔	↔	↔
Pine Creek at Highway 50 near Sapinero, CO	–	↑	↔	↔	↔	–	↔	↔
Curecanti Creek near Sapinero, CO	–	↔	↔	↔	↔	–	↔	↔
Blue Creek at Highway 50 near Sapinero, CO	–	↔	↔	↔	↔	–	↔	↔
Morrow Point Reservoir below Blue Creek near Sapinero, CO	–	↔	↔	–	↔	↔	↔	↔
Morrow Point Reservoir above Morrow Point Dam near Cimarron, CO	–	↑	CENS	–	↔	↔	↔	↔
Cimarron River below Squaw Creek, near Cimarron, CO	–	↔	↔	↔	↔	–	↓	↔
Crystal Reservoir at Crystal Creek near Cimarron, CO	–	↔	↔	–	↔	–	↔	↔
Crystal Reservoir at Crystal Dam near Cimarron, CO	–	↔	↔	–	↔	–	↔	↔
Gunnison River below Gunnison Tunnel, CO	–	↔	↔	↔	↔	–	↓	↔
Red Rock Canyon near NPS boundary near Montrose, CO	–	↔	↔	↔	↔	–	↔	↔
Red Rock Canyon at mouth near Montrose, CO	–	↔	↔	↓	↔	–	↔	↔

† See page xvi for key to symbols.

†† Interim value.

††† Using discrete measurements. Current state water-quality standards require the use of continuous monitoring in streams and depth profiles in reservoirs.

Table ii. Trends in major ions, Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014.[†]

Site	Calcium	Chloride	Magnesium
Gunnison River at Cnty Rd 32 below Gunnison, CO	↔	–	↔
Beaver Creek at Highway 50 near Gunnison, CO	↔	↔	↔
Steuben Creek near mouth near Gunnison, CO	↔	↓	↔
East Elk Creek near mouth near Sapinero, CO	↔	↔	↔
Red Creek near mouth near Sapinero, CO	↔	↓	↔
West Elk Creek below forest boundary near Sapinero, CO	↔	–	↔
Soap Creek above Chance Creek near Sapinero, CO	↔	↔	↔
Cebolla Creek at Powderhorn, CO	↔	–	↔
Lake Fork Gunnison River below Gateview, CO	↔	↔	↔
Blue Mesa Reservoir below Highway 149 near Gunnison, CO	↔	–	↔
Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	↔	–	↔
Blue Mesa Reservoir above Soap Creek near Sapinero, CO	↔	–	↔
Pine Creek at Highway 50 near Sapinero, CO	↔	↔	↔
Curecanti Creek near Sapinero, CO	↔	–	↔
Blue Creek at Highway 50 near Sapinero, CO	↔	↔	↔
Morrow Point Reservoir below Blue Creek near Sapinero, CO	↔	–	↔
Morrow Point Reservoir above Morrow Point Dam near Cimarron, CO	↔	–	↔
Cimarron River below Squaw Creek, near Cimarron, CO	↔	↔	↔
Crystal Reservoir at Crystal Creek near Cimarron, CO	↔	–	↔
Crystal Reservoir at Crystal Dam near Cimarron, CO	↔	–	↔
Gunnison River below Gunnison Tunnel, CO	↔	–	↔
Red Rock Canyon near NPS boundary near Montrose, CO	↔	–	↔
Red Rock Canyon at mouth near Montrose, CO	↔	–	↔

[†] See page xvi for key to symbols.

Table iii. Trends in nutrients, Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014.†

Site	Ammonia	Ammonia, un-ionized	Kjeldahl Nitrogen	Nitrate	Nitrite	Nitrite + Nitrate	Orthophosphate (d)	Phosphorus ††
Gunnison River at Cnty Rd 32 below Gunnison, CO	CENS	–	↔	–	CENS	↔	↔	↔
Beaver Creek at Highway 50 near Gunnison, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Steuben Creek near mouth near Gunnison, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
East Elk Creek near mouth near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Red Creek near mouth near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
West Elk Creek below forest boundary near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Soap Creek above Chance Creek near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Cebolla Creek at Powderhorn, CO	CENS	–	↔	–	CENS	CENS	↔	↔
Lake Fork Gunnison River below Gateview, CO	CENS	CENS	CENS	CENS	CENS	CENS	CENS	↔
Blue Mesa Reservoir below Highway 149 near Gunnison, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Blue Mesa Reservoir above Soap Creek near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Pine Creek at Highway 50 near Sapinero, CO	CENS	CENS	↔	CENS	CENS	↑	↔	↔
Curecanti Creek near Sapinero, CO	CENS	–	–	–	CENS	CENS	–	↔
Blue Creek at Highway 50 near Sapinero, CO	CENS	CENS	↔	CENS	CENS	CENS	↔	↔
Morrow Point Reservoir below Blue Creek near Sapinero, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Morrow Point Reservoir above Morrow Point Dam near Cimarron, CO	CENS	CENS	–	CENS	CENS	CENS	–	↔
Cimarron River below Squaw Creek, near Cimarron, CO	CENS	CENS	↔	CENS	CENS	↔	↔	↔
Crystal Reservoir at Crystal Creek near Cimarron, CO	CENS	–	–	–	CENS	CENS	–	↔
Crystal Reservoir at Crystal Dam near Cimarron, CO	CENS	–	–	–	CENS	CENS	–	↔
Gunnison River below Gunnison Tunnel, CO	CENS	–	↔	CENS	CENS	↔	↔	↔
Red Rock Canyon near NPS boundary near Montrose, CO	CENS	CENS	–	↔	↔	↓	–	↓
Red Rock Canyon at mouth near Montrose, CO	CENS	–	–	–	CENS	↔	–	↓

† See page xvi for key to symbols. †† Interim value.

Table iv. Trends in trace elements, Curecanti National Recreation Area and Black Canyon of the Gunnison National Park, 2001–2014.†

Site	Cadmium	Copper	Lead	Manganese	Selenium	Silver	Zinc
Gunnison River at Cnty Rd 32 below Gunnison, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Beaver Creek at Highway 50 near Gunnison, CO	CENS	CENS	CENS	↔	CENS	CENS	CENS
Steuben Creek near mouth near Gunnison, CO	CENS	CENS	CENS	↔	CENS	CENS	CENS
East Elk Creek near mouth near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Red Creek near mouth near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
West Elk Creek below forest boundary near Sapinero, CO	CENS	CENS	CENS	↔	CENS	CENS	CENS
Soap Creek above Chance Creek near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Cebolla Creek at Powderhorn, CO	CENS	CENS	CENS	↔	–	CENS	CENS
Lake Fork Gunnison River below Gateview, CO	↔	↔	↔	↔	↔	CENS	↔
Blue Mesa Reservoir below Highway 149 near Gunnison, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Blue Mesa Reservoir above Soap Creek near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Pine Creek at Highway 50 near Sapinero, CO	CENS	CENS	CENS	↔	↑	CENS	CENS
Curecanti Creek near Sapinero, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Blue Creek at Highway 50 near Sapinero, CO	CENS	CENS	CENS	↓	↔	CENS	CENS
Morrow Point Reservoir below Blue Creek near Sapinero, CO	CENS	CENS	CENS	↑	↔	CENS	CENS
Morrow Point Reservoir above Morrow Point Dam near Cimarron, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Cimarron River below Squaw Creek, near Cimarron, CO	CENS	↓	CENS	↔	↓	CENS	CENS
Crystal Reservoir at Crystal Creek near Cimarron, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Crystal Reservoir at Crystal Dam near Cimarron, CO	CENS	CENS	CENS	↔	↓	CENS	CENS
Gunnison River below Gunnison Tunnel, CO	CENS	CENS	CENS	↔	↔	CENS	CENS
Red Rock Canyon near NPS boundary near Montrose, CO	CENS	↓	CENS	↔	↔	CENS	CENS
Red Rock Canyon at mouth near Montrose, CO	CENS	↓	CENS	↔	↔	CENS	CENS

† See page xvi for key to symbols.

Acknowledgements

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1 Introduction

The overall mission of the National Park Service (NPS) is to conserve the natural and cultural resources of the National Park System for the enjoyment of this and future generations. Together, Curecanti National Recreation Area (CURE) and Black Canyon of the Gunnison National Park (BLCA) protect almost 300 square kilometers (116 mi^2) surrounding the Gunnison River in western Colorado, including 40 kilometers (25 mi) of the Gunnison River and the three reservoirs of the Aspinall unit of the Colorado River Storage Project. Water resources make up about 25% of CURE's area, including reservoirs, rivers, streams, and springs (Cudlip et al. 1996). Sport fishing and other water-based recreation drew over 800,000 visitors to CURE in 2013 and a portion of the over 175,000 visitors to BLCA.

Maintaining unimpaired water quality is a high priority for park managers at CURE and BLCA. NPS staff began collecting regular water-quality data in the early 1980s and established a rigorous long-term monitoring program in 2000 (Malick and Cudlip 1999). Excellent water quality documented in many tributaries led the State of Colorado to designate four streams in CURE as Outstanding National Resource Waters in 2012: Beaver Creek, East Elk Creek, Red Creek, and West Elk Creek (CDPHE 2012). Evaluations of water-quality data have also documented exceedances of state water-quality standards at some sites in the parks (Thoma et al. 2008; Van Grinsven et al. 2010; Hackbarth and Weissinger 2013; Hackbarth and Weissinger 2016). In 2006, the parks began cooperating with the Northern Colorado Plateau Network (NCPN), a regional NPS program, to evaluate and analyze data within a standard framework for 12 national parks on the northern Colorado Plateau.

CURE and BLCA are situated in a mosaic of public and private lands with a history of multiple land uses. Potential land uses that may affect water quality include agricultural practices, conversion of wildlands to developed properties, increased population, livestock grazing, increased visitor use, hydrologic diversions and dams, and historical mining (Evenden et al. 2002). Wildfire can also affect water quality, and dual threats of climate warming and previous fire suppression have tended to increase the size and severity of wildfires that now occur (Westerling et al. 2006).

Water-quality data are important not only for pinpointing problem areas, but also for showing long-term changes in watersheds and streams. Analysis of water-quality trends can indicate whether conditions are improving or degrading in the streams and reservoirs of CURE and BLCA, providing valuable information to park managers for use in management decisions. Long-term datasets can also document variability in the aquatic system.

The purpose of the NCPN water-quality monitoring program can be framed in a series of general questions that can be answered quantitatively via measurable objectives:

1. What are the ranges in water-quality parameters for selected streams of NCPN parks?
2. What are the current status and long-term trends in selected water-quality parameters at surface-water sites monitored in NCPN parks?
3. How does surface-water quality in NCPN parks compare to State of Colorado standards for designated beneficial uses?

1.1 Purpose and scope

The purpose of this report is to evaluate water-quality data collected at long-term monitoring sites in CURE and BLCA from 2001 to 2014 for temporal trends in constituent concentrations, and to compare concentrations to designated beneficial uses and water-quality standards for the State of Colorado. This period was selected to provide an assessment of data since the beginning of the monitoring program and for a re-evaluation of monitoring priorities for CURE and BLCA. The 14-year period of record analyzed in this study is recognized as a relatively short period for trend analysis, as inter-annual variability in streams can have an influence on water-quality trends that is larger than the influence of anthropogenic change. It is, however, use-

ful as a status check of the program and as a means of highlighting the most significant problem areas for park managers.

Twenty-three sites were evaluated for as many as 23 constituents. Constituents included core parameters, such as flow, water temperature, dissolved oxygen, pH, and specific conductance, as well as laboratory analyses, including fecal indicator bacteria (*Escherichia coli*), major ions, trace elements, and nutrients (Table 1-1). All data are publicly available in the Environmental Protection Agency's Water Quality Portal under organization 11NPSWRD_WQX (WQP; https://www.waterqualitydata.us/portal/).

1.2 Study area description

Adapted from O'Dell and others (2005), Appendix A

Curecanti National Recreation Area protects 17,433 hectares (43,078 acres) and is composed of a chain of three reservoirs impounded by hydropower-producing dams on the Gunnison River. The reservoirs comprise the Wayne N. Aspinall Unit of the Colorado River Storage Project, operated by the U.S. Bureau of Reclamation. Elevations range from 1,981 meters (6,500 ft) at East Portal to 2,896 meters (9,500 ft) near Sheep Knob.

The Upper Gunnison River watershed, upstream of CURE's western boundary, drains approximately 10,270 square kilometers (3,965 mi^2). Approximately 18 kilometers (11 mi) of the Gunnison River and 85 kilometers (53 mi) of tributary streams are located within the recreation area boundary. The easternmost portion of CURE is composed of a riverine system. The Gunnison River then flows into Blue Mesa Reservoir, providing a substantial portion of the inflow to the system. Blue Mesa Reservoir, one of three reservoirs and the largest body of water entirely within Colorado, is situated in the Gunnison River Valley, a relatively broad alluvial valley bordered by steep bluffs and high mesas. Many high-mountain streams form tributaries that enter Curecanti's reservoirs downstream, contributing additional flows. Morrow Point and Crystal reservoirs, both narrow, fjord-like lakes, are situated downstream, in the steep-sided Black Canyon of the Gunnison River. Water-quality sites in or near CURE include one site on the Gunnison River upstream of the reservoirs, three sites on Blue Mesa Reservoir, eight sites on tributaries to Blue Mesa Reservoir, two sites on Morrow Point Reservoir, three sites on tributaries to Morrow Point Reservoir, two sites on Crystal Reservoir, and one site on a tributary to Crystal Reservoir (Figure 1-1, Table 1-2).

The boundary between CURE and BLCA is located just downstream of the outfall of Crystal Dam and the Gunnison Tunnel diversion. BLCA protects 12,159 hectares (30,045 ac), about half of which is designated wilderness. Elevations vary from 1,645 meters (5,400 ft) at canyon bottom to 2,675 meters (8,775 ft) on Signal Hill. Canyon walls rise precipitously 610 meters (2,000 ft) or more above the Gunnison River, which roars in the canyon depths at an average gradient of 29 meters (95 ft) per mile in the park. The river runs for 22.5 kilometers (14 mi) before exiting the park.

The upstream water impoundments have dramatically altered the hydrologic regime and aquatic ecology of the canyon. Native fish species compete with non-native rainbow and brown trout. The present excellent

Table 1-1. Water-quality parameters evaluated by the Northern Colorado Plateau Network's water-quality monitoring program.

Sample type	Parameters
Core parameters	Chlorophyll-*a*, dissolved oxygen, *Escherichia coli,* flow, pH, Secchi disk depth, specific conductance, water temperature
Major ions	Calcium, chloride, magnesium
Nutrients	Ammonia, un-ionized ammonia, Kjeldahl nitrogen, nitrate, nitrite, nitrite plus nitrate, dissolved orthophosphate, total phosphorus
Trace elements	Cadmium, copper, lead, manganese, selenium, silver, zinc

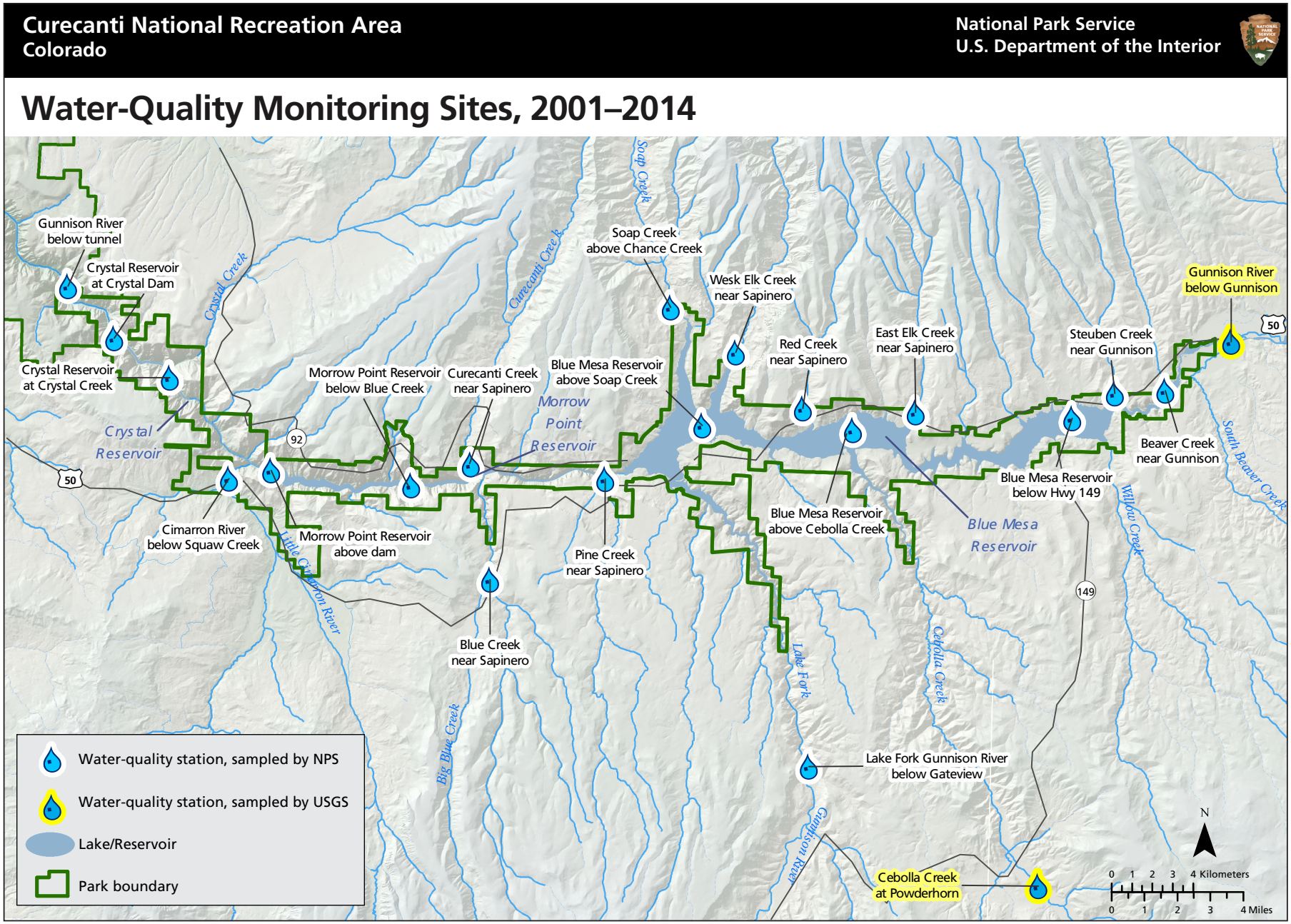


Figure 1-1. Overview of Curecanti National Recreation Area and water-quality sites included in this report. Upstream to downstream flow is from east to west.

Table 1-2. Long-term water-quality monitoring sites in Curecanti National Recreation Area.

Location	Site ID	Site name	Latitude	Longitude
Northern tributaries to Blue Mesa Reservoir, upstream to downstream	CURE_383103106594200	Gunnison River at County Road 32 below Gunnison, CO	38.517491°	106.995601°
	CURE_382943107015300	Beaver Creek at Hwy 50 near Gunnison, CO	38.495269°	107.031991°
	CURE_382937107033500	Steuben Creek near mouth near Gunnison, CO	38.493602°	107.060326°
	CURE_382900107101600	East Elk Creek near mouth near Sapinero, CO	38.483326°	107.171719°
	CURE_382902107140400	Red Creek near mouth near Sapinero, CO	38.483882°	107.235054°
	CURE_383028107162200	West Elk Creek below forest boundary near Sapinero, CO	38.50777°	107.273388°
	CURE_383137107183600	Soap Creek above Chance Creek near Sapinero, CO	38.526936°	107.310611°
Southern tributaries to Blue Mesa Reservoir, upstream to downstream	CURE_381633107054700	Cebolla Creek at Powderhorn, CO	38.275828°	107.096995°
	CURE_381934107133500	Lake Fork Gunnison River below Gateview, CO	38.326105°	107.227°
Blue Mesa Reservoir, upstream to downstream	CURE_382856107050000	Blue Mesa Reservoir below Hwy 149 near Gunnison, CO	38.482214°	107.083938°
	CURE_382829107122200	Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	38.474715°	107.20672°
	CURE_382831107172600	Blue Mesa Reservoir above Soap Creek near Sapinero, CO	38.47527°	107.291166°
Tributaries to Morrow Point Reservoir, upstream to downstream	CURE_382702107203900	Pine Creek at Hwy 50 near Sapinero, CO	38.450547°	107.344779°
	CURE_09125000	Curecanti Creek near Sapinero, CO	38.455234°	107.420221°
	CURE_382418107242600	Blue Creek at Hwy 50 near Sapinero, CO	38.404991°	107.407835°
Morrow Point Reservoir, upstream to downstream	CURE_382644107271000	Morrow Point Reservoir below Blue Creek near Sapinero, CO	38.445545°	107.453391°
	CURE_382702107315400	Morrow Point Reservoir above Morrow Point Dam near Cimarron, CO	38.450544°	107.532281°
Tributary to Crystal Reservoir	CURE_09127000	Cimarron River below Squaw Creek, near Cimarron, CO	38.446377°	107.555614°
Crystal Reservoir, upstream to downstream	CURE_382924107352300	Crystal Reservoir at Crystal Creek near Cimarron, CO	38.489987°	107.590336°
	CURE_383024107371800	Crystal Reservoir at Crystal Dam near Cimarron, CO	38.506654°	107.62228°

conditions for brown and rainbow trout have led to the Colorado "Gold Medal Waters" fishery designation for the Gunnison River through the park and lower gorge. Water-quality sites within BLCA include one site on the Gunnison River and two sites in Red Rock Canyon, a tributary canyon that is not a natural stream but rather contains an irrigation return flow ditch (Table 1-3, Figure 1-2).

The Bureau of Reclamation (BOR) manages the three dams in CURE to maximize water storage, hydropower production, and downstream irrigation. BLCA was granted a water right for the "preservation of the spectacular gorges and additional features of scenic, scientific and educational purposes." The water right maintains peak and shoulder flows to maintain sediment transport and prevent the permanent establishment of channel-stabilizing vegetation. This water-right amount is determined annually based on the forecasted inflow to the most upstream of the three reservoirs, Blue Mesa. While the water right is for high peak flows, current peak flows are capped to prevent flooding in downstream communities.

In addition to the water right, the Upper Colorado River Endangered Fish Recovery Program (of which the NPS is a standing member) worked with the Bureau of Reclamation (BOR) to sign a Record of Decision (ROD) in 2012. This ROD utilizes the Aspinall Unit operations to avoid jeopardy to endangered species while maintaining and continuing to meet its Congressionally authorized purposes. The intent of the proposed action is to assist in species recovery. There is no legally binding water right for this water, but an assurance from the BOR that they will minimize any adverse effects of reservoir operations on native fish habitat.

1.3 Climate

The climate at BLCA and CURE varies based on elevation and topography, but conditions are generally cool and wet (Table 1-4). For the years analyzed in this report, maximum and minimum temperatures and precipitation fluctuated above and below the 30-year average (1971–2000; Figure 1-3).

Table 1-3. Long-term water-quality monitoring sites in Black Canyon of the Gunnison National Park, upstream to downstream.

Site ID	Site name	Latitude	Longitude
BLCA_09128000	Gunnison River below Gunnison Tunnel, CO	38.529153°	107.648947°
BLCA_383418107471401	Red Rock Canyon near NPS boundary near Montrose, CO	38.571652°	107.787837°
BLCA_383537107471500	Red Rock Canyon at mouth near Montrose, CO	38.593597°	107.788115°

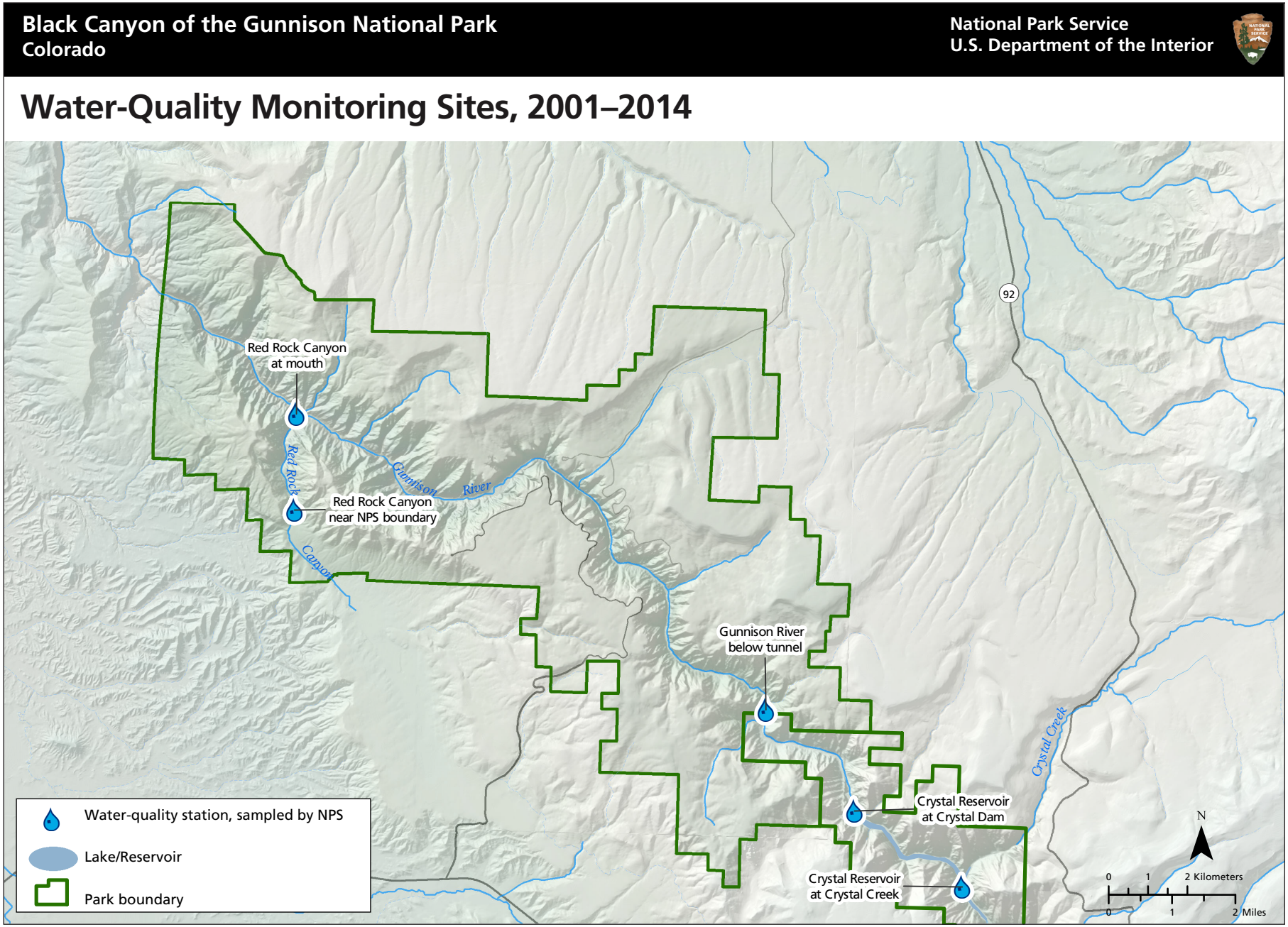


Figure 1-2. Overview of Black Canyon of the Gunnison National Park and water-quality sites included in this report. Upstream to downstream flow is from southeast to northwest.

Table 1-4. Average climate data for three weather stations in or near Curecanti National Recreation Area and Black Canyon of the Gunnison National Park for their periods of record.[†]

Location (COOP Station ID)	Period of record	Elevation	Average annual maximum temperature	Average annual minimum temperature	Average annual precipitation	Average annual snowfall
Gunnison 3 SW, CO (053662)	1893–2016	2,323 m (7,620 ft)	13.0°C (55.4°F)	-6.9°C (19.6°F)	26.2 cm (10.3 in)	126.0 cm (49.6 in)
Cimarron, CO (051609)	1951–2016	2,137 m (7,010 ft)	15.4°C (59.8°F)	-4.8°C (23.3°F)	33.8 cm (13.3 in)	161.8 cm (63.7 in)
Black Canyon Gunnison, CO (050754)	2003–2016	2,484 m (8,150 ft)	14.7°C (58.4°F)	-1.9°C (28.5°F)	56.6 cm (22.3 in)	305.3 cm (120.2 in)

[†] Data accessed from the Western Regional Climate Center, 8/7/2017.

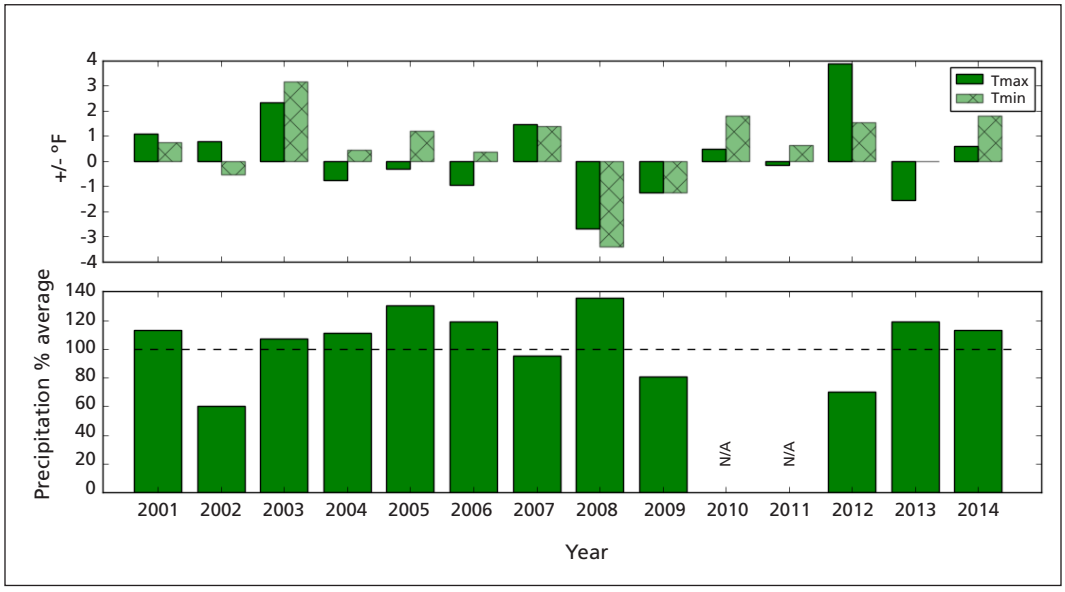


Figure 1-3. Departures in temperature and precipitation from 2001 to 2014 in comparison to the 30-year average (1971–2000) at the Gunnison 3 SW COOP station near Gunnison, Colorado, at the upstream end of Curecanti National Recreation Area. Figure accessed 8/7/2017 at www.climateanalyzer.org.

2 Methods

2.1 Field data collection

Monthly visits to each site occurred from May to October in order to capture a wide range of flow conditions and land-use activities during high-use periods for recreation and agriculture. Additional samples were sometimes taken in other months, depending on logistical and budget constraints of the program.

Field data collection methods follow standards outlined in the U.S. Geological Survey (USGS)'s National Field Manual (USGS, variously dated). Two of the sites, Gunnison River at County Road 32 and Cebolla Creek, were monitored by the USGS. The remaining sites were sampled by NPS personnel. Manual streamflow measurements were made at the time of sampling using an AquaCalc 500 pygmy meter or a Sontek Flowtracker handheld acoustic doppler velocimeter. Beginning in 2011, a Sontek RiverSurveyor M9 was used to collect streamflow measurements when streams were deemed unwadeable due to high flows. At sites for the Gunnison River at County Road 32, Cimarron River, the Lake Fork of the Gunnison, and the Gunnison River below Gunnison Tunnel, discharge data from USGS gage data were used.

During each sampling event, water temperature, pH, specific conductance, and dissolved oxygen were measured in the field using a calibrated Hydrolab MS4a from 2001 to 2009 and a Hydrolab MS5 from 2010 to 2014. The dissolved-oxygen probe was changed from a membrane probe to a luminescent probe starting in 2013. Streamwater samples were collected following the USGS equal width increment (EWI) method, using isokinetic samplers when velocities were above 1.5 feet per second (ft/s). When velocities were below 1.5 ft/s, the EWI method was applied using a non-isokinetic dip sampler. Reservoir water samples were collected using a Van-Dorn water sampler lowered to a depth of 1 meter. The raw sample was brought back to the lab for processing, where the sample was split and filtered. All sample aliquots, except for total (unfiltered) nutrients, were filtered using a 0.45-micron capsule filter. Sample aliquots for metals analysis were preserved with nitric acid. Sample aliquots for total nutrients were preserved with sulfuric acid. A separate grab sample was collected from a well-mixed portion of the channel or just below the reservoir surface and put on ice for *Escherichia coli* analysis back in the lab.

2.2 Analytic methods and quality assurance

Processed water samples were sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for analysis of major ions, nutrients, and trace elements using USGS-approved analytical methods. *Escherichia coli* was analyzed in the park lab using a membrane filtration procedure onto modified mTec agar gel plates (Thoma et al. 2008).

Once each month, alternating field-blank and duplicate samples were collected. In the field blanks, constituents were either not detected in or were below concentrations that would affect the data interpretation. The relative percent difference between replicates was less than 30 percent (or less than analytical uncertainty) for all samples. Individual results exceeding the 95th percentile for each dataset were inspected. Laboratory re-analysis was requested when appropriate. Quality-assurance results did not indicate the need to eliminate any analytical data.

2.3 Trend analysis

Concentration data were evaluated for monotonic trends using a seasonal Kendall test adjusted for serial correlation (see Glossary for definitions of statistical terms). Data summary and analysis were completed using the freeware, R v.3.3.3 (R Core Team 2017). Seasonal Kendall tests and Sen-slope estimates were calculated using the EnvStats package for R (Millard 2013). Practices followed those outlined in the standard USGS approach to the seasonal Kendall analysis as described in Schertz et al. 1991.

The seasonal Kendall is a non-parametric test, meaning it scores concentrations as higher or lower than a seasonal median value, but it does not evaluate the magnitude of the departure from the median. For this

reason, the seasonal Kendall test is robust for evaluating water-quality datasets, which often contain extreme concentrations and censored values.

The seasonal Kendall test accounts for expected seasonal variation in water-quality parameters by comparing concentrations within user-defined seasons (e.g., monthly, quarterly, semi-annual) (Hirsch and Helsel 2002). For example, if the season is set to monthly, then samples collected during May are always compared to other samples from May, while August samples are always compared to August samples. The trends for each defined season are then combined to determine if there is an overall trend for that constituent. Seasons with opposite trends are cancelled out in this analysis and would result in an overall evaluation of no trend. A consistent trend across seasons would result in an overall upward or downward trend.

Data were summarized and evaluated to determine the number of samples available for each parameter and site combination (e.g., dissolved oxygen at Blue Creek). Sampling frequency varied greatly from 2001 to 2014, with at least some samples collected in every month of the year for the period of record. The months of May–October were sampled reliably. This period captures spring snowmelt and base flow conditions. Because of the spotty nature of the data, the months of November–April were excluded from the analysis. Trend analyses only apply to the May–October season, which corresponds to the recreation season and the season of greatest biological activity. Our data do not provide information about winter conditions.

Site and parameter combinations with fewer than five years or 20 observations during May–October were excluded from analysis due to the limited ability to detect trends in very short or small datasets (Schertz et al. 1991). If more than one sample was available per month, then the sample that had a concurrent flow measurement was preferentially retained. If multiple samples had flow measurements, then the first sample of the month was used. Datasets longer than 10 years were corrected for the possibility of serial correlation. Trends were evaluated at p=0.05 for statistical significance: that is, at a level that indicates it is very likely a trend exists in the data.

2.3.1 Detection limits and data censoring

Some water-quality parameters, especially nutrients and trace elements, typically have very low concentrations that are close to the laboratory reporting limits. Water samples without detectable levels of an analyte are reported as below the reporting limit (e.g., <0.04 µg/L for dissolved lead) and are referred to as censored data because a cut-off, rather than a true value, is reported. As analytical methods or laboratory practices change, the reporting limits can also change, so it is common for multiple reporting limits to apply to a single water-quality parameter over time. For example, for dissolved lead, the reporting limit decreased from 0.12 µg/L in 2001 to 0.04 µg/L after 2013.

For datasets with multiple reporting limits, we first investigated the use of censored regression using maximum likelihood estimation (Helsel and Hirsch 2002). Censored regression is a parametric statistical approach based on a presumed distribution of the data, usually a lognormal distribution. The residuals from each censored regression must be evaluated to ensure that the distributional assumptions of the model are met. In our datasets, log-transforming the data was not adequate for meeting distributional requirements for censored regressions, which can be easily skewed by outlying data (Helsel 2012).

Because assumptions for parametric tests were not met, the non-parametric seasonal Kendall test was the preferred alternative for trend testing, even for datasets with multiple reporting limits (Schertz et al. 1991). The seasonal Kendall test requires a single reporting limit so observations can be ranked appropriately. Accordingly, datasets with multiple censoring levels were re-censored to the highest reporting limit over the period of record. In the above example for lead, all concentrations during the period of record that were non-detects or were detected concentrations below the 0.12 µg/L reporting limit were set to the reporting limit and evaluated as ties during the seasonal Kendall analysis.

Detection limits for selenium were higher

from 2001 to 2005 than most detections later in the record. Selenium is of special interest because loading to the Colorado River must be reduced according to a Total Maximum Daily Loading plan developed by the State of Colorado (CDHPE 2011). For this reason, when a selenium dataset consisted primarily of non-detects from 2001 to 2005, we removed that period from our analysis and used data from 2006–2014.

Site and parameter combinations with <50% of the dataset composed of non-detects (censored data) were analyzed for trends in raw concentrations using the seasonal Kendall test. For site and parameter combinations with <5% censored concentrations, a non-parametric slope of the magnitude of the trend, called a Sen slope, was calculated to represent the median annual change in a parameter. We calculated a median annual rate of change as (Sen slope/median value) ∗100, as well as an estimate of total change over the period of record (as annual rate of change ∗ number of years in record). For datasets with >5% censored data, the Sen slope is biased towards being a low estimate of the rate of change, so no slope estimates or rates of change are presented (Scherz et al. 1991). Site and parameter combinations with >50% censored data are summarized in this report but were excluded from trend analysis due to the limited ability to detect trends in highly censored datasets.

2.3.2 Relationships to flow

Many water-quality parameters change in concentration with changes in streamflow. Flow-related variability may be large compared to water-quality changes in response to other drivers, such as land-use changes or other human activities. Adjusting concentrations for flow can reduce variability in the dataset and make it easier to detect trends that stem from causes other than changes in streamflow.

For datasets with <5% censored data, we investigated the relationship between flow and concentration using Generalized Additive Models (GAMs) of flow and the parameter value using the function "gam" from the R package mgcv (Wood 2006). GAMs are a non-parametric extension of Generalized Linear Models that have no a priori assumptions about the shape of the response (e.g., linear, quadratic). Parameters that are sensitive to sediment loads, including fecal indicator bacteria, nitrogen species, and total phosphorus, were log-transformed prior to the GAM. A 5% cutoff for censored data is the recommended approach for flow adjustment outlined in Schertz and others (1991), although the use of GAMs is not included in the manual.

Two models were run for each set. One model was set to a constant value of the parameter mean. The second model included a smoothed function using generalized cross-validation. Because of the small size of many of our datasets, we set gamma to 1.4 to reduce overfitting of sparse data. We then compared the constant and smoothed models using the Akaike Information Criterion (AIC) to determine whether adjusting for flow substantially improved model fit. We considered models with a difference in AIC (ΔAIC) of >4 as improved models (Burnham and Anderson 2002).

If ΔAIC was ≤4, then no flow-adjustment was made to the dataset. If ΔAIC was >4, then we visually inspected the GAMs for overfitting of the data. If GAMs were relatively smooth, the residuals from the smoothed GAM, referred to as the flow adjusted concentration (FAC), were analyzed with a seasonal Kendall test, with or without an adjustment for serial correlation, depending on the length of the dataset.

2.3.3 Strengths and limitations of our approach

The seasonal Kendall test is best suited to detecting monotonic changes over time. It is a standard approach to testing for trends in water quality because it can appropriately evaluate datasets that violate the assumptions of many other statistical tests. However, there are some significant limitations to this approach. Data reduction to one reporting limit can result in the loss of considerable information from the dataset. Short-term changes in water-quality parameters may not be captured in a test for long-term trends. A focus on seasonal median concentrations

may also ignore trends in low or high concentrations in the dataset.

Climate variability can also affect water-quality trend analysis because constituent concentrations often vary with discharge. While we attempt to address this issue using flow-adjusted concentrations, flow adjustment is not possible for highly censored datasets. Even when flow adjustment can be performed, the relative proportion of instream flows based on groundwater versus surface water inputs can also affect parameter concentrations. In years with a high snowpack, higher and longer run-off periods can elevate base flows, likely corresponding to lower concentrations of dissolved constituents. During drought periods, when streams are predominantly fed by groundwater, higher concentrations of dissolved constituents are likely.

2.4 Water-quality standards comparisons

When applicable, concentration data were compared to general and segment-specific water-quality standards published by the State of Colorado in 5 CCR 1002, Regulations 31–37 (http://www.colorado.gov/cs/Satellite/CDPHE-WQCC/CBON/1251590840282, accessed 9/30/2012). The focus of this report is primarily on aquatic life, ecosystem health, and recreation safety. For this reason, we present results compared to aquatic-life and recreation classifications. The report presents exceedances of a water-quality standard only if they occurred for more than 15% of results, similar to the State of Colorado's approach for most water-quality parameters (CDPHE 2017). This approach minimizes reporting of short-duration changes in water chemistry that may result from natural variability associated with weather events, which may not be of management concern. For a complete list of beneficial uses and associated water-quality standards used in this report, see Appendix A.

In 2017, the State of Colorado updated water-quality standards to require continuous data for water temperature in streams and profile data for water temperature and dissolved oxygen in lakes and reservoirs (CDPHE 2017). Because these types of data were not collected from 2001 to 2014, we compare water-temperature and dissolved-oxygen data to discrete sampling criteria used in previous assessments. Several parameters, including nutrients and *E. coli*, are compared using summary statistics rather than discrete values in state evaluations. Exceedances in this report, therefore, are meant to inform managers of potential problems rather than to reflect regulatory definitions. Regulatory comparisons are made by the State of Colorado in their 303(d) reports to Congress.

3 Results and Discussion

3.1 Summary of trends and exceedances

No trend was detected for most water-quality parameters at most sites in CURE and BLCA. Out of 493 site and parameter combinations analyzed, only 22 (4.5%) had a statistically significant upward or downward trend in raw concentrations over time (p=0.05; Table 3-1). Trends mostly indicated improvements in water quality, including decreasing nutrients in Red Rock Canyon (BLCA), and decreases in chloride and metals at several sites. Copper decreased at three sites, and selenium decreased at two sites. However, Pine Creek (CURE) had several trends of concern, including increasing nitrite plus nitrate and increasing selenium concentrations. Changes in raw concentrations were most common at Pine Creek (dissolved oxygen, nitrite plus nitrate, selenium), Cimarron River (CURE; specific conductance, copper, and selenium), and both sites in Red Rock Canyon. Both sites in Red Rock Canyon had decreases in phosphorus and copper, while nitrite plus nitrate decreased at the upstream site and flow decreased at the downstream site.

For 127 site and parameter combinations that were adjusted for flow, 10 (7.9%) had significant trends over time (Table 3-2). Trends in flow-adjusted concentrations were most common at Pine Creek (dissolved oxygen, specific conductance, calcium, and chloride) and Blue Creek (dissolved oxygen, pH, manganese).

Of 331 evaluations, concentrations met state aquatic-life and recreation water-quality standards on greater than 85% of visits for 307 site and parameter combinations (92.7%). State aquatic-life water-quality chronic standards were exceeded on 15% or more visits for 24 site and parameter combinations (Table 3-3). The most common exceedance noted was for phosphorus, which is an interim value not yet enforced by the State of Colorado. Water temperature, dissolved oxygen, and *E. coli* also exceeded water-quality standards at several sites. Selenium exceeded standards on almost all visits at two sites in Red Rock Canyon. Exceedances were most common at Cimarron River (*Escherichia coli*, water temperature, phosphorus), East Elk Creek (dissolved oxygen, water temperature, phosphorus), and Red Creek (dissolved oxygen, water temperature, phosphorus). All Blue Mesa Reservoir sites exceeded standards for dissolved oxygen and water temperature.

Table 3-1. Sites and parameters with statistically significant trends in raw concentrations over time.[†]

Parameter	Site	Raw trend	Test statistic	p-value
Dissolved oxygen (mg/L)	Pine Creek at Highway 50 near Sapinero	↑	0.159	0.012
	Morrow Point Reservoir above Morrow Point Dam near Cimarron	↑	0.283	0.026
Flow (cfs)	Red Rock Canyon at mouth near Montrose	↓	-0.312	0.043
pH	Steuben Creek near mouth near Gunnison	↓	-0.255	0.021
	East Elk Creek near mouth near Sapinero	↑	0.393	0.036
	West Elk Creek below forest boundary near Sapinero	↓	-0.283	0.045
Specific conductance (µS/cm)	Cimarron River below Squaw Creek, near Cimarron	↓	-0.278	0.052
	Gunnison River below Gunnison Tunnel	↓	-0.432	0.035
Chloride (d) (mg/L)	Steuben Creek near mouth near Gunnison	↓	-0.485	0.014
	Red Creek near mouth near Sapinero	↓	-0.486	0.016
Nitrite + Nitrate (d) (mg/L as N)	Pine Creek at Highway 50 near Sapinero	↑	0.198	0.012
	Red Rock Canyon near NPS boundary near Montrose	↓	-0.417	0.017
Phosphorus (mg/L as P)	Red Rock Canyon near NPS boundary near Montrose	↓	-0.323	0.051
	Red Rock Canyon at mouth near Montrose	↓	-0.398	0.043
Copper (d) (µg/L)	Cimarron River below Squaw Creek, near Cimarron	↓	-0.538	0.003
	Red Rock Canyon near NPS boundary near Montrose	↓	-0.494	0.005
	Red Rock Canyon at mouth near Montrose	↓	-0.720	0.001
Manganese (d) (µg/L)	Blue Creek at Highway 50 near Sapinero	↓	-0.375	0.022
	Morrow Point Reservoir below Blue Creek near Sapinero	↑	0.290	0.028
Selenium (d) (µg/L)	Pine Creek at Highway 50 near Sapinero	↑	0.288	0.046
	Cimarron River below Squaw Creek, near Cimarron	↓	-0.322	0.020
	Crystal Reservoir at Crystal Dam near Cimarron	↓	-0.484	0.001

[†] Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

Table 3-2. Sites and parameters with statistically significant trends in flow-adjusted concentrations (FAC) over time.[†]

Parameter	Site	FAC trend	Test statistic	p-value
Dissolved oxygen (mg/L)	Pine Creek at Highway 50 near Sapinero	↑	0.111	0.029
	Blue Creek at Highway 50 near Sapinero	↑	0.244	0.037
pH	Lake Fork Gunnison River below Gateview	↓	-0.202	0.028
	Blue Creek at Highway 50 near Sapinero	↓	-0.230	0.041
Specific conductance (µS/cm)	Pine Creek at Highway 50 near Sapinero	↓	-0.439	0.004
Calcium (d) (mg/L)	Pine Creek at Highway 50 near Sapinero	↓	-0.279	0.018
Chloride (d) (mg/L)	Pine Creek at Highway 50 near Sapinero	↓	-0.540	0.020
Magnesium (d) (mg/L)	Lake Fork Gunnison River below Gateview	↑	0.339	0.037
Nitrite + Nitrate (d) (mg/L as N)	Red Rock Canyon at mouth near Montrose	↓	-0.468	0.024
Manganese (d) (µg/L)	Blue Creek at Highway 50 near Sapinero	↓	-0.385	0.036

[†] Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

Table 3-3. Parameter and sites that exceeded the relevant state water-quality standard or interim value at 15% or more of visits.

Parameter	Site	Samples	Exceedances	Percent exceedances
Dissolved oxygen (mg/L)	East Elk Creek near mouth near Sapinero	56	11	19.6
	Red Creek near mouth near Sapinero	59	19	32.2
	Blue Mesa Reservoir below Highway 149 near Gunnison	56	13	23.2
	Blue Mesa Reservoir above Cebolla Creek near Sapinero	56	23	41.1
	Blue Mesa Reservoir above Soap Creek near Sapinero	54	21	38.9
Escherichia coli (cfu/100 mL)	Blue Creek at Highway 50 near Sapinero	65	15	23.1
	Cimarron River below Squaw Creek, near Cimarron	63	26	41.3
	Red Rock Canyon near NPS boundary near Montrose	44	33	75.0
Water temperature (°C)	East Elk Creek near mouth near Sapinero	56	13	23.2
	Red Creek near mouth near Sapinero	59	26	44.1
	Blue Mesa Reservoir below Highway 149 near Gunnison	57	19	33.3
	Blue Mesa Reservoir above Cebolla Creek near Sapinero	57	20	35.1
	Blue Mesa Reservoir above Soap Creek near Sapinero	55	17	30.9
	Cimarron River below Squaw Creek, near Cimarron	57	18	31.6
Phosphorus (mg/L as P)	Beaver Creek at Highway 50 near Gunnison	26	10	38.5
	Steuben Creek near mouth near Gunnison	25	6	24.0
	East Elk Creek near mouth near Sapinero	28	22	78.6
	Red Creek near mouth near Sapinero	30	30	100.0
	Pine Creek at Highway 50 near Sapinero	33	23	69.7
	Blue Creek at Highway 50 near Sapinero	34	6	17.6
	Cimarron River below Squaw Creek, near Cimarron	33	11	33.3
	Red Rock Canyon near NPS boundary near Montrose	42	19	45.2
Selenium (d) (µg/L)	Red Rock Canyon near NPS boundary near Montrose	42	41	97.6
	Red Rock Canyon at mouth near Montrose	42	42	100.0

3.2 Northern tributaries to Blue Mesa Reservoir, upstream to downstream

3.2.1 Gunnison River at County Road 32 below Gunnison, Colorado

The Gunnison River at County Road 32 is sampled either from the County Road 32 bridge or just downstream of the bridge, when wadeable. The site is located about four miles upstream from where Blue Mesa Reservoir begins. This site is below the town of Gunnison (population circa 16,000), and directly downstream from the town's wastewater treatment plant discharge. There are also heavy cattle grazing and large irrigation withdrawals and return flows along this segment of river. This site is co-located with USGS gaging station 09114500.

Summary statistics and trend analysis results are presented in Table 3-4. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured streamflow during sampling visits.
- There were no statistically significant trends in raw or flow-adjusted concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for dissolved oxygen, pH, ammonia, nitrite, cadmium, copper, manganese, silver, selenium, and zinc.
- There were <5% exceedances for *E. coli*, water temperature, phosphorus, and lead.
- Median and 85th percentile values remained similar to what was reported for WY1995–WY2001 (Spahr 2004).

Table 3-4. Summary statistics for water-quality parameters at Gunnison River near Gunnison, CO, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	5/31/2001	9/3/2014	40	0	uncensored	7.89	8.55	9.22	none	not adjusted
Escherichia coli (cfu/100 mL)	5/31/2001	9/3/2014	43	1	uncensored	6.3	27	75.2	none	none
Flow (cfs)	5/31/2001	9/3/2014	40	0	uncensored	389	590	1827	none	–
pH	5/31/2001	9/3/2014	40	0	uncensored	8.09	8.30	8.50	none	none
Specific conductance (µS/cm)	5/31/2001	9/3/2014	41	0	uncensored	212	230	265	none	none
Water temperature (°C)	5/31/2001	9/3/2014	42	0	uncensored	7.6	12.3	15.0	none	not adjusted
Calcium (d) (mg/L)	5/31/2001	9/3/2014	40	0	uncensored	30.7	34.5	39.4	none	none
Magnesium (d) (mg/L)	5/31/2001	9/3/2014	40	0	uncensored	6.16	7.06	8.24	none	none
Ammonia (d) (mg/L as N)	5/31/2001	9/3/2014	40	36	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	5/31/2001	9/3/2014	30	2	uncensored	0.120	0.186	0.297	none	none
Nitrite (d) (mg/L as N)	5/31/2001	9/3/2014	40	40	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	5/31/2001	9/3/2014	40	8	censored	<0.016	0.038	0.066	none	–
Orthophosphate (d) (mg/L as P)	5/31/2001	9/3/2014	38	5	censored	0.006	0.010	0.027	none	–
Phosphorus (mg/L as P)	5/31/2001	9/3/2014	40	0	uncensored	0.021	0.029	0.048	none	not adjusted
Cadmium (d) (µg/L)	5/31/2001	9/3/2014	40	38	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	5/31/2001	9/3/2014	38	31	none	<1	<1	1.05	–	–
Lead (d) (µg/L)	5/31/2001	9/3/2014	40	23	none	<0.08	<0.08	0.142	–	–
Manganese (d) (µg/L)	5/31/2001	9/3/2014	40	0	uncensored	11.54	15.65	21.85	none	none
Selenium (d) (µg/L)	5/25/2006	9/3/2014	24	0	uncensored	0.09	0.11	0.17	none	none
Silver (d) (µg/L)	5/31/2001	9/3/2014	40	40	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	5/31/2001	9/3/2014	40	23	none	<2	<2	5.1	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

3.2.2 Beaver Creek at Highway 50 near Gunnison, Colorado

Beaver Creek has been designated an Outstanding National Resource Water by the State of Colorado (CDPHE 2012). The stream is sampled at the CURE Beaver Creek picnic area north of US Highway 50. The Beaver Creek watershed is used for livestock grazing and recreation. Directly upstream from the NPS monitoring site is land acquired by Colorado Parks and Wildlife (CPW). This land was historically used for grazing, but since the CPW acquisition it has been used for big-game winter habitat. CPW also installed a small dam along their upstream boundary with Bureau of Land Management (BLM) in 1997 to provide habitat for Colorado cutthroat trout. Further upstream from the BLM land, in the Gunnison National Forest, lies the West Elk Wilderness, managed by the U.S. Forest Service.

Summary statistics and trend analysis results are presented in Table 3-5. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There were no statistically significant trends in raw or flow-adjusted concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, silver, selenium, and zinc.
- There were <5% exceedances for dissolved oxygen and <10% exceedances for *E. coli* and water temperature.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 35% of sample visits (10 of 26; Figure 3-1). Phosphorus exceedances occurred throughout the period of record, but no visible signs of eutrophication have been noted in the stream.

Table 3-5. Summary statistics for water-quality parameters at Beaver Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/7/2001	9/4/2014	54	0	uncensored	7.43	8.16	9.23	none	none
Escherichia coli (cfu/100 mL)	8/7/2001	9/4/2014	62	2	uncensored	3	20.5	51.9	none	not adjusted
Flow (cfs)	8/7/2001	9/4/2014	55	0	uncensored	3.73	19.1	69.9	none	–
pH	8/7/2001	9/4/2014	55	0	uncensored	7.5	7.76	7.91	none	none
Specific conductance (µS/cm)	8/7/2001	9/4/2014	55	0	uncensored	57.1	88.7	124	none	none
Water temperature (°C)	8/7/2001	9/4/2014	55	0	uncensored	6.5	11.1	14.4	none	none
Calcium (d) (mg/L)	8/7/2001	9/4/2014	54	0	uncensored	7.5	11.8	18.3	none	none
Chloride (d) (mg/L)	5/6/2008	9/26/2012	24	0	uncensored	0.138	0.245	0.437	none	not adjusted
Magnesium (d) (mg/L)	8/7/2001	9/4/2014	54	0	uncensored	1.33	1.99	3.09	none	none
Ammonia (d) (mg/L as N)	8/7/2001	9/4/2014	54	54	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/2/2009	9/4/2014	28	28	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	6/2/2009	9/4/2014	25	25	none	<0.019	<0.019	<0.019	–	–
Nitrite (d) (mg/L as N)	8/7/2001	9/4/2014	54	54	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/7/2001	9/4/2014	54	54	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	10/3/2001	9/4/2014	26	1	uncensored	0.071	0.097	0.152	none	none
Cadmium (d) (µg/L)	8/7/2001	9/4/2014	54	54	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/7/2001	9/4/2014	54	54	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/7/2001	9/4/2014	54	54	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/7/2001	9/4/2014	54	1	uncensored	11.99	21.94	46.59	none	none
Selenium (d) (µg/L)	5/31/2006	9/4/2014	37	36	none	<0.08	<0.08	<0.08	–	–
Silver (d) (µg/L)	8/7/2001	9/4/2014	54	54	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/7/2001	9/4/2014	54	54	none	<2.8	<2.8	<2.8	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

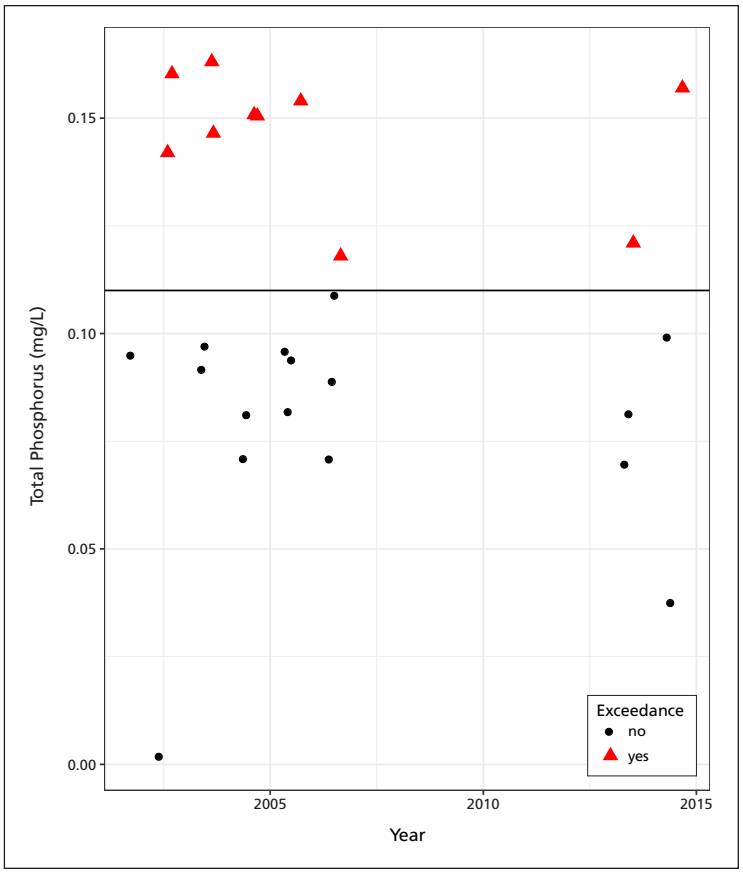


Figure 3-1. Phosphorus exceedances at Beaver Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.2.3 Steuben Creek near mouth near Gunnison, Colorado

Steuben Creek is sampled along County Road 20, at the edge of the CURE boundary. The stream originates in the West Elk Wilderness (managed by U.S. Forest Service), then flows through privately owned land before entering NPS property and flowing into Blue Mesa Reservoir. There are about 15 residences in the watershed with private wells and septic systems along Steuben Creek. A road along Steuben Creek leads to the U.S. Forest Service (USFS) boundary. The road is periodically treated with magnesium chloride as a dust suppressant.

Summary statistics and trend analysis results are presented in Table 3-6. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured streamflow during sampling visits.
- At Steuben Creek, pH decreased over the period of record, with a median annual decline of -0.03 pH units (Kendall's tau = -0.255, p = 0.021; Figure 3-2). The cause of a decline in pH is unknown.
- Raw concentrations of chloride decreased, with a median annual decline of 0.05 mg/L, for a total decline of -59% over the period of record (Kendall's tau = -0.485, p = 0.014; Figure 3-3). From 2001 to 2014, the county attempted to improve application of dust suppressants, such as magnesium chloride, on dirt roads to decrease overflow into creeks. Reductions in chloride concentrations may be related to more targeted applications of dust suppressants in the watershed.

Exceedances

- There were no exceedances of state water-quality standards for dissolved oxygen, pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, and zinc.
- There were <5% exceedances for water temperature and selenium and <10% exceedances for *E. coli*.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 24% of sample visits (6 of 25; Figure 3-4). No visible signs of eutrophication have been noted in the stream.

Table 3-6. Summary statistics for water-quality parameters at Steuben Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/7/2001	9/22/2014	52	0	uncensored	7.79	8.52	9.68	none	none
Escherichia coli (cfu/100 mL)	8/7/2001	9/22/2014	59	1	uncensored	2.7	19	73.6	none	not adjusted
Flow (cfs)	8/7/2001	9/22/2014	52	0	uncensored	1.58	6.38	42.7	none	–
pH	8/7/2001	9/22/2014	53	0	uncensored	7.57	7.84	8.02	↓	none
Specific conductance (µS/cm)	8/7/2001	9/22/2014	53	0	uncensored	48.0	77.5	92.0	none	none
Water temperature (°C)	8/7/2001	9/22/2014	53	0	uncensored	5.7	9.1	13.4	none	none
Calcium (d) (mg/L)	8/7/2001	9/22/2014	52	0	uncensored	5.89	9.46	12.27	none	none
Chloride (d) (mg/L)	5/6/2008	9/27/2012	23	0	uncensored	0.32	0.45	0.74	↓	not adjusted
Magnesium (d) (mg/L)	8/7/2001	9/22/2014	52	0	uncensored	1.03	1.60	1.94	none	none
Ammonia (d) (mg/L as N)	8/7/2001	9/22/2014	53	53	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/2/2009	9/22/2014	28	28	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	6/2/2009	9/22/2014	26	26	none	<0.018	<0.018	<0.018	–	–
Nitrite (d) (mg/L as N)	8/7/2001	9/22/2014	52	52	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/7/2001	9/22/2014	53	52	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/7/2001	9/22/2014	25	0	uncensored	0.059	0.076	0.115	none	not adjusted
Cadmium (d) (µg/L)	8/7/2001	9/22/2014	52	52	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/7/2001	9/22/2014	52	52	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/7/2001	9/22/2014	52	52	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/7/2001	9/22/2014	51	0	uncensored	4.07	6.56	11.8	none	none
Selenium (d) (µg/L)	6/5/2006	9/22/2014	36	30	none	<0.08	<0.08	<0.08	–	–
Silver (d) (µg/L)	8/7/2001	9/22/2014	52	52	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/7/2001	9/22/2014	52	52	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

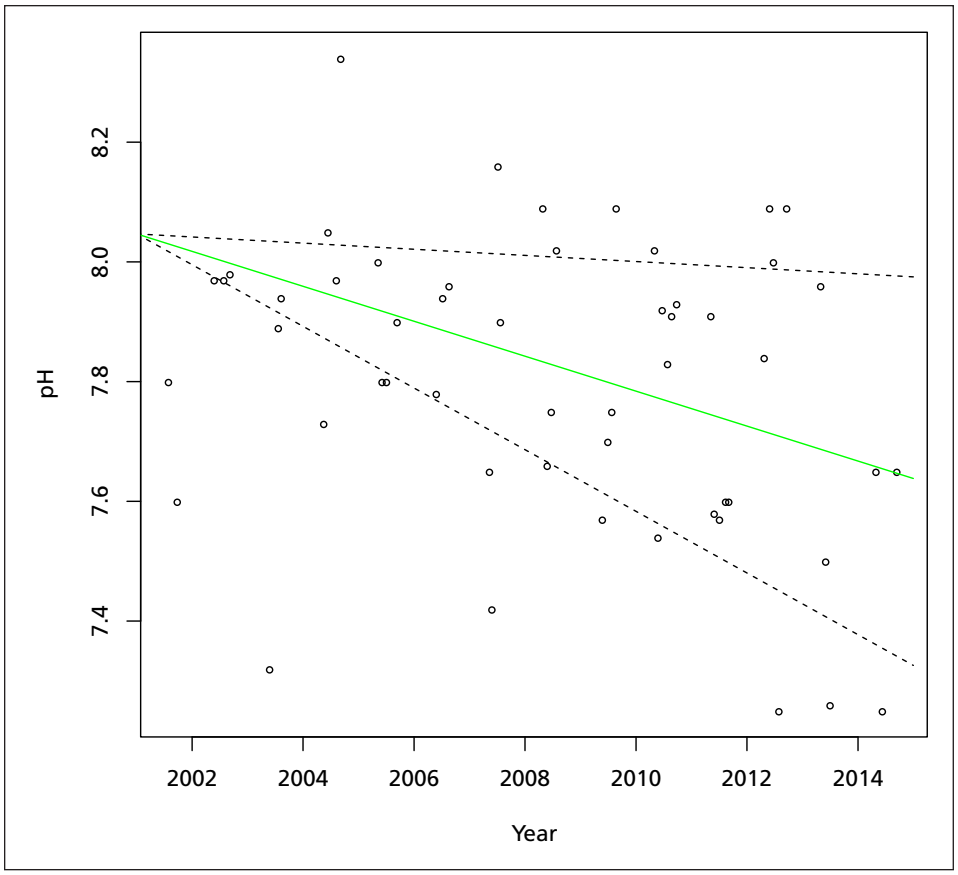


Figure 3-2. Statistically significant decrease in pH over time at Steuben Creek (Kendall's tau = -0.255, p = 0.02). The estimated trend of -0.03 pH units per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

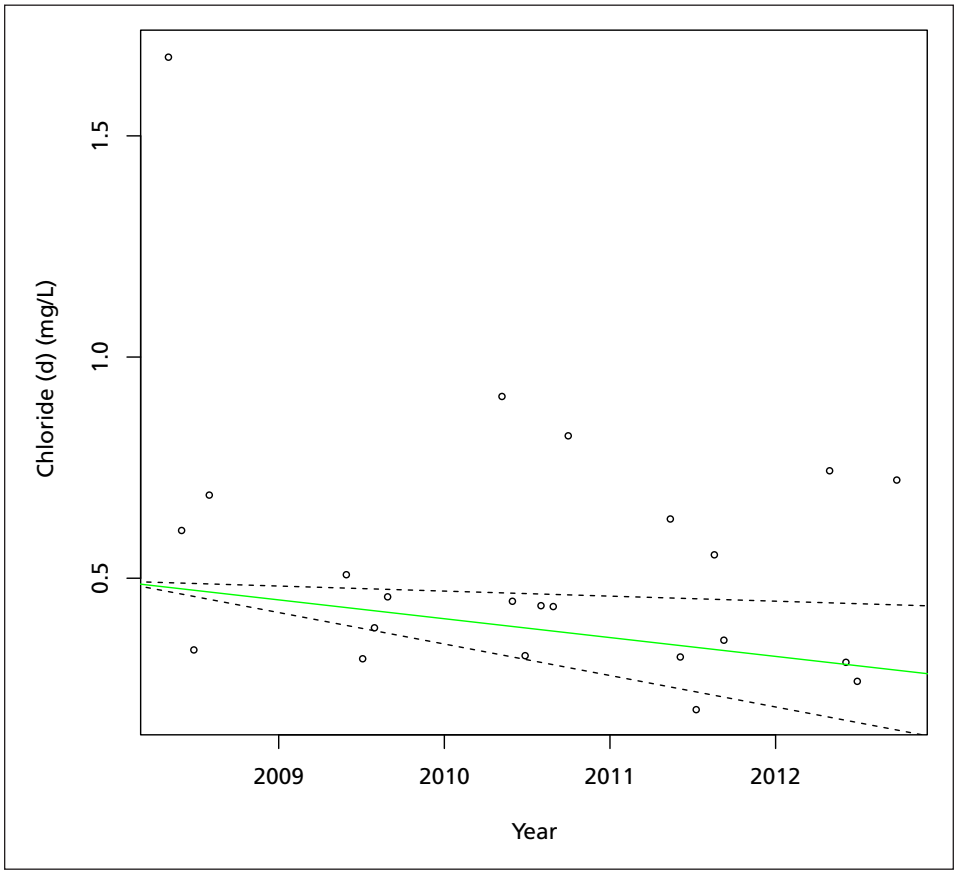


Figure 3-3. Statistically significant decrease in chloride over time at Steuben Creek (Kendall's tau = -0.483, p = 0.01). The estimated trend of -0.05 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

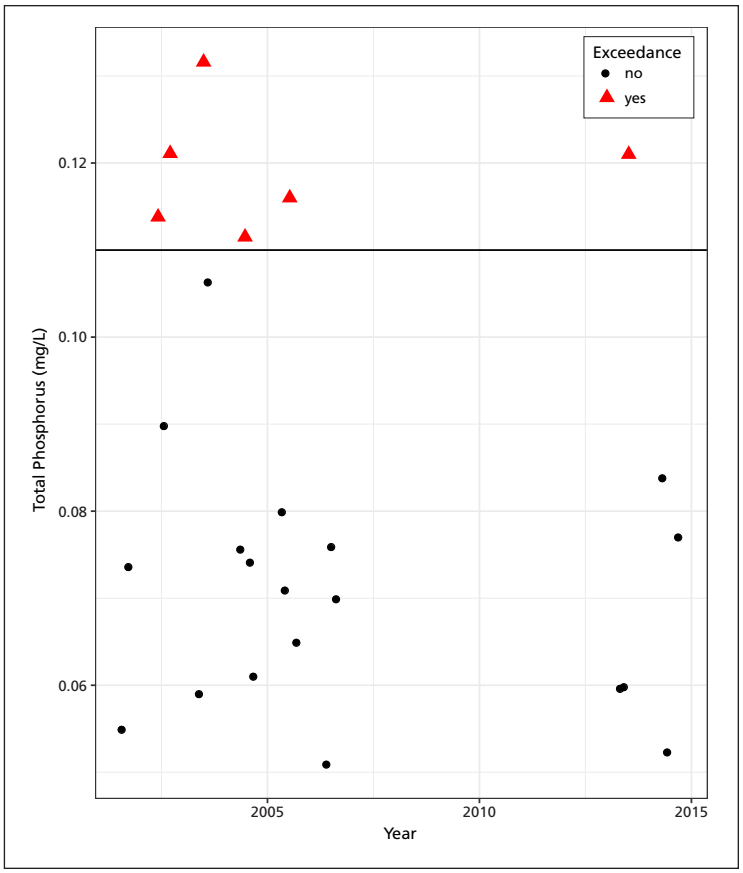


Figure 3-4. Phosphorus exceedances at Steuben Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.2.4 East Elk Creek near mouth near Sapinero, Colorado

East Elk Creek has been designated an Outstanding National Resource Water by the State of Colorado (CDPHE 2012). The monitoring location is located at the NPS East Elk Creek campground. East Elk Creek flows through USFS land, CPW land, and BLM land before entering CURE and emptying into the north side of Blue Mesa Reservoir. There is frequent beaver activity throughout the stream and near the monitoring site. Commercial logging of aspen and spruce occurs in the headwaters and along the eastern boundary of the watershed. Upstream land use also includes livestock grazing.

Summary statistics and trend analysis results are presented in Table 3-7. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There was a statistically significant increase in raw pH at a median annual rate of 0.02 pH units over the period of record (Kendall's tau = 0.393, p = 0.036; Figure 3-5). The cause of the increase is unknown.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, and zinc.
- There were <10% exceedances for silver.
- Dissolved oxygen was below the aquatic-life cold-water 1 minima of 7.0 mg/L on 20% of sample visits (11 of 56; Figure 3-6).
- Seasonally dependent water temperature criteria were exceeded on 23% of sample visits (13 of 56; Figure 3-7). Continuous water temperature monitoring could be implemented at this site to better characterize water temperature in comparison to updated state standards.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 79% of sample visits (22 of 28; Figure 3-8). Despite observed instances of low dissolved oxygen and high phosphorus concentrations, no visible signs of eutrophication have been noted in the stream.

Table 3-7. Summary statistics for water-quality parameters at East Elk Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/8/2001	9/2/2014	56	0	uncensored	6.80	7.59	8.77	none	none
Escherichia coli (cfu/100 mL)	8/8/2001	9/2/2014	63	4	censored	2	9	37.4	none	–
Flow (cfs)	8/8/2001	9/2/2014	56	0	uncensored	1.43	3.61	27.0	none	–
pH	8/8/2001	9/2/2014	56	0	uncensored	7.44	7.64	7.78	↑	not adjusted
Specific conductance (µS/cm)	8/8/2001	9/2/2014	56	0	uncensored	60.3	101.5	126	none	none
Water temperature (°C)	8/8/2001	9/2/2014	56	0	uncensored	7.9	13.5	16.8	none	none
Calcium (d) (mg/L)	8/8/2001	9/2/2014	55	0	uncensored	7.1	12.6	16.2	none	none
Chloride (d) (mg/L)	5/8/2008	9/11/2012	24	0	uncensored	0.338	0.410	0.528	none	not adjusted
Magnesium (d) (mg/L)	8/8/2001	9/2/2014	55	0	uncensored	1.37	2.53	3.27	none	none
Ammonia (d) (mg/L as N)	8/8/2001	9/2/2014	56	55	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	5/21/2009	9/2/2014	28	28	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	5/21/2009	9/2/2014	26	25	none	<0.014	<0.014	<0.014	–	–
Nitrite (d) (mg/L as N)	8/8/2001	9/2/2014	56	55	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/8/2001	9/2/2014	56	56	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/8/2001	9/2/2014	28	0	uncensored	0.103	0.194	0.243	none	none
Cadmium (d) (µg/L)	8/8/2001	9/2/2014	55	54	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/8/2001	9/2/2014	55	55	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/8/2001	9/2/2014	55	55	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/8/2001	9/2/2014	55	0	uncensored	20.67	56.03	160.95	none	none
Selenium (d) (µg/L)	5/31/2006	9/2/2014	37	2	uncensored	0.05	0.07	0.09	none	none
Silver (d) (µg/L)	8/8/2001	9/2/2014	55	55	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/8/2001	9/2/2014	55	55	none	<2.8	<2.8	<2.8	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

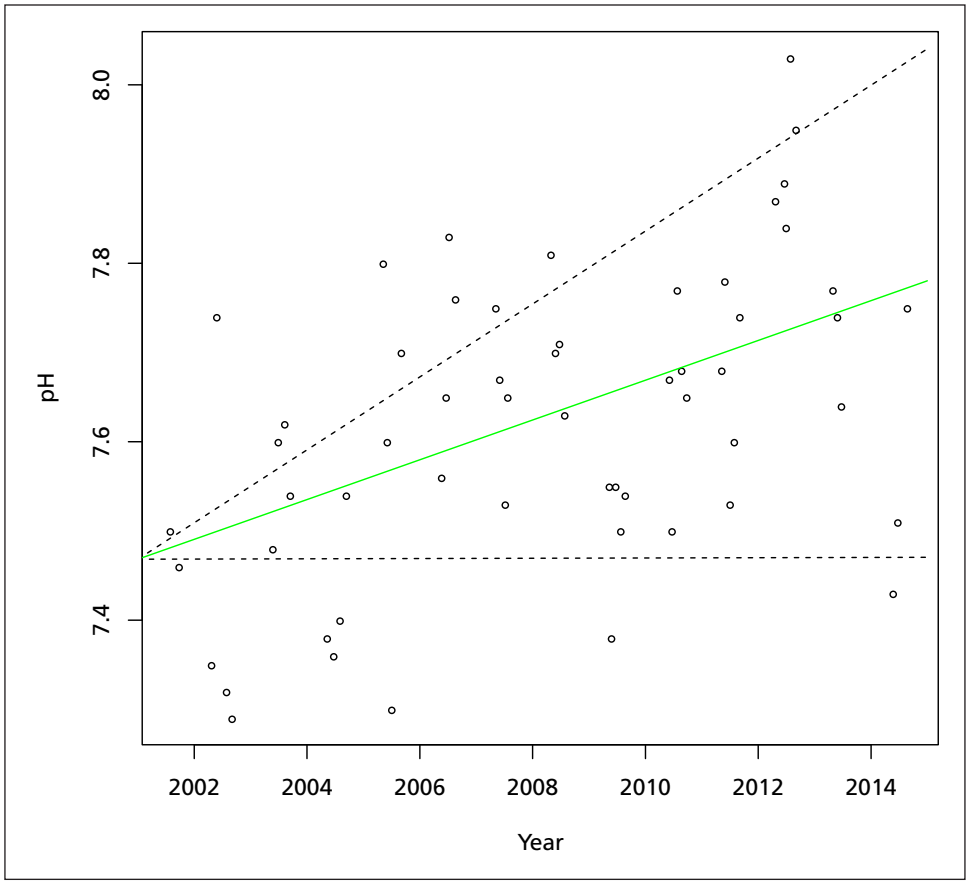


Figure 3-5. Statistically significant increase in pH over time at East Elk Creek (Kendall's tau = 0.393, p = 0.04). The estimated trend of 0.02 pH units per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

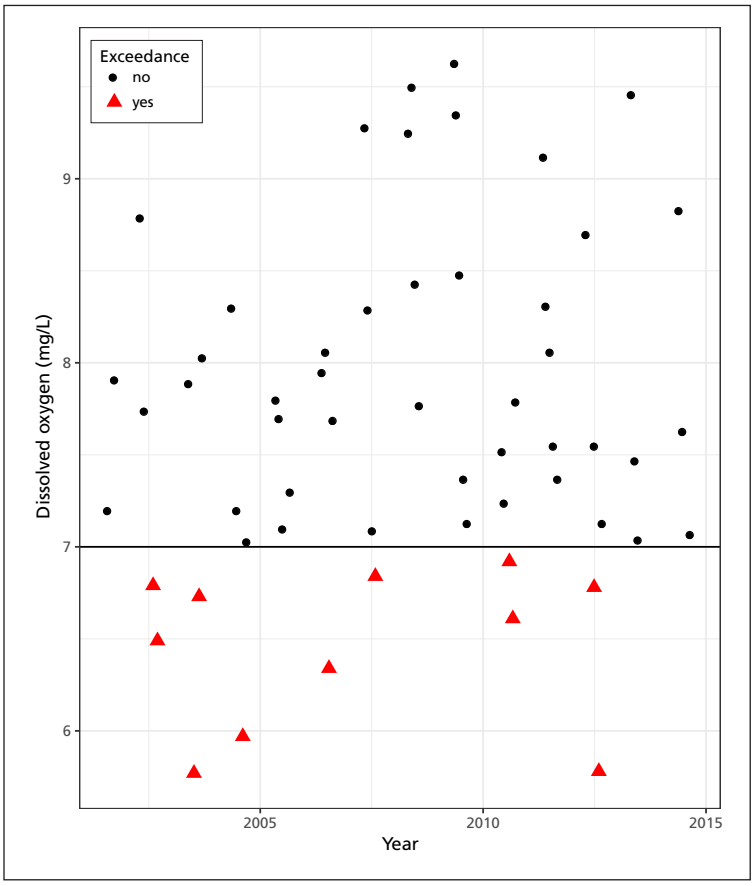


Figure 3-6. Dissolved oxygen exceedances at East Elk Creek. The black line indicates the aquatic-life cold-water 1 standard of 7.0 mg/L.

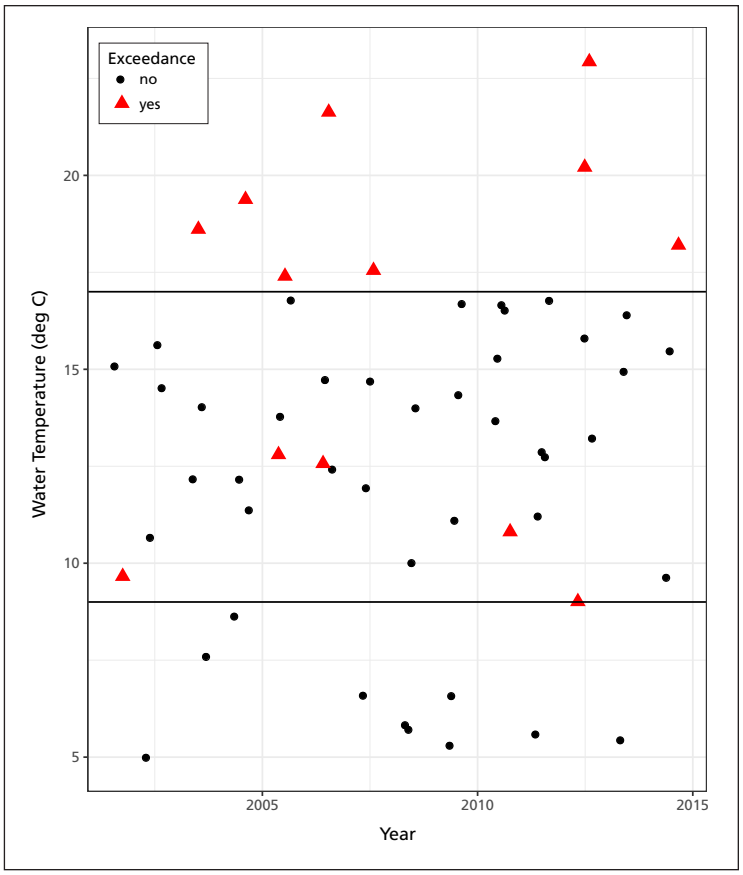


Figure 3-7. Water temperature exceedances at East Elk Creek. The lower line represents the aquatic-life cold-water 1 winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.

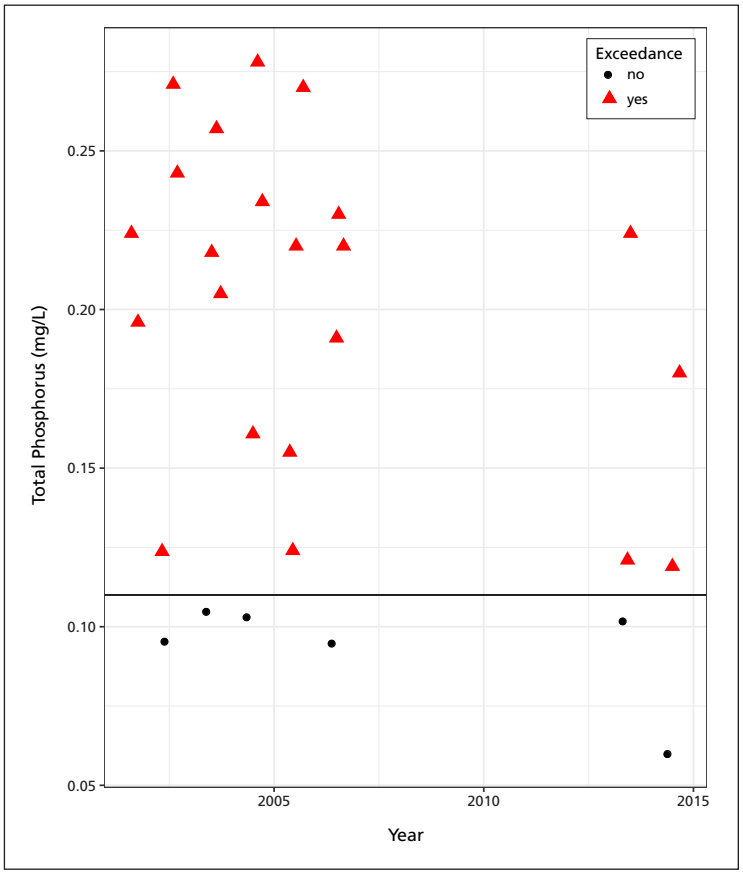


Figure 3-8. Phosphorus exceedances at East Elk Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.2.5 Red Creek near mouth near Sapinero, Colorado

Red Creek is a designated Outstanding National Resource Water by the State of Colorado (CDPHE 2012). Samples are collected at the NPS Red Creek Campground. Red Creek flows through USFS, CPW, and BLM land upstream of the park. There is commercial logging for spruce in the headwaters, as well as cattle grazing. Beaver activity is heavy around the sampling site.

Summary statistics and trend analysis results are presented in Table 3-8. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Raw concentrations of chloride decreased, with a median annual decline of -0.03 mg/L (Kendall's tau = -0.486, p = 0.016; Figure 3-9), for an approximately -35% decline over the period of record. From 2001 to 2014, the county attempted to better target the application of dust suppressants, such as magnesium chloride, on dirt roads to decrease overflow into creeks. Reductions in chloride concentrations may be related to more targeted applications of dust suppressants in the watershed.

Exceedances

- There were no exceedances of state water-quality standards for pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <10% exceedances for *E. coli*.
- Dissolved oxygen was below the aquatic-life cold-water 1 minima of 7.0 mg/L on 32% of sample visits (19 of 59; Figure 3-10).
- Seasonally dependent water temperature criteria were exceeded on 44% of sample visits (26 of 59; Figure 3-11). Continuous water temperature monitoring could be implemented at this site to better characterize water temperature in comparison to updated state standards.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 100% of sample visits (30 of 30; Figure 3-12). Despite observed instances of low dissolved oxygen and high phosphorus concentrations, no visible signs of eutrophication have been noted in the stream.

Table 3-8. Summary statistics for water-quality parameters at Red Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/8/2001	9/24/2014	59	0	uncensored	6.69	7.40	8.40	none	none
Escherichia coli (cfu/100 mL)	8/8/2001	9/24/2014	65	33	uncensored	<20	<20	72.6	none	none
Flow (cfs)	8/8/2001	9/24/2014	58	0	uncensored	0.237	0.811	8.44	none	–
pH	8/8/2001	9/24/2014	59	0	uncensored	7.63	7.84	7.95	none	not adjusted
Specific conductance (µS/cm)	8/8/2001	9/24/2014	59	0	uncensored	80.9	165	236	none	none
Water temperature (°C)	8/8/2001	9/24/2014	59	0	uncensored	9.0	15.3	18.3	none	none
Calcium (d) (mg/L)	8/8/2001	9/24/2014	59	0	uncensored	10.1	21.0	31.8	none	none
Chloride (d) (mg/L)	5/8/2008	9/11/2012	25	0	uncensored	0.42	0.48	0.60	↓	not adjusted
Magnesium (d) (mg/L)	8/8/2001	9/24/2014	59	0	uncensored	2.14	4.84	7.57	none	none
Ammonia (d) (mg/L as N)	8/8/2001	9/24/2014	59	57	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	5/26/2009	9/24/2014	30	30	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	5/26/2009	9/24/2014	28	28	none	<0.014	<0.014	<0.014	–	–
Nitrite (d) (mg/L as N)	8/8/2001	9/24/2014	59	57	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/8/2001	9/24/2014	59	56	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/8/2001	9/24/2014	30	0	uncensored	0.153	0.192	0.238	none	none
Cadmium (d) (µg/L)	8/8/2001	9/24/2014	59	59	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/8/2001	9/24/2014	59	59	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/8/2001	9/24/2014	59	59	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/8/2001	9/24/2014	59	1	uncensored	30.2	58.9	145.4	none	not adjusted
Selenium (d) (µg/L)	5/23/2006	9/24/2014	40	0	uncensored	0.09	0.10	0.12	none	none
Silver (d) (µg/L)	8/8/2001	9/24/2014	59	59	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/8/2001	9/24/2014	59	59	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

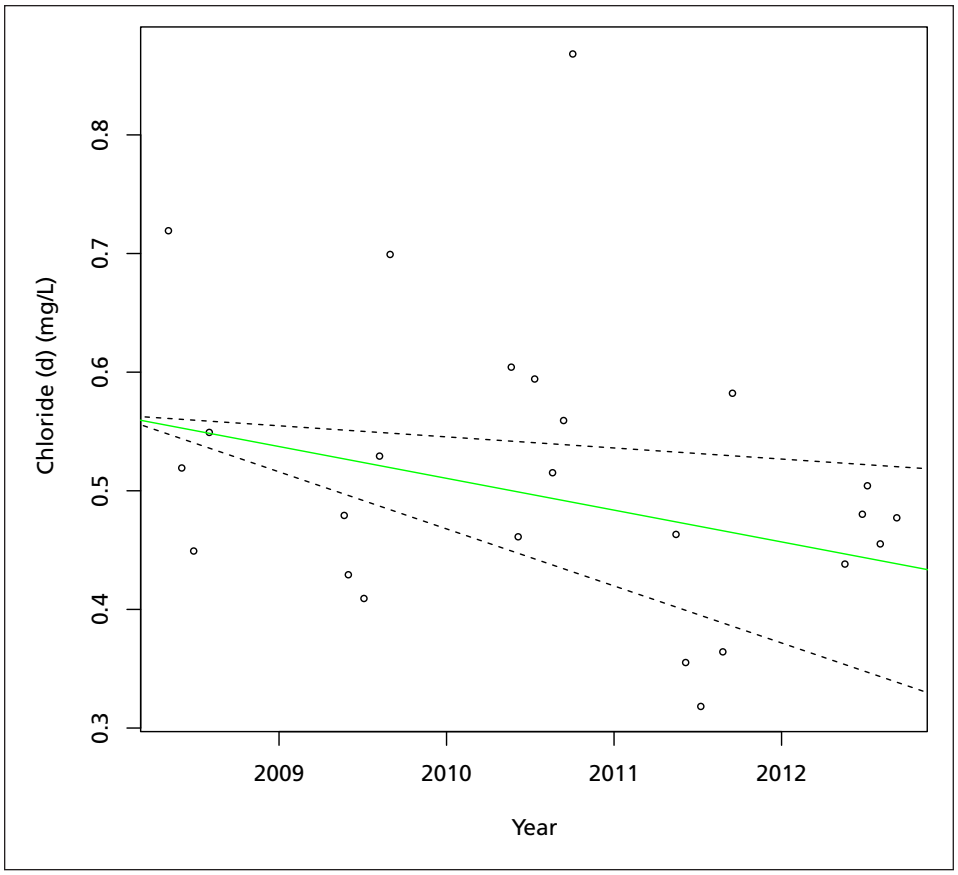


Figure 3-9. Statistically significant decrease in chloride over time at Red Creek (Kendall's tau = -0.486, p = 0.02). The estimated trend of -0.03 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

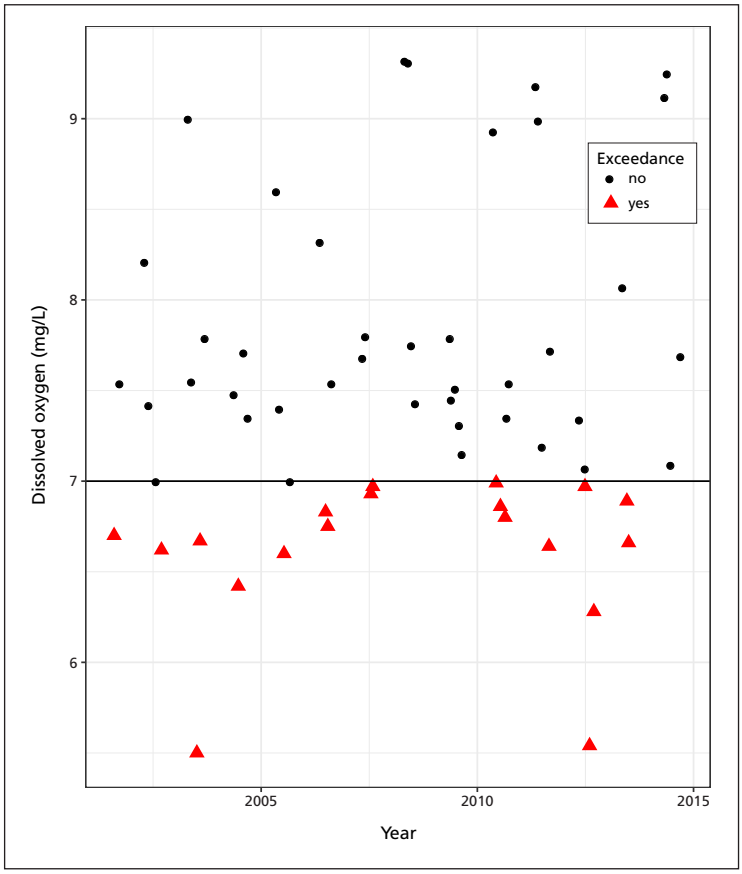


Figure 3-10. Dissolved oxygen exceedances at Red Creek. The black line indicates the aquatic-life cold-water 1 standard of 7.0 mg/L.

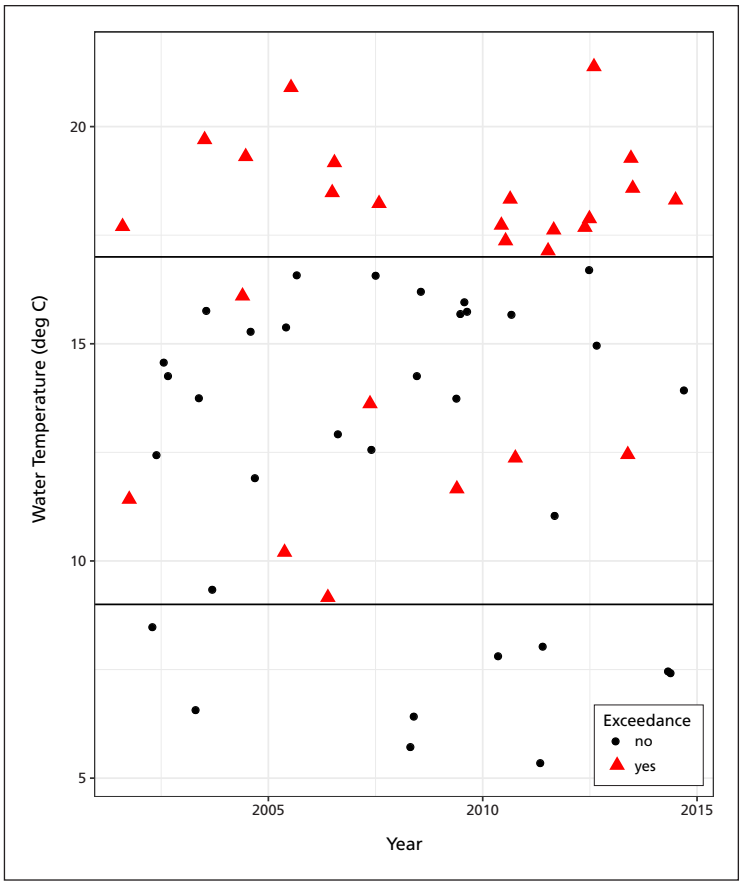


Figure 3-11. Water temperature exceedances at Red Creek. The lower line represents the aquatic-life cold-water 1 winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.

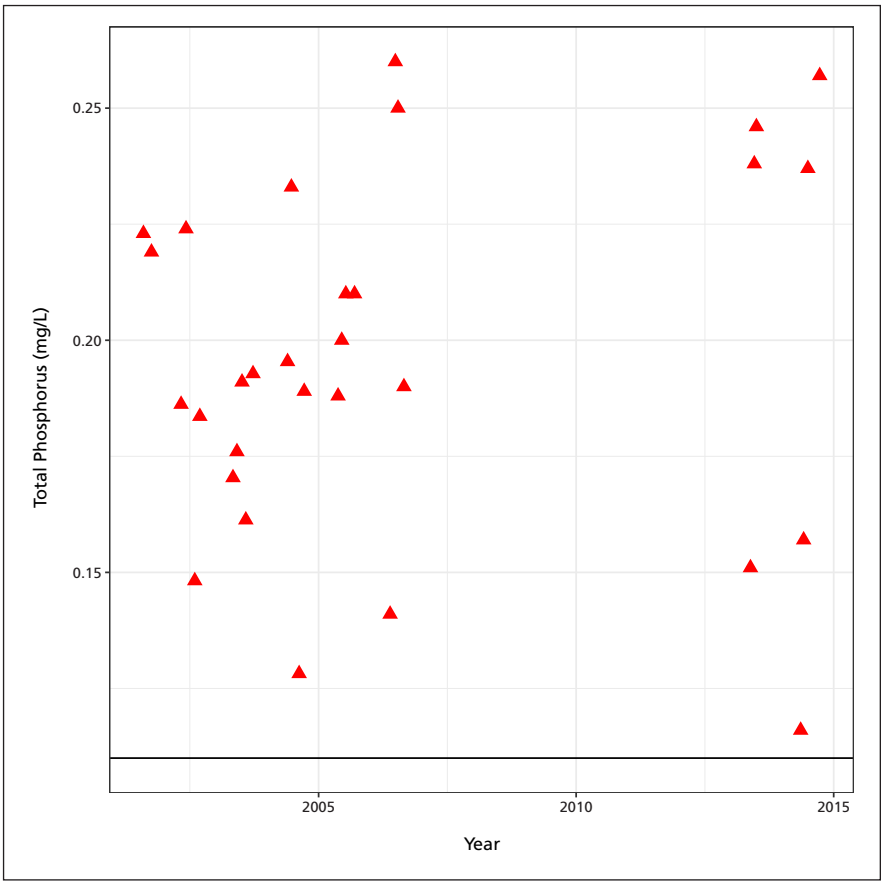


Figure 3-12. All samples exceeded the interim phosphorus criterion at Red Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.2.6 West Elk Creek below forest boundary near Sapinero, Colorado

West Elk Creek has been designated an Outstanding National Resource Water by the State of Colorado (CDPHE 2012). A majority of West Elk Creek lies in the West Elk Wilderness, managed by the USFS. The creek then crosses through BLM land and into NPS land before entering Blue Mesa Reservoir. This area is only accessible by boat or multiday hiking from USFS lands. There is a boat-in campground near the sampling site and an historic mill nearby where logging occurred in the 20th century. There is limited grazing upstream due to the steep terrain of the watershed.

Summary statistics and trend analysis results are presented in Table 3-9. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Raw pH decreased over time at a median annual rate of -0.02 pH units (Kendall's tau = -0.283, p = 0.05; Figure 3-13). The cause of the decrease is unknown.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, pH, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for dissolved oxygen and <10% exceedances for water temperature.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 11% of sample visits (3 of 28). No visible signs of eutrophication have been noted in the stream.

Table 3-9. Summary statistics for water-quality parameters at West Elk Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/21/2001	9/17/2014	50	0	uncensored	7.75	8.39	9.26	none	none
Escherichia coli (cfu/100 mL)	8/21/2001	9/17/2014	51	3	censored	1	4	20.5	none	–
Flow (cfs)	8/21/2001	9/17/2014	52	0	uncensored	4.23	17.3	76.7	none	–
pH	8/21/2001	9/17/2014	50	0	uncensored	7.64	7.89	8.12	↓	not adjusted
Specific conductance (µS/cm)	8/21/2001	9/17/2014	52	0	uncensored	49.6	64.4	86.0	none	none
Water temperature (°C)	8/21/2001	9/17/2014	51	0	uncensored	6.7	10.4	13.8	none	none
Calcium (d) (mg/L)	8/21/2001	9/17/2014	51	0	uncensored	6.23	7.47	10.55	none	none
Magnesium (d) (mg/L)	8/21/2001	9/17/2014	51	0	uncensored	1.18	1.45	1.99	none	none
Ammonia (d) (mg/L as N)	8/21/2001	9/17/2014	52	52	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/24/2009	9/17/2014	22	22	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	6/24/2009	9/17/2014	22	22	none	<0.028	<0.028	<0.028	–	–
Nitrite (d) (mg/L as N)	8/21/2001	9/17/2014	52	51	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/21/2001	9/17/2014	52	45	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/21/2001	9/17/2014	28	0	uncensored	0.052	0.067	0.097	none	none
Cadmium (d) (µg/L)	8/21/2001	9/17/2014	51	51	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/21/2001	9/17/2014	51	50	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/21/2001	9/17/2014	51	51	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/21/2001	9/17/2014	52	0	uncensored	1.16	1.74	2.84	none	not adjusted
Selenium (d) (µg/L)	5/30/2006	9/17/2014	33	30	none	<0.08	<0.08	<0.08	–	–
Silver (d) (µg/L)	8/21/2001	9/17/2014	51	51	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/21/2001	9/17/2014	51	50	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

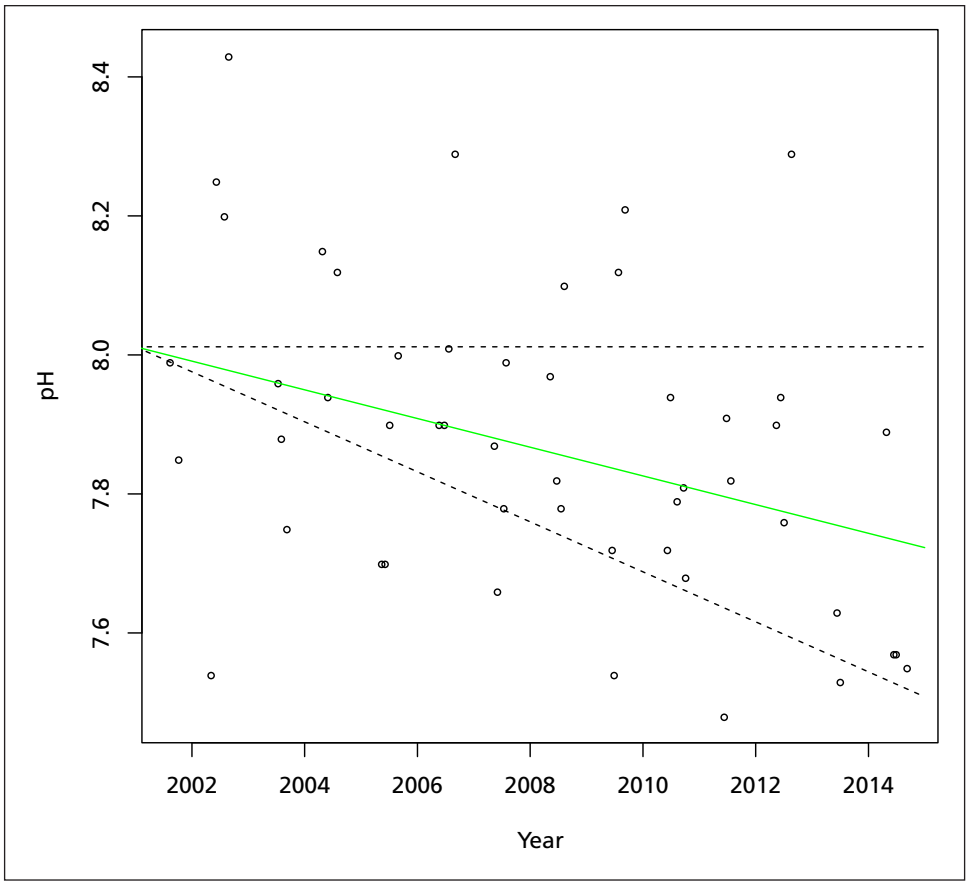


Figure 3-13. Statistically significant decrease in pH over time at West Elk Creek (Kendall's tau = -0.283, p = 0.05). The estimated trend of -0.02 pH units per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.2.7 Soap Creek above Chance Creek near Sapinero, Colorado

This sample site is located about one mile north of the NPS Ponderosa Campground. Bridge samples are collected during high flows and, when the creek is wadeable, samples are collected just downstream of the bridge. There are about 3,840 acres of private land in the Soap Creek watershed, surrounded primarily by USFS land, a small portion of BLM land, and NPS land. These private lands contain five residences. There are irrigation withdrawals from a portion of Soap Creek (Big Soap Park, private land). There is a USFS campground about a mile upstream of the sampling site. Four-wheel-drive roads continue up into the drainage to access private lands. The private lands were historically managed as farm and ranch lands and are still used for minimal cattle grazing today.

Summary statistics and trend analysis results are presented in Table 3-10. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There were no statistically significant trends in raw or flow-adjusted water-quality parameters.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, silver, selenium, and zinc.
- There were <10% exceedances for dissolved oxygen and phosphorus.
- Seasonally dependent water temperature criteria were exceeded on 12.5% of sample visits (7of 56). Continuous water temperature monitoring could be implemented at this site to better characterize water temperature in comparison to updated state standards.

Table 3-10. Summary statistics for water-quality parameters at Soap Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/15/2001	9/24/2014	55	0	uncensored	7.65	8.63	9.57	none	none
Escherichia coli (cfu/100 mL)	8/15/2001	9/24/2014	57	2	uncensored	3	11	25.6	none	none
Flow (cfs)	10/9/2001	9/24/2014	53	0	uncensored	8.38	27.5	154	none	–
pH	8/15/2001	9/24/2014	56	0	uncensored	7.81	8.08	8.53	none	none
Specific conductance (µS/cm)	8/15/2001	9/24/2014	56	0	uncensored	72.3	101	135	none	none
Water temperature (°C)	8/15/2001	9/24/2014	56	0	uncensored	6.6	10.8	15.1	none	none
Calcium (d) (mg/L)	8/15/2001	9/24/2014	56	0	uncensored	9.3	13.2	18.0	none	none
Chloride (d) (mg/L)	5/27/2008	9/18/2012	23	0	uncensored	0.24	0.32	0.45	none	not adjusted
Magnesium (d) (mg/L)	8/15/2001	9/24/2014	56	0	uncensored	1.70	2.53	3.44	none	none
Ammonia (d) (mg/L as N)	8/15/2001	9/24/2014	55	55	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/17/2009	9/24/2014	27	27	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	6/17/2009	9/24/2014	25	25	none	<0.03	<0.03	<0.03	–	–
Nitrite (d) (mg/L as N)	8/15/2001	9/24/2014	55	55	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/15/2001	9/24/2014	55	51	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/15/2001	9/24/2014	28	0	uncensored	0.028	0.039	0.052	none	not adjusted
Cadmium (d) (µg/L)	8/15/2001	9/24/2014	56	55	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/15/2001	9/24/2014	56	55	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/15/2001	9/24/2014	56	56	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/15/2001	9/24/2014	56	0	uncensored	1.51	2.38	4.34	none	not adjusted
Selenium (d) (µg/L)	6/20/2006	9/24/2014	38	0	uncensored	0.069	0.091	0.118	none	none
Silver (d) (µg/L)	8/15/2001	9/24/2014	56	56	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/15/2001	9/24/2014	56	56	none	<2.8	<2.8	<2.8	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

3.3 Southern tributaries to Blue Mesa Reservoir, upstream to downstream

3.3.1 Cebolla Creek at Powderhorn, Colorado

Cebolla Creek is sampled from a bridge on County Road 29 about 11 miles upstream from the NPS boundary. This watershed is made up of USFS land, BLM land, and private land. There are multiple private ranches with cattle grazing operations and irrigation diversions. There are two current proposals for private mining operations within this watershed.

Summary statistics and trend analysis results are presented in Table 3-11. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There were no statistically significant trends in raw or flow-adjusted concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for ammonia, nitrite, cadmium, copper, lead, manganese, silver, and zinc.
- There were <5% exceedances for *E. coli* and pH and <10% exceedances for dissolved oxygen, water temperature, and phosphorus.

Table 3-11. Summary statistics for water-quality parameters at Cebolla Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/9/2001	9/2/2014	41	0	uncensored	7.49	8.20	9.01	none	not adjusted
Escherichia coli (cfu/100 mL)	8/9/2001	9/2/2014	46	0	uncensored	11.3	26	67.5	none	not adjusted
Flow (cfs)	8/9/2001	9/2/2014	42	0	uncensored	38.2	57.1	146	none	–
pH	8/9/2001	9/2/2014	42	0	uncensored	7.50	7.80	8.09	none	none
Specific conductance (µS/cm)	8/9/2001	9/2/2014	42	0	uncensored	125	143	167	none	none
Water temperature (°C)	8/9/2001	9/2/2014	41	0	uncensored	7.4	12.4	16.8	none	not adjusted
Calcium (d) (mg/L)	8/9/2001	9/2/2014	42	0	uncensored	15.2	18.2	21.4	none	none
Magnesium (d) (mg/L)	8/9/2001	9/2/2014	42	0	uncensored	2.88	3.20	3.89	none	none
Ammonia (d) (mg/L as N)	8/9/2001	9/2/2014	42	38	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/9/2001	9/2/2014	24	2	censored	0.119	0.223	0.318	none	–
Nitrite (d) (mg/L as N)	8/9/2001	9/2/2014	42	42	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/9/2001	9/2/2014	42	37	none	<0.022	<0.022	<0.022	–	–
Orthophosphate (d) (mg/L as P)	8/9/2001	9/2/2014	33	0	uncensored	0.032	0.041	0.100	none	not adjusted
Phosphorus (mg/L as P)	8/9/2001	9/2/2014	42	0	uncensored	0.050	0.067	0.083	none	none
Cadmium (d) (µg/L)	8/9/2001	9/2/2014	42	41	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/9/2001	9/2/2014	42	35	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/9/2001	9/2/2014	42	42	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/9/2001	9/2/2014	42	0	uncensored	14.03	23.01	45.34	none	not adjusted
Silver (d) (µg/L)	8/9/2001	9/2/2014	42	42	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/9/2001	9/2/2014	42	40	none	<2	<2	<2	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

3.3.2 Lake Fork Gunnison River below Gateview, Colorado

The Lake Fork of the Gunnison River is sampled on BLM land at the Red Bridge Campground adjacent to NPS property. Bridge samples are collected from Red Bridge during high flows and, when wadeable, samples are collected upstream of the bridge. A majority of the Lake Fork flows through private land in and around Lake City, as well as some USFS land, BLM land, and NPS land. Henson Creek, the largest tributary to the Lake Fork, originates in the BLM American Flats Wilderness. The Lake Fork watershed has a history of large silver and gold mines, with two mines still currently in operation. Abandoned mine reclamation projects are ongoing. Lake San Cristobal, the second-largest natural lake in Colorado, is located on the Lake Fork River. This lake has recently been developed to increase storage and control releases. There is a hydroelectric power facility upstream as well as a wastewater treatment plant that discharges into the Lake Fork. Many private residences also have septic systems along the river. There are many paved and dirt roads that parallel the Lake Fork, with regular magnesium-chloride treatments on the dirt roads to suppress dust. Lastly, there are irrigated meadows on private land with active cattle grazing throughout the watershed. This site is co-located with USGS gaging station 09124500.

Summary statistics and trend analysis results are presented in Table 3-12. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Flow-adjusted pH decreased over time at a median annual rate of -0.02 pH units (Kendall's tau = -0.202, p = 0.028; Figure 3-14). The cause of decreased pH is unknown.
- Flow-adjusted magnesium increased at a median annual rate of 0.04 mg/L (Kendall's tau = 0.339, p = 0.037; Figure 3-15). Increases in flow-adjusted magnesium concentrations may be related to the use of magnesium-chloride dust suppressants in the watershed, although there was no corresponding increase in chloride concentrations. Some other sites with dust suppressants in their watersheds have shown decreases in chloride concentrations. Tributaries located both to the north and south of Blue Mesa Reservoir are in Gunnison County, and dust suppressants would be applied by the same county department.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, pH, chloride, ammonia, nitrite, cadmium, manganese, selenium, silver, and zinc.
- There were <5% exceedances for dissolved oxygen, water temperature, phosphorus, copper, and lead.

Table 3-12. Summary statistics for water-quality parameters at Lake Fork Gunnison River, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/9/2001	9/22/2014	57	0	uncensored	7.60	8.18	9.26	none	none
Escherichia coli (cfu/100 mL)	8/9/2001	9/22/2014	63	3	uncensored	1	6	15	none	not adjusted
Flow (cfs)	8/9/2001	9/22/2014	55	0	uncensored	108	231	720	none	–
pH	8/9/2001	9/22/2014	57	0	uncensored	7.70	7.99	8.20	none	↓
Specific conductance (µS/cm)	8/9/2001	9/22/2014	57	0	uncensored	116	149	180	none	none
Water temperature (°C)	8/9/2001	9/22/2014	57	0	uncensored	7.5	11.6	15.3	none	none
Calcium (d) (mg/L)	8/9/2001	9/22/2014	57	0	uncensored	16.1	20.8	25.5	none	none
Chloride (d) (mg/L)	5/22/2008	9/24/2012	23	0	uncensored	0.44	0.74	0.91	none	none
Magnesium (d) (mg/L)	8/9/2001	9/22/2014	57	0	uncensored	2.05	2.68	3.34	none	↑
Ammonia (d) (mg/L as N)	8/9/2001	9/22/2014	56	56	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/3/2009	9/22/2014	26	26	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/9/2001	9/22/2014	27	15	none	<0.1	<0.1	0.149	–	–
Nitrate (d) (mg/L as NO_3)	6/3/2009	9/22/2014	25	25	none	<0.261	<0.261	<0.261	–	–
Nitrite (d) (mg/L as N)	8/9/2001	9/22/2014	56	56	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/9/2001	9/22/2014	56	41	none	<0.022	<0.022	0.046	–	–
Orthophosphate (d) (mg/L as P)	8/9/2001	7/24/2007	26	14	none	<0.007	<0.007	0.015	–	–
Phosphorus (mg/L as P)	8/9/2001	9/22/2014	34	0	uncensored	0.015	0.021	0.050	none	none
Cadmium (d) (µg/L)	8/9/2001	9/22/2014	57	0	uncensored	0.039	0.057	0.086	none	none
Copper (d) (µg/L)	8/9/2001	9/22/2014	57	8	censored	0.802	1.148	1.674	none	–
Lead (d) (µg/L)	8/9/2001	9/22/2014	57	0	uncensored	0.131	0.191	0.316	none	not adjusted
Manganese (d) (µg/L)	8/9/2001	9/22/2014	57	0	uncensored	8.39	12.39	19.64	none	not adjusted
Selenium (d) (µg/L)	5/16/2006	9/22/2014	38	0	uncensored	0.058	0.069	0.084	none	none
Silver (d) (µg/L)	8/9/2001	9/22/2014	57	57	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/9/2001	9/22/2014	57	1	uncensored	3.9	5.8	10.0	none	none

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

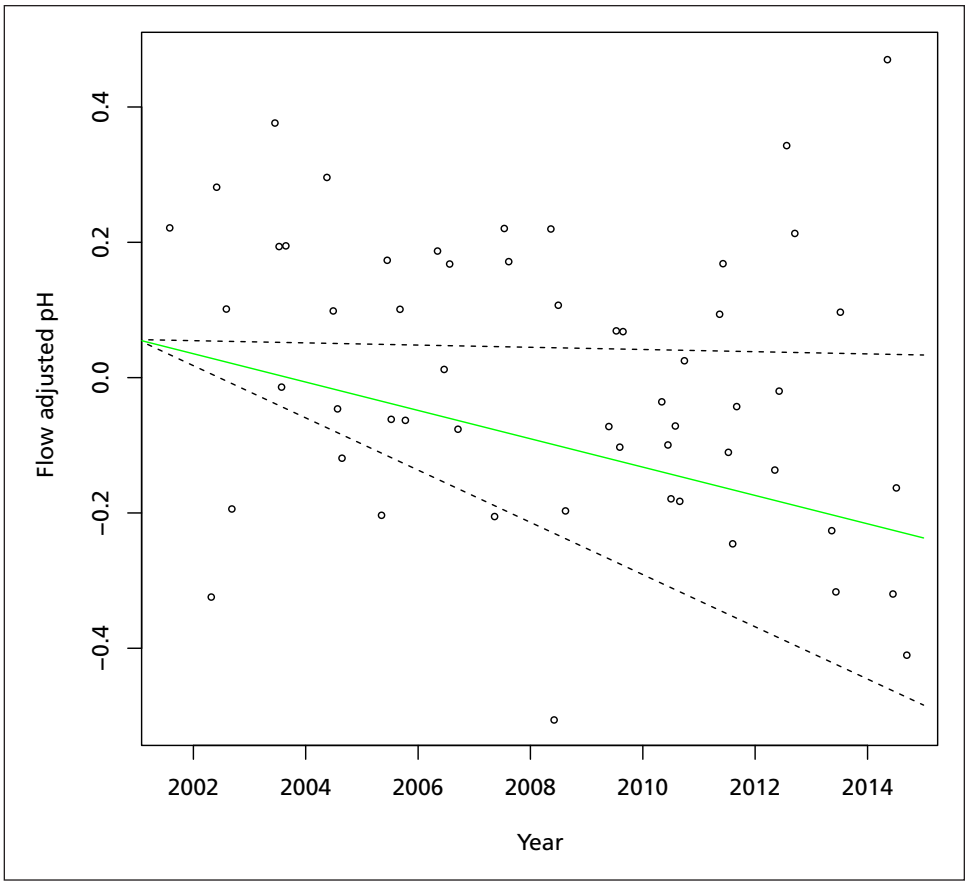


Figure 3-14. Statistically significant decrease in flow-adjusted pH over time at the Lake Fork Gunnison River (Kendall's tau = -0.202, p = 0.03). The estimated trend of -0.02 pH units per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

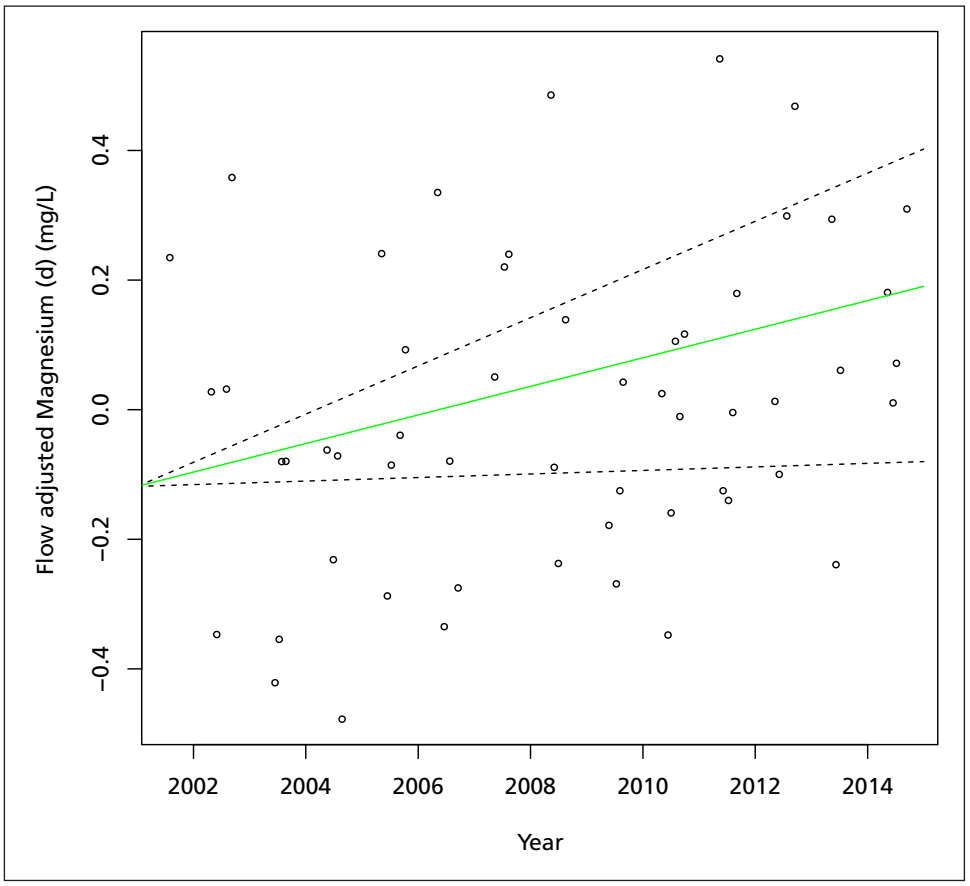


Figure 3-15. Statistically significant increase in flow-adjusted magnesium concentrations over time at the Lake Fork of the Gunnison River (Kendall's tau = 0.339, p = 0.04). The estimated trend of 0.04 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.4 Blue Mesa Reservoir

Blue Mesa Reservoir is the most upstream reservoir in the Aspinall Unit. It is also the shallowest of the three reservoirs. Limited fish kills were observed in the Cebolla Basin area near the middle of the reservoir in 2013, following a winter with extremely low snowpack and low inputs into the reservoir.

3.4.1 Blue Mesa Reservoir below Highway 149 near Gunnison, Colorado

This site is located in the Iola basin of Blue Mesa Reservoir. The sample is collected from the deepest point over the old Gunnison River channel near the Stevens Creek boat ramp. This basin is located on the eastern side of the reservoir and is the most upstream basin, with the Gunnison River as the only perennial tributary. During low water years, this site can be too shallow to access.

Summary statistics and trend analysis results are presented in Table 3-13. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There were no trends in raw concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, ammonia, nitrite, phosphorus, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for pH and <10% exceedances for chlorophyll-*a*. Although this site remained in compliance for chlorophyll-*a* during our period of record, the presence of fish kills in the reservoir in 2013 suggests that algal blooms are a concern in the reservoir.
- Dissolved oxygen was below the reservoir water-quality standard minima of 7.0 mg/L on 23% of sample visits (13 of 56; Figure 3-16). Seasonally dependent water temperature criteria were exceeded on 33% of sample visits (19 of 57; Figure 3-17). Lake profiles for dissolved oxygen and water temperature monitoring have been implemented at this site to better characterize these parameters in comparison to updated state standards. The NPS is also working with the state to increase nutrient sampling in the reservoir to better understand conditions that could lead to fish kills, particularly in low water years.

Table 3-13. Summary statistics for water-quality parameters at Blue Mesa Reservoir below highway 149 near Gunnison, Colorado, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Chlorophyll-*a*, uncorrected for pheophytin (µg/L)	5/28/2009	7/29/2013	22	0	uncensored	1.42	2.14	5.86	none
Dissolved oxygen (mg/L)	8/21/2001	9/4/2014	56	0	uncensored	6.85	7.47	8.52	none
Escherichia coli (cfu/100 mL)	8/21/2001	9/4/2014	56	21	censored	<1	1	5.8	none
pH	8/21/2001	9/4/2014	57	0	uncensored	8.15	8.37	8.61	none
Secchi Disk Depth (m)	5/28/2009	9/4/2014	28	0	uncensored	1.90	3.28	4.36	none
Specific conductance (µS/cm)	8/21/2001	9/4/2014	57	0	uncensored	186	213	241	none
Water temperature (°C)	8/21/2001	9/4/2014	57	0	uncensored	12.5	17.5	20.2	none
Calcium (d) (mg/L)	8/21/2001	9/4/2014	57	0	uncensored	26.3	31.0	35.7	none
Magnesium (d) (mg/L)	8/21/2001	9/4/2014	57	0	uncensored	5.41	6.12	7.20	none
Ammonia (d) (mg/L as N)	8/21/2001	9/4/2014	56	54	none	<0.02	<0.02	<0.02	–
Ammonia, un-ionized (mg/L)	5/28/2009	9/4/2014	28	28	none	<0.02	<0.02	<0.02	–
Nitrate (d) (mg/L as NO_3)	5/28/2009	9/4/2014	28	28	none	<0.024	<0.024	<0.024	–
Nitrite (d) (mg/L as N)	8/21/2001	9/4/2014	57	56	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/21/2001	9/4/2014	57	53	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/21/2001	9/4/2014	57	0	uncensored	0.011	0.023	0.037	none
Cadmium (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/21/2001	9/4/2014	57	49	none	<1	<1	<1	–
Lead (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/21/2001	9/4/2014	57	0	uncensored	1.22	3.51	23.5	none
Selenium (d) (µg/L)	5/24/2006	9/4/2014	40	0	uncensored	0.122	0.156	0.207	none
Silver (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/21/2001	9/4/2014	57	55	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

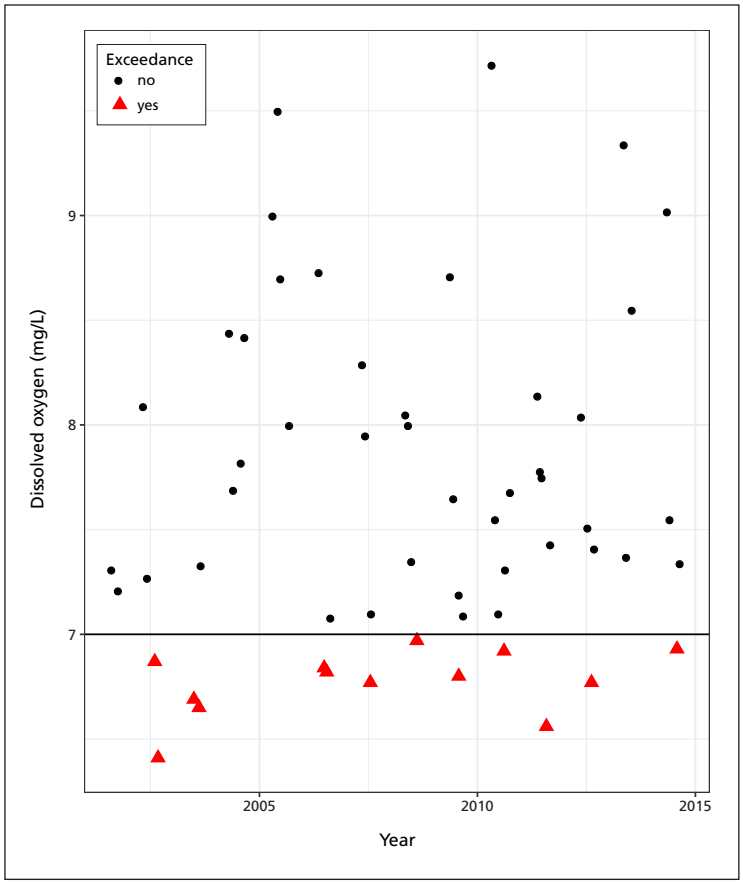


Figure 3-16. Dissolved oxygen exceedances in Blue Mesa Reservoir below Highway 149. The black line indicates the reservoir standard of 7.0 mg/L.

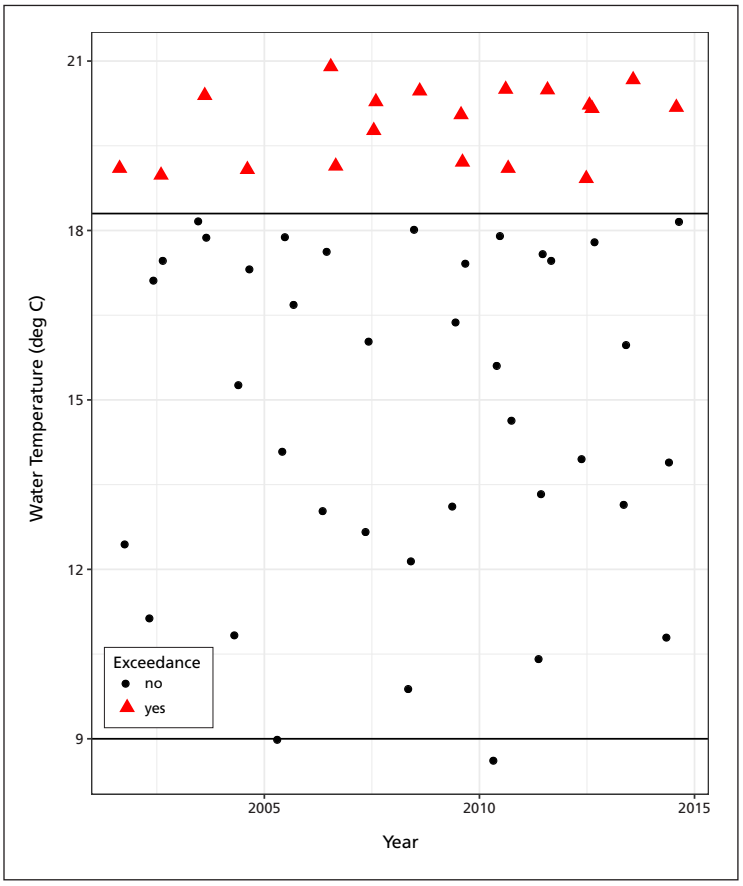


Figure 3-17. Water temperature exceedances in Blue Mesa Reservoir below Highway 149. The lower line represents the reservoir winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.

3.4.2 Blue Mesa Reservoir above Cebolla Creek near Sapinero, Colorado

This site is located over the deepest point of the old Gunnison River channel, across from the Cebolla Creek inlet in Blue Mesa Reservoir. This site represents the middle section of the reservoir between upstream and downstream sections, with inputs from Cebolla Creek, East Elk Creek, and Red Creek.

Summary statistics and trend analysis results are presented in Table 3-14. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There were no statistically significant trends in raw concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for chlorophyll-*a*, *E. coli*, pH, ammonia, nitrite, phosphorus, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- Dissolved oxygen was below the reservoir water-quality standard minima of 7.0 mg/L on 41% of sample visits (23 of 56; Figure 3-18). Seasonally dependent water temperature criteria were exceeded on 35% of sample visits (20 of 57; Figure 3-19). Localized fish kills in the Cebolla Basin in 2013 indicate that low dissolved oxygen levels are of management concern. Lake profiles for dissolved oxygen and water temperature monitoring have been implemented at this site to better characterize these parameters in comparison to updated state standards. The NPS is also working with the state to increase nutrient sampling in the reservoir to better understand conditions that could lead to fish kills, particularly in low water years.

Table 3-14. Summary statistics for water-quality parameters at Blue Mesa Reservoir above Cebolla Creek, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Chlorophyll-*a*, uncorrected for pheophytin (µg/L)	5/28/2009	7/29/2013	21	0	uncensored	0.84	1.61	2.97	none
Dissolved oxygen (mg/L)	8/21/2001	9/4/2014	56	0	uncensored	6.71	7.41	8.80	none
Escherichia coli (cfu/100 mL)	8/21/2001	9/4/2014	55	53	none	<3	<3	<3	–
pH	8/21/2001	9/4/2014	57	0	uncensored	8.29	8.42	8.59	none
Secchi Disk Depth (m)	5/28/2009	9/4/2014	28	0	uncensored	2.87	4.10	5.00	none
Specific conductance (µS/cm)	8/21/2001	9/4/2014	57	0	uncensored	184	203	223	none
Water temperature (°C)	8/21/2001	9/4/2014	57	0	uncensored	12.2	17.7	20.2	none
Calcium (d) (mg/L)	8/21/2001	9/4/2014	57	0	uncensored	25.5	28.4	32.5	none
Magnesium (d) (mg/L)	8/21/2001	9/4/2014	57	0	uncensored	5.18	5.71	6.35	none
Ammonia (d) (mg/L as N)	8/21/2001	9/4/2014	56	55	none	<0.02	<0.02	<0.02	–
Ammonia, un-ionized (mg/L)	5/28/2009	9/4/2014	28	28	none	<0.02	<0.02	<0.02	–
Nitrate (d) (mg/L as NO_3)	5/28/2009	9/4/2014	28	25	none	<0.014	<0.014	<0.014	–
Nitrite (d) (mg/L as N)	8/21/2001	9/4/2014	56	55	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/21/2001	9/4/2014	57	56	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/21/2001	9/4/2014	55	9	uncensored	<0.008	0.012	0.022	none
Cadmium (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/21/2001	9/4/2014	57	52	none	<1	<1	<1	–
Lead (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/21/2001	9/4/2014	57	0	uncensored	0.62	1.46	6.68	none
Selenium (d) (µg/L)	5/24/2006	9/4/2014	40	0	uncensored	0.109	0.156	0.199	none
Silver (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/21/2001	9/4/2014	57	57	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

Figure 3-18. Dissolved oxygen exceedances in Blue Mesa Reservoir above Cebolla Creek. The black line indicates the reservoir standard of 7.0 mg/L.

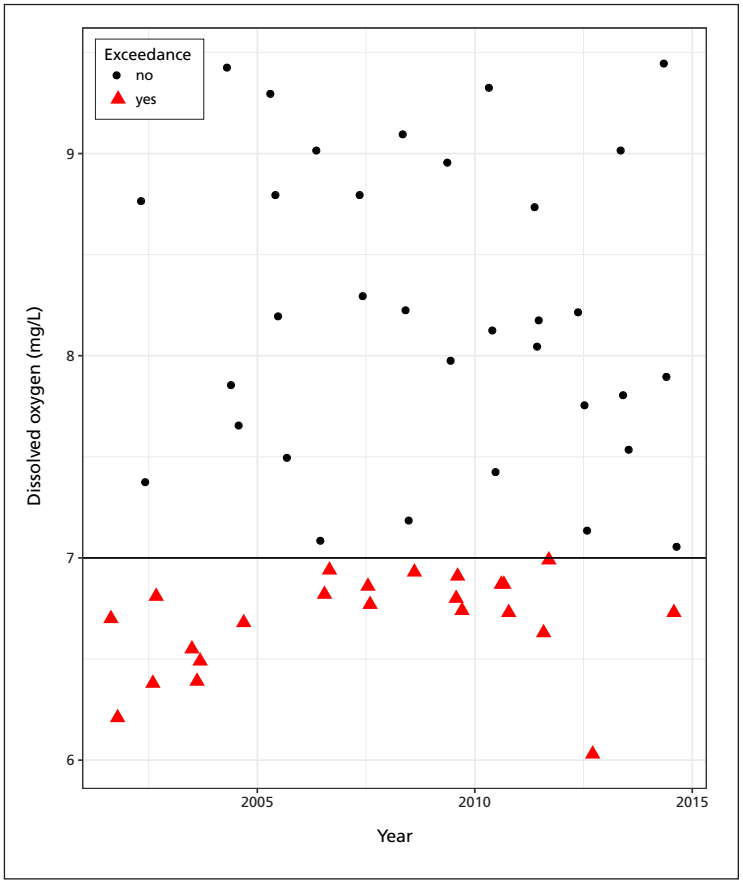
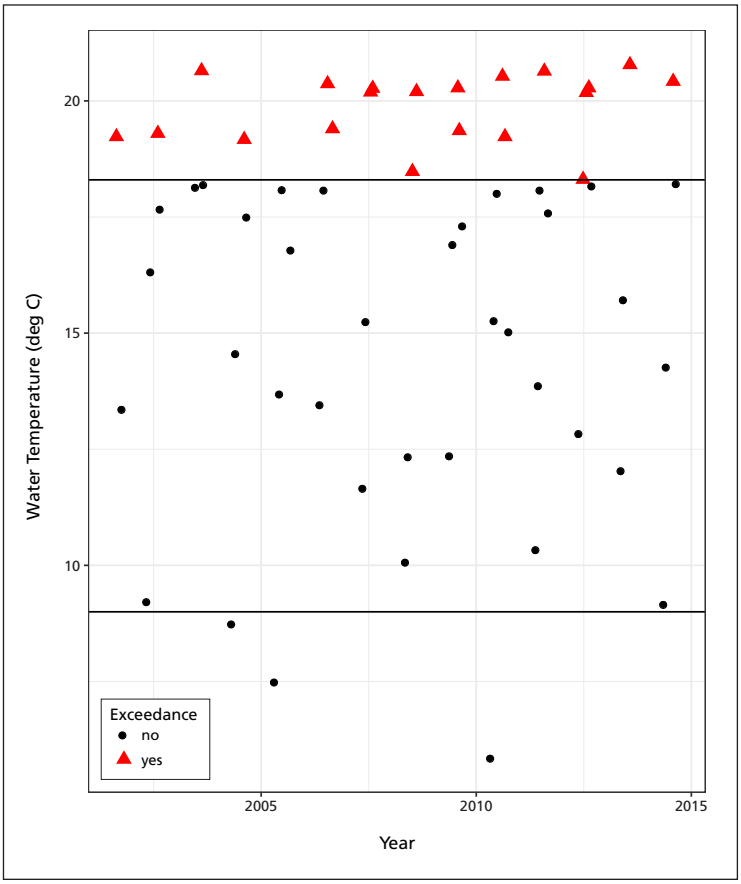


Figure 3-19. Water temperature exceedances in Blue Mesa Reservoir above Cebolla Creek. The lower line represents the reservoir winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.



3.4.3 Blue Mesa Reservoir above Soap Creek near Sapinero, Colorado

This site is located in the Sapinero basin of Blue Mesa Reservoir, closest to the dam. The sample is collected over the deepest point of the old Gunnison River channel, between the Lake Fork and Soap Creek inlets. This basin is located on the western side of the reservoir, with inputs from West Elk Creek, Soap Creek, and the Lake Fork of the Gunnison River.

Summary statistics and trend analysis results are presented in Table 3-15. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There were no statistically significant trends in raw concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for chlorophyll-*a*, *E. coli*, pH, ammonia, nitrite, phosphorus, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- Dissolved oxygen was below the reservoir water-quality standard minima of 7.0 mg/L on 39% of sample visits (21 of 54; Figure 3-20). Seasonally dependent water temperature criteria were exceeded on 31% of sample visits (17 of 55; Figure 3-21). Lake profiles for dissolved oxygen and water temperature monitoring have been implemented at this site to better characterize these parameters in comparison to updated state standards. The NPS is also working with the state to maximize nutrient sampling in the reservoir to better understand conditions that could lead to impairment, particularly in low water years.

Table 3-15. Summary statistics for water-quality parameters at Blue Mesa Reservoir above Soap Creek, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Chlorophyll-*a*, uncorrected for pheophytin (µg/L)	5/28/2009	7/29/2013	22	0	uncensored	0.77	1.33	2.19	none
Dissolved oxygen (mg/L)	8/21/2001	9/4/2014	54	0	uncensored	6.75	7.36	8.95	none
Escherichia coli (cfu/100 mL)	8/21/2001	9/4/2014	54	32	none	<1	<1	1	–
pH	8/21/2001	9/4/2014	55	0	uncensored	8.17	8.39	8.52	none
Secchi Disk Depth (m)	5/28/2009	9/4/2014	28	0	uncensored	2.59	3.79	4.91	none
Specific conductance (µS/cm)	8/21/2001	9/4/2014	55	0	uncensored	178	188	209	none
Water temperature (°C)	8/21/2001	9/4/2014	55	0	uncensored	10.9	17.2	19.8	none
Calcium (d) (mg/L)	8/21/2001	9/4/2014	56	0	uncensored	24.4	27.0	30.5	none
Magnesium (d) (mg/L)	8/21/2001	9/4/2014	56	0	uncensored	4.71	5.14	5.63	none
Ammonia (d) (mg/L as N)	8/21/2001	9/4/2014	55	54	none	<0.02	<0.02	<0.02	–
Ammonia, un-ionized (mg/L)	5/28/2009	9/4/2014	27	27	none	<0.02	<0.02	<0.02	–
Nitrate (d) (mg/L as NO_3)	5/28/2009	9/4/2014	28	28	none	<0.0348	<0.0348	<0.0348	–
Nitrite (d) (mg/L as N)	8/21/2001	9/4/2014	56	56	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/21/2001	9/4/2014	56	55	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/21/2001	9/4/2014	56	23	uncensored	<0.008	0.009	0.015	none
Cadmium (d) (µg/L)	8/21/2001	9/4/2014	56	56	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/21/2001	9/4/2014	56	46	none	<1	<1	1	–
Lead (d) (µg/L)	8/21/2001	9/4/2014	56	50	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/21/2001	9/4/2014	56	0	uncensored	0.50	1.09	5.18	none
Selenium (d) (µg/L)	5/30/2006	9/4/2014	39	0	uncensored	0.100	0.140	0.171	none
Silver (d) (µg/L)	8/21/2001	9/4/2014	56	56	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/21/2001	9/4/2014	56	55	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

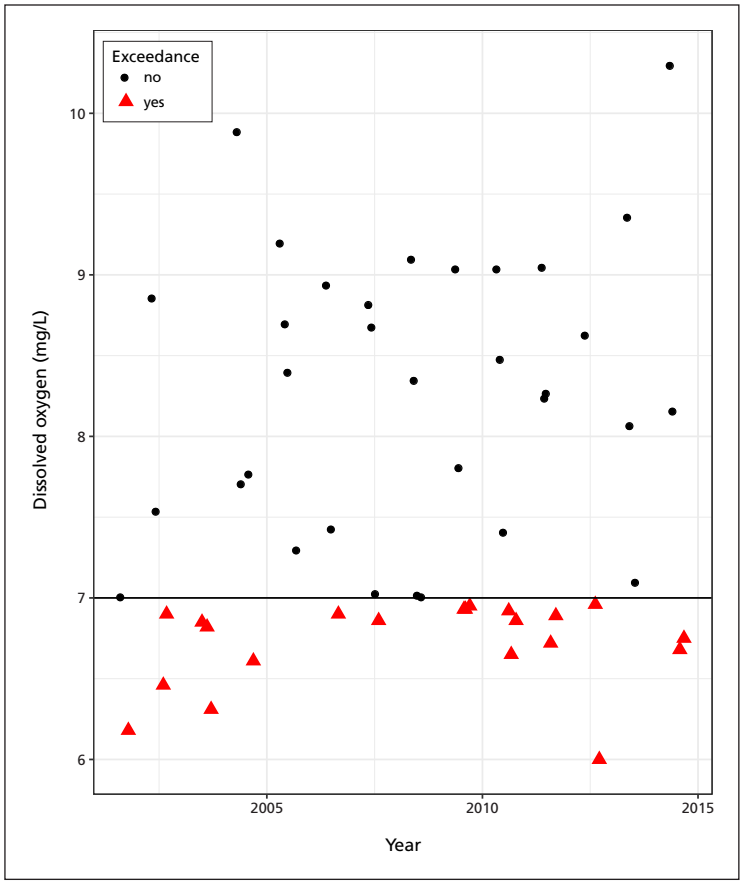


Figure 3-20. Dissolved oxygen exceedances in Blue Mesa Reservoir above Soap Creek. The black line indicates the reservoir standard of 7.0 mg/L.

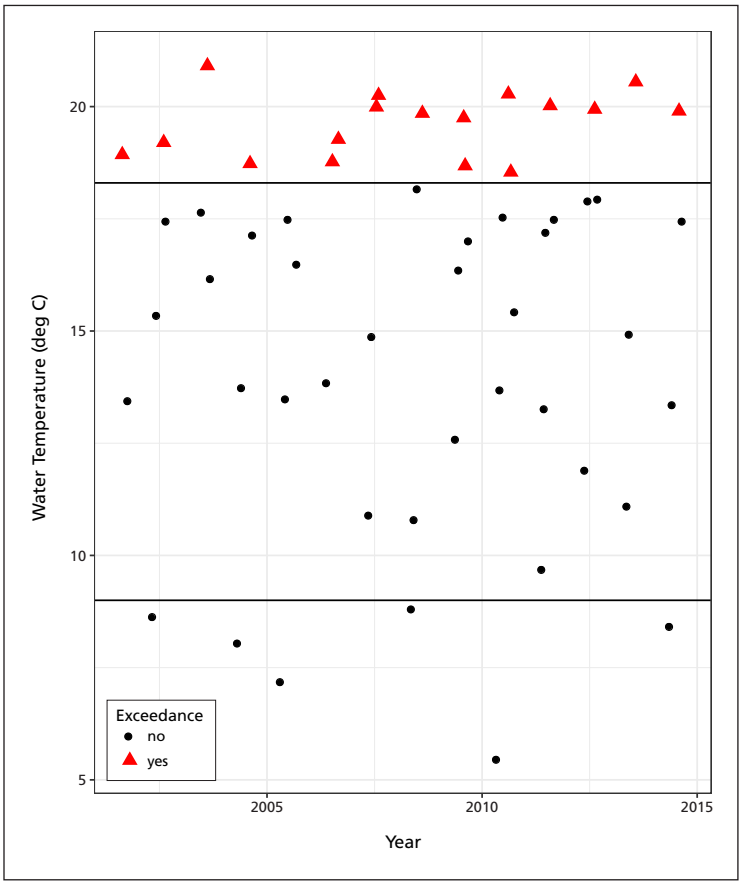


Figure 3-21. Water temperature exceedances in Blue Mesa Reservoir above Soap Creek. The lower line represents the reservoir winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.

3.5 Tributaries to Morrow Point Reservoir

3.5.1 Pine Creek at Highway 50 near Sapinero, Colorado

The Pine Creek samples are collected from a point next to the NPS Pine Creek Trail, about 100 feet from the trailhead. This site is located at the end of a small pool between steep, rocky sections. Pine Creek is a popular trail for NPS visitors to access Morrow Point Reservoir. Pit toilets are located at the trailhead just upstream of the monitoring site. Some paved and dirt roads parallel about three miles of the creek, and magnesium chloride is used as a dust suppressant in dry months. The stream is predominantly spring-fed. Private residences along the stream were historically used as cattle ranches but have been converted to private residences. There are about 20 homes currently in this watershed with septic systems and private wells. There is Ute tribal land in the headwaters that is used primarily for grazing.

Summary statistics and trend analysis results are presented in Table 3-16. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There were several statistically significant trends in raw and flow-adjusted concentrations in Pine Creek.
- Raw and flow-adjusted dissolved oxygen increased over time. Dissolved oxygen increased by 5.2% over the period of record at a median annual rate of 0.03 mg/L (Kendall's tau = 0.159, p = 0.012; Figure 3-22); flow-adjusted dissolved oxygen had a slope of 0.04 (Kendall's tau = 0.111, p=0.029; Figure 3-23).
- Flow-adjusted specific conductance decreased (Kendall's tau = -0.439, p = 0.004, slope = -0.99; Figure 3-24), as did flow-adjusted concentrations of calcium (Kendall's tau = -0.279, p = 0.018, slope = -0.14; Figure 3-25), and chloride (Kendall's tau = -0.54, p = 0.02, slope = -0.14; Figure 3-26).
- Raw concentrations of nitrite plus nitrate increased by 53% over the period of record at a median annual rate of 0.001 mg/L (Kendall's tau = 0.198, p = 0.05; Figure 3-27).
- Raw concentrations of selenium increased 19% at a rate of 0.002 µg/L per year (Kendall's tau = 0.288, p = 0.05; Figure 3-28).

Exceedances

- There were no exceedances of state water-quality standards for pH, chloride, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for dissolved oxygen and *E. coli* and <10% exceedances for water temperature.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 70% of sample visits (23 of 33; Figure 3-29). No visible signs of eutrophication have been noted in the stream.

Changes in water quality in Pine Creek are a mixture of improving and degrading trends. The watershed is fairly small and undeveloped. No significant changes in land use have occurred during the period of record, with the exception of the development of a few private residences. Decreases in flow-adjusted concentrations of calcium and chloride, and in specific conductance, may be linked to better targeting of dust suppressants on roads over time, with less spillover into the creek—and a switch from calcium chloride to magnesium chloride. Increases in dissolved oxygen may simply be due to variability within the cascading pool-drop system, which makes precise re-location of the sampling point over time difficult. Increases in nitrite plus nitrate and selenium are concerning but still at low concentrations. Residential septic systems or park pit toilets could contribute to increases in nitrite plus nitrate concentrations and could be checked for leaks. The sampling site at Pine Creek is located in the Mancos Shale, a well-known geologic source for selenium.

Table 3-16. Summary statistics for water-quality parameters at Pine Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/13/2001	9/8/2014	55	0	uncensored	7.6	8.06	8.99	↑	↑
Escherichia coli (cfu/100 mL)	8/13/2001	9/8/2014	63	0	uncensored	3	15	63.3	none	not adjusted
Flow (cfs)	10/11/2001	9/8/2014	53	0	uncensored	1.38	2.51	7.23	none	–
pH	8/13/2001	9/8/2014	55	0	uncensored	7.92	8.10	8.25	none	none
Specific conductance (µS/cm)	8/13/2001	9/8/2014	55	0	uncensored	103	128	141	none	↓
Water temperature (°C)	8/13/2001	9/8/2014	55	0	uncensored	8.1	12.4	15.0	none	none
Calcium (d) (mg/L)	8/13/2001	9/8/2014	55	0	uncensored	13.4	17.1	19.1	none	↓
Chloride (d) (mg/L)	6/17/2008	9/27/2012	22	0	uncensored	1.21	1.57	2.06	none	↓
Magnesium (d) (mg/L)	8/13/2001	9/8/2014	55	0	uncensored	2.70	3.32	3.70	none	none
Ammonia (d) (mg/L as N)	8/13/2001	9/8/2014	54	54	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/8/2009	9/8/2014	27	27	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/13/2001	9/8/2014	26	2	censored	0.188	0.260	0.426	none	–
Nitrate (d) (mg/L as NO_3)	6/8/2009	9/8/2014	25	24	none	<0.06	<0.06	<0.06	–	–
Nitrite (d) (mg/L as N)	8/13/2001	9/8/2014	54	54	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/13/2001	9/8/2014	54	0	uncensored	0.012	0.027	0.051	↑	none
Orthophosphate (d) (mg/L as P)	8/13/2001	9/25/2006	22	0	uncensored	0.044	0.068	0.085	none	not adjusted
Phosphorus (mg/L as P)	8/13/2001	9/8/2014	33	0	uncensored	0.098	0.125	0.150	none	none
Cadmium (d) (µg/L)	8/13/2001	9/8/2014	55	53	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/13/2001	9/8/2014	55	46	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/13/2001	9/8/2014	55	50	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/13/2001	9/8/2014	55	0	uncensored	6.7	10.7	15.7	none	none
Selenium (d) (µg/L)	5/17/2006	9/8/2014	37	0	uncensored	0.080	0.094	0.119	↑	not adjusted
Silver (d) (µg/L)	8/13/2001	9/8/2014	55	55	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/13/2001	9/8/2014	55	50	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

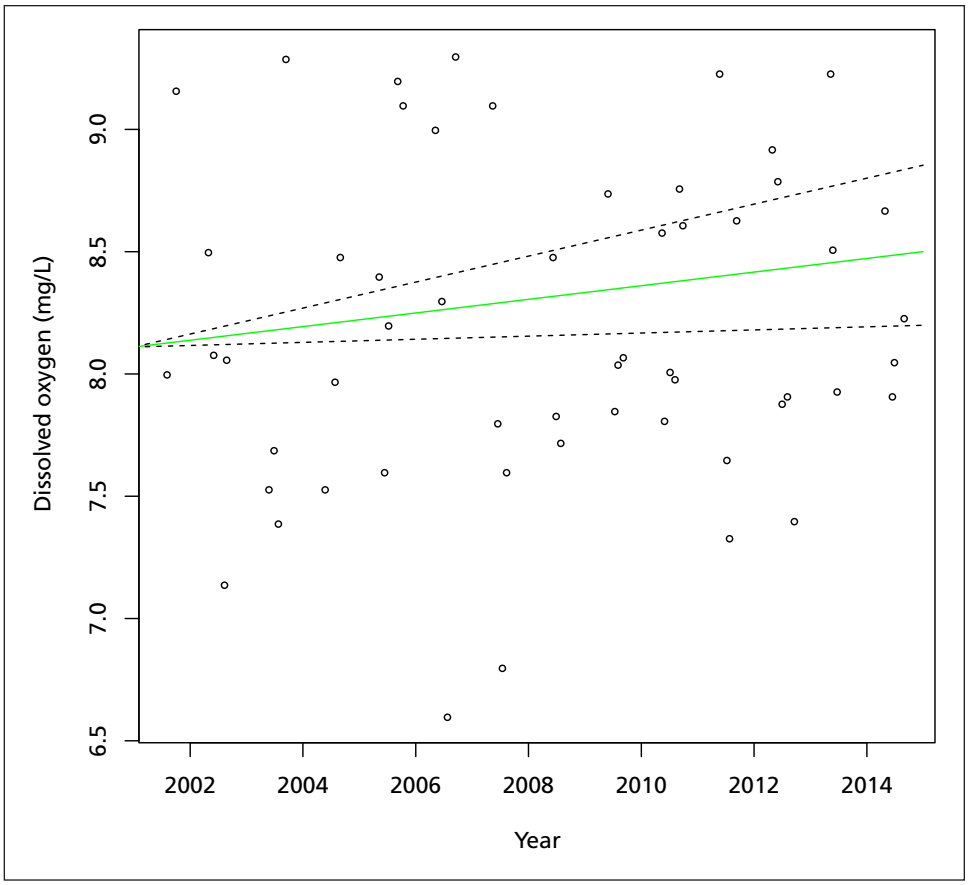


Figure 3-22. Statistically significant increase in dissolved oxygen over time at Pine Creek (Kendall's tau = 0.159, p = 0.01). The estimated trend of 0.03 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

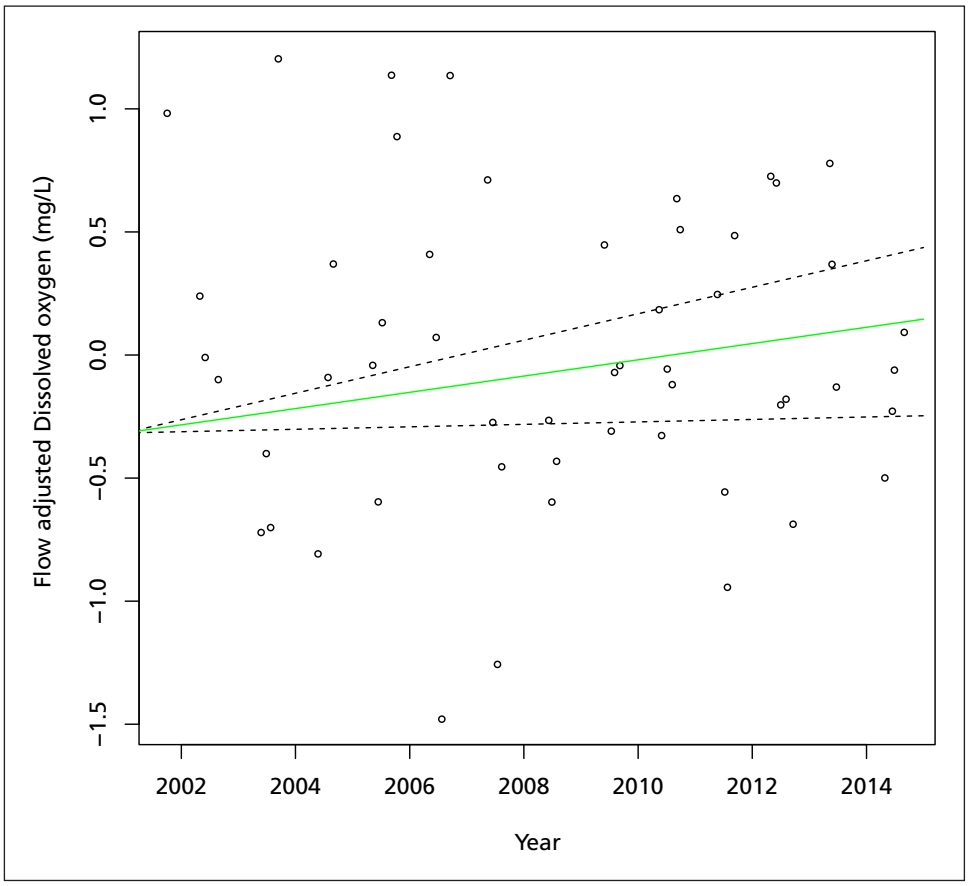


Figure 3-23. Statistically significant increase in flow-adjusted dissolved oxygen over time at Pine Creek (Kendall's tau = 0.111, p = 0.03). The estimated trend of 0.04 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

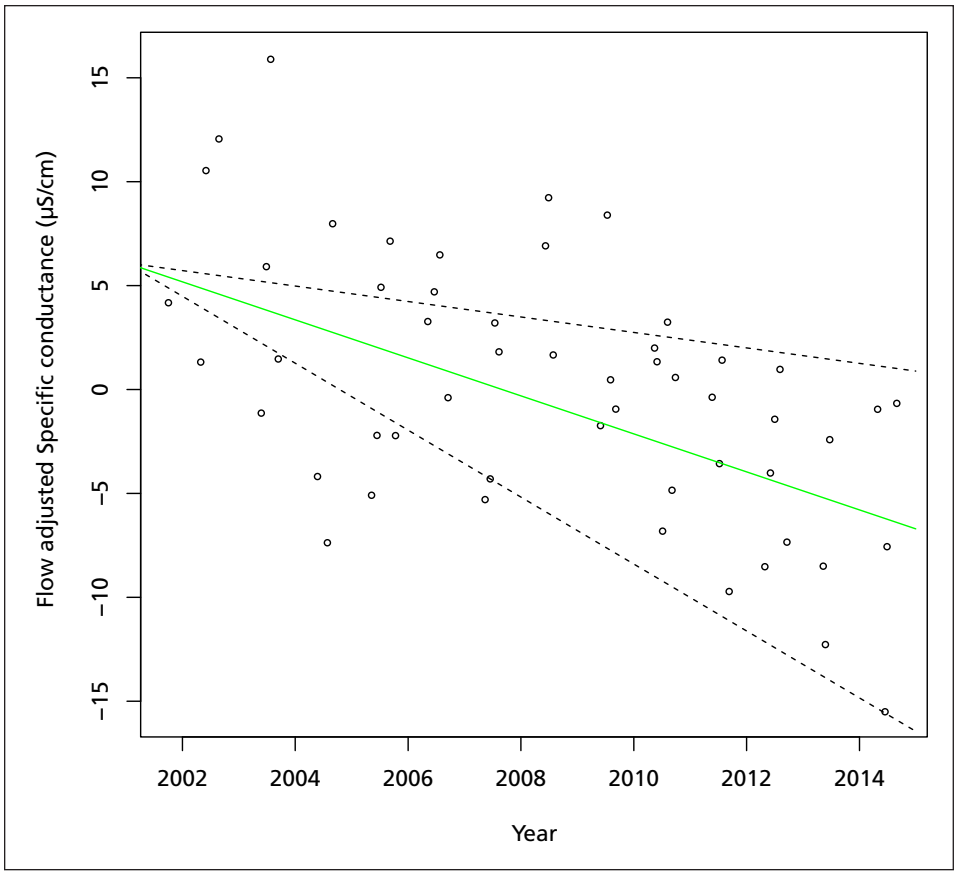


Figure 3-24. Statistically significant decrease in flow-adjusted specific conductance over time at Pine Creek (Kendall's tau = -0.439, $p < 0.01$). The estimated trend of -0.99 µS/cm per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

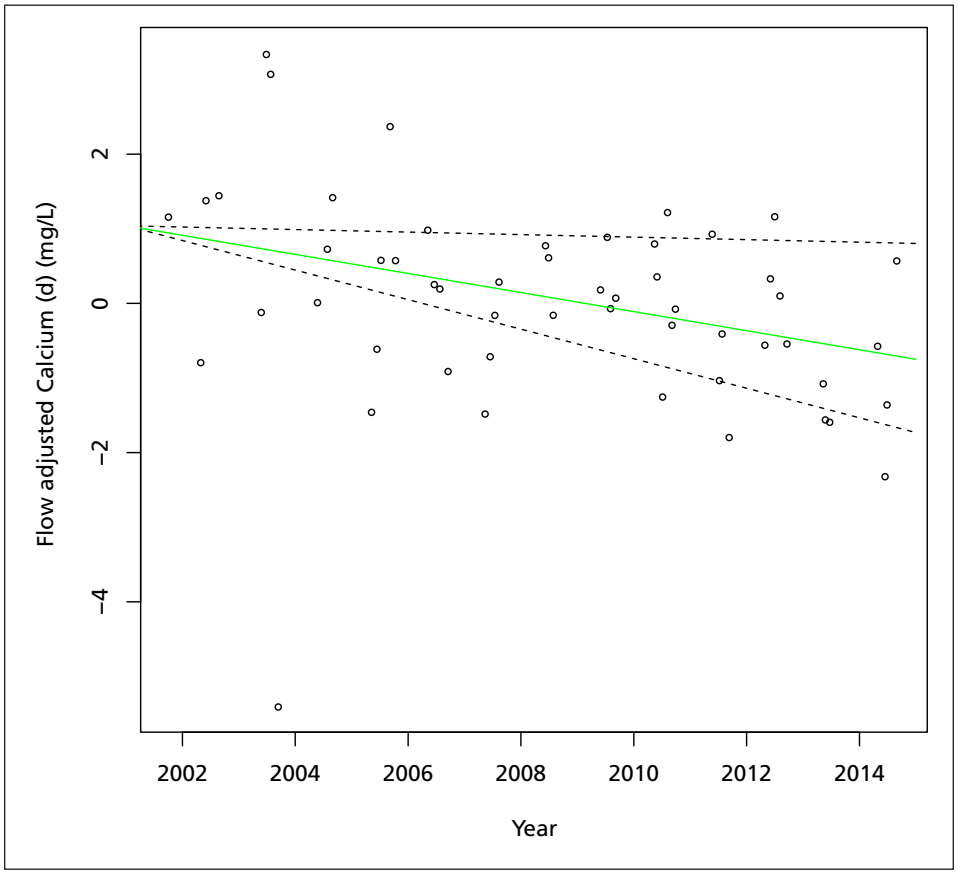


Figure 3-25. Statistically significant decrease in flow-adjusted calcium over time at Pine Creek (Kendall's tau = -0.279, $p = 0.02$). The estimated trend of -0.14 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

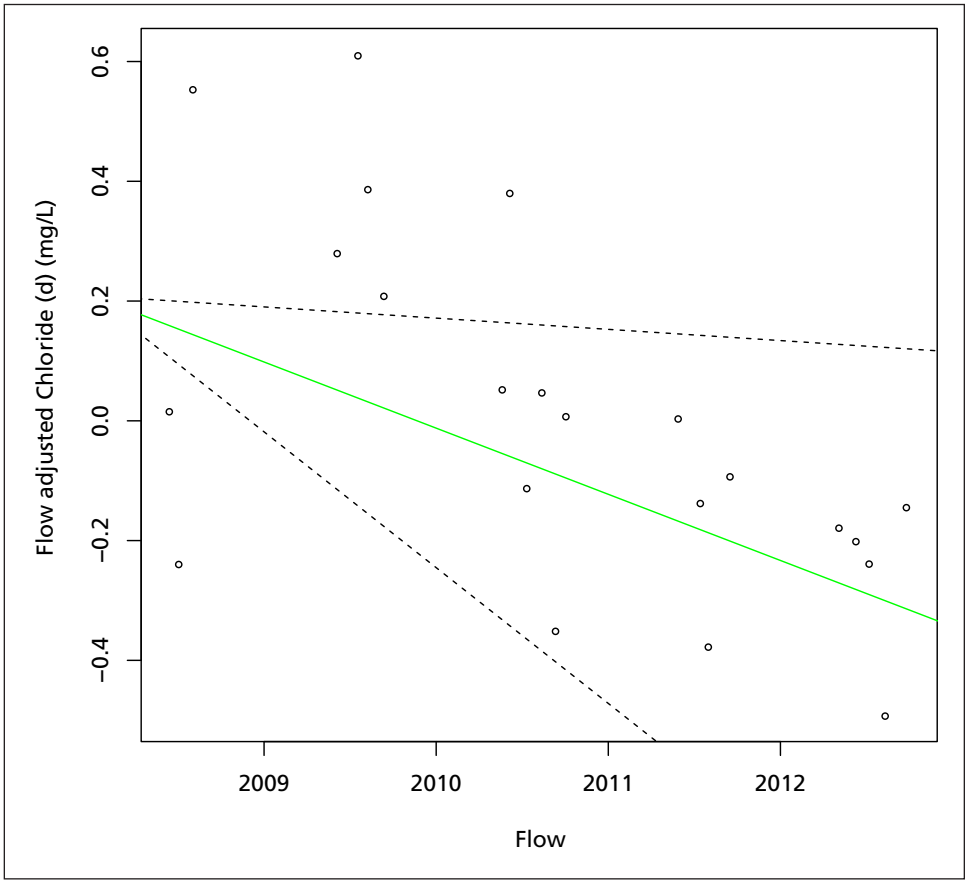


Figure 3-26. Statistically significant decrease in flow-adjusted chloride over time at Pine Creek (Kendall's tau = -0.54, p = 0.02). The estimated trend of -0.14 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

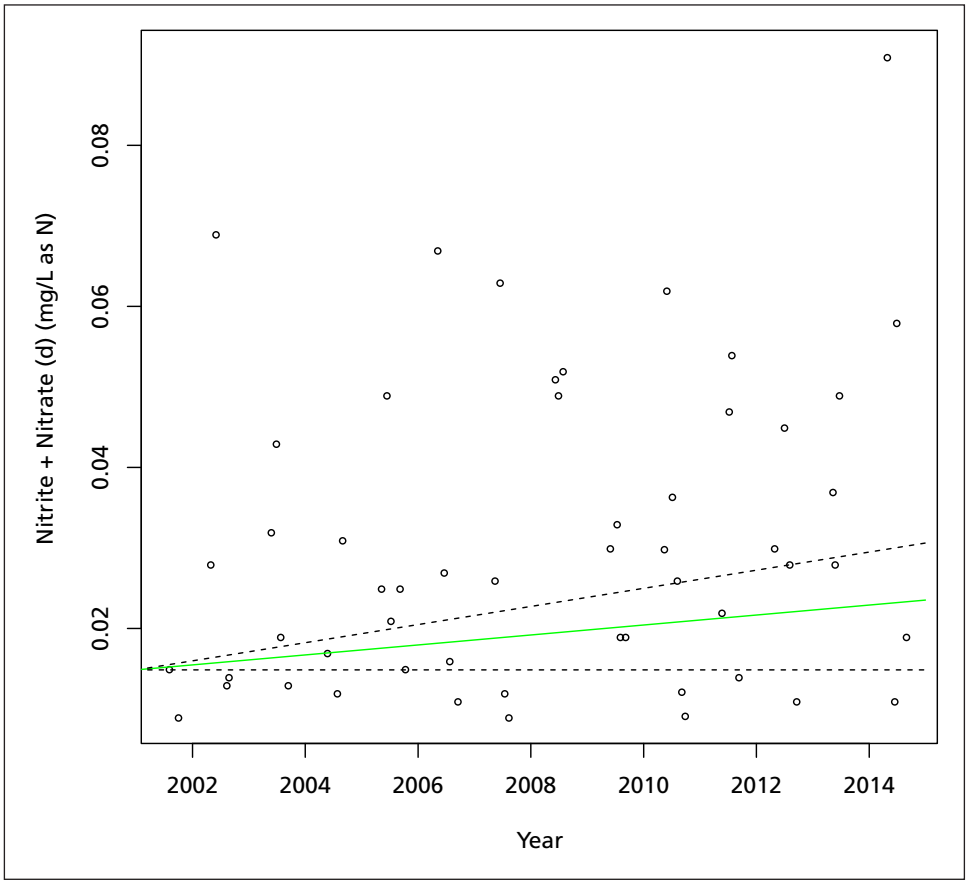


Figure 3-27. Statistically significant increase in nitrite plus nitrate over time at Pine Creek (Kendall's tau = 0.198, p = 0.05). The estimated trend of 0.001 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

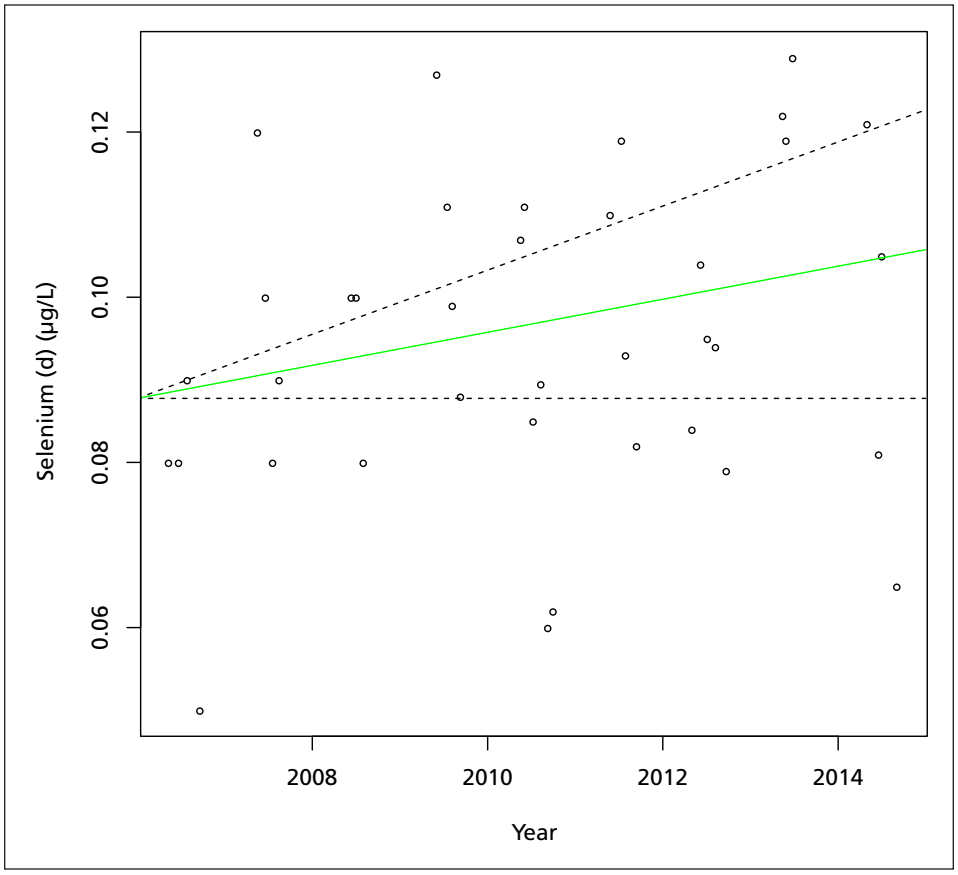


Figure 3-28. Statistically significant increase in selenium over time at Pine Creek (Kendall's tau = 0.288, p = 0.05). The estimated trend of 0.002 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

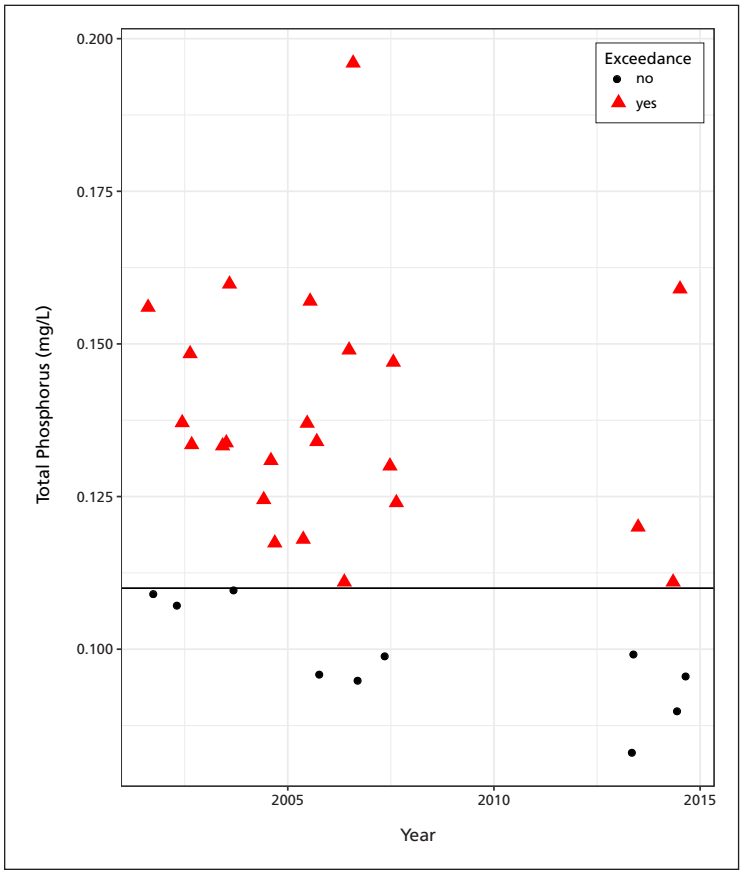


Figure 3-29. Phosphorus exceedances at Pine Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.5.2 Curecanti Creek near Sapinero, Colorado

The NPS samples Curecanti Creek about 1.5 miles downstream along the NPS Curecanti Creek Trail, which is accessed via the Pioneer Point trailhead. The majority of the watershed is USFS land. The stream also flows through private land before entering NPS land, where the creek empties into Morrow Point Reservoir. Agricultural irrigation on private lands influences stream flow. Cattle grazing is prevalent on both private and USFS lands. The Curecanti Trail parallels the stream along the NPS land. The USGS also samples water quality on this stream at an upstream site closer to Highway 92.

Summary statistics and trend analysis results are presented in Table 3-17. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- There were no statistically significant trends in raw or flow-adjusted concentrations over time.

Exceedances

- There were no exceedances of state water-quality standards for dissolved oxygen, pH, ammonia, nitrite, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for water temperature and phosphorus. *E. coli* exceeded the segment-specific water-quality standard of 126 cfu/100 mL on 13% of visits (6 of 48).

Table 3-17. Summary statistics for water-quality parameters at Curecanti Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/15/2001	9/18/2014	45	0	uncensored	7.77	8.24	9.13	none	none
Escherichia coli (cfu/100 mL)	8/15/2001	9/18/2014	48	0	uncensored	9.2	42	111.6	none	none
Flow (cfs)	8/15/2001	9/18/2014	45	0	uncensored	4.43	12.4	66.1	none	–
pH	8/15/2001	9/18/2014	46	0	uncensored	7.65	7.93	8.20	none	none
Specific conductance (µS/cm)	8/15/2001	9/18/2014	47	0	uncensored	51.8	88.4	109	none	none
Water temperature (°C)	8/15/2001	9/18/2014	47	0	uncensored	7.4	11.5	13.7	none	none
Calcium (d) (mg/L)	8/15/2001	9/18/2014	47	0	uncensored	6.9	11.3	14.5	none	none
Magnesium (d) (mg/L)	8/15/2001	9/18/2014	47	0	uncensored	1.10	1.83	2.26	none	none
Ammonia (d) (mg/L as N)	8/15/2001	9/18/2014	46	46	none	<0.02	<0.02	<0.02	–	–
Nitrite (d) (mg/L as N)	8/15/2001	9/18/2014	45	45	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/15/2001	9/18/2014	46	45	none	<0.022	<0.022	<0.022	–	–
Phosphorus (mg/L as P)	8/15/2001	9/18/2014	24	0	uncensored	0.045	0.058	0.084	none	none
Cadmium (d) (µg/L)	8/15/2001	9/18/2014	47	47	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/15/2001	9/18/2014	47	47	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/15/2001	9/18/2014	47	47	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/15/2001	9/18/2014	46	0	uncensored	2.48	5.23	8.00	none	none
Selenium (d) (µg/L)	6/21/2006	9/18/2014	30	24	uncensored	<0.08	<0.08	0.08065	none	none
Silver (d) (µg/L)	8/15/2001	9/18/2014	47	47	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/15/2001	9/18/2014	47	47	none	<2.8	<2.8	<2.8	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

3.5.3 Blue Creek at Highway 50 near Sapinero, Colorado

Blue Creek is monitored on BLM land just downstream of the Highway 50 crossing below the confluence of Big Blue Creek and Little Blue Creek. The stream originates in the USFS Uncompahgre Wilderness. The majority of both creeks flows through private property with private wells and septic tanks. Natural streamflow has been altered due to several small reservoirs on private land. There are grazing, commercial logging, and recreational uses throughout the watershed.

Summary statistics and trend analysis results are presented in Table 3-18. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Flow-adjusted dissolved oxygen increased over time (slope = 0.06, Kendall's tau = 0.244, p = 0.037; Figure 3-30).
- Flow-adjusted pH decreased over time (Kendall's tau = -0.23, p = 0.041, slope = -0.02; Figure 3-31).
- Raw and flow-adjusted concentrations of manganese decreased by – 5.6% (raw Kendall's tau = -0.374, p = 0.02, slope = -.71 µg/L; flow-adjusted Kendall's tau = -0.385, p = 0.036, slope = -0.50; Figure 3-32, 3-33).

There were no significant changes in land use in the watershed during the period investigated here, and the causes of these trends are unknown.

Exceedances

- There were no exceedances of state water-quality standards for pH, chloride, ammonia, nitrite, cadmium, manganese, selenium, silver, and zinc.
- There were <5% exceedances for lead and <10% exceedances for dissolved oxygen and copper.
- Seasonally dependent water temperature criteria were exceeded on 12% of sample visits (7 of 57).
- *E. coli* exceeded the segment-specific water-quality standard of 126 cfu/100 mL on 23% of visits (15 of 65; Figure 3-34). *E. coli* can bond with sediment mobilized during higher flow events, and high *E. coli* values often correlate with higher flows. However, exceedances on Blue Creek often occurred during lower flows (Figure 3-35), suggesting that sediment is not the cause of *E. coli* exceedances. Managers may wish to investigate potential sources of *E. coli* contamination in Blue Creek.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 18% of sample visits (6 of 34; Figure 3-36). No visible signs of eutrophication have been noted in the stream.

Table 3-18. Summary statistics for water-quality parameters at Blue Creek, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/14/2001	9/8/2014	56	0	uncensored	7.58	8.37	9.30	none	↑
Escherichia coli (cfu/100 mL)	8/14/2001	9/8/2014	65	0	uncensored	8.6	49	164	none	none
Flow (cfs)	8/14/2001	9/8/2014	56	0	uncensored	10.3	20.2	101	none	–
pH	8/14/2001	9/8/2014	56	0	uncensored	7.62	7.90	8.20	none	↓
Specific conductance (µS/cm)	8/14/2001	9/8/2014	57	0	uncensored	54.4	77.6	97.6	none	none
Water temperature (°C)	8/14/2001	9/8/2014	57	0	uncensored	6.0	10.9	14.5	none	none
Calcium (d) (mg/L)	8/14/2001	9/8/2014	57	0	uncensored	6.1	8.7	11.6	none	none
Chloride (d) (mg/L)	5/14/2008	9/27/2012	23	0	uncensored	0.56	1.06	1.70	none	none
Magnesium (d) (mg/L)	8/14/2001	9/8/2014	57	0	uncensored	1.31	1.80	2.46	none	none
Ammonia (d) (mg/L as N)	8/14/2001	9/8/2014	56	55	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/8/2009	9/8/2014	26	26	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/14/2001	9/8/2014	27	2	censored	0.190	0.264	0.383	none	–
Nitrate (d) (mg/L as NO_3)	6/8/2009	9/8/2014	25	25	none	<0.032	<0.032	<0.032	–	–
Nitrite (d) (mg/L as N)	8/14/2001	9/8/2014	56	53	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/14/2001	9/8/2014	56	46	none	<0.022	<0.022	0.026	–	–
Orthophosphate (d) (mg/L as P)	8/14/2001	8/23/2007	25	0	uncensored	0.025	0.042	0.056	none	none
Phosphorus (mg/L as P)	8/14/2001	9/8/2014	34	0	uncensored	0.069	0.085	0.111	none	none
Cadmium (d) (µg/L)	8/14/2001	9/8/2014	57	56	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/14/2001	9/8/2014	57	48	none	<1	<1	<1	–	–
Lead (d) (µg/L)	8/14/2001	9/8/2014	57	50	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/14/2001	9/8/2014	57	0	uncensored	8.8	12.7	20.0	↓	↓
Selenium (d) (µg/L)	5/17/2006	9/8/2014	38	12	censored	<0.06	0.064	0.086	none	–
Silver (d) (µg/L)	8/14/2001	9/8/2014	57	57	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/14/2001	9/8/2014	57	51	none	<2.8	<2.8	<2.8	–	–

[†] FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. **Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.**

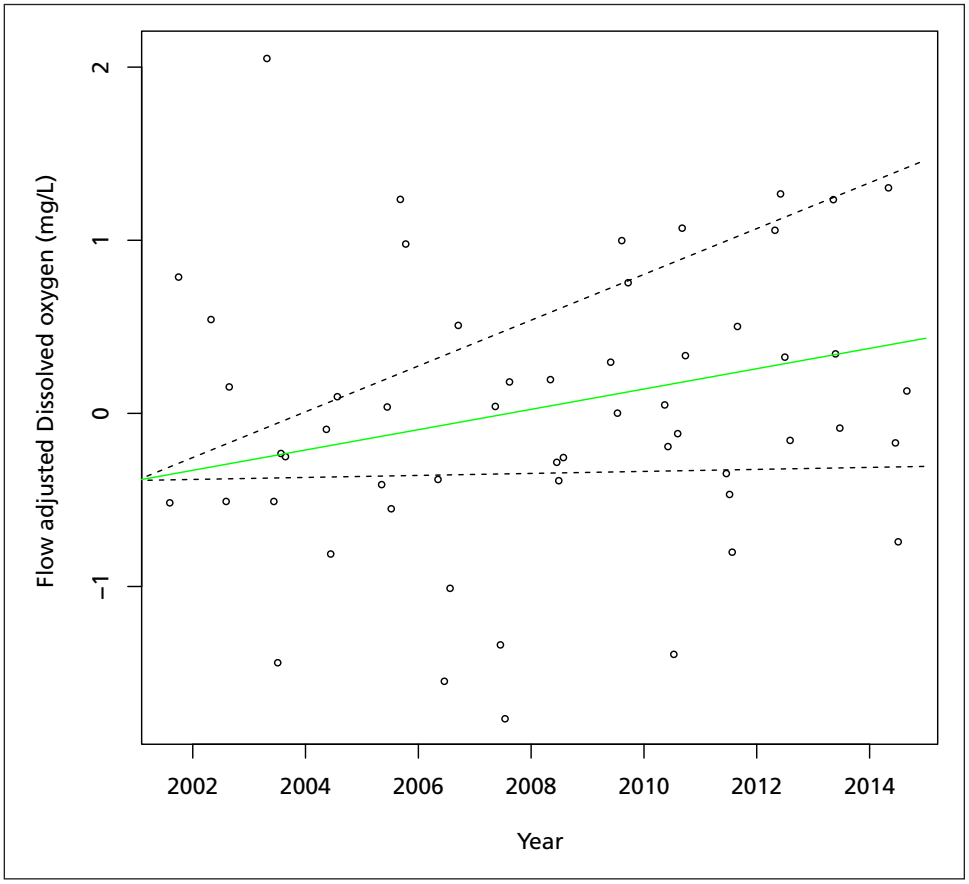


Figure 3-30. Statistically significant increase in flow-adjusted dissolved oxygen over time at Blue Creek (Kendall's tau = 0.244, p = 0.04). The estimated trend of 0.06 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

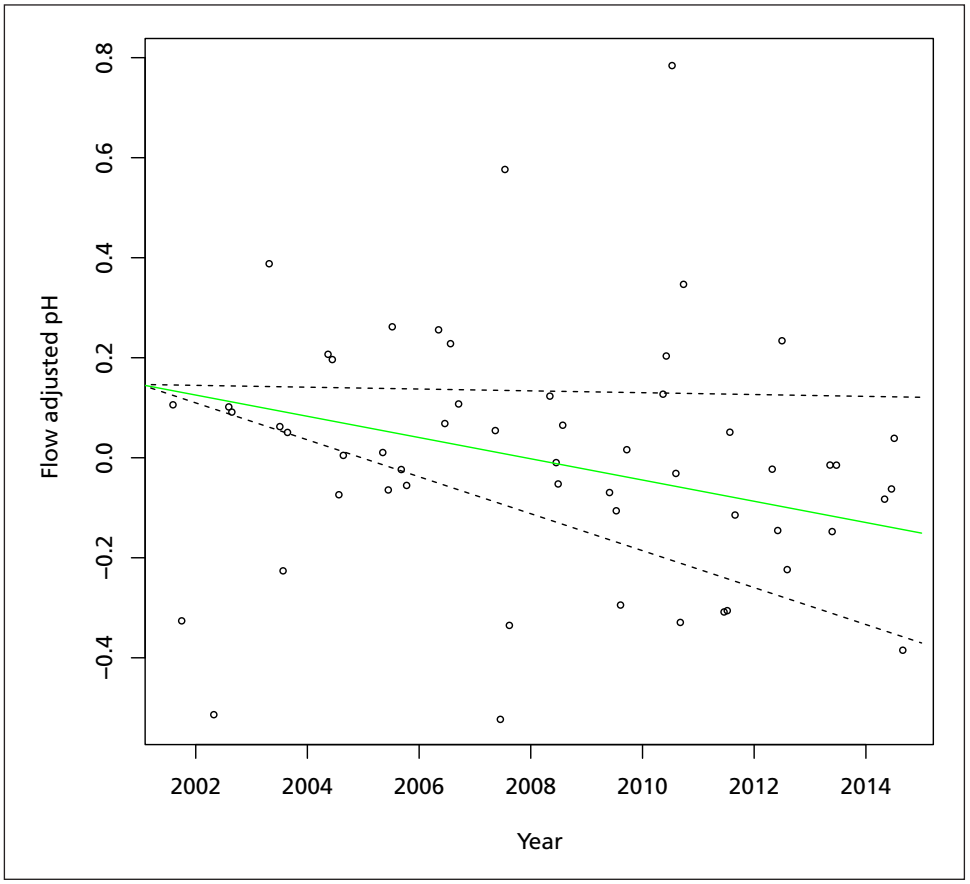


Figure 3-31. Statistically significant decrease in flow-adjusted pH over time at Blue Creek (Kendall's tau = -0.23, p = 0.04). The estimated trend of -0.02 pH units per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

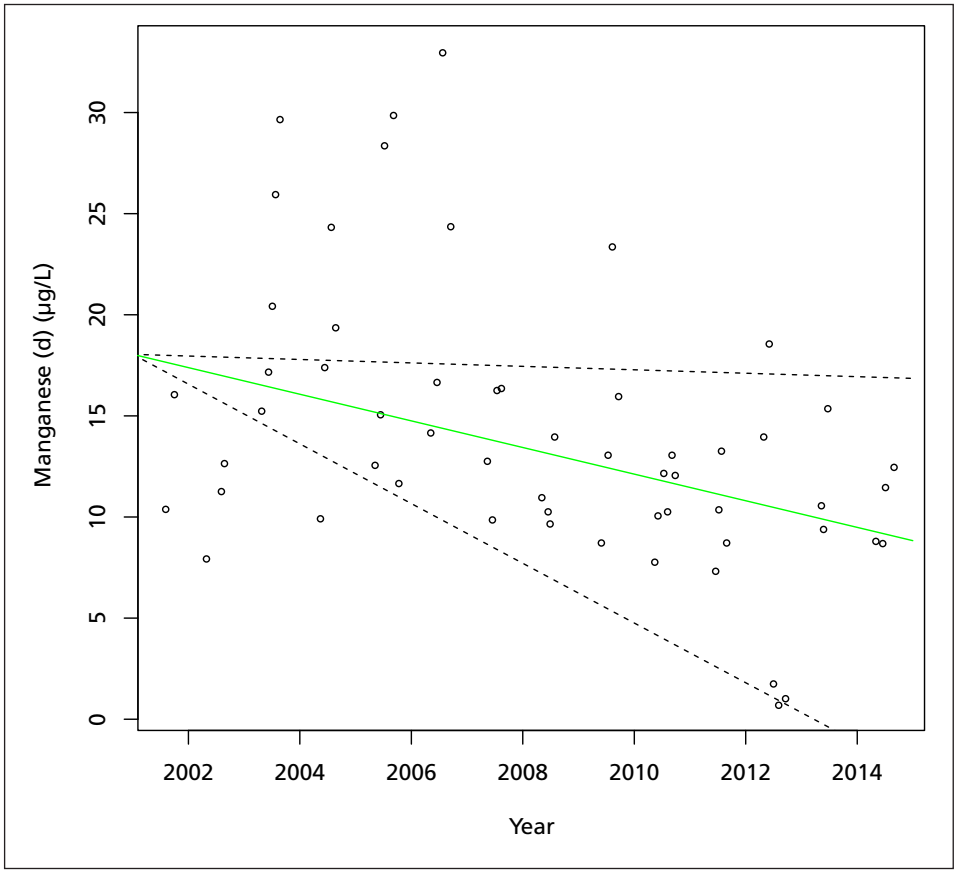


Figure 3-32. Statistically significant decrease in manganese over time at Blue Creek (Kendall's tau = -0.375, p = 0.02). The estimated trend of -0.71 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

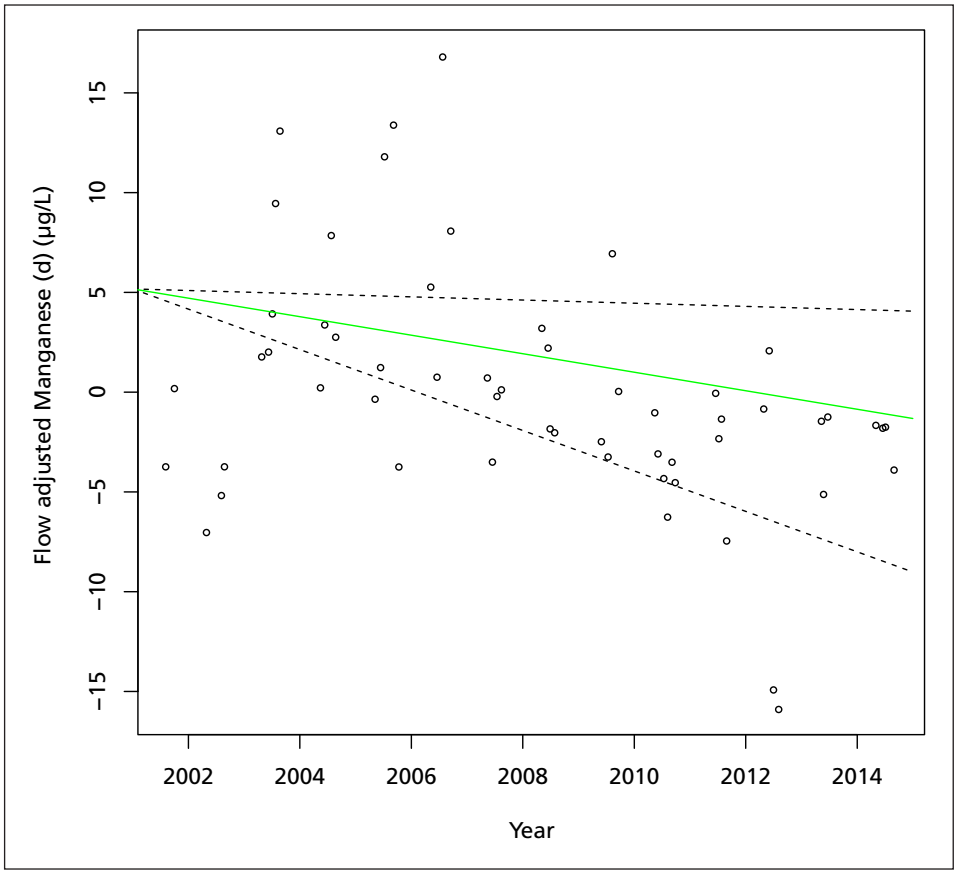


Figure 3-33. Statistically significant decrease in flow-adjusted manganese over time at Blue Creek (Kendall's tau = -0.385, p = 0.04). The estimated trend of -0.50 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

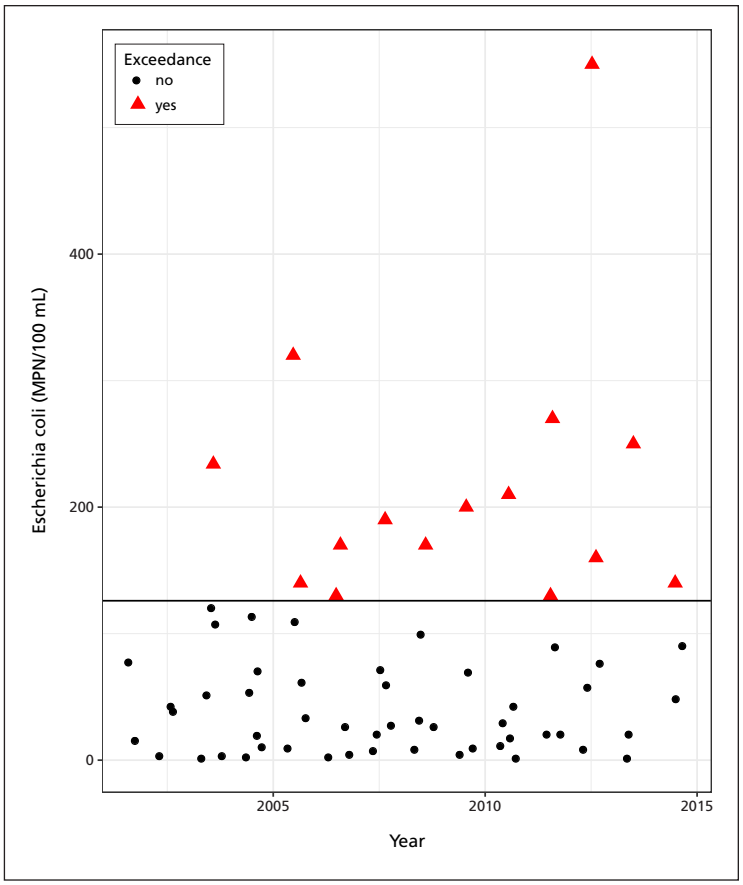


Figure 3-34. *E. coli* exceedances at Blue Creek. The black line indicates the segment-specific standard of 126 cfu/100 mL.

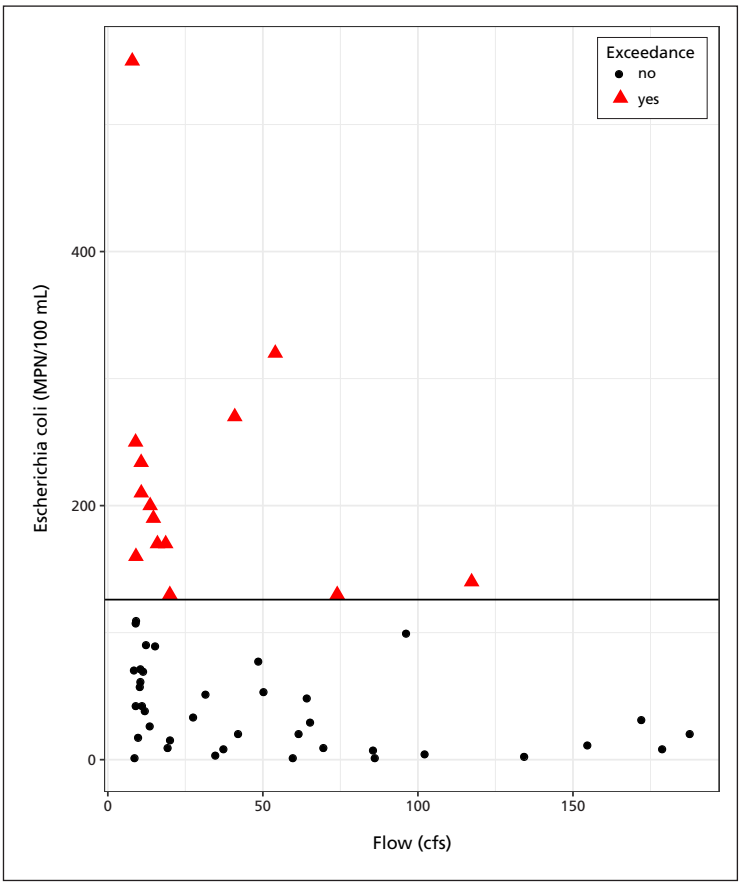


Figure 3-35. *Escherichia coli* exceedances on Blue Creek occurred mostly during lower flow conditions. The black line indicates the segment-specific standard of 126 cfu/100 mL.

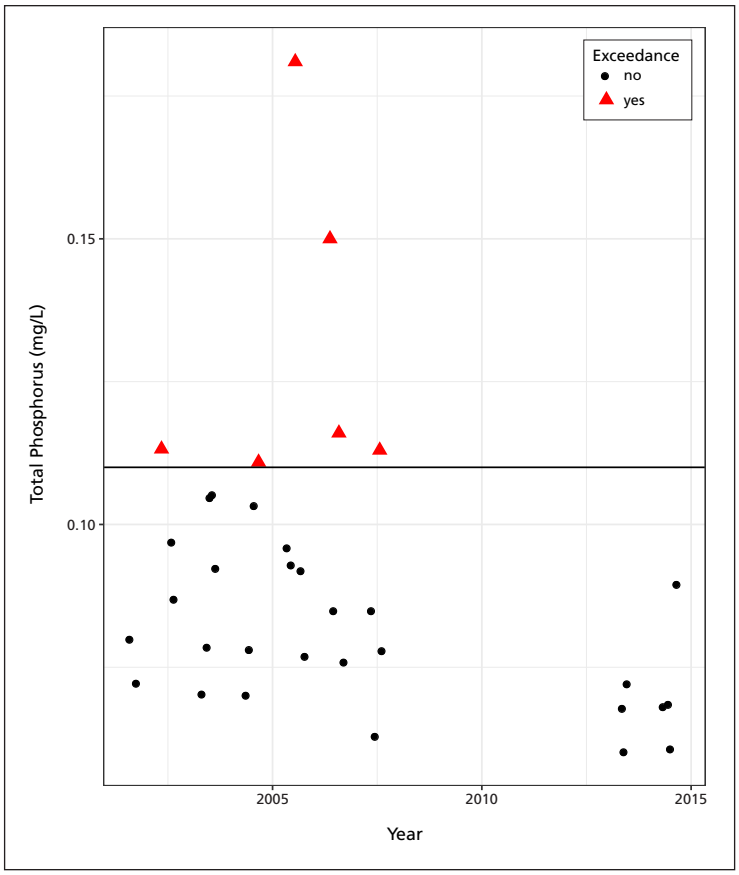


Figure 3-36. Phosphorus exceedances at Blue Creek. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.6 Morrow Point Reservoir

Morrow Point Reservoir is the second of the three consecutive reservoirs in the Aspinall Unit. This reservoir is much narrower and consistently deeper than the upstream Blue Mesa Reservoir. The main tributaries to this reservoir are outflows from the Blue Mesa Dam, Curecanti Creek, Pine Creek, and Blue Creek. Recreational use on the reservoir is limited to the NPS tour boat, one fishing guide boat, and any boats hand-carried down one of the steep trails.

3.6.1 Morrow Point Reservoir below Blue Creek near Sapinero, Colorado

This sample is collected from the eastern side of the reservoir, known locally as Kokanee Bay.

Summary statistics and trend analysis results are presented in Table 3-19. Also see Tables i–iv and 3-1 to 3-3.

Trends

- Raw concentrations of manganese increased by 98% over the period of record at a median rate of 0.10 µg/L per year (Kendall's tau = 0.29, p = 0.028; Figure 3-37).
- Increases in manganese were also noted in Blue Creek, a tributary to the reservoir. The cause of the trend in manganese is unknown.

Exceedances

- There were no exceedances of state water-quality standards for dissolved oxygen, *E. coli*, water temperature, ammonia, nitrite, phosphorus, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for pH.

Table 3-19. Summary statistics for water-quality parameters at Morrow Point Reservoir below Blue Creek, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Dissolved oxygen (mg/L)	8/13/2001	9/15/2014	51	0	uncensored	7.71	8.21	9.49	none
Escherichia coli (cfu/100 mL)	8/13/2001	9/15/2014	52	26	censored	<1	<1	1	none
pH	8/13/2001	9/15/2014	52	0	uncensored	8.03	8.22	8.40	none
Secchi Disk Depth (m)	6/15/2009	9/15/2014	22	0	uncensored	1.87	3.49	5.66	none
Specific conductance (µS/cm)	8/13/2001	9/15/2014	52	0	uncensored	154	173	191	none
Water temperature (°C)	8/13/2001	9/15/2014	52	0	uncensored	9.9	14.3	16.9	none
Calcium (d) (mg/L)	8/13/2001	9/15/2014	52	0	uncensored	21.1	24.1	27.8	none
Magnesium (d) (mg/L)	8/13/2001	9/15/2014	52	0	uncensored	4.04	4.71	5.30	none
Ammonia (d) (mg/L as N)	8/13/2001	9/15/2014	52	52	none	<0.02	<0.02	<0.02	–
Ammonia, un-ionized (mg/L)	6/15/2009	9/15/2014	23	23	none	<0.02	<0.02	<0.02	–
Nitrate (d) (mg/L as NO_3)	6/15/2009	9/15/2014	23	22	none	<0.015	<0.015	<0.015	–
Nitrite (d) (mg/L as N)	8/13/2001	9/15/2014	52	51	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/13/2001	9/15/2014	52	49	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/13/2001	9/15/2014	52	8	uncensored	<0.008	0.013	0.023	none
Cadmium (d) (µg/L)	8/13/2001	9/15/2014	52	51	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/13/2001	9/15/2014	52	51	none	<1	<1	<1	–
Lead (d) (µg/L)	8/13/2001	9/15/2014	52	50	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/13/2001	9/15/2014	52	0	uncensored	0.8	1.4	2.8	↑
Selenium (d) (µg/L)	6/1/2006	9/15/2014	33	0	uncensored	0.100	0.110	0.133	none
Silver (d) (µg/L)	8/13/2001	9/15/2014	52	52	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/13/2001	9/15/2014	52	52	none	<2.8	<2.8	<2.8	–

† Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

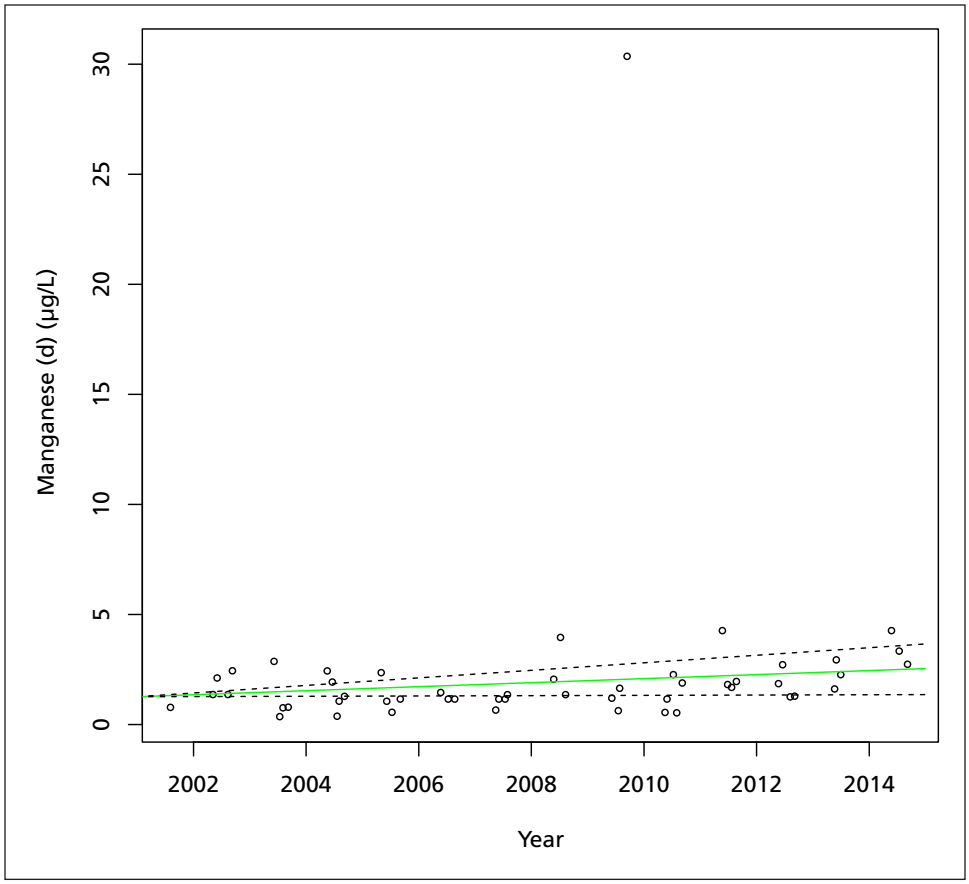


Figure 3-37. Statistically significant increase in manganese over time at Morrow Point Reservoir below Blue Creek (Kendall's tau = 0.29, p = 0.03). The estimated trend of 0.10 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.6.2 Morrow Point Reservoir above Morrow Point Dam near Cimarron, Colorado

This sample is collected from the western side of the reservoir, near the Hermit's Rest camp site that can be accessed by hikers and boaters.

Summary statistics and trend analysis results are presented in Table 3-20. Also see Tables i–iv and 3-1 to 3-3.

Trends

- Raw dissolved oxygen increased by 8.6% over the period of record at a median rate of 0.05 mg/L per year (Kendall's tau = 0.283, p = 0.03; Figure 3-38). While the increase corresponds with the implementation of higher peak flows from the BLCA water-right agreement in 2008, dissolved-oxygen measurements taken 1 meter below the surface can also be influenced by the weather, time of day, and algal blooms. Lake profiles for dissolved oxygen may allow the park to better understand trends in dissolved oxygen over time.

Exceedances

- There were no exceedances of state water-quality standards for *E. coli*, pH, ammonia, nitrite, phosphorus, cadmium, copper, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for dissolved oxygen and <10% exceedances for water temperature.

Table 3-20. Summary statistics for water-quality parameters at Morrow Point Reservoir above Morrow Point Dam, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples			Percentile			Seasonal Kendall results
	Start	End	Total	Censored	Test type	15th	Median	85th	Raw trend
Dissolved oxygen (mg/L)	8/13/2001	9/15/2014	51	0	uncensored	7.64	8.19	9.48	↑
Escherichia coli (cfu/100 mL)	8/13/2001	9/15/2014	51	31	none	<1	<1	1	–
pH	8/13/2001	9/15/2014	52	0	uncensored	8.19	8.36	8.53	none
Secchi Disk Depth (m)	6/15/2009	9/15/2014	23	0	uncensored	2.56	3.75	7.32	none
Specific conductance (µS/cm)	8/13/2001	9/15/2014	52	0	uncensored	160	177	190	none
Water temperature (°C)	8/13/2001	9/15/2014	52	0	uncensored	10.0	14.7	17.6	none
Calcium (d) (mg/L)	8/13/2001	9/15/2014	52	0	uncensored	22.3	24.8	28.0	none
Magnesium (d) (mg/L)	8/13/2001	9/15/2014	52	0	uncensored	4.25	4.74	5.30	none
Ammonia (d) (mg/L as N)	8/13/2001	9/15/2014	52	52	none	<0.02	<0.02	<0.02	–
Ammonia, un-ionized (mg/L)	6/15/2009	9/15/2014	23	23	none	<0.02	<0.02	<0.02	–
Nitrate (d) (mg/L as NO_3)	6/15/2009	9/15/2014	23	22	none	<0.016	<0.016	<0.016	–
Nitrite (d) (mg/L as N)	8/13/2001	9/15/2014	52	52	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/13/2001	9/15/2014	52	50	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/13/2001	9/15/2014	52	20	censored	<0.008	0.010	0.018	none
Cadmium (d) (µg/L)	8/13/2001	9/15/2014	52	52	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/13/2001	9/15/2014	52	50	none	<1	<1	<1	–
Lead (d) (µg/L)	8/13/2001	9/15/2014	52	51	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/13/2001	9/15/2014	52	1	uncensored	0.594	0.873	2.26	none
Selenium (d) (µg/L)	6/1/2006	9/15/2014	33	1	uncensored	0.100	0.112	0.129	none
Silver (d) (µg/L)	8/13/2001	9/15/2014	52	52	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/13/2001	9/15/2014	52	52	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

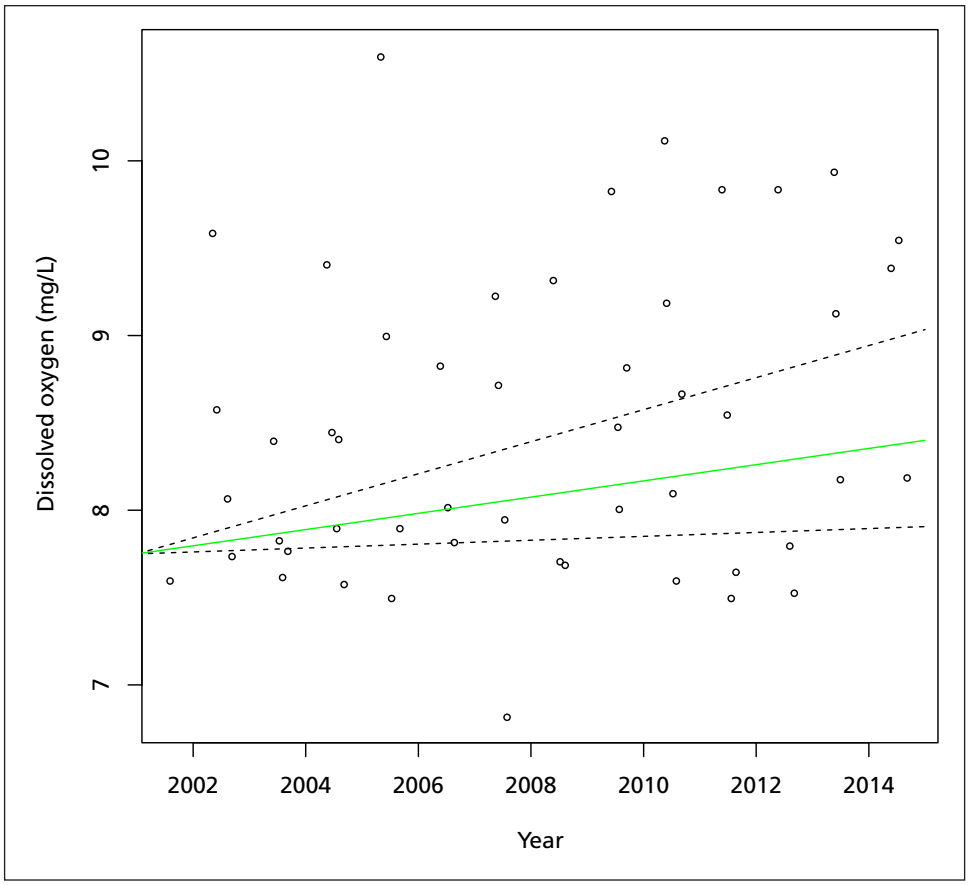


Figure 3-38. Statistically significant increase in dissolved oxygen over time at Morrow Point Reservoir above Morrow Point Dam (Kendall's tau = 0.283, p = 0.03). The estimated trend of 0.05 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.7 Tributary to Crystal Reservoir

3.7.1 Cimarron River below Squaw Creek near Cimarron, Colorado

The Cimarron River watershed covers 229 square miles. Beginning in the USFS Uncompahgre Wilderness, the river then comes to Silver Jack Reservoir. Below the reservoir, there is a large diversion for the Cimarron Canal. The river than continues along private lands with multiple irrigation withdrawals. The NPS monitors the river below its confluence with Squaw Creek, before the river enters Crystal Reservoir. Bridge samples are collected during high flows and, when wadeable, the river is sampled upstream of the bridge. Dirt and paved roads parallel the river all the way up into the headwaters. Commercial logging, grazing, and water development occur throughout USFS and BLM managed lands. Private lands are used for agriculture, grazing, and recreation. There are many private homes with wells and septic systems. The geology in this watershed is different than in the surrounding watersheds, containing highly erodible soils. This leads to noticeably turbid water during runoff periods. This site is co-located with USGS gaging station 09127000, established in 2011.

Summary statistics and trend analysis results are presented in Table 3-21. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Raw specific conductance decreased by -37% over the period record, at a median rate of -12 µS/cm per year (Kendall's tau = -0.278, p = 0.05; Figure 3-39).
- Raw copper concentrations decreased (Kendall's tau = -0.538, p = 0.003; Figure 3-40); because more than 5% of the dataset was censored, no estimate of slope is presented. Raw selenium concentrations decreased by -77% over the period of record at a median rate of -0.041 µg/L per year (Kendall's tau = -0.322, p = 0.02; Figure 3-41). There have been no significant changes in land use in the watershed, and the causes of these trends are unknown. There were no statistically significant trends in flow-adjusted concentrations.

Exceedances

- There were no exceedances of the state water-quality standards for chloride, ammonia, nitrate, nitrite, cadmium, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for dissolved oxygen, pH, and copper.
- *E. coli* exceeded the segment-specific water-quality standard of 126 cfu/100 mL on 41% of visits (26 of 63; Figure 3-42). *E. coli* can bond with sediment mobilized during higher flow events. However, exceedances on the Cimarron River occurred over a range of flows, including during lower flow events (Figure 3-43), suggesting that sediment is not the only cause of *E. coli* exceedances. Managers may wish to investigate other potential sources of *E. coli* contamination in the Cimarron River.
- Seasonally dependent water temperature criteria were exceeded on 32% of sample visits (18 of 57; Figure 3-44). Continuous water temperature monitoring could be implemented at this site to better characterize water temperature in comparison to updated state standards.
- Phosphorus exceeded the aquatic-life cold-water 1 interim standard of 0.11 mg/L on 33% of sample visits (11 of 33; Figure 3-45). No visible signs of eutrophication have been noted in the stream.

Table 3-21. Summary statistics for water-quality parameters at Cimarron River, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/14/2001	9/16/2014	56	0	uncensored	7.87	8.84	9.47	none	not adjusted
Escherichia coli (cfu/100 mL)	8/14/2001	9/16/2014	63	0	uncensored	17.6	92	209.1	none	not adjusted
Flow (cfs)	7/27/2001	9/16/2014	56	0	uncensored	31.5	63.2	309	none	–
pH	7/27/2001	9/16/2014	57	0	uncensored	8.17	8.44	8.80	none	none
Specific conductance (µS/cm)	7/27/2001	9/16/2014	57	0	uncensored	179	452	630	↓	none
Water temperature (°C)	7/27/2001	9/16/2014	57	0	uncensored	9.1	13.1	17.0	none	none
Calcium (d) (mg/L)	8/14/2001	9/16/2014	56	0	uncensored	19.5	44.7	61.2	none	none
Chloride (d) (mg/L)	5/20/2008	9/19/2012	23	0	uncensored	1.27	2.40	3.58	none	none
Magnesium (d) (mg/L)	8/14/2001	9/16/2014	56	0	uncensored	7.65	20.6	27.8	none	none
Ammonia (d) (mg/L as N)	8/14/2001	9/16/2014	54	54	none	<0.02	<0.02	<0.02	–	–
Ammonia, un-ionized (mg/L)	6/16/2009	9/16/2014	26	26	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/14/2001	9/16/2014	26	3	censored	0.228	0.408	0.520	none	
Nitrate (d) (mg/L as NO_3)	6/16/2009	9/16/2014	24	24	none	<0.127	<0.127	<0.127	–	–
Nitrite (d) (mg/L as N)	8/14/2001	9/16/2014	53	51	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/14/2001	9/16/2014	54	18	censored	<0.016	0.027	0.094	none	–
Orthophosphate (d) (mg/L as P)	8/14/2001	9/13/2007	28	5	censored	<0.006	0.021	0.044	none	–
Phosphorus (mg/L as P)	8/14/2001	9/16/2014	33	0	uncensored	0.063	0.084	0.256	none	not adjusted
Cadmium (d) (µg/L)	8/14/2001	9/16/2014	56	56	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/14/2001	9/16/2014	56	15	censored	<0.8	1.01	2.19	↓	–
Lead (d) (µg/L)	8/14/2001	9/16/2014	56	52	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/14/2001	9/16/2014	56	0	uncensored	10.1	18.2	27.7	none	none
Selenium (d) (µg/L)	7/27/2001	9/16/2014	57	0	uncensored	0.312	0.748	1.239	↓	none
Silver (d) (µg/L)	8/14/2001	9/16/2014	56	56	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/14/2001	9/16/2014	56	52	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

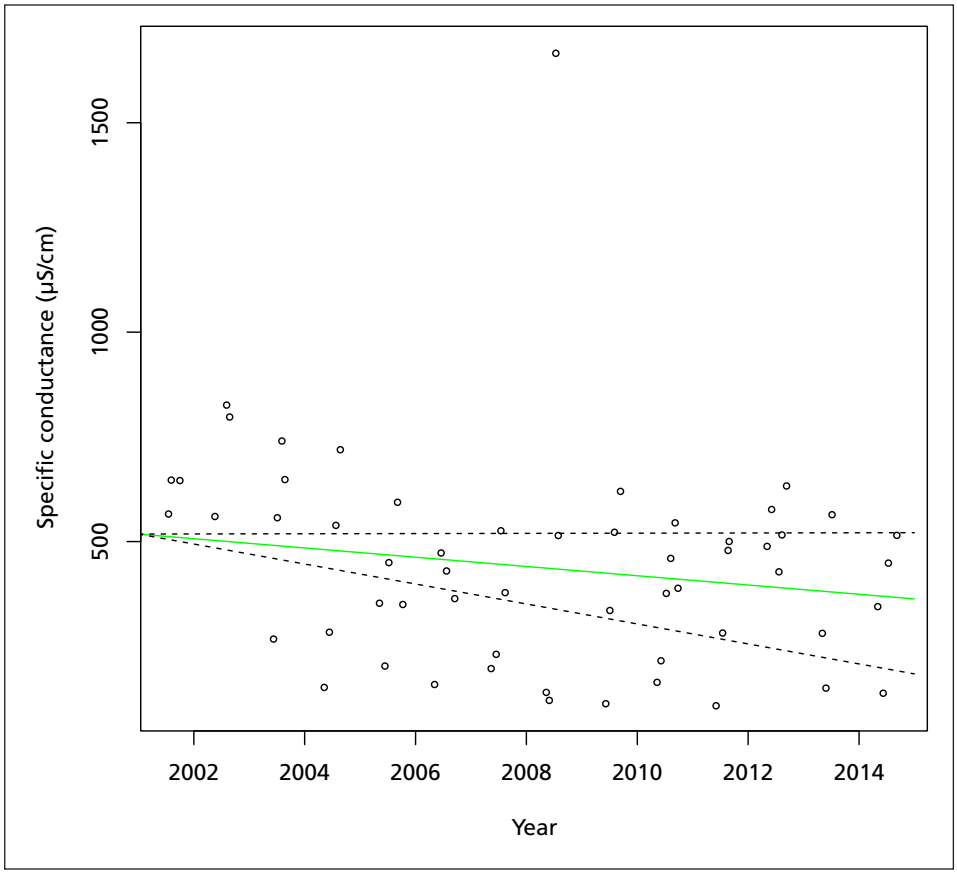


Figure 3-39. Statistically significant decrease in specific conductance over time at the Cimarron River (Kendall's tau = -0.278, p = 0.05). The estimated trend of -12 µS/cm per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

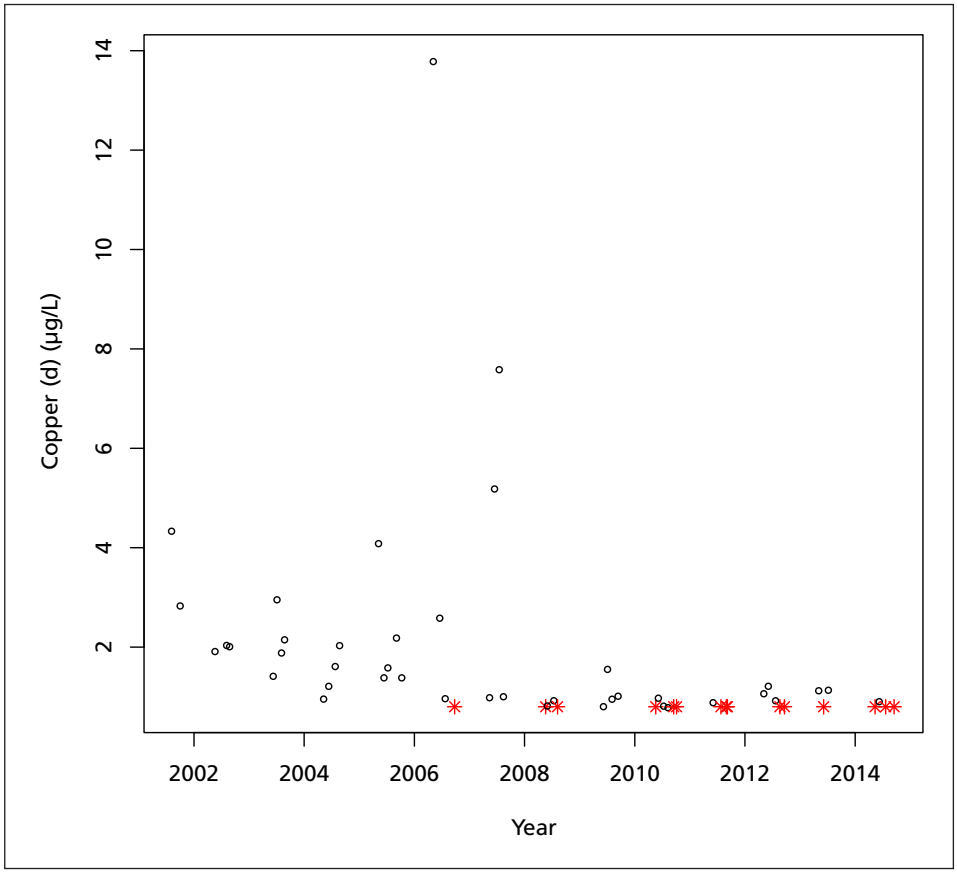


Figure 3-40. Statistically significant decrease in copper over time at the Cimarron River (Kendall's tau = -0.538, p < 0.01). Censored data are presented as red stars at the highest reporting limit. Because more than 5% of the data were censored, no slope is estimated.

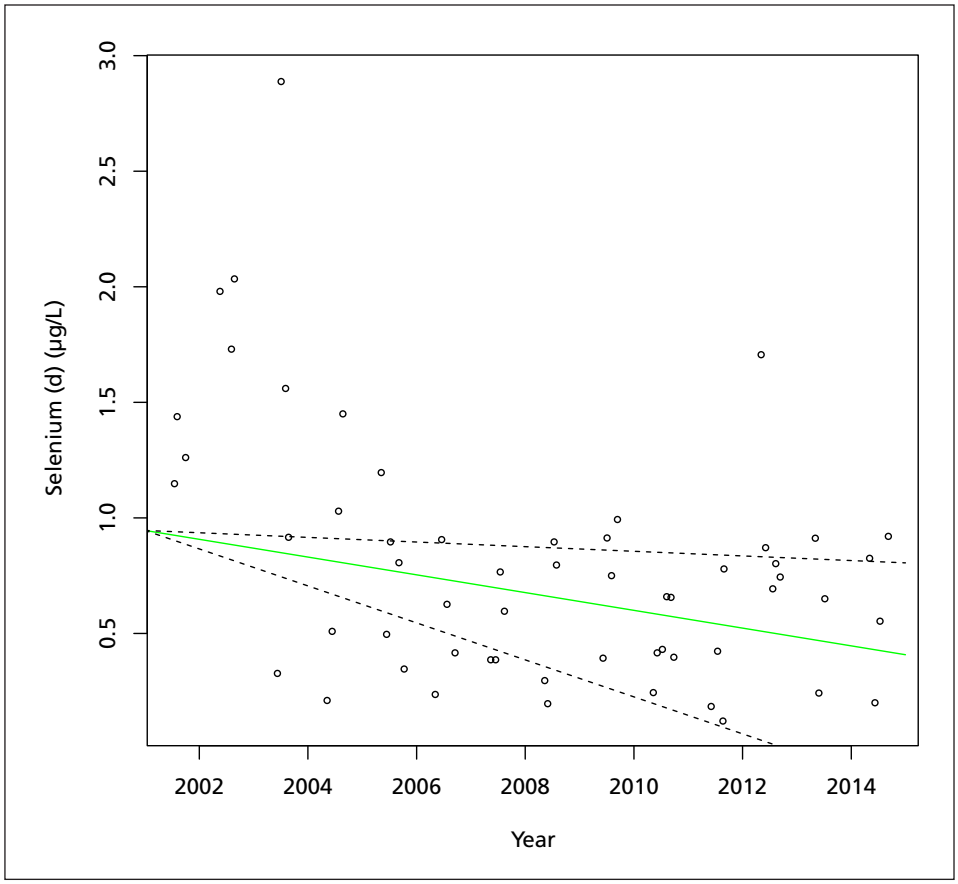


Figure 3-41. Statistically significant decrease in selenium over time at the Cimarron River (Kendall's tau = -0.322, p = 0.02). The estimated trend of -0.041 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

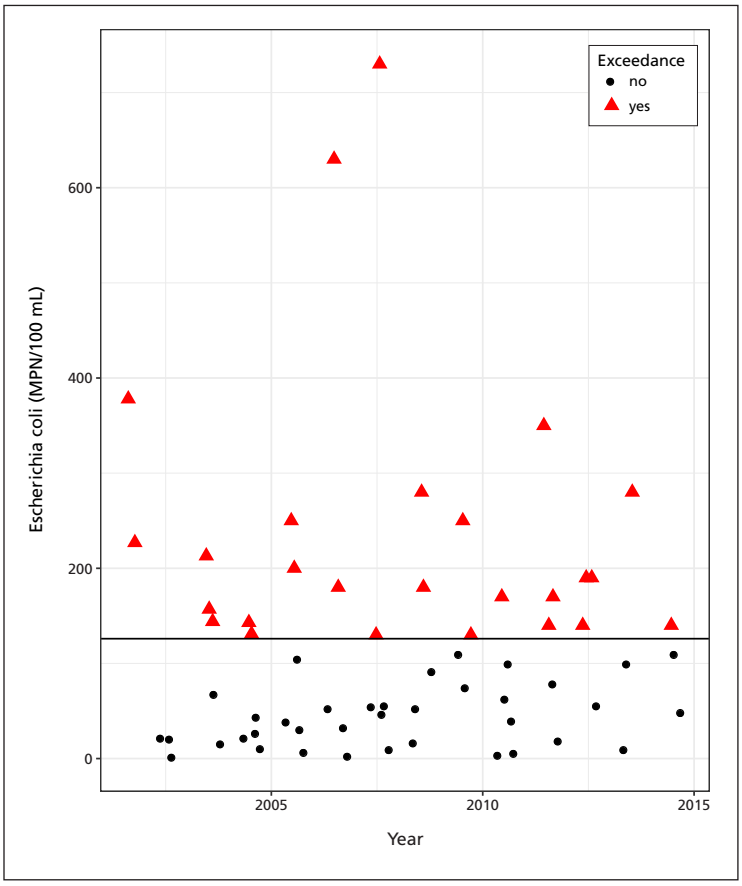


Figure 3-42. *E. coli* exceedances in the Cimarron River. The black line indicates the segment-specific standard of 126 cfu/100 mL.

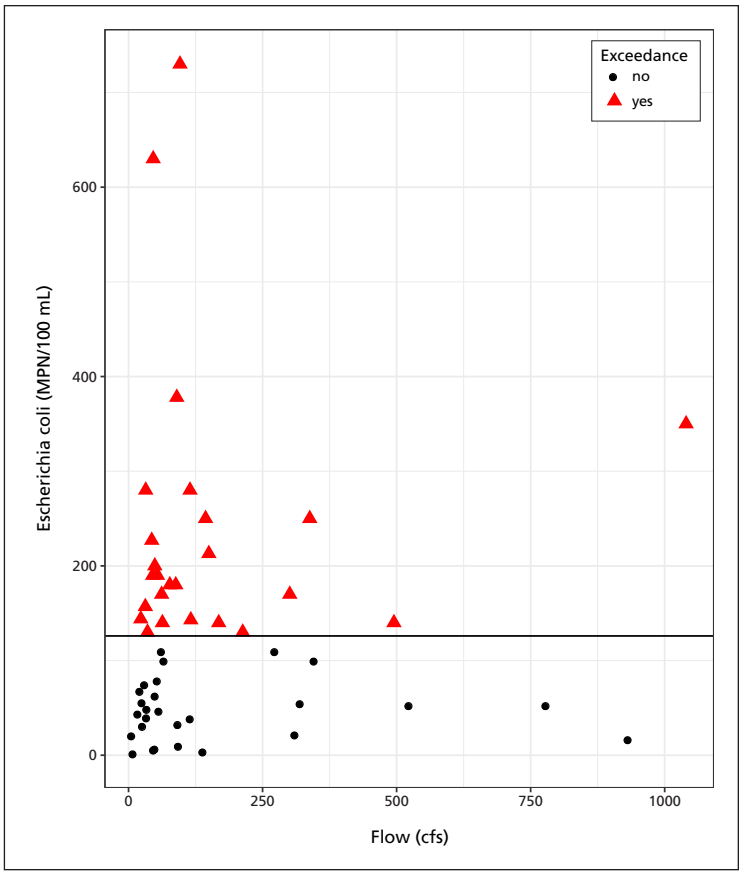


Figure 3-43. Relationship of *E. coli* and flow at the Cimarron River. *E. coli* exceedances occurred across a broad range of flows. The black line indicates the segment-specific standard of 126 cfu/100 mL.

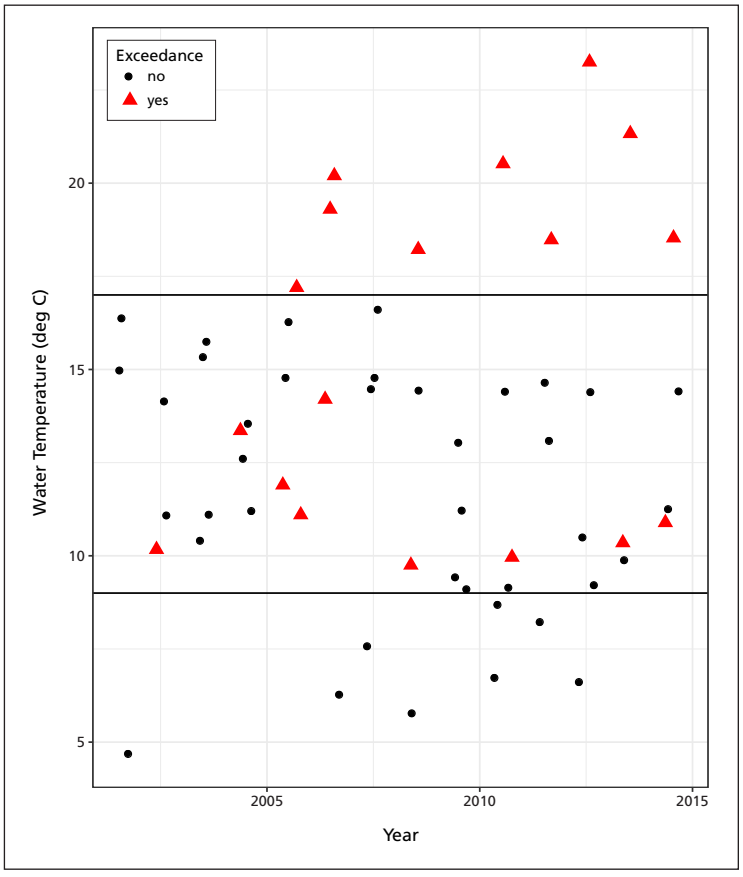


Figure 3-44. Water temperature exceedances in the Cimarron River. The lower line represents the aquatic life cold water 1 winter standard of 9.0°C and the upper line represents the growing season standard of 17.0°C.

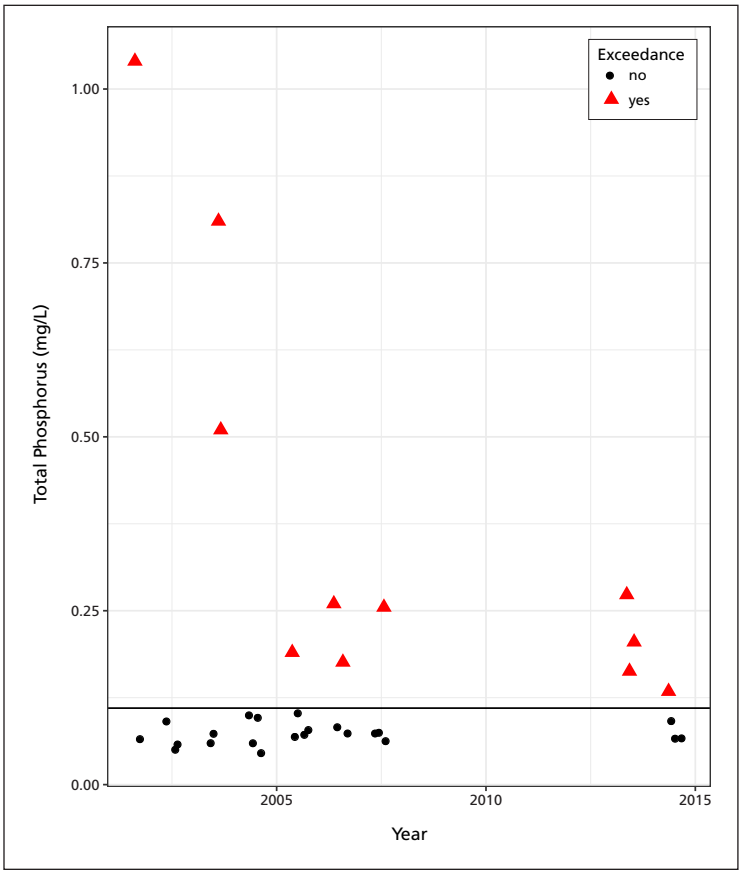


Figure 3-45. Phosphorus exceedances in the Cimarron River. The black line indicates the aquatic-life cold-water 1 interim value of 0.11 mg/L.

3.8 Crystal Reservoir

Crystal Reservoir is the most downstream of the three consecutive reservoirs of the Aspinall Unit. Recreation is limited to hand-carried watercraft. The main input is the release from Morrow Point Reservoir. This narrow reservoir is formed by surrounding steep canyon walls. Crystal Dam provides environmental flood releases to BLCA as part of the Black Canyon Water Right.

3.8.1 Crystal Reservoir at Crystal Creek near Cimarron, Colorado

This site is located on the eastern side of the reservoir across from the perennial Crystal Creek inlet. Summary statistics and trend analysis results are presented in Table 3-22. Also see Tables i–iv and 3-1 to 3-3. There were no statistically significant trends or water-quality exceedances over the period of record.

Table 3-22. Summary statistics for water-quality parameters at Crystal Reservoir at Crystal Creek, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Dissolved oxygen (mg/L)	8/28/2001	7/23/2013	40	0	uncensored	8.06	8.55	9.49	none
Escherichia coli (cfu/100 mL)	8/28/2001	7/23/2013	39	7	censored	<1	1	4.3	none
pH	8/28/2001	7/23/2013	40	0	uncensored	7.98	8.18	8.36	none
Specific conductance (µS/cm)	8/28/2001	7/23/2013	40	0	uncensored	175	202	212	none
Water temperature (°C)	8/28/2001	7/23/2013	40	0	uncensored	11.4	14.0	15.4	none
Calcium (d) (mg/L)	8/28/2001	7/23/2013	40	0	uncensored	23.0	27.3	29.8	none
Magnesium (d) (mg/L)	8/28/2001	7/23/2013	40	0	uncensored	5.07	5.72	6.22	none
Ammonia (d) (mg/L as N)	8/28/2001	7/23/2013	39	38	none	<0.02	<0.02	<0.02	–
Nitrite (d) (mg/L as N)	8/28/2001	7/23/2013	39	38	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/28/2001	7/23/2013	39	32	none	<0.016	<0.016	0.017	–
Phosphorus (mg/L as P)	8/28/2001	7/23/2013	39	0	uncensored	0.012	0.019	0.029	none
Cadmium (d) (µg/L)	8/28/2001	7/23/2013	40	40	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/28/2001	7/23/2013	40	39	none	<1	<1	<1	–
Lead (d) (µg/L)	8/28/2001	7/23/2013	40	40	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/28/2001	7/23/2013	40	0	uncensored	1.63	3.61	6.82	none
Selenium (d) (µg/L)	6/22/2006	7/23/2013	21	0	uncensored	0.138	0.164	0.200	none
Silver (d) (µg/L)	8/28/2001	7/23/2013	40	40	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/28/2001	7/23/2013	40	40	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored.

3.8.2 Crystal Reservoir at Crystal Dam near Cimarron, Colorado

This site is located on the western side of the reservoir upstream of the dam.

Summary statistics and trend analysis results are presented in Table 3-23. Also see Tables i–iv and 3-1 to 3-3.

Trends

- Raw concentrations of selenium decreased by -45% over the period of record at a median rate of -0.009 µg/L per year (Kendall's tau = -0.484, p = 0.001; Figure 3-46). Upon investigating the graph, concentrations in the earlier part of the record appeared unusually consistent, but they were recorded as detected and quantified values well above the contemporary reporting limit of 0.08 µg/L. These values were also reviewed according to standard quality assurance procedures. We retained these values rather than err on the side of removing valid data, but the cause of this trend is unknown.

Exceedances

- There were no water-quality exceedances over the period of record.

Table 3-23. Summary statistics for water-quality parameters at Crystal Reservoir at Crystal Dam, including concentrations at the 15th, 50th, and 85th percentiles; seasonal Kendall trend results for raw concentrations; and the number of samples that were censored.[†]

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results
	Start	End	Total	Censored		15th	Median	85th	Raw trend
Dissolved oxygen (mg/L)	8/28/2001	7/23/2013	41	0	uncensored	7.90	8.40	9.35	none
Escherichia coli (cfu/100 mL)	8/28/2001	7/23/2013	40	17	censored	<1	1	1	none
pH	8/28/2001	7/23/2013	41	0	uncensored	8.13	8.40	8.62	none
Specific conductance (µS/cm)	8/28/2001	7/23/2013	41	0	uncensored	171	198	209	none
Water temperature (°C)	8/28/2001	7/23/2013	41	0	uncensored	11.9	14.5	16.5	none
Calcium (d) (mg/L)	8/28/2001	7/23/2013	41	0	uncensored	22.7	26.2	29.5	none
Magnesium (d) (mg/L)	8/28/2001	7/23/2013	41	0	uncensored	4.88	5.69	6.14	none
Ammonia (d) (mg/L as N)	8/28/2001	7/23/2013	40	37	none	<0.02	<0.02	<0.02	–
Nitrite (d) (mg/L as N)	8/28/2001	7/23/2013	40	38	none	<0.0023	<0.0023	<0.0023	–
Nitrite + Nitrate (d) (mg/L as N)	8/28/2001	7/23/2013	40	39	none	<0.022	<0.022	<0.022	–
Phosphorus (mg/L as P)	8/28/2001	7/23/2013	40	0	uncensored	0.009	0.015	0.028	none
Cadmium (d) (µg/L)	8/28/2001	7/23/2013	41	41	none	<0.04	<0.04	<0.04	–
Copper (d) (µg/L)	8/28/2001	7/23/2013	41	24	none	<0.8	<0.8	0.887	–
Lead (d) (µg/L)	8/28/2001	7/23/2013	41	41	none	<0.12	<0.12	<0.12	–
Manganese (d) (µg/L)	8/28/2001	7/23/2013	40	0	uncensored	1.11	3.05	6.78	none
Selenium (d) (µg/L)	6/22/2006	7/23/2013	22	0	uncensored	0.139	0.161	0.200	↓
Silver (d) (µg/L)	8/28/2001	7/23/2013	41	41	none	<1	<1	<1	–
Zinc (d) (µg/L)	8/28/2001	7/23/2013	41	41	none	<2.8	<2.8	<2.8	–

[†] Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

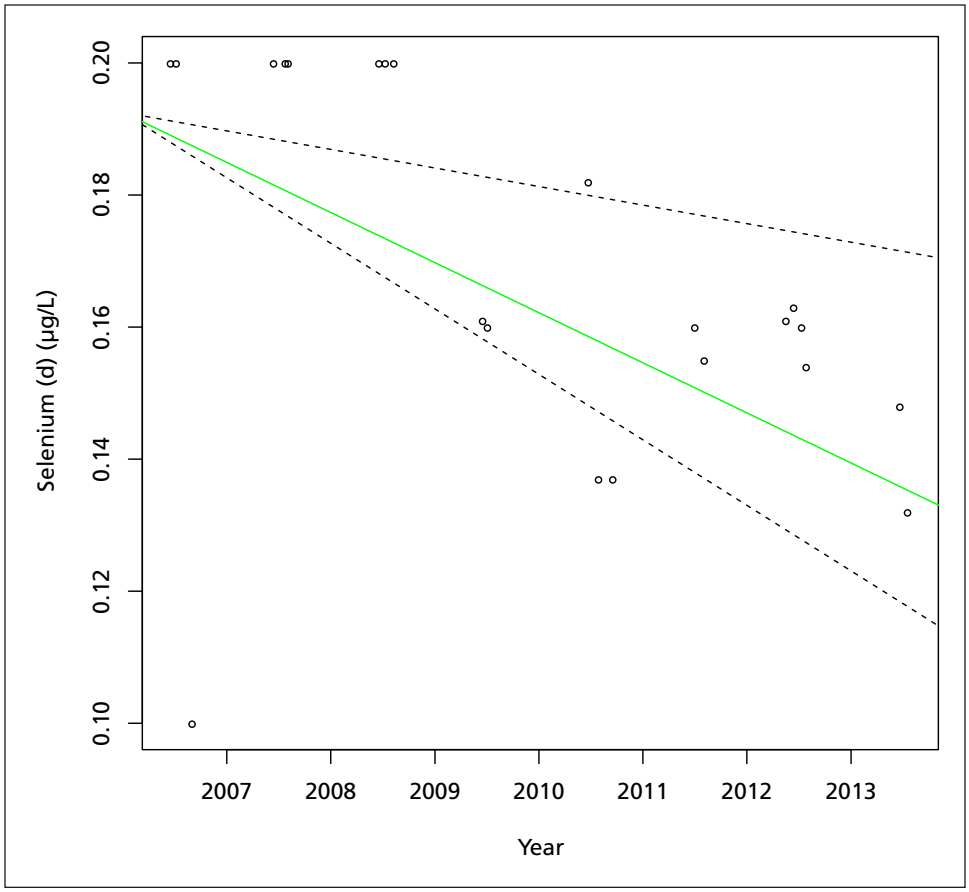


Figure 3-46. Statistically significant decrease in selenium over time at Crystal Reservoir at Crystal Dam (Kendall's tau = -0.484, $p < 0.01$). The estimated trend of -0.009 µg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.9 Black Canyon of the Gunnison National Park, upstream to downstream

3.9.1 Gunnison River below Gunnison Tunnel, Colorado

This site is located at the USGS gaging station 09128000, below the Gunnison Tunnel diversion after the Crystal Dam outfall at the boundary for BLCA. Samples are collected using a bridge sampler from the cableway across the river. This is a popular recreation area located downstream from the NPS East Portal Campground and trails along the river for angler access. The hydrograph is dam-controlled. In 2008, higher peak flows were reintroduced into the system in accordance with the BLCA water-right agreement. Spring peak flows can be triggered by snowpack levels, but peaks are capped due to the potential for flooding in downstream communities.

Summary statistics and trend analysis results are presented in Table 3-24. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Raw specific conductance decreased by -19% at a median rate of -3 µS/cm per year (Kendall's tau = -0.432, p = 0.04; Figure 3-47). The cause of this trend is unknown.

Exceedances

- There were no exceedances of state water-quality standards for dissolved oxygen, *E. coli*, pH, water temperature, ammonia, nitrite, cadmium, lead, manganese, selenium, silver, and zinc.
- There were <5% exceedances for phosphorus and copper.

Table 3-24. Summary statistics for water-quality parameters at Gunnison River below the diversion tunnel, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/28/2001	9/10/2014	50	0	uncensored	8.65	9.23	9.97	none	none
Escherichia coli (cfu/100 mL)	8/28/2001	9/10/2014	52	8	censored	<1	2	9	none	–
Flow (cfs)	6/20/2001	9/10/2014	53	0	uncensored	468	646	1144	none	–
pH	8/28/2001	9/10/2014	49	0	uncensored	7.97	8.16	8.31	none	not adjusted
Specific conductance (µS/cm)	6/20/2001	9/10/2014	53	0	uncensored	173	191	210	↓	none
Water temperature (°C)	6/20/2001	9/10/2014	54	0	uncensored	8.5	10.7	12.2	none	none
Calcium (d) (mg/L)	8/28/2001	9/10/2014	48	0	uncensored	22.9	26.1	29.1	none	none
Magnesium (d) (mg/L)	8/28/2001	9/10/2014	48	0	uncensored	4.98	5.42	5.96	none	none
Ammonia (d) (mg/L as N)	8/28/2001	9/10/2014	50	50	none	<0.02	<0.02	<0.02	–	–
Kjeldahl Nitrogen (mg/L)	8/28/2001	9/10/2014	26	1	uncensored	0.142	0.188	0.266	none	not adjusted
Nitrate (d) (mg/L as NO_3)	6/29/2009	9/10/2014	20	20	none	<0.087	<0.087	<0.087	–	–
Nitrite (d) (mg/L as N)	8/28/2001	9/10/2014	50	49	none	<0.0023	<0.0023	<0.0023	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/28/2001	9/10/2014	49	13	censored	<0.016	0.028	0.051	none	–
Orthophosphate (d) (mg/L as P)	8/28/2001	9/27/2006	22	9	censored	<0.006	0.007	0.013	none	–
Phosphorus (mg/L as P)	8/28/2001	9/10/2014	32	0	uncensored	0.018	0.025	0.036	none	not adjusted
Cadmium (d) (µg/L)	8/28/2001	9/10/2014	49	49	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/28/2001	9/10/2014	49	41	none	<1	<1	1.07	–	–
Lead (d) (µg/L)	8/28/2001	9/10/2014	49	43	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/28/2001	9/10/2014	50	1	uncensored	1.07	1.80	3.15	none	not adjusted
Selenium (d) (µg/L)	5/15/2006	9/10/2014	31	0	uncensored	0.121	0.143	0.165	none	not adjusted
Silver (d) (µg/L)	8/28/2001	9/10/2014	49	49	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/28/2001	9/10/2014	49	45	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

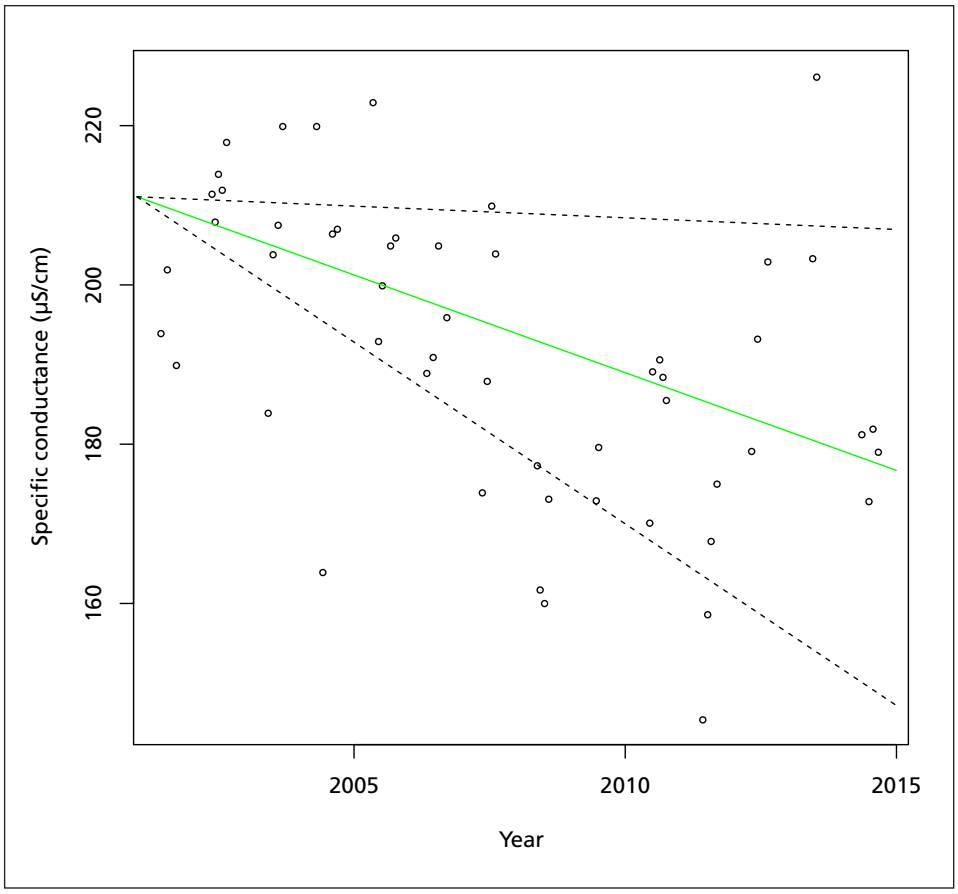


Figure 3-47. Statistically significant decrease in specific conductance over time at the Gunnison River below Gunnison Tunnel (Kendall's tau = -0.432, p = 0.04). The estimated trend of -3 µS/cm per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

3.9.2 Red Rock Canyon

Red Rock Canyon feeds into the Black Canyon of the Gunnison River. A majority of the water entering Red Rock Canyon comes from the Cimarron River via the Cimarron Canal and Vernal Mesa Ditch, which were built to provide irrigation water for private land in Bostwick Park in the upstream section of the canyon. These ditches and the Bostwick Park area are located within a Mancos Shale layer rich in selenium. Irrigation of areas with Mancos Shale is a known contributor to selenium exceedances in the Colorado River basin (CDPHE 2011). Streamflow in the canyon is heavily reliant upon irrigation return flow from the Bostwick Park area. There is heavy grazing in Bostwick Park, with occasional stray cattle grazing in or near the monitoring site on NPS land. An easement granted recreational access through the private land, but access was limited by the NPS permitting system required for overnight use in the canyon. In December 2017, this private land was purchased by the NPS. As part of the purchase agreement, an easement allows the previous landowner to continue irrigating and grazing the purchased property in some capacity through 2028.

Red Rock Canyon was added to the Colorado 303(d) List of Impaired Waters in 2008 for dissolved-selenium impairment. A Total Maximum Daily Load (TMDL) Assessment was approved on February 14, 2011, finding that the average amount of selenium load that would need to be reduced at this site for water years 2004 and 2005 was 217 pounds, or 93% of the mean annual load (CDPHE 2011). This high percentage of load reduction represents almost the entire mean annual load at this site. There are no point-source discharges to Red Rock Canyon Creek; therefore, load reductions would come from reductions in non-point source loads, such as agricultural practices. The segment was delisted on March 30, 2012.

3.9.2.1 Red Rock Canyon near NPS boundary near Montrose, Colorado

This site is located at the NPS Wilderness boundary at Red Rock Canyon, adjacent to the former private property purchased by the NPS. Occasional trespass cattle grazed at or near the monitoring location during the period of record.

Summary statistics and trend analysis results are presented in Table 3-25. Also see Tables i–iv and 3-1 to 3-3.

Trends

- There was no trend in measured flow during sampling visits.
- Raw concentrations of nitrate plus nitrite concentrations decreased by -66% at a median rate of -0.03 mg/L per year (Kendall's tau = -0.417, p = 0.02; Figure 3-48).
- Raw concentrations of phosphorus decreased by -65% at a median rate of -0.009 mg/L per year (Kendall's tau = -0.323, p = 0.05; Figure 3-49).
- Raw concentrations of copper decreased (Kendall's tau = -0.494, p = 0.005; Figure 3-50); because more than 5% of the dataset was censored, no estimate of slope is presented.

Exceedances

- There were no exceedances of state water-quality standards for water temperature, ammonia, nitrite, cadmium, copper, lead, manganese, silver, and zinc.
- There were <5% exceedances for pH and <10% exceedances for dissolved oxygen.
- *E. coli* exceeded the segment-specific water-quality standard of 126 cfu/100 mL on 75% of visits (33 of 44; Figure 3-51).
- Phosphorus exceeded the aquatic-life warm-water 2 interim standard of 0.17 mg/L on 45% of sample visits (19 of 42; Figure 3-52).
- Selenium exceeded the aquatic-life warm-water 2 interim standard of 4.6 µg/L on 98% of sample visits (41 of 42; Figure 3-53).

Continued management action is needed to bring irrigation return flows in Red Rock Canyon into compliance with state water-quality standards. A state plan for reducing selenium loading, the recent purchase of private land inholdings upstream of the canyon by the National Park Service, and a phase-

out of livestock grazing upstream of the canyon may assist in bringing these waters into compliance.

Improvements in water quality in Red Rock Canyon, including decreases in nitrite plus nitrate, total phosphorus, and copper concentrations, may be linked to a change in irrigation practices by one of the private landowners, from flood irrigation to a sprinkler system from 2006 to 2008. Flood irrigation picks up sediment from soils, which can contain high concentrations of *E. coli*, metals, and nutrients, particularly as irrigation continues over time (EPA 2005). Sprinkler systems, while using the same quantity of water, better target crops and reduce overland flow. A change from flood irrigation to sprinkler irrigation should also decrease selenium concentrations in the stream, but no trend in selenium was observed.

Table 3-25. Summary statistics for water-quality parameters at Red Rock Canyon near the NPS boundary, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	7/16/2003	9/16/2014	43	0	uncensored	7.44	8.06	8.78	none	not adjusted
Escherichia coli (cfu/100 mL)	7/16/2003	9/16/2014	44	0	uncensored	90.4	238	571	none	none
Flow (cfs)	7/16/2003	9/16/2014	42	0	uncensored	0.290	2.42	6.21	none	–
pH	7/16/2003	9/16/2014	43	0	uncensored	8.01	8.24	8.43	none	not adjusted
Specific conductance (µS/cm)	7/16/2003	9/16/2014	43	0	uncensored	729	830	918	none	none
Water temperature (°C)	7/16/2003	9/16/2014	43	0	uncensored	12.2	14.6	17.0	none	not adjusted
Calcium (d) (mg/L)	7/16/2003	9/16/2014	42	0	uncensored	86.3	99.7	111.9	none	none
Magnesium (d) (mg/L)	7/16/2003	9/16/2014	42	0	uncensored	34.7	40.4	46.7	none	none
Ammonia (d) (mg/L as N)	7/16/2003	9/16/2014	43	30	none	<0.02	<0.02	0.025	–	–
Ammonia, un-ionized (mg/L)	6/18/2009	9/16/2014	21	21	none	<0.02	<0.02	<0.02	–	–
Nitrate (d) (mg/L as NO_3)	6/18/2009	9/16/2014	21	2	uncensored	0.244	0.440	0.642	none	not adjusted
Nitrite (d) (mg/L as N)	7/16/2003	9/16/2014	43	1	uncensored	0.002	0.004	0.008	none	not adjusted
Nitrite + Nitrate (d) (mg/L as N)	7/16/2003	9/16/2014	43	0	uncensored	0.376	0.546	0.728	↓	none
Phosphorus (mg/L as P)	7/16/2003	9/16/2014	42	0	uncensored	0.079	0.167	0.289	↓	none
Cadmium (d) (µg/L)	7/16/2003	9/16/2014	42	40	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	7/16/2003	9/16/2014	42	17	censored	<1	1.12	1.83	↓	–
Lead (d) (µg/L)	7/16/2003	9/16/2014	42	41	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	7/16/2003	9/16/2014	43	0	uncensored	18.1	30.2	45.0	none	none
Selenium (d) (µg/L)	7/16/2003	9/16/2014	42	0	uncensored	12.2	16.3	23.0	none	none
Silver (d) (µg/L)	7/16/2003	9/16/2014	42	42	none	<0.2	<0.2	<0.2	–	–
Zinc (d) (µg/L)	7/16/2003	9/16/2014	42	41	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

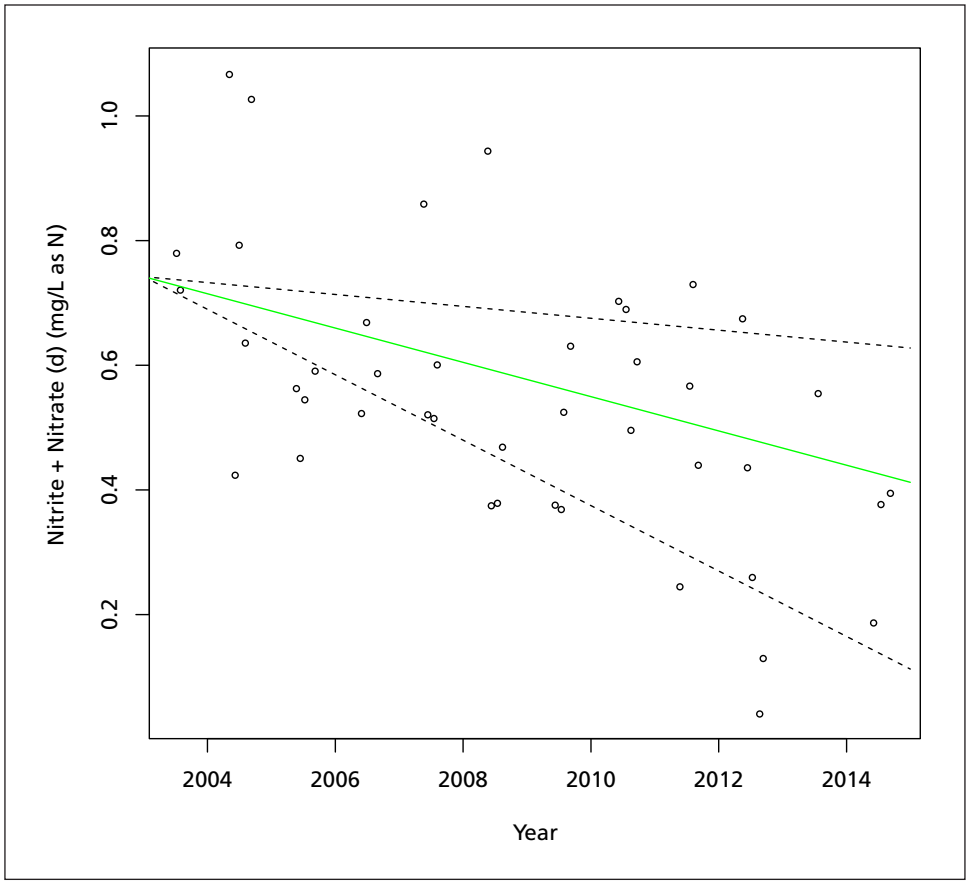


Figure 3-48. Statistically significant decrease in nitrite plus nitrate over time at Red Rock Canyon near the upstream NPS boundary (Kendall's tau = -0.417, p = 0.02). The estimated trend of -0.03 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

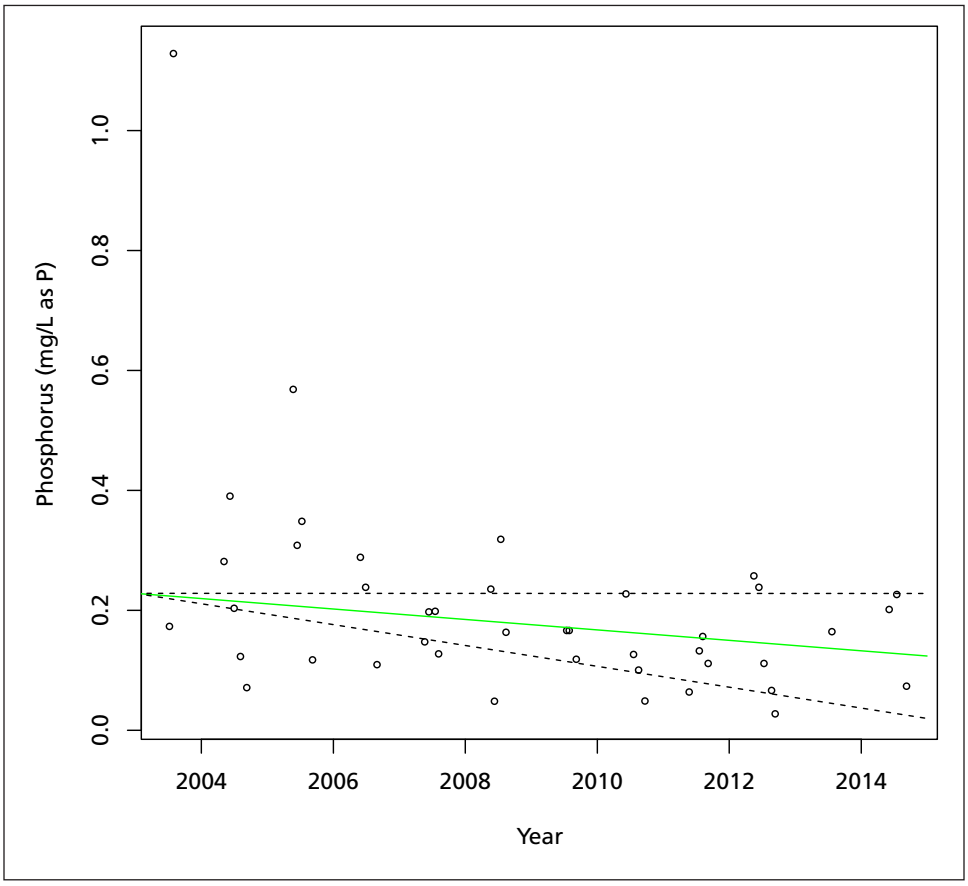


Figure 3-49. Statistically significant decrease in total phosphorus over time at Red Rock Canyon near the upstream NPS boundary (Kendall's tau = -0.323, p = 0.05). The estimated trend of -0.009 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

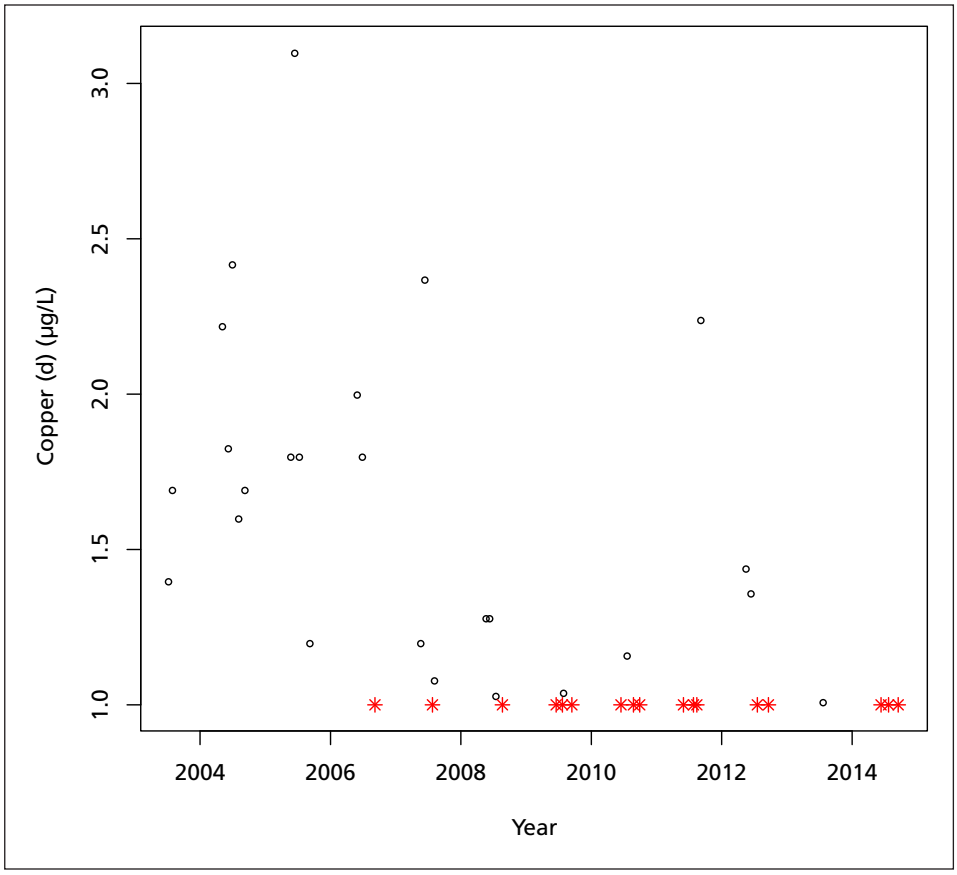


Figure 3-50. Statistically significant decrease in copper at Red Rock Canyon near the upstream NPS boundary over time (Kendall's tau = -0.720, $p < 0.01$). Censored data are presented as red stars at the highest reporting limit. Because more than 5% of the data were censored, no estimate of the slope is presented.

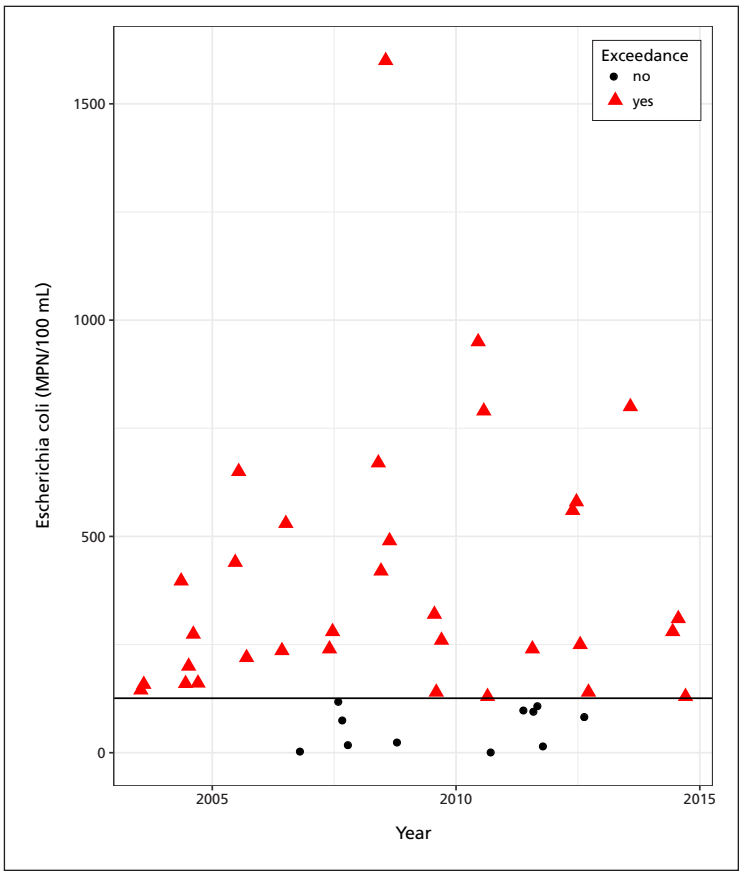


Figure 3-51. *E. coli* exceedances at Red Rock Canyon near the upstream NPS boundary. The black line indicates the segment-specific standard of 126 cfu/100 mL.

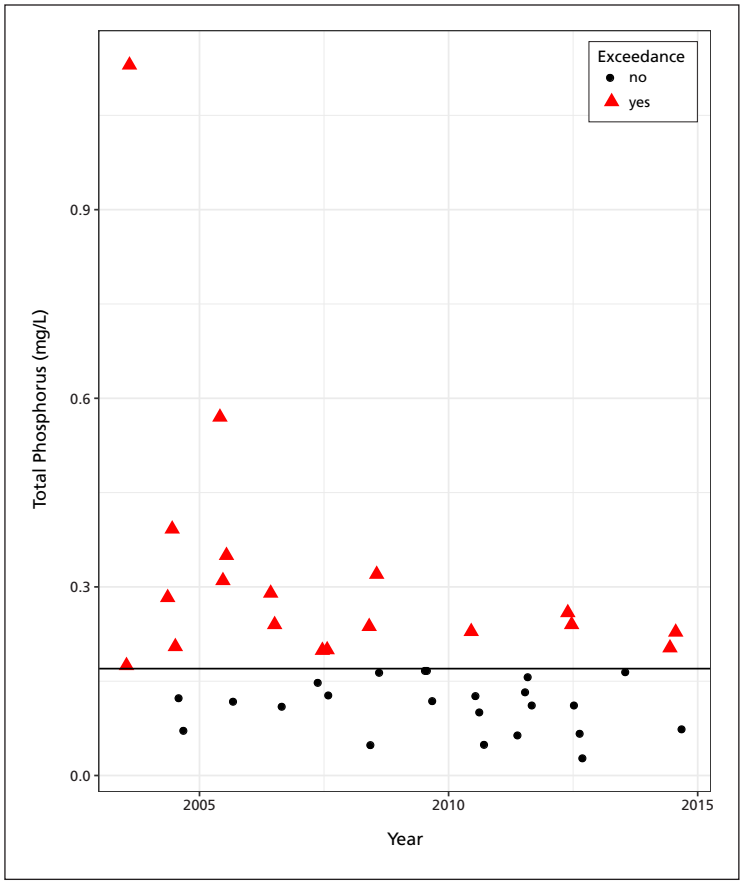


Figure 3-52. Phosphorus exceedances at Red Rock Canyon near the upstream NPS boundary. The black line indicates the aquatic-life warm-water 2 interim value of 0.17 mg/L.

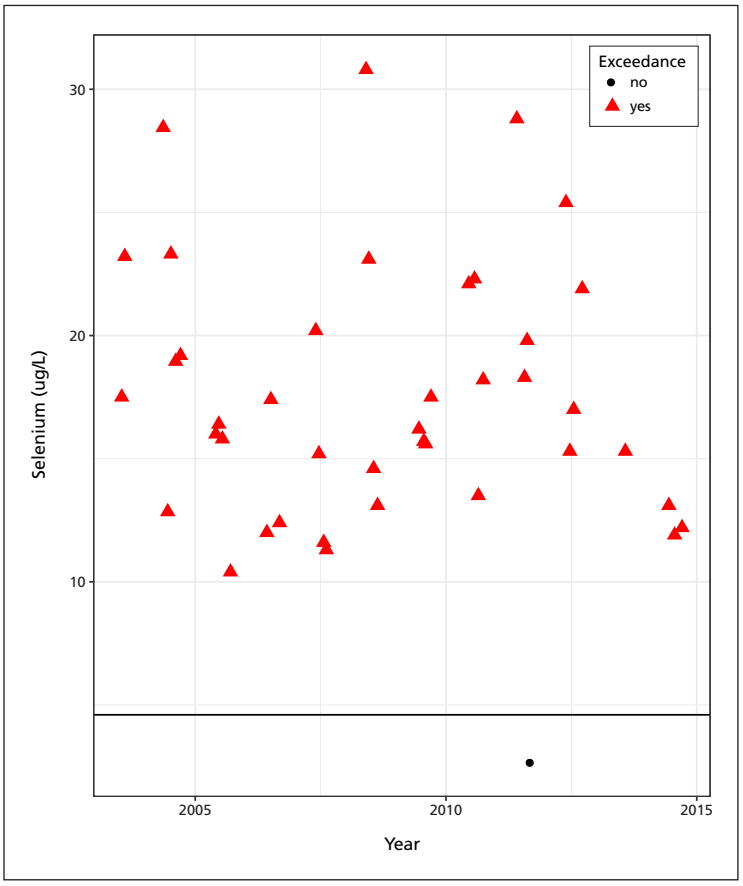


Figure 3-53. Selenium exceedances at Red Rock Canyon near the upstream NPS boundary. The black line indicates the aquatic-life warm-water 2 standard of 4.6 µg/L.

3.9.2.2 Red Rock Canyon at mouth near Montrose, Colorado

This sampling location is located at the bottom of Red Rock Canyon in NPS Wilderness, 150 feet upstream of where the stream enters the Gunnison River. A couple of small areas near the monitoring site are used for camping by overnight permit holders.

Summary statistics and trend analysis results are presented in Table 3-26. Also see Tables i–iv and 3-1 to 3-3.

Trends

- Measured flow during sampling visits decreased by -8.2% over time at the downstream site in Red Rock Canyon, at a median rate of -0.18 cfs per year (Kendall's tau = -0.312, p = 0.04; Figure 3-54). Flows are largely related to irrigation practices, and this trend is likely an artifact of changes in irrigation practices. Trends in raw concentrations may be affected by this decrease in flow.
- Flow-adjusted concentrations of nitrate plus nitrite decreased (Kendall's tau = -0.468, p = 0.02, slope of log(conc.) = -0.042; Figure 3-55). Raw concentrations of phosphorus decreased by -13.2% at a median rate of -0.007 mg/L per year (Kendall's tau = -0.398, p = 0.04; Figure 3-56). Raw concentrations of copper decreased (Kendall's tau = -0.72, p = 0.001; Figure 3-57); because more than 5% of the dataset was censored, no estimate of slope is presented. Although flow was not stationary over time, which can affect trend analysis, trends in nitrite plus nitrate, total phosphorus, and copper concentrations were similar to those seen at the upstream site in Red Rock Canyon. As suggested above, these improvements in water quality may be linked to a change in irrigation practices by one of the private landowners, from flood irrigation to a sprinkler system from 2006 to 2008. However, a concomitant decrease in selenium was not observed.

Exceedances

- There were no exceedances of state water-quality standards for pH, water temperature, ammonia, nitrite, cadmium, copper, lead, manganese, silver, and zinc.
- There were <5% exceedances for dissolved oxygen and <10% exceedances for *E. coli* and phosphorus.
- Selenium exceeded the aquatic-life warm-water 2 interim standard of 4.6 µg/L on 100% of sample visits (42 of 42; Figure 3-58). Continued management action is needed to bring irrigation return flows in Red Rock Canyon into compliance with state water-quality standards.

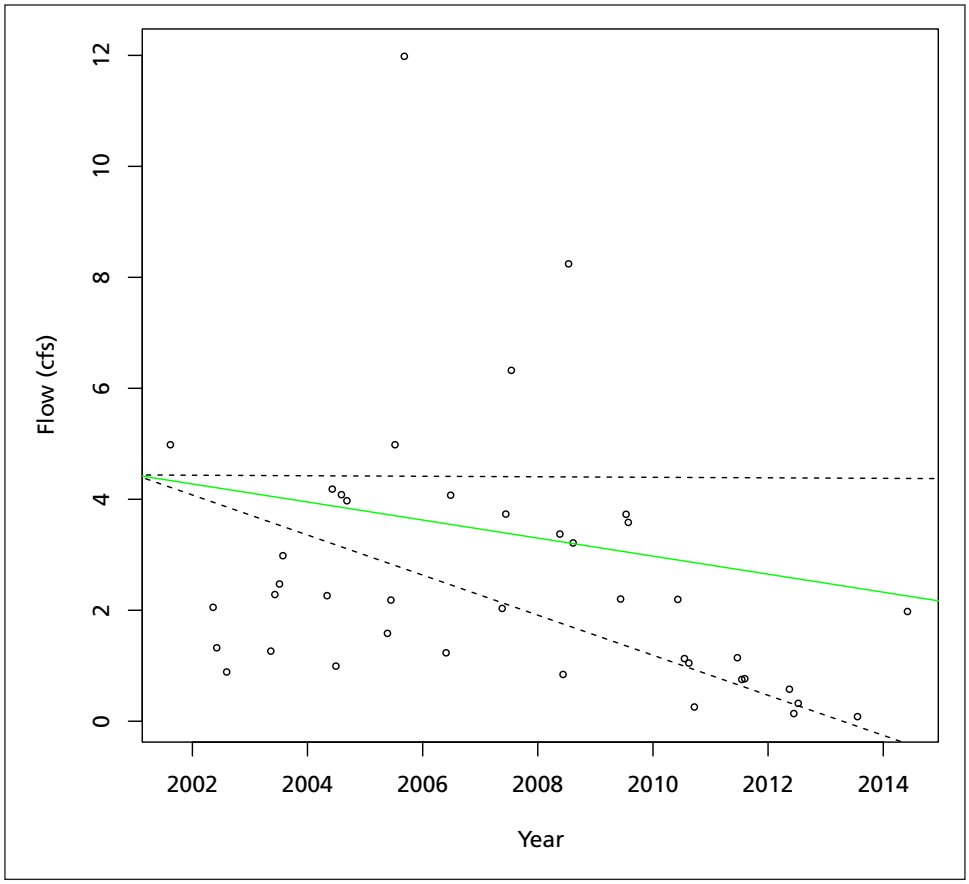


Figure 3-54. Flow recorded during monthly sampling visits at Red Rock Canyon near its mouth. The statistically significant decrease in flow is presented by a Sen slope of -0.18 cfs per year (solid green line) with the 95% confidence interval of the slope estimate (dashed lines; Kendall's tau = -0.312, p = 0.04).

Table 3-26. Summary statistics for water-quality parameters at Red Rock Canyon at mouth, including the number of samples that were censored; concentrations at the 15th, 50th, and 85th percentiles; and seasonal Kendall trend results for raw and flow-adjusted concentrations (FAC).†

Parameter	Sampling dates		Samples		Test type	Percentile			Seasonal Kendall results	
	Start	End	Total	Censored		15th	Median	85th	Raw trend	FAC trend
Dissolved oxygen (mg/L)	8/23/2001	6/12/2014	41	0	uncensored	7.99	8.51	9.07	none	none
Escherichia coli (cfu/100 mL)	8/23/2001	6/12/2014	39	3	censored	3	35	64.3	none	–
Flow (cfs)	8/23/2001	6/12/2014	42	0	uncensored	0.795	2.14	4.10	↓	–
pH	8/23/2001	6/12/2014	42	0	uncensored	8.33	8.48	8.60	none	none
Specific conductance (µS/cm)	8/23/2001	6/12/2014	43	0	uncensored	815	888	939	none	not adjusted
Water temperature (°C)	8/23/2001	6/12/2014	42	0	uncensored	11.2	12.7	15.3	none	not adjusted
Calcium (d) (mg/L)	8/23/2001	6/12/2014	42	0	uncensored	90.7	99.6	108.9	none	not adjusted
Magnesium (d) (mg/L)	8/23/2001	6/12/2014	42	0	uncensored	40.1	47.3	51.0	none	none
Ammonia (d) (mg/L as N)	8/23/2001	6/12/2014	43	39	none	<0.02	<0.02	<0.02	–	–
Nitrite (d) (mg/L as N)	8/23/2001	6/12/2014	43	35	none	<0.0023	<0.0023	0.003	–	–
Nitrite + Nitrate (d) (mg/L as N)	8/23/2001	6/12/2014	43	0	uncensored	0.591	0.825	1.158	none	↓
Phosphorus (mg/L as P)	8/23/2001	6/12/2014	43	0	uncensored	0.017	0.053	0.122	↓	none
Cadmium (d) (µg/L)	8/23/2001	6/12/2014	42	42	none	<0.04	<0.04	<0.04	–	–
Copper (d) (µg/L)	8/23/2001	6/12/2014	42	19	censored	<1	1.39	1.96	↓	–
Lead (d) (µg/L)	8/23/2001	6/12/2014	42	42	none	<0.12	<0.12	<0.12	–	–
Manganese (d) (µg/L)	8/23/2001	6/12/2014	41	0	uncensored	0.70	1.14	2.60	none	not adjusted
Selenium (d) (µg/L)	8/23/2001	6/12/2014	42	0	uncensored	30.6	43.2	60.0	none	none
Silver (d) (µg/L)	8/23/2001	6/12/2014	42	42	none	<1	<1	<1	–	–
Zinc (d) (µg/L)	8/23/2001	6/12/2014	42	40	none	<2.8	<2.8	<2.8	–	–

† FAC trend is marked "–" if flow adjustment was not appropriate (e.g., for censored datasets). Raw trend is marked "–" if no analysis was run because the dataset was >50% censored. Significant trends are indicated by blue (decreasing) and orange (increasing) arrows.

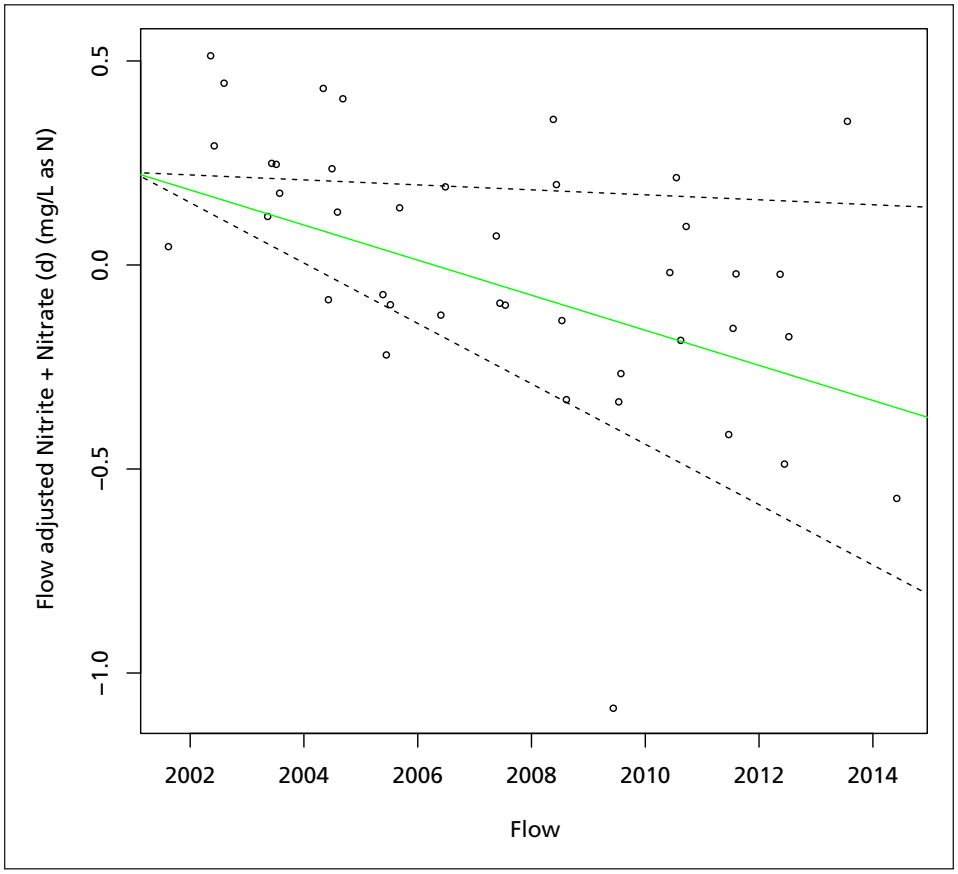


Figure 3-55. Statistically significant decrease in flow-adjusted log transformed nitrite plus nitrate over time at the mouth of Red Rock Canyon (Kendall's tau = -0.468, p = 0.02). The estimated trend of -0.042 per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

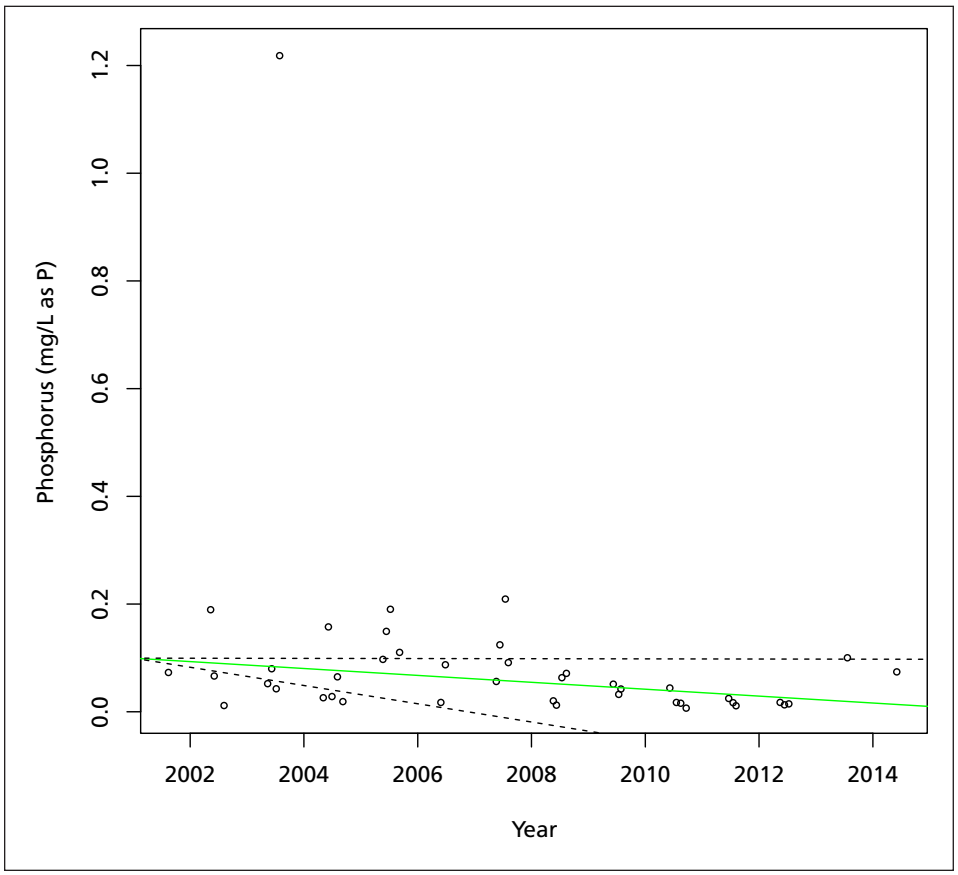


Figure 3-56. Statistically significant decrease in total phosphorus over time at the mouth of Red Rock Canyon (Kendall's tau = -0.398, p = 0.04). The estimated trend of -0.007 mg/L per year is presented by a Sen slope (solid green line) with the 95% confidence interval of the slope estimate (dashed lines).

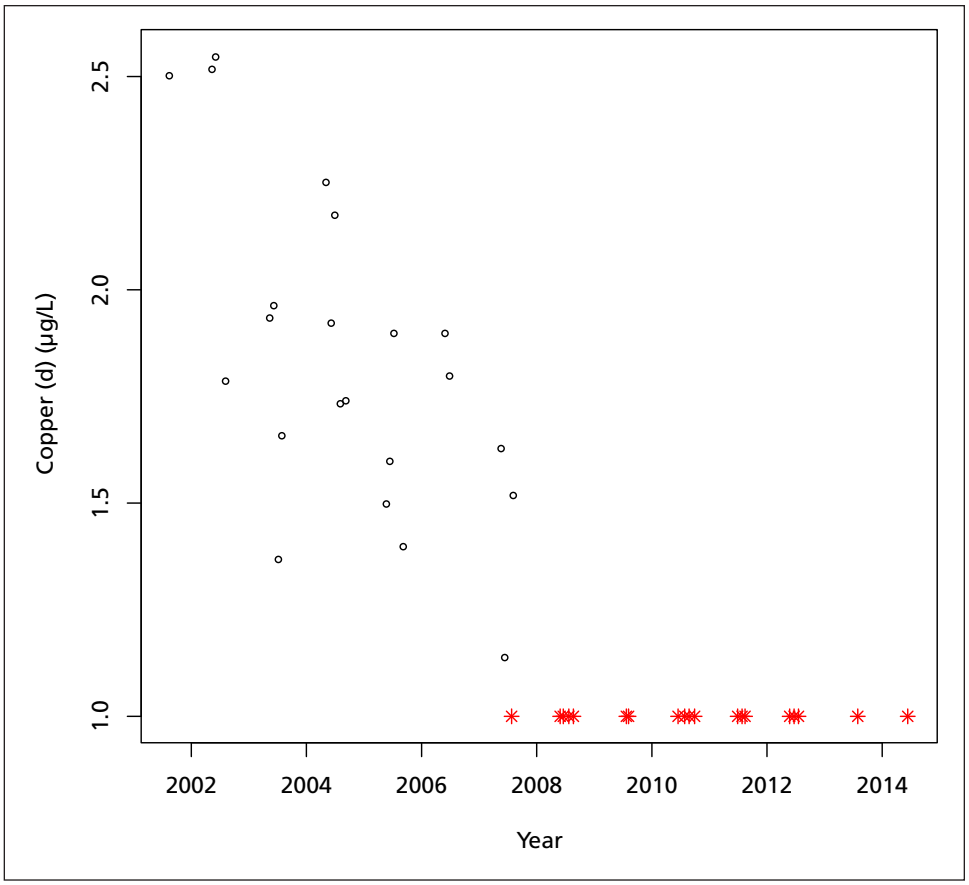


Figure 3-57. Statistically significant decrease in copper at the mouth of Red Rock Canyon over time (Kendall's tau = -0.72, $p < 0.01$). Censored data are presented as red stars at the highest reporting limit. Because more than 5% of the data were censored, no estimate of slope is presented.

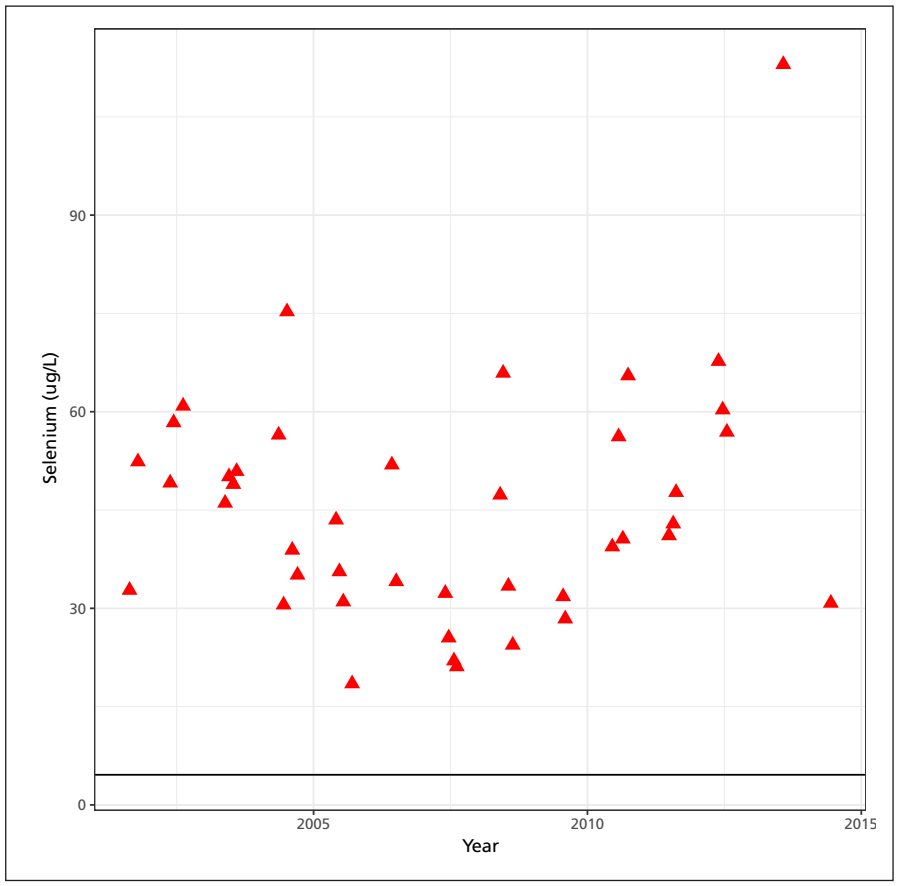


Figure 3-58. All selenium samples exceeded the water-quality standard at the mouth of Red Rock Canyon. The black line indicates the aquatic-life warm-water 2 standard of 4.6 µg/L.

4 Conclusions

Overall, water quality at CURE and BLCA was good and showed few significant trends. At the majority of water-quality sites, parameters did not have statistically significant trends in concentrations over time and did not exceed state water-quality standards on 15% or more of visits.

Trends in concentrations at several sites may indicate improving water quality, including decreases in nutrients, chloride, and metals. Water quality improved in the Cimarron River, with decreases in copper and selenium concentrations, although exceedances of fecal indicator bacteria, phosphorus, and water temperature were common. Decreases in chloride concentrations at several streams, including Pine Creek, Steuben Creek, and Red Creek, may indicate improved targeting of magnesium-chloride dust suppressants on adjacent dirt roads, with less spillover into the creeks. Increases in nitrite plus nitrate and selenium at Pine Creek are concerning but still at low concentrations. Residential septic systems or park pit toilets could contribute to increases in nitrite plus nitrate concentrations and could be checked for leaks. There have been no major land-use or management changes in these areas. Further monitoring and assessment of these sites and parameters is necessary to determine if changes are influenced by sampling frequency and timing or other factors upstream.

Improvements in water quality in Red Rock Canyon, including decreases in total phosphorus, nitrite plus nitrate, and copper concentrations, may be linked to a change in irrigation practices, from flood irrigation to a sprinkler system from 2006 to 2008, which reduces overland flow. However, improvements in water quality in Red Rock Canyon have not been sufficient to bring water quality within state standards. The interim value for total phosphorus and the standard for fecal indicator bacteria (*Escherichia coli*) are still regularly exceeded at the upstream site in Red Rock Canyon. Selenium concentrations still exceed the state aquatic-life standard at both the upstream and downstream sites at almost all visits. Selenium concentrations would also be expected to decrease as overland irrigation flows are curtailed, but a decreasing trend in selenium concentrations was not observed. Continued management action is needed to bring irrigation return flows in Red Rock Canyon into compliance with state water-quality standards. A state plan for reducing selenium loading, the recent purchase of private-land inholdings upstream of the canyon by NPS, and a phase-out of livestock grazing upstream of the canyon may help bring these sites into compliance.

Water-quality standard comparisons support previously recognized management issues, including dissolved oxygen and water temperature in Blue Mesa Reservoir and two tributaries (East Elk Creek and Red Creek). Because the State of Colorado has updated its standards to require lake-profile data for water temperature and dissolved oxygen in reservoirs and continuous temperature data in streams, the NPS has updated its monitoring program so data are more comparable to current standards.

Total phosphorus regularly exceeds the state's interim water-quality value at many tributary sites. While human activities that increase erosion, such as livestock grazing, roads, and agricultural activity, can contribute phosphorus to water bodies, volcanic rock, such as the andesitic lava flows and breccia common in the region, can also be naturally high in phosphorus (Thornberry-Erlich 2005; Porder and Ramachandran 2013). Research also suggests that higher-elevation Rocky Mountain streams are historically limited by nitrogen availability rather than phosphorus (Williams et al. 1996). High phosphorus concentrations have not resulted in observations of algal blooms or other indicators of eutrophication in tributaries at BLCA or CURE. Exceedances of the interim standards for phosphorus without additional signs of impairment suggest that phosphorus may be naturally occurring from a geologic origin in this area.

However, evidence of eutrophication has been noted in Blue Mesa Reservoir in low water years, even as phosphorus concentrations have remained below the interim state water-quality value. Several localized fish kills were observed in 2013 in the middle of

the reservoir, and the most upstream site in the reservoir occasionally exceeded the interim chlorophyll-*a* standard for cold-water reservoirs. An earlier investigation of nutrients in the reservoirs suggested that nitrogen likely limits algal growth in Blue Mesa Reservoir (Bauch and Malick 2003). Park monitoring has been updated to include collecting dissolved oxygen and water temperature at multiple depths for better comparison with state water-quality standards. NPS personnel are also coordinating with the state to increase nutrient sampling in the reservoir. Investigations into sources of nutrients in watersheds in this area, particularly nitrogen species, may assist land managers in developing a plan for improving water quality in Blue Mesa Reservoir.

Continued exceedances of fecal coliforms in Blue Creek, the Cimarron River, and the upstream site in Red Rock Canyon support the need for management action to improve public health and safety in these streams. The NPS will continue to reach out to local landowners and coordinate with local watershed protection groups to reduce the amount of exceedances found in this report.

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Appendix A. State of Colorado Water-Quality Beneficial Uses and Standards

This appendix contains the State of Colorado water-quality designated beneficial uses and associated water-quality standards for sites analyzed in and near Curecanti National Recreation Area and Black Canyon of the Gunnison National Park. Beneficial uses assessed in this report include cold- and warm-water aquatic life (ALCW1 and ALWW2), reservoir-specific aquatic life (Res), and recreation uses (existing RecE and undetermined RecU). Beneficial uses not included in this report include drinking water and agricultural standards. Segment-specific standards may also exist, as noted in Table A1. Where a segment-specific standard exists, the segment-specific standard supersedes the beneficial-use standard and is explained in the text, as for *E. coli* in Red Rock Canyon, with a segment-specific standard of 126 cfu/100 mL. Each designated beneficial use is associated with multiple water-quality standards (Table A2).

Table A1. State designated beneficial uses associated with water bodies in and near Black Canyon of the Gunnison National Park.

Site ID	Site name	Latitude	Longitude	Designated beneficial uses
BLCA_09128000	Gunnison R bl Gunnison Tunnel, CO	38.529	-107.649	ALCW1, RecE, LG1
BLCA_383537107471500	Red Rock Canyon at mouth nr Montrose, CO	38.594	-107.788	ALWW2, RecE, LG4c
BLCA_383418107471401	Red Rock Canyon nr NPS boundary nr Montrose, CO	38.572	-107.788	ALWW2, RecE, LG4c

Table A2. State designated beneficial uses associated with water bodies in and near Curecanti National Recreation Area.

Site ID	Site name	Latitude	Longitude	Designated beneficial uses
CURE_382943107015300	Beaver Creek at HWY 50 nr Gunnison, CO	38.495	-107.032	ALCW1, RecU, UG26
CURE_382418107242600	Blue Creek at HWY 50 nr Sapinero, CO	38.405	-107.408	ALCW1, RecU, UG26
CURE_381633107054700	Cebolla Creek at Powderhorn, CO	38.276	-107.097	ALCW1, RecU, UG29b
CURE_09127000	Cimarron R bl Squaw Creek nr Cimarron, CO	38.446	-107.556	ALCW1, RecU, UG26
CURE_09125000	Curecanti Creek nr Sapinero, CO	38.455	-107.420	ALCW1, RecU, UG26
CURE_382900107101600	East Elk Creek nr mouth nr Sapinero, CO	38.483	-107.172	ALCW1, RecU, UG26
CURE_383103106594200	Gunnison R at Cnty Rd 32 bl Gunnison, CO	38.517	-106.996	ALCW1, RecE, UG14
CURE_381934107133500	Lake Fork Gunnison R bl Gateview, CO	38.326	-107.227	ALCW1, RecE, UG29b
CURE_382702107203900	Pine Creek at HWY 50 nr Sapinero, CO	38.451	-107.345	ALCW1, RecU, UG26
CURE_382902107140400	Red Creek nr mouth nr Sapinero, CO	38.484	-107.235	ALCW1, RecU, UG26
CURE_383137107183600	Soap Creek ab Chance Creek nr Sapinero, CO	38.527	-107.311	ALCW1, RecU, UG26
CURE_382937107033500	Steuben Creek nr mouth nr Gunnison, CO	38.494	-107.060	ALCW1, RecU, UG26
CURE_383028107162200	West Elk Creek bl forest boundary nr Sapinero, CO	38.508	-107.273	ALCW1, RecU, UG26
CURE_382829107122200	Blue Mesa Reservoir ab Cebolla Cr nr Sapinero, CO	38.475	-107.207	ALCW1, RecE, Res
CURE_382831107172600	Blue Mesa Reservoir ab Soap Cr nr Sapinero, CO	38.475	-107.291	ALCW1, RecE, Res
CURE_382856107050000	Blue Mesa Reservoir bl HWY 149 nr Gunnison, CO	38.482	-107.084	ALCW1, RecE, Res
CURE_382924107352300	Crystal Reservoir at Crystal Creek nr Cimarron, CO	38.490	-107.590	ALCW1, RecE, Res
CURE_383024107371800	Crystal Reservoir at Crystal Dam nr Cimarron, CO	38.507	-107.622	ALCW1, RecE, Res
CURE_382702107315400	Morrow Pt Reservoir ab Morrow Pt Dam nr Cimarron, CO	38.451	-107.532	ALCW1, RecE, Res
CURE_382644107271000	Morrow Pt Reservoir bl Blue Cr nr Sapinero, CO	38.446	-107.453	ALCW1, RecE, Res

Table A3. Water-quality standards associated with designated beneficial uses for the State of Colorado.

Parameter	Type	ALCW1[†,††]	ALWW2[†,††]	Res	RecE	RecU
Chlorophyll-*a*, uncorrected for pheophytin (µg/L)	interim	–	–	8	–	–
Dissolved oxygen (mg/L)	low	7.0	5.0	–	3.0	3.0
Escherichia coli (cfu/100 mL)	–	–	–	126	126	126
pH	low	6.5	6.5	6.5	6.5	6.5
pH	–	9.0	9.0	9.0	9.0	9.0
Water temperature (°C)	summer	17.0	28.7	17.0	–	–
Water temperature (°C)	winter	9.0	14.3	9.0	–	–
Chloride (d) (mg/L)	–	250	–	250	–	–
Ammonia (d) (mg/L as N)	–	pH Dep.	pH Dep.	–	–	–
Nitrite (d) (mg/L as N)	–	0.05	–	0.05	–	–
Phosphorus (mg/L as P)	interim	0.110	0.170	0.025	–	–
Cadmium (d) (µg/L)	–	HD	HD	–	–	–
Copper (d) (µg/L)	–	HD	HD	–	–	–
Lead (d) (µg/L)	–	HD	HD	–	–	–
Manganese (d) (µg/L)	–	HD	HD	–	–	–
Selenium (d) (µg/L)	–	4.6	4.6	–	–	–
Silver (d) (µg/L)	–	HD	HD	–	–	–
Zinc (d) (µg/L)	–	HD	HD	–	–	–

[†] pH Dep. = Standard is dependent on concurrently measured pH value.

[††] HD = Standard is dependent on concurrently measured hardness concentration. For most water-quality standards, a value higher than the standard value is considered an exceedance, or an indicator of poor water-quality. If poor water quality is indicated by a value lower than the water-quality standard, the type is indicated as "low" in the table.

Appendix B. Generalized Additive Models (GAMs) Used in Statistically Significant Flow-Adjusted Concentration Tests

Flow and concentration relationships were fit with a smoothed Generalized Additive Model (GAM; red line) and a constant model equal to the concentration mean (dashed line). Models were compared using the Akaike Information Criterion (delta AIC). GAMs with ΔAIC >4 were considered better fits than the constant model. Residuals from the model were tested for trends using an uncensored seasonal Kendall test. Only GAMs for parameters with statistically significant trends in flow-adjusted concentrations are presented here.

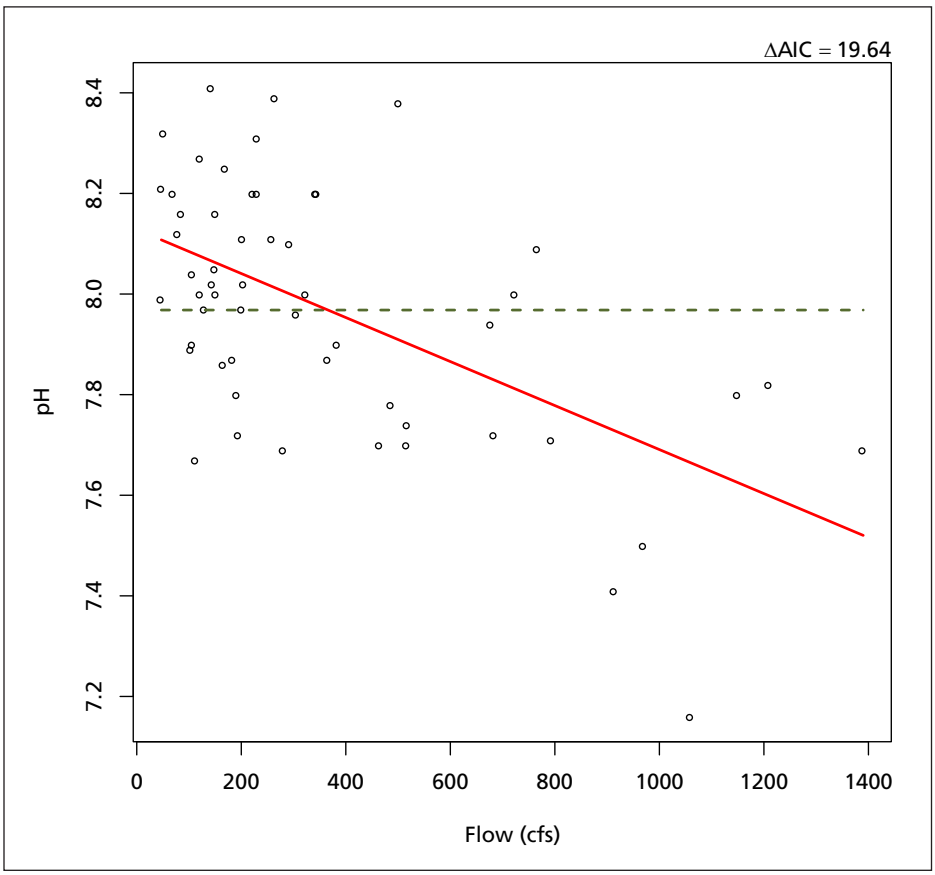


Figure B1. GAM of pH on flow at Lake Fork of the Gunnison River below Gateview. Residuals from the model were tested for trends over time.

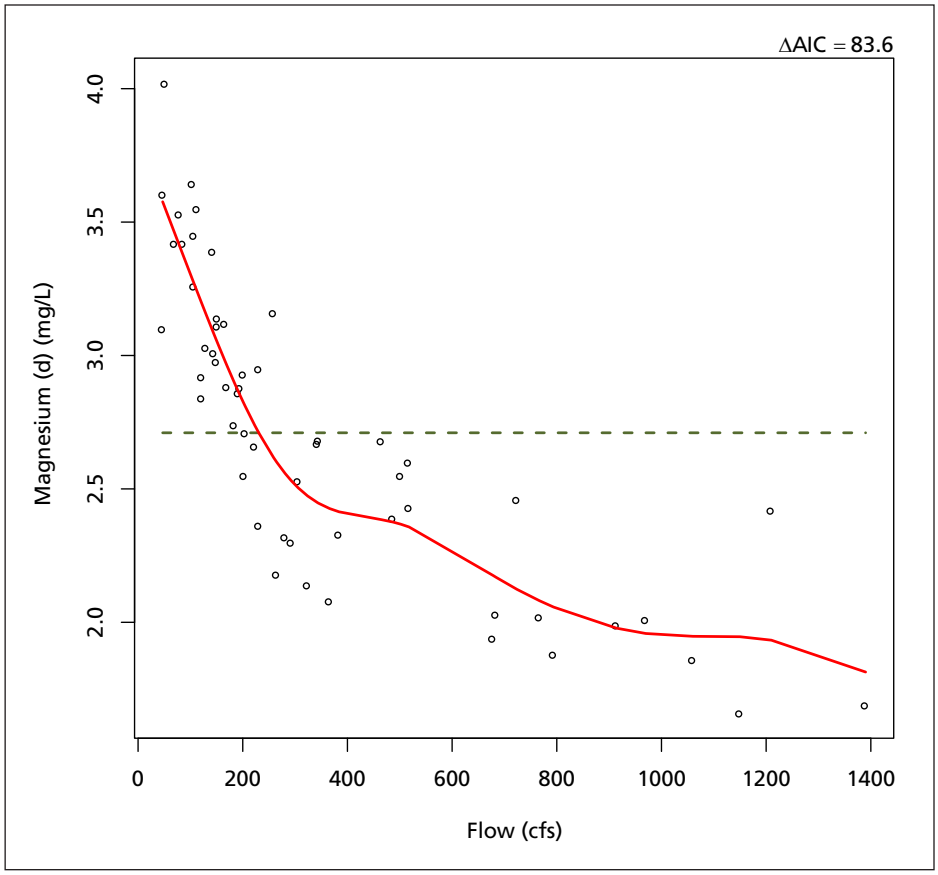


Figure B2. GAM of magnesium on flow at Lake Fork of the Gunnison River below Gateview. Residuals from the model were tested for trends over time.

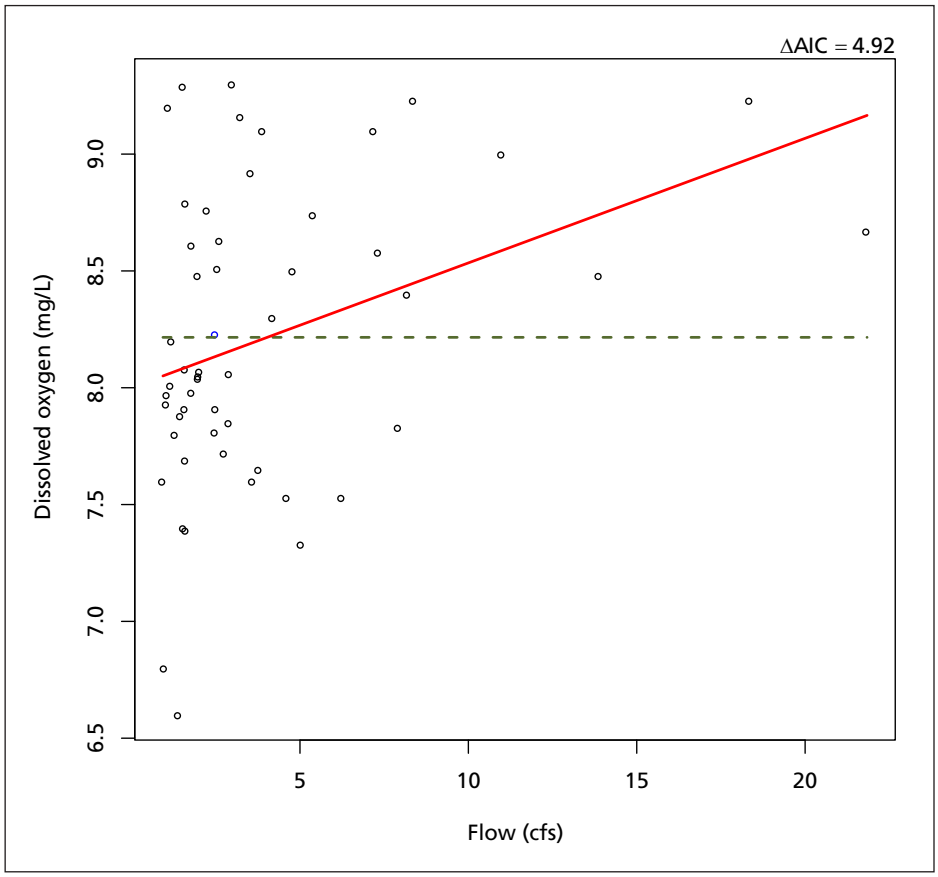


Figure B3. GAM of dissolved oxygen on flow at Pine Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

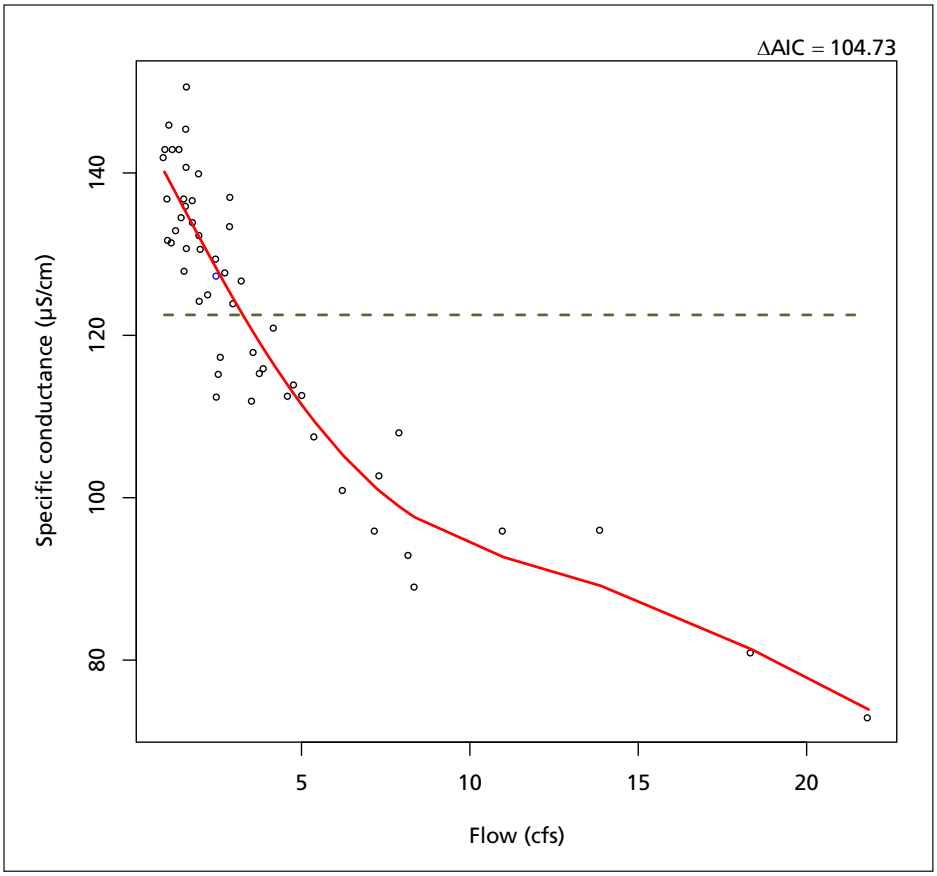


Figure B4. GAM of specific conductance on flow at Pine Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

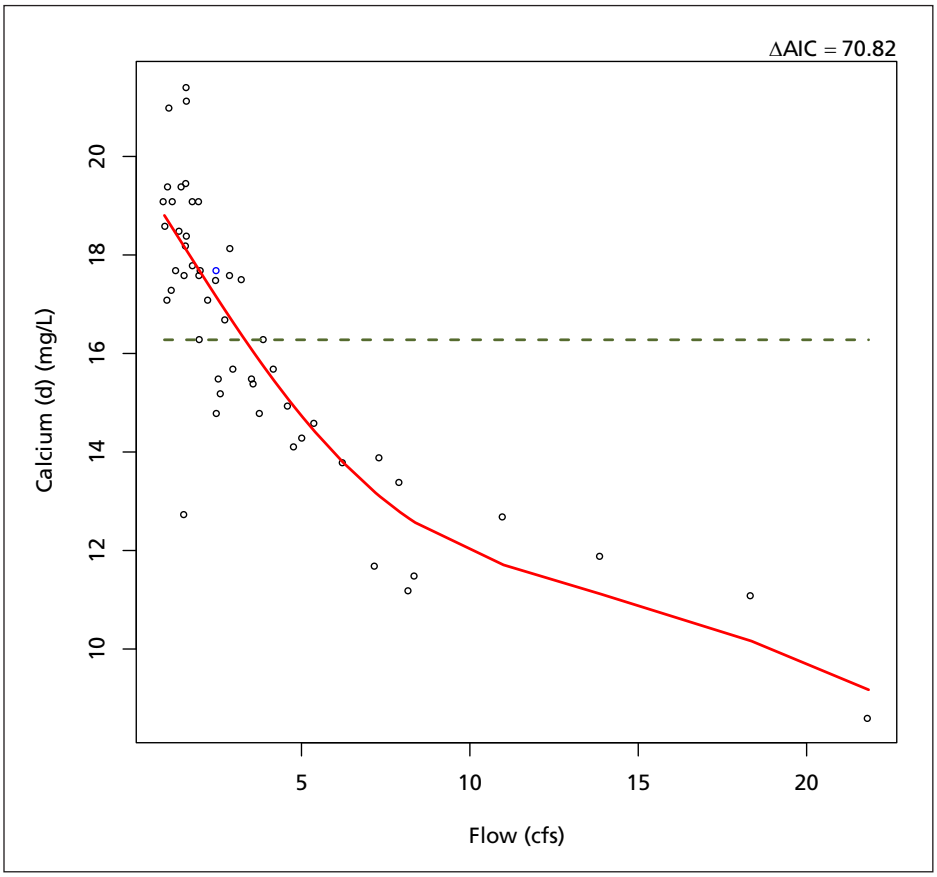


Figure B5. GAM of calcium on flow at Pine Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

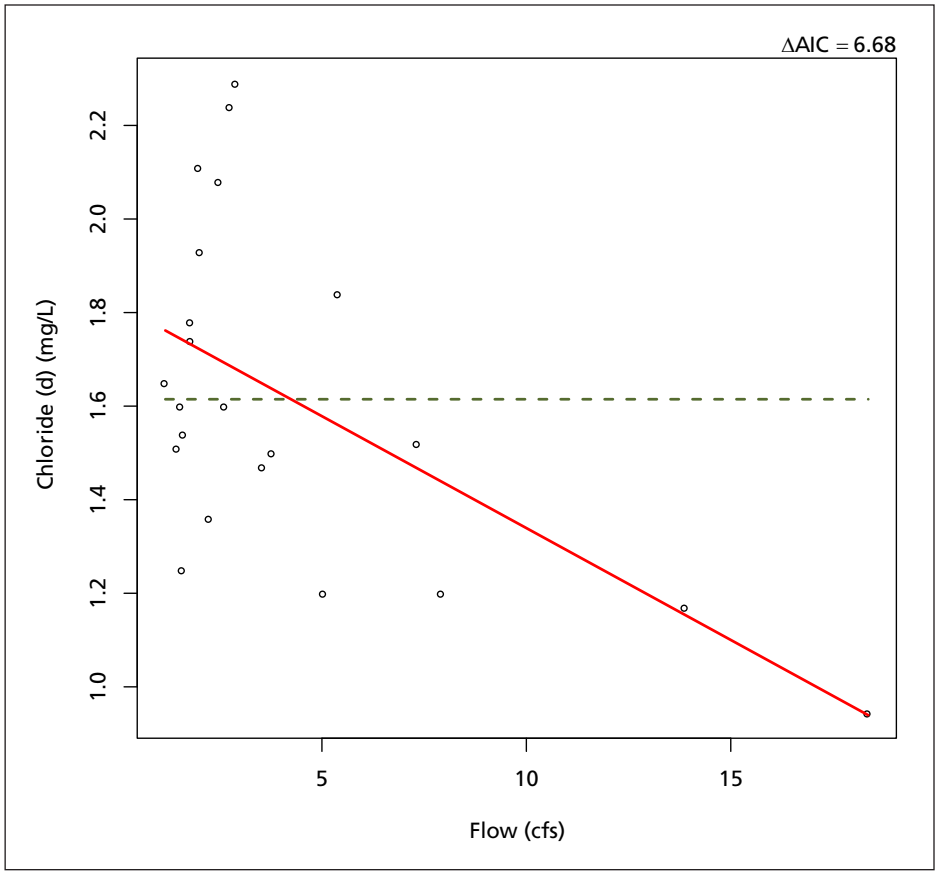


Figure B6. GAM of chloride on flow at Pine Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

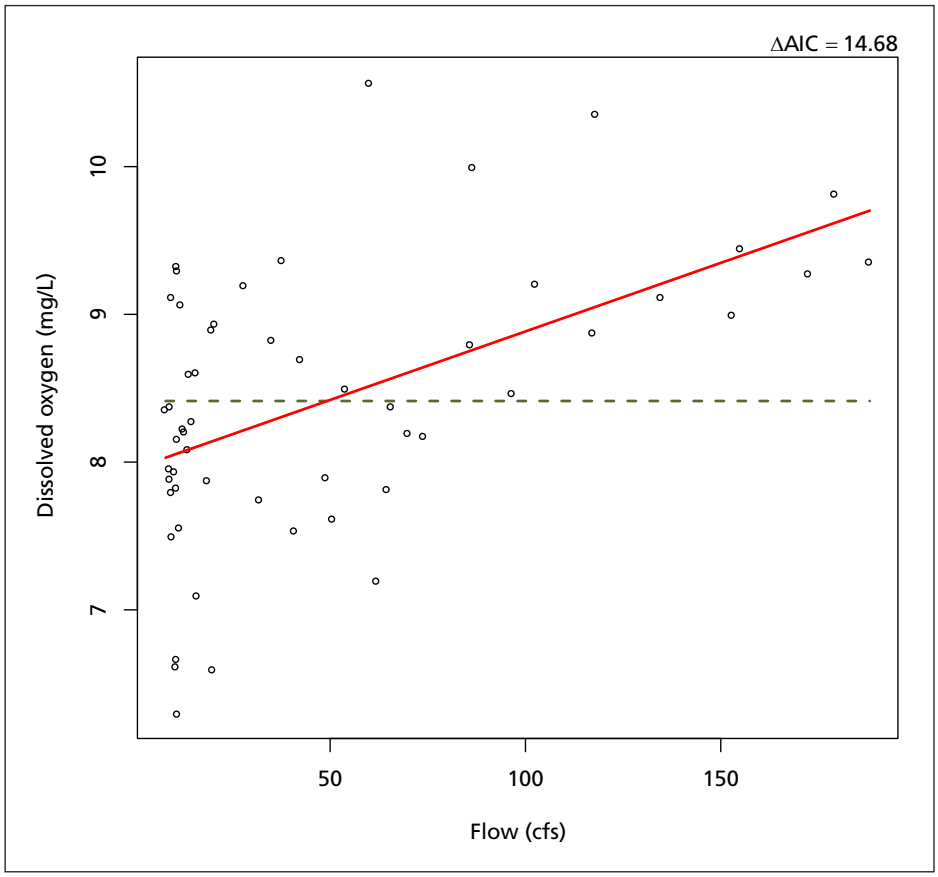


Figure B7. GAM of dissolved oxygen on flow at Blue Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

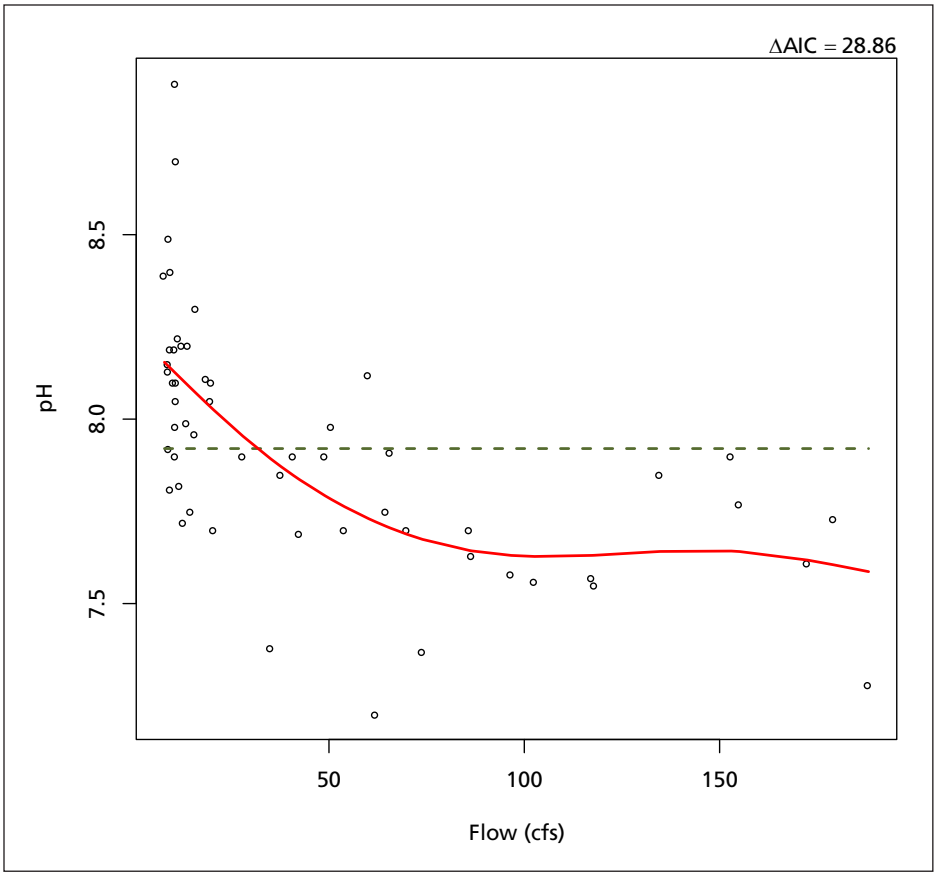


Figure B8. GAM of pH on flow at Blue Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

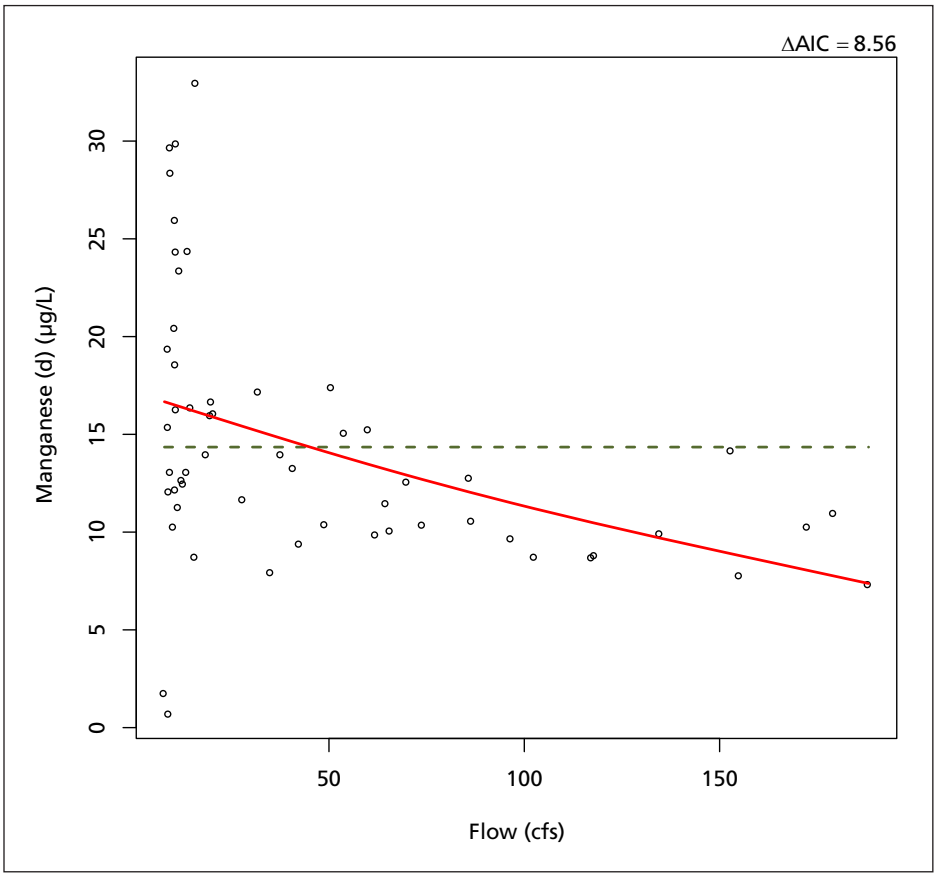


Figure B9. GAM of manganese on flow at Blue Creek at Highway 50 near Sapinero. Residuals from the model were tested for trends over time.

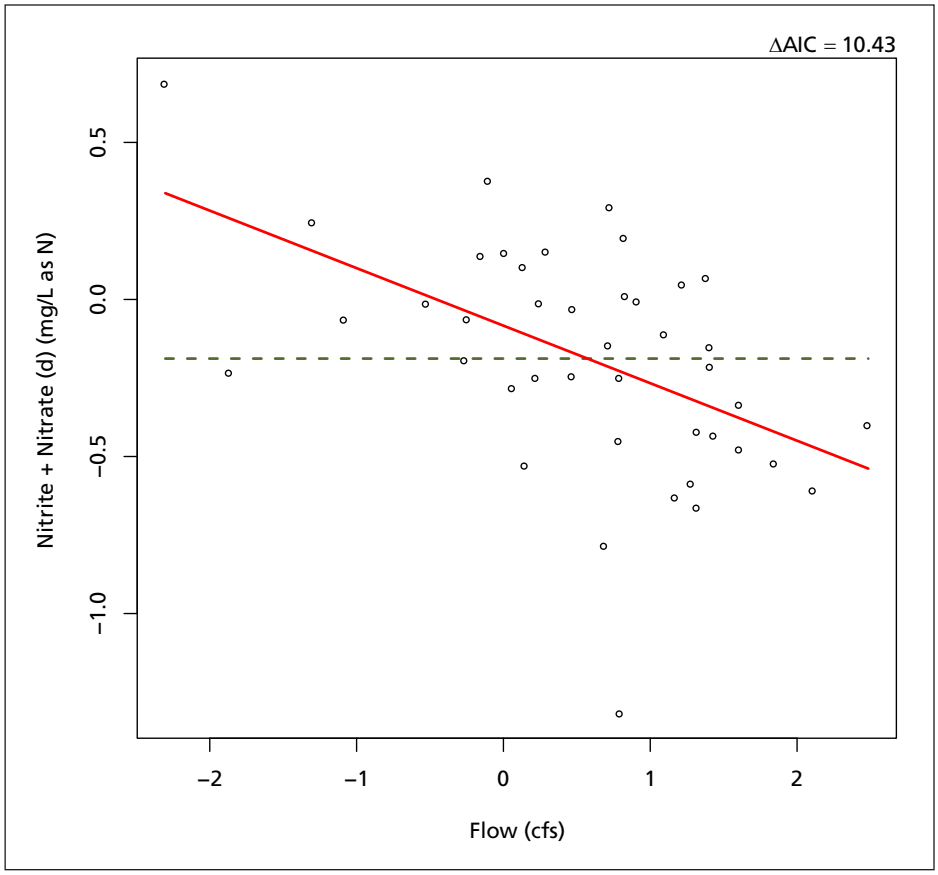


Figure B10. GAM of log (nitrite plus nitrate) on log (flow) at Red Rock Canyon at mouth near Montrose. Residuals from the model were tested for trends over time.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

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