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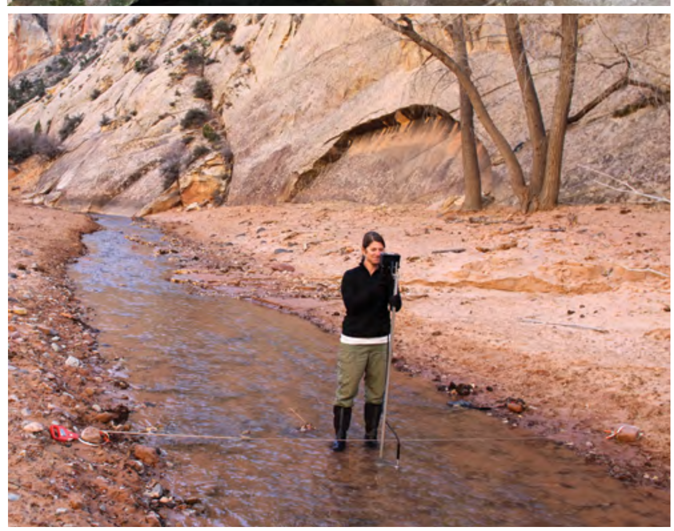
Natural Resource Stewardship and Science

Water Quality in the Northern Colorado Plateau Network, Water Years 2010–2012

Natural Resource Technical Report NPS/NCPN/NRTR—2013/831



ON THE COVER

Left: The Narrows, Zion National Park (NPS/M. Neidig). *Top right:* Springs monitoring, Hovenweep National Monument (NPS). *Bottom right:* Field work on Oak Creek, Capitol Reef National Park (NPS).

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Abstract

Water quality monitoring in National Park Service units of the Northern Colorado Plateau Network (NCPN) is made possible through partnerships between the National Park Service Inventory & Monitoring Program, individual park units, the U.S. Geological Survey, and the State of Utah's Division of Water Quality. This report evaluates data from site visits made at 75 different locations on NCPN streams and rivers in or near 11 NCPN park units between October 1, 2009 and September 30, 2012. Evaluation of water quality parameters relative to state water quality standards indicated that 26,051 (96.9%) of the 26,873 total designated beneficial-use evaluations completed for the period covered in this report did not exceed state water quality standards (Figure A).

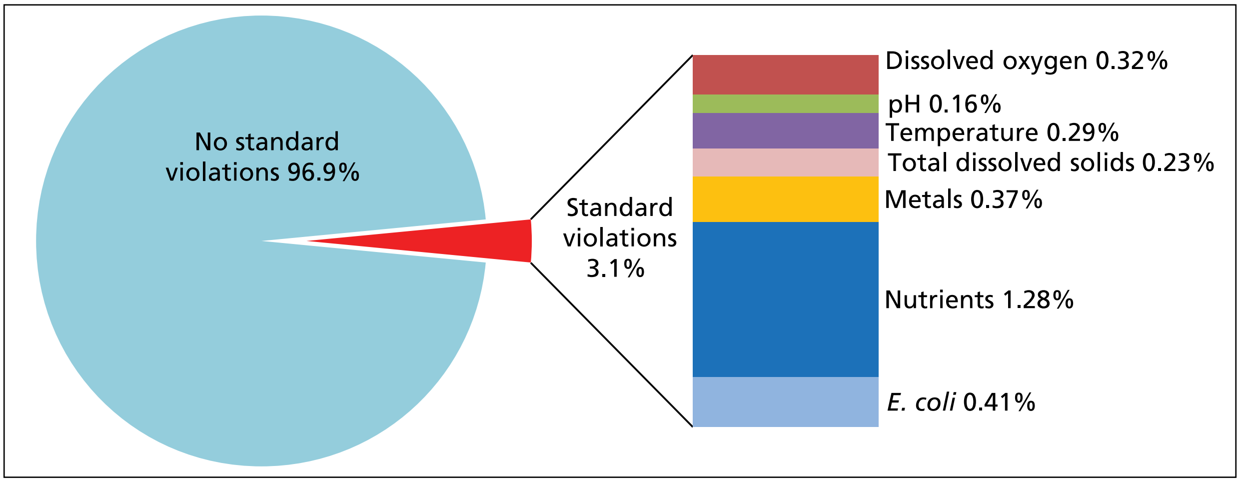

Figure A. Percentage of use evaluations that exceeded standards, and the causes of exceedances at selected sites sampled in NCPN park units, October 1, 2009–September 30, 2012.

While some exceedances were reoccurring and may have been caused by human activities in the watersheds, many were due to naturally occurring conditions characteristic of the geographic setting. The most common exceedances or indications of impairment, in order of abundance, were due to elevated nutrients, elevated bacteria (*E. coli*), elevated trace metals, low dissolved oxygen, elevated temperature, elevated total dissolved solids, and elevated pH (Figure B). An emerging concern is the number of water temperature exceedances at six national park units. Water temperatures are predicted to increase as the climate changes due to higher air temperatures and lower instream flows.

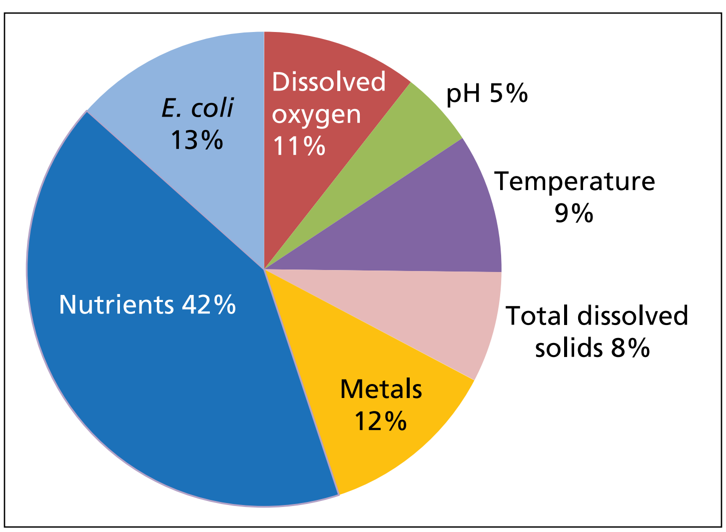

Figure B. Most commonly exceeded water quality standards in NCPN park units, October 1, 2009–September 30, 2012.

Acronyms, Abbreviations, and Codes

Park acronyms	
ARCH	Arches National Park
BLCA	Black Canyon of the Gunnison National Park
BRCA	Bryce Canyon National Park
CANY	Canyonlands National Park
CARE	Capitol Reef National Park
CURE	Curecanti National Recreation Area
DINO	Dinosaur National Monument
GOSP	Golden Spike National Historic Site
HOVE	Hovenweep National Monument
NABR	Natural Bridges National Monument
TICA	Timpanogos Cave National Monument
ZION	Zion National Park
General acronyms and abbreviations	
303(d)	Section 303(d) of Clean Water Act, requiring a reporting of waters not meeting criteria
AB	above
BL	below
BLM-WSA	Bureau of Land Management Wilderness Study Area
BNDRY	boundary
cfs	cubic feet per second
cfu	colony forming units
ck	creek
CNFL	confluence
CNTY	county
CO	Colorado
CR	county road
CWA	Clean Water Act
DO	dissolved oxygen
E. coli	Escherichia coli bacteria
EPA	U.S. Environmental Protection Agency
fk	fork
GPRA	Government Performance and Results Act
HWY	highway
mg/L	milligrams per liter
MPN	most probable number
NFVR	North Fork Virgin River
NHS	national historic site
NPS	National Park Service
NCPN	Northern Colorado Plateau Network
NM	national monument
NP	national park
NR	near
NRA	national recreation area
NWQL	National Water Quality Laboratory
ONRW	Outstanding Natural Resource Waters
OHV	off-highway vehicle
SEUG	Southeast Utah Group (includes ARCH, CANY, HOVE, and NABR)

SOP	standard operating procedure
TDS	total dissolved solids
TMDL	total maximum daily load
TP	total phosphorus
μg/L	micrograms per liter
UT	Utah
UDWQ	Utah Division of Water Quality
UDEQ	Utah Department of Environmental Quality
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
Type of standard	
AC	Acute
CH	Chronic
Colorado designated use codes	
AG	Agriculture
ALCW1	Aquatic Life Cold Water Class 1
ALCW2	Aquatic Life Cold Water Class 2
ALWW1	Aquatic Life Warm Water Class 1
ALWW2	Aquatic Life Warm Water Class 2
DWS	Drinking water
RecE	Existing primary-contact recreation
RecU	Undetermined use recreation
Res	Reservoir-specific aquatic life standards
Standards for assessed Colorado stream segments within Colorado park units	
LC3	Lower Colorado River basin segment 3 aquatic life standard
LG1	Lower Gunnison River basin segment 1 aquatic life standard
LG4c	Lower Gunnison River basin segment 4c aquatic life standard
LYG2	Lower Yampa/Lower Green River basin segment 2 aquatic life standard
LYG19a	Lower Yampa/Lower Green River basin segment 19a aquatic life standard
UG14	Upper Gunnison River basin segment 14 aquatic life standard
UG26	Upper Gunnison River basin segment 26 aquatic life standard
UG29b	Upper Gunnison River basin segment 29b aquatic life standard
Utah designated use codes	
1C	Drinking water
2A	Primary-contact recreation
2B	Secondary-contact recreation
3A	Cold water game fish
3B	Warm water game fish
3C	Non-game fish
3D	Waterfowl
4	Agricultural use
NoCrk	Zion National Park North Creek TDS standard

Acknowledgements

Thanks to Helen Thomas and Russ DenBleyker, of the Northern Colorado Plateau Network (NCPN), and Dean Tucker (NPS-Water Resources Division), who helped transition the network's water quality data into the National Park Service's NPSTORET database. Aneth Wight (NCPN) produced all of the maps for this report. Special thanks to Lenora Sullivan and Calah Seese (Utah Division of Water Quality) for providing Utah laboratory data management and consultation. Thanks also to park staff, especially Matt Malick (Black Canyon of the Gunnison National Park and Curecanti National Recreation Area), Mary Moran (Southeast Utah Group), and Dave Sharrow (Zion National Park)—each of whom also contributed to this report—and Cami McKinney (Timpanogos Cave National Monument) and Tamara Naumann (Dinosaur National Monument), for their continued support and consultation. An additional thanks is owed to David Thoma and Dusty Perkins (NCPN) for reviewing this document.

1 Introduction

1.1 Background

The Northern Colorado Plateau Network (NCPN) consists of 16 park units in Utah, Colorado, Arizona, and Wyoming (Figure 1-1). Through comprehensive scoping processes, water quality and quantity were identified as vital signs that should be monitored by the network (O'Dell et al. 2005). The water-dependent ecosystems in these landscapes are protected by the National Park Service (NPS) Organic Act, NPS Management Policies, and the Clean Water Act (CWA).

Under authority of the U.S. Environmental Protection Agency (EPA), U.S. states have developed a regulatory system under the CWA that provides for specific concentrations or measures for water quality constituents that protect a class of uses. The protected uses vary by state, but generally include irrigated agriculture, domestic water supply, cold-water aquatic life, warm-water aquatic life, water-based recreation, and livestock watering.

1.2 Program justification

In order to mitigate past and future threats to park water resources, managers need objective information on status and trends in surface-water quality and quantity.

Section 4.3.6 of the NPS Management Policies sets forth expectations for park managers regarding water resources (NPS 2006):

> The pollution of surface waters and groundwaters by both point and nonpoint sources can impair the natural functioning of aquatic and terrestrial ecosystems and diminish the utility of park waters for visitor use and enjoyment. The Service will determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside the parks. The Service will
>
> a) work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection for park waters;
>
> b) take all necessary actions to maintain or restore the quality of surface waters and groundwaters within the parks consistent with the Clean Water Act and all other applicable Federal, State, and local laws and regulations; and
>
> c) enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

1.3 Long-term monitoring objectives

Measurable objectives of this long-term monitoring program focus on status and trends in water quality parameters, and include the following:

a) Establish range and variability of water quality parameters under base flow conditions as they vary with seasonal and climatic conditions using descriptive statistics.

b) Determine status and trends in selected water quality parameters as a function of flow, season, and climatic conditions, using trend-analysis techniques.

c) Compare water quality data against state criteria for acute and chronic exceedance.

d) Analyze long-term data for designation as Outstanding National Resource Waters (ONRW).

e) Determine point and nonpoint sources of pollution within watersheds via association with ancillary data or knowledge of land-management practices or activities in the watersheds.

1.4 Management outcomes

The knowledge gained by achieving the measurable objectives of this monitoring will be used to evaluate and report on the condition of water bodies in NCPN park units. Additionally, it can be used to inform park managers about water resources in order to:

Northern Colorado Plateau Network
Utah, Colorado, Arizona, and Wyoming

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Water Quality Monitoring Sites, 2010–2012

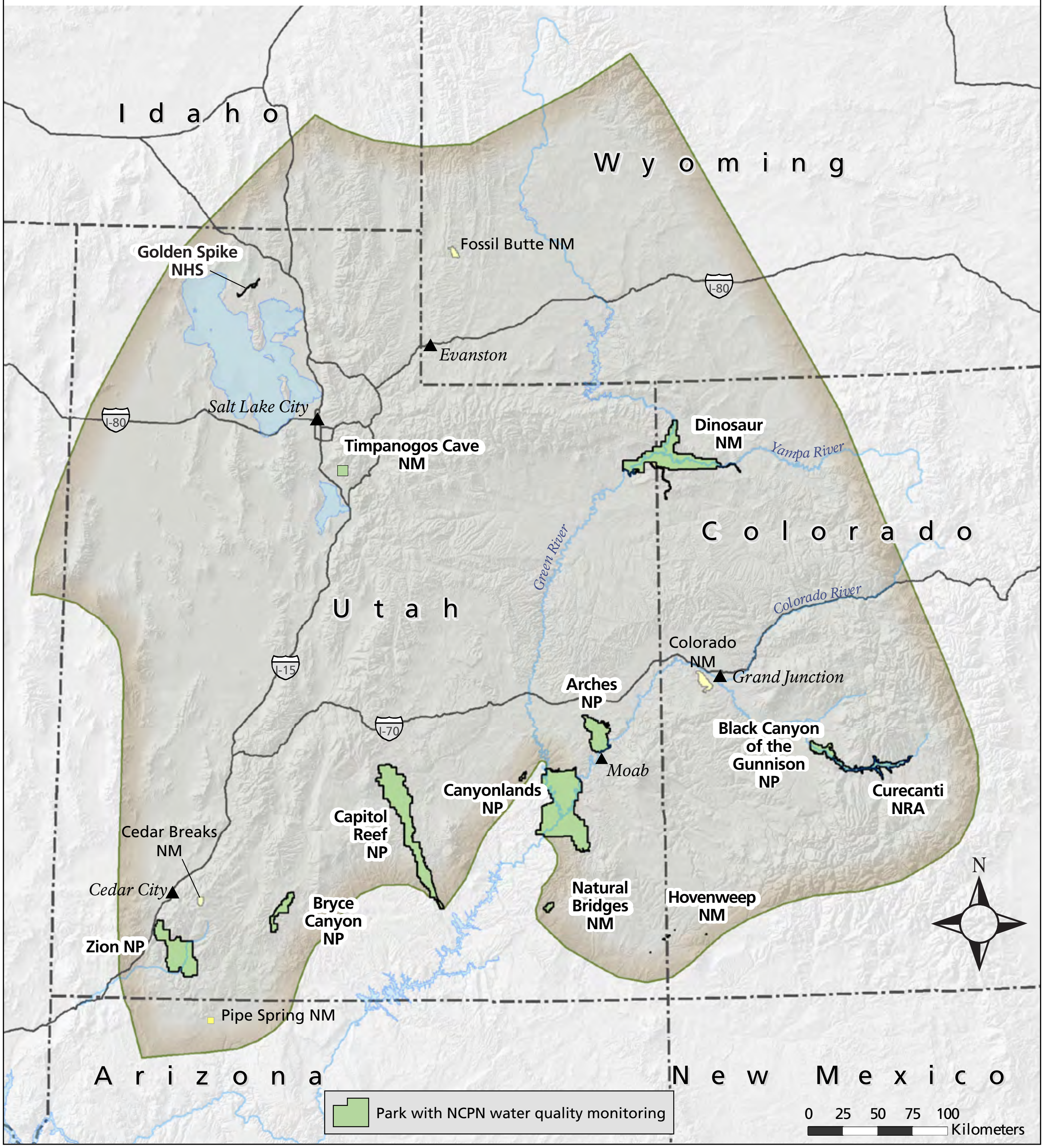


Figure 1-1. Park units of the Northern Colorado Plateau Network. Water quality is monitored in the highlighted parks.

a) Maintain waters that vary within their natural chemical and biological ranges and meet applicable federal and state water quality criteria.

   Justification: Waters that vary within their natural ranges can typically support healthy aquatic ecosystems and most beneficial uses.

b) Improve water quality of impaired waters.

   Justification: The NPS GPRA goal is that 99.3% of streams and rivers managed by the NPS will meet state and federal water quality standards.

c) Demonstrate and maintain high water quality where it exists.

   Justification: The antidegradation provision of the Clean Water Act specifies that high-quality waters will be maintained (USEPA 2006; Section 303).

1.5 Report scope and objectives

This is the third report on activities and results of the NCPN water quality monitoring program. It focuses on sites monitored by NCPN staff and by cooperating staff and agencies working in and near NCPN parks. Although long-term data records exist for some of these sites, the period considered in this report is from October 1, 2009 through September 30, 2012, water years 2010–2012.

The State of Utah is currently transitioning all of its water quality data to a new database. For this reason, data from sites in Utah sampled by the state during this time period were not available for analysis.

The objectives of this report are to:

a) evaluate exceedances of water quality standards,

b) provide descriptive statistics for water quality data,

c) identify and characterize potential sources of water quality contamination, and

d) provide resource managers with pertinent information about these data.

2 Methods

2.1 Target population

The target population for NCPN water quality monitoring is a subset of potential daytime water quality measurements in perennial streams and rivers, selected through a judgmental or targeted process involving the participation of park resource managers, NCPN staff, U.S. Geological Survey (USGS) staff, and other water quality specialists (O'Dell et al. 2005; Thoma et al. 2007).

Specific water sources were selected based on the following hierarchy:

a) 303(d)-listed waters, where previous sampling indicated that one or more parameters regularly approached or exceeded criteria or recommended levels.

b) Waters with demonstrated threat levels, where an analysis of available data indicated that measured conditions regularly approached or exceeded criteria or recommended levels, but where the frequency of exceedance or the quality of the data did not support a 303(d) listing.

c) Waters identified as important, but for which little or no water quality information existed (i.e., data gaps).

d) Waters of management concern, where past sampling may not have indicated constituent values of concern, but where anthropogenic activities indicated that contamination was a significant threat.

e) Other perennial waters with no specific threat.

Perennial waters were preferentially selected over ephemeral or seasonal water sources because they support year-round ecological process and function and have established criteria that allow monitoring for CWA compliance. Seventy-five sites in or near 11 NCPN units were sampled between October 1, 2009 and September 30, 2012 (see Appendix A).

2.2 Laboratory and field methods

Approximately 30 parameters were measured for each site visit. The core parameters, or those measured in the field, included dissolved oxygen, pH, temperature, specific conductance, and flow. Other parameters measured in the laboratory from samples collected in the field fell into general categories, including metals, nutrients, total dissolved solids, and bacteria.

Field methods used to collect data for this report are outlined in the NCPN Standard Operating Procedures (SOPs) for Water Quality (Thoma et al. 2007). Specifically, SOPs 3–11 outline the techniques for measurement of core parameters and sample collection and handling in the field.

Laboratory analytical methods are discussed in detail in SOPs 11–13 (Thoma et al. 2007). The NCPN ensures comparability of the laboratory data created by this monitoring program by using the USGS National Water Quality Laboratory (NWQL) methods for Colorado parks (SOP 12), and the EPA standard methods, or methods outlined in Standard Methods for Analysis of Water and Wastewater, for Utah parks (APHA 1998; SOP 13). Details of the quality-control process for NWQL and the Utah Public Health Laboratory are provided in SOP 7, Appendices A and B (Thoma et al. 2007).

2.3 Partnerships

The NCPN water quality monitoring program is a collaborative venture between the NCPN, Black Canyon of the Gunnison National Park (BLCA), Curecanti National Recreation Area (CURE), the Southeast Utah Group (SEUG), Timpanogos Cave National Monument (TICA), the USGS, and the Utah Division of Water Quality (UDWQ). NCPN, TICA, and SEUG personnel conduct field work and deliver samples to the Utah Public Health Laboratory according to a partnership agreement between the NPS and the UDWQ. BLCA and CURE conduct field work and have laboratory analysis conducted at the NWQL, in Lakewood, Colorado, via agreements with the USGS. Dinosaur National Monument sites are visited by USGS personnel, who deliver samples to the NWQL for laboratory analysis.

Other nearby sites (outside park boundaries) that are routinely monitored by the states of Colorado and Utah are also considered. Regardless of which entity performed the field work or laboratory analysis, the data were stewarded through the NPSTORET database v1.83, which was used for this analysis.

2.4 Understanding water quality data and standards

The sampling methodology used in the NCPN water quality monitoring program has implications for data interpretation. Monthly grab samples represent conditions at the point and time of sampling; they do not represent the condition of the entire water body, spatially or temporally. Samples are routinely collected several times per year in order to build a database that represents the range of conditions that occur, with a focus on base flow conditions. Thus, rare and short-term events are often not captured.

This report contains terminology that may not be readily understood by non-specialists. For clarification purposes, various terms and concepts that may cause confusion will be defined here. A water quality standard refers to an individual *parameter* and its associated *beneficial-use designation*, in conjunction with a *criterion*, which is the numeric component against which a result is compared. For example, the standard for chronic selenium (parameter) for cold-water game fish (beneficial-use designation) is 4.6 µg/L (numeric criterion). Water quality standards for the states of Utah and Colorado used in this report are included in Appendices B and C, respectively.

One site visit yields approximately 30 water quality parameter measurements, or results. Each result is then evaluated against a water quality standard; this is referred to as a "use evaluation" in this report. Each beneficial-use designation may contain distinct criteria for one parameter, and each site may contain up to four distinct beneficial-use designations. Therefore, one parameter measurement from one site visit may result in multiple use evaluations.

Over the course of the study period, one site may have a different number of results for each parameter. For example, the NCPN may have visited one monitoring site 24 times during the period covered in this report; however, not all parameters may have been measured during each site visit. This is especially true for metals results. Laboratory analysis for metal concentrations is typically performed quarterly, whereas other parameters, such as nutrients and dissolved oxygen, are determined for each site visit.

2.4.1 Chronic and acute standards

For a single parameter, numeric criteria for water quality standards address potential effects of both chronic exposure over an extended period of time (months) and acute exposure over a short period of time (hours or days). Permitted levels are much lower for chronic exposure than for acute exposure. Criteria for chronic exposure are not directly comparable to the results obtained from a one-time monthly grab sample. From a compliance standpoint, the acute instantaneous criteria afford the only direct comparison for such data. However, from a resource-conservation standpoint, instantaneous grab-sample data, when compared against more stringent chronic criteria, can provide a means of early warning and an indication of a problem that may require more attention. Exceedances in this report, therefore, are meant to inform managers of potential problems rather than to reflect regulatory definitions.

For these reasons, parameter results were compared against the chronic standards to create the graphical and tabular data included in this report. Each exceedance was then re-evaluated against the less-stringent acute criteria. If a chronic exceedance also exceeded the acute standard, then documentation was provided in the results section for that individual site.

2.4.2 Phosphorus as an indication of impairment

The State of Utah does not have a water quality standard for total phosphorus. Rather, the value of 0.05 mg/L is used as an indication of impairment meant to be considered with other parameters, such as dissolved oxygen. If low dissolved oxygen concentrations were observed commensurate with elevated total phosphorus concentrations (above 0.05 mg/L), the collective results might then indicate impairment due to eutrophication. Corroborating evidence may include other chemical parameters associated with eutrophication—such as elevated nutrient concentrations or low dissolved oxygen concentrations—and bioassessments.

The State of Colorado has established interim values for total phosphorus that are scheduled to go into effect in 2022. For state regulatory purposes, total phosphorus is evaluated as an annual median value or average summer value, depending on the type of water body. For the purposes of this report, any individual value that exceeded the designated total phosphorus interim value was reported as an exceedance.

2.4.3 Rules for applying standards

When criteria for a parameter differed by designated beneficial use, or within a use class by aquatic-life stage, the more stringent standard was used as the basis for comparison in this report. Results that exceeded the more stringent standard (chronic standard) were then compared against the less stringent standard (acute standard) (see Section 2.4.1). The goal is to provide advance warning of an impending problem before it becomes severe, rather than to meet regulatory definitions of impairment.

2.4.4 Frequency of exceedances for reporting

This report presents beneficial-use evaluation exceedances only if they occurred for more than 10% of results. 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. It also follows the assessment guidelines used by the UDWQ in preparing their list of impaired water bodies.

Summary statistics displayed at the beginning of each results section refer to the number of use evaluations performed for all sites in or near that NPS unit. The term "evaluation" is used throughout this report in connection with exceedance analyses. Thus, tables and results sections for individual sites refer to "evaluations" instead of "site visits." The total number of evaluations is synonymous with the total number of site visits when an individual parameter is compared against an individual beneficial-use designation at one monitoring site.

2.4.5 Regulatory authority

The National Park Service does not have regulatory authority over waters in the U.S., or even the authority to make assessments for designated beneficial use. For that reason, this report compares water quality data to designated beneficial-use criteria without stating whether a designated beneficial use was attained. Those designations are left to the states, in their triennial 305(b) reports to Congress. However, the NPS participates with states in collecting data used in the protection of water bodies under state jurisdiction.

2.5 Site-specific standards and triennial reviews

A triennial review process allows stakeholders to provide feedback about water quality standards, criteria, and designated beneficial uses. Through this process, the regulatory agencies may re-classify a water body's designated use or establish standards appropriate for the use. This process is especially relevant in cases where uses have not been assigned, perhaps due to a lack of use data, and in situations where natural conditions preclude a water body from meeting its designated beneficial use. For instance, a use-attainability analysis may indicate that a water body cannot achieve its beneficial designated use due to naturally elevated parameter concentrations that have been observed in that stream or stream segment. If the historical data record is not long enough, or reasonable supporting evidence does not exist, then the state may choose not to change a water quality standard or reclassify a designated use during the triennial review, but may provide guidance on how to further investigate the particular issue.

Some NCPN water quality monitoring sites may be suitable candidates for a use-attainability analysis and establishment of site-specific criteria, due to naturally elevated total phosphorus or total dissolved solids concentrations that may be derived from soil and bedrock weathering. If commensurate measurements at a site, such as dissolved oxygen or nitrogen concentrations, do not indicate that elevated total phosphorus concentrations are causing eutrophication of the water body, then the water body may be considered for a different use classification or a water body-specific standard.

Results displayed in this report highlight and characterize such scenarios, but do not necessarily contain the breadth of supporting documentation required for submission to the triennial review process. Completion of a long-term trend-analysis report will significantly improve the NCPN's ability to determine which candidate sites and associated water quality standards merit inclusion in a use-attainment assessment.

3 Results

3.1 Arches National Park

3.1.1 Water quality summary

A total of 2,882 designated beneficial-use evaluations were completed for water quality results obtained at nine sites in or near Arches National Park (NP) between October 1, 2009 and September 30, 2012. Of those 2,882 evaluations, 93 (3.2 %) exceeded water quality standards or indications of impairment (Figure 3-1). Standards were exceeded for six constituent categories—most commonly, total dissolved solids, nutrients, *E. coli*, and dissolved oxygen (Figure 3-2).

3.1.2 Reportable exceedances

All nine sites that were monitored in or around Arches NP had exceedances of water quality standards or indications of impairment for the states of Utah or Colorado (Figure 3-3, Table 3-1). The Dolores River near Cisco, Utah, and the Colorado River near Cisco, Utah, exceeded the agricultural-use standard for total dissolved solids for the State of Utah for 2% and 4% of evaluations, respectively. The following discussion focuses only on sites that had exceedances for more than 10% of evaluations.

Colorado River near Colorado–Utah State Line. This site is located in the state of Colorado, and is thus subject to Colorado state water quality standards. Selenium concentrations exceeded the chronic aquatic life warm-water class 1 standard for 14% of evaluations. Total phosphorus levels exceeded the aquatic life warm-water class 1 interim standard for 25% of evaluations.

Freshwater Spring. Dissolved-oxygen concentrations at Freshwater Spring exceeded the chronic (5.5 mg/L) and acute (3.0 mg/L) standards for warm-water game fish for 50% and 17 % of evaluations, respectively.

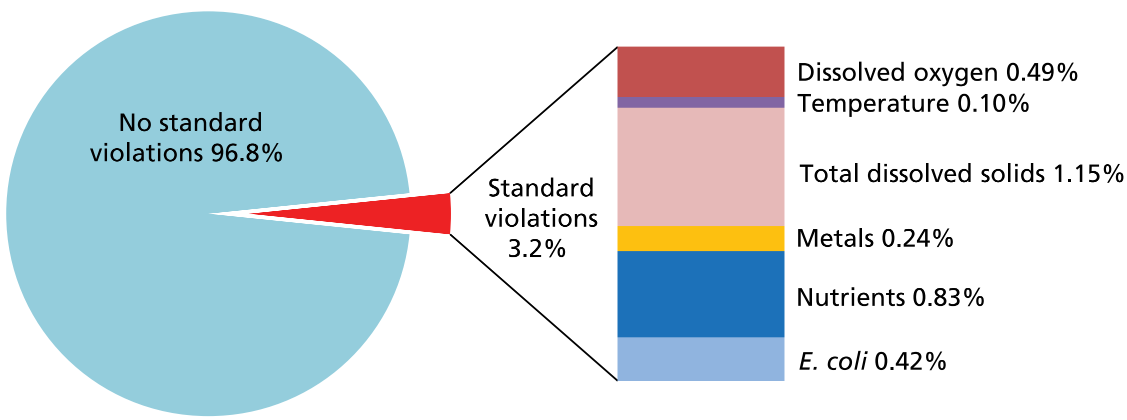


Figure 3-1. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Arches NP, October 1, 2009–September 30, 2012.

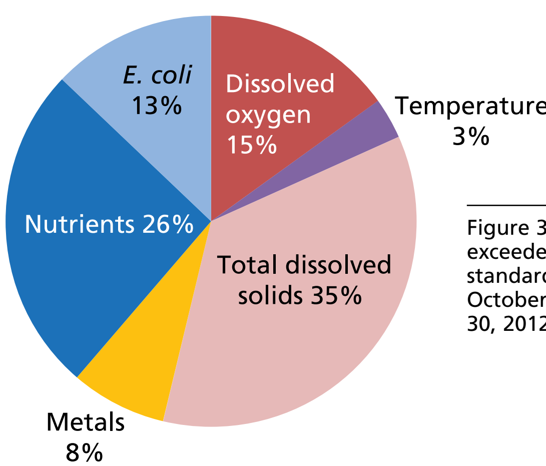


Figure 3-2. Most commonly exceeded water quality standards at Arches NP, October 1, 2009–September 30, 2012.

Water Quality Monitoring Sites, 2010–2012

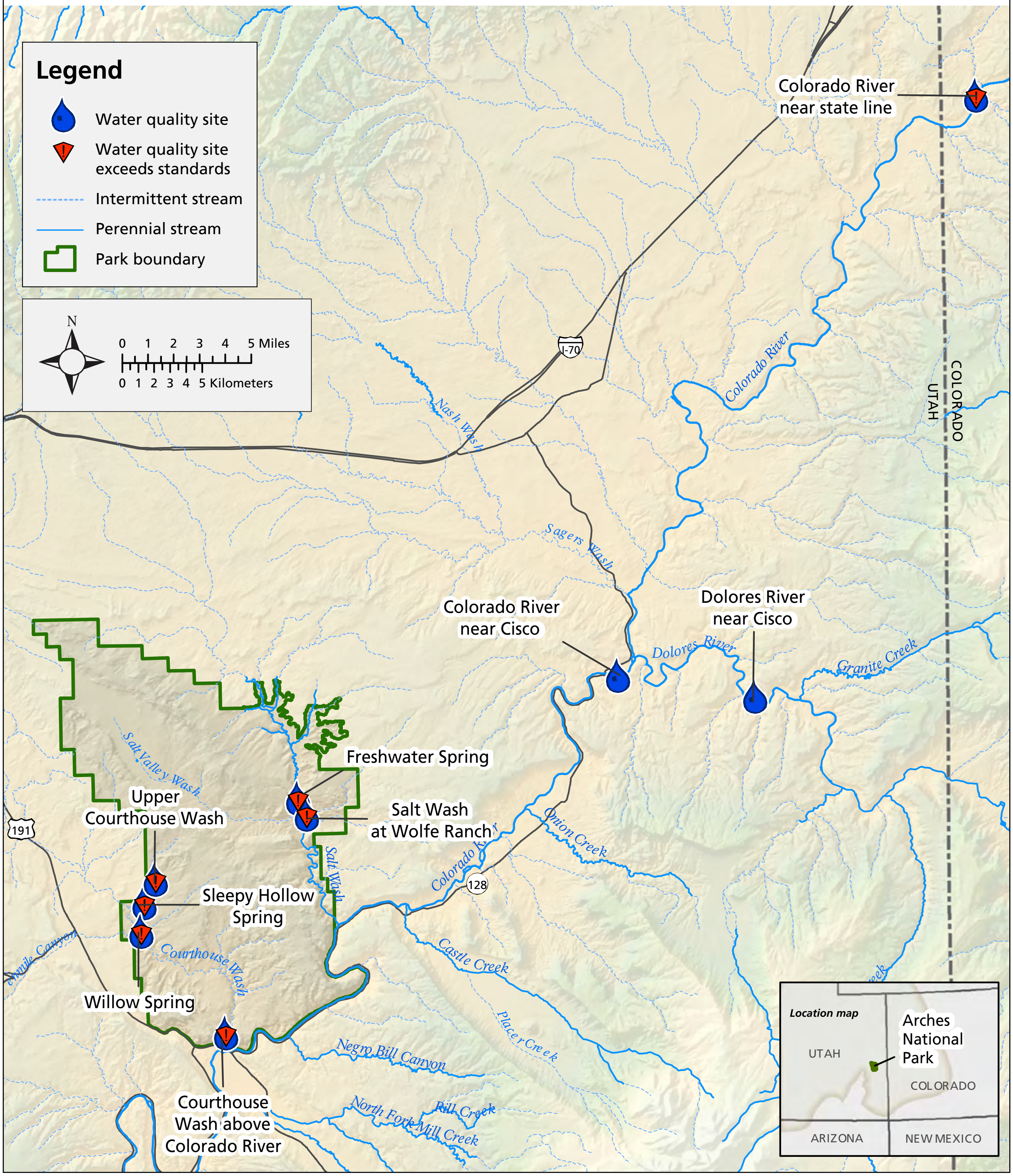


Figure 3-3. Water quality monitoring locations in and near Arches National Park, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-1. Exceedances of surface water quality standards for sites sampled in or near Arches NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituents	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Colorado River near Colorado-Utah State Line	ALWW1	Phosphorus, Total	0.17	mg/L	12	25
	ALWW1	Selenium, Dissolved	4.6	µg/L	21	14
Freshwater Spring	3B	Dissolved oxygen	5.5	mg/L	6	50
Salt Wash at Wolfe Ranch	3B	Aluminum, Dissolved	87	µg/L	12	17
	3B	Dissolved oxygen	5.5	mg/L	24	13
	2A, 3B	Phosphorus, Total	0.05	mg/L	31	13
	4	Total dissolved solids	1200	mg/L	31	97
Courthouse Wash above Colorado River	2A, 3B	Phosphorus, Total	0.05	mg/L	11	27
Upper Courthouse Wash	1C	Arsenic, Dissolved	10	µg/L	4	25
	3B	Dissolved oxygen	5.5	mg/L	4	75
	2A	*E. coli*	126	MPN/100ml	9	33
	1C	*E. coli*	206	MPN/100ml	9	22
	2A	*E. coli*	409	MPN/100ml	9	11
	1C	*E. coli*	668	MPN/100ml	9	11
	2A, 3B	Phosphorus, Total	0.05	mg/L	10	20
	3B	Temperature, water	27	°C	11	18
Sleepy Hollow Spring	3B	Dissolved oxygen	5.5	mg/L	7	29
Willow Spring	3B	Dissolved oxygen	5.5	mg/L	4	75

Use codes: ALWW1 = aquatic life warm-water class 1 (CO standard); 2A = primary-contact recreation; 3B = warm-water game fish; 1C = drinking water; 4 = agricultural use

Salt Wash at Wolfe Ranch. This site exceeded the chronic dissolved-oxygen standard for warm-water game fish for 13% of evaluations, but never exceeded the acute standard. The standard for aluminum for warm-water game fish was exceeded for 17% of evaluations. Total dissolved solids exceeded the standard for agricultural use for 97% of evaluations. Total phosphorus exceeded the indication of impairment criteria for primary-contact recreation and warm-water game fish for 13% of evaluations.

Courthouse Wash above Colorado River. Near its confluence with the Colorado River, Courthouse Wash had exceedances for total phosphorus for 27% of evaluations. Total phosphorus exceeded the indication of impairment criteria for primary-contact recreation and early life stages of warm-water game fish.

Upper Courthouse Wash. Located just outside the park boundary fence, this site had exceedances for arsenic, dissolved oxygen, *E. coli*, temperature, and total phosphorus. Dissolved arsenic concentrations exceeded the Utah drinking-water supply standards for 25% of evaluations. Dissolved-oxygen levels exceeded the chronic and acute standards for warm-water game fish for 75% of evaluations. *E. coli* concentrations exceeded the chronic (126 MPN) and acute (409 MPN) standards for primary-contact recreation for 33% and 11% of evaluations, respectively. *E. coli* concentrations exceeded the chronic (206 MPN) and acute (668 MPN) drinking-water supply standards for 22% and 11% of evaluations, respectively. Water temperatures exceeded the warm-water game fish standard for 18% of evaluations. Total phosphorus exceeded the indication of impairment criteria for primary-contact recreation and warm-water game fish for 20% of evaluations.

Sleepy Hollow Spring. Dissolved-oxygen concentrations at Sleepy Hollow Spring failed to meet the chronic and acute standards for warm-water game fish for 29% of evaluations.

Willow Spring. Dissolved-oxygen concentrations at Willow Spring failed to meet the chronic and acute standards for warm-water game fish for 75% and 50% of evaluations, respectively.

3.1.3 Discussion

3.1.3.1 Total dissolved solids

As in past years, total dissolved solids (TDS) concentrations at Salt Wash at Wolfe Ranch exceeded standards. The cause of these exceedances is likely geologic in origin, as there are few human activities near Salt Wash that could contribute to such high TDS levels. Elevated TDS concentrations in surface water and groundwater are not uncommon in the Moab area, where they result from the underground weathering of the near subsurface salt dome (Baars and Doelling 1987; Chaffin 2002). Mineral-rich clay and shale deposits of the Morrison and Mancos formations exposed near the sample site may also contribute TDS to Salt Wash during overland flow events. The results presented are consistent with over 10 years of sampling in Arches NP, as described by Schelz and Moran (2004) and Van Grinsven and others (2010).

3.1.3.2 Dissolved oxygen

Low dissolved-oxygen concentrations that exceed the warm-water game fish standard are likely the result of two factors: hydrologic setting and summertime low-flow conditions. Exceedances at Freshwater Spring, Sleepy Hollow Spring, and Willow Spring were likely hydrologic in origin. At these sites, discharge of oxygen-depleted groundwater is a natural phenomenon, and indicates that the water has been underground long enough for complete or significant biological consumption of dissolved oxygen to have occurred. At Salt Wash at Wolfe Ranch, Upper Courthouse Wash, and Willow Spring, the potential existence of stagnant or semi-stagnant pools caused by summer low-flow conditions can cause depleted oxygen concentrations. In these pools, a lack of shade may increase temperature, decreasing oxygen solubility. In concert with high temperatures, the decomposition of organic matter, which is an oxygen-consuming biological activity, can further deplete oxygen concentrations.

3.1.3.3 Nutrients

At Courthouse Wash and Salt Wash, observations of elevated total phosphorus levels occurred primarily during turbid conditions following rain events, indicating that their source is likely derived from overland flow. Natural sources of phosphorus likely occur within the Courthouse Wash and Salt Wash watersheds. However, accelerated weathering from grazing and off-highway vehicle (OHV) use upstream from the park boundary may contribute to the observed total phosphorus levels. Occasional cattle and OHV trespass have occurred within the park boundary at the Upper Courthouse Wash site (10–15 miles upstream from the Courthouse Wash above the Colorado River site). Elevated total phosphorus concentrations in Courthouse Wash and Salt Wash are consistent with 16 years of data collected from 1990 to 2006 (Brown and Thoma 2012).

3.1.3.4 Metals

The source of elevated selenium concentrations in the Upper Colorado River basin has been well documented (Tuttle 2009; BLM-USGS 2010). Spatially extensive deposits of Mancos Shale exist in the Book Cliffs range of eastern Utah and western Colorado, directly adjacent to the Colorado River near the Utah–Colorado state line site (Figure 3-4). This layer was deposited in a shallow sea environment during the Cretaceous period, and contains an abundance of salt (NaCl), as well as evaporite (gypsum, $CaSO_4$) and iron sulfide (pyrite) minerals. The pyrite found in this deposit contains an unusually large selenium component in the form of lead selenide (PbSe). Once exposed to the atmosphere, oxidative processes readily convert the reduced form of selenium to selenate. Additionally, dissolution processes produce sulfate salts ($NaSO_4$) when the sodium from the salt is exchanged with the calcium from gypsum. Once formed, the selenate quickly associates with the $NaSO_4$, and is carried into the Colorado River through surface water recharge. Although the source and process of selenium erosion is natural, these conditions can be anthropogenically accelerated by certain land uses, such as OHV recreation, grazing, and irrigation (USGS-BLM 2010). The Colorado River from Moab upstream to the state boundary was added to Utah's 303(d) list for selenium impairment in 2006.

Two of twelve samples collected from Salt Wash at Wolfe Ranch exceeded the chronic dissolved aluminum standard (87 µg/L) for warm-water game fish, but never exceeded the acute standard (750 µg/L). Mancos Shale, which can be a source for elevated concentrations of aluminum, is exposed in Salt Valley near the sample site in Arches NP (Baars and Doelling 1987), as well as in the upper reaches of Salt Wash, approximately 15 miles upstream from the sample site. Mineral-rich clays found in the Morrison Formation near the sample site may also contribute aluminum to Salt Wash during overland flow events. It is likely that the observed aluminum levels in Salt Wash are natural in origin, and do not warrant much concern, because observations of elevated levels were infrequent.

One of four samples collected from Upper Courthouse Wash exceeded the dissolved arsenic standard for Utah drinking-water supply. Arsenic entering water sources from erosion of natural deposits is likely the cause of elevated concentrations at Upper Courthouse Wash. Elevated arsenic levels were infrequent at this site and do not warrant immediate concern.

3.1.3.5 *E. coli*

The primary-contact recreation and drinking-water supply standards for *E. coli* were exceeded at Upper Courthouse Wash. Possible sources of *E. coli* contamination could be domestic animals, humans, wildlife, or a combination thereof. One sample exceeded all four beneficial-use evaluations. There was evidence of cattle trespass in the area and cow feces were observed in the stream.

During high-discharge events, runoff from the watershed contributes large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli*, are carried into streams, along with the silts and sands being eroded during overland flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies, and is able to survive for prolonged periods of time when attached to sediments (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during high-turbidity discharge events.

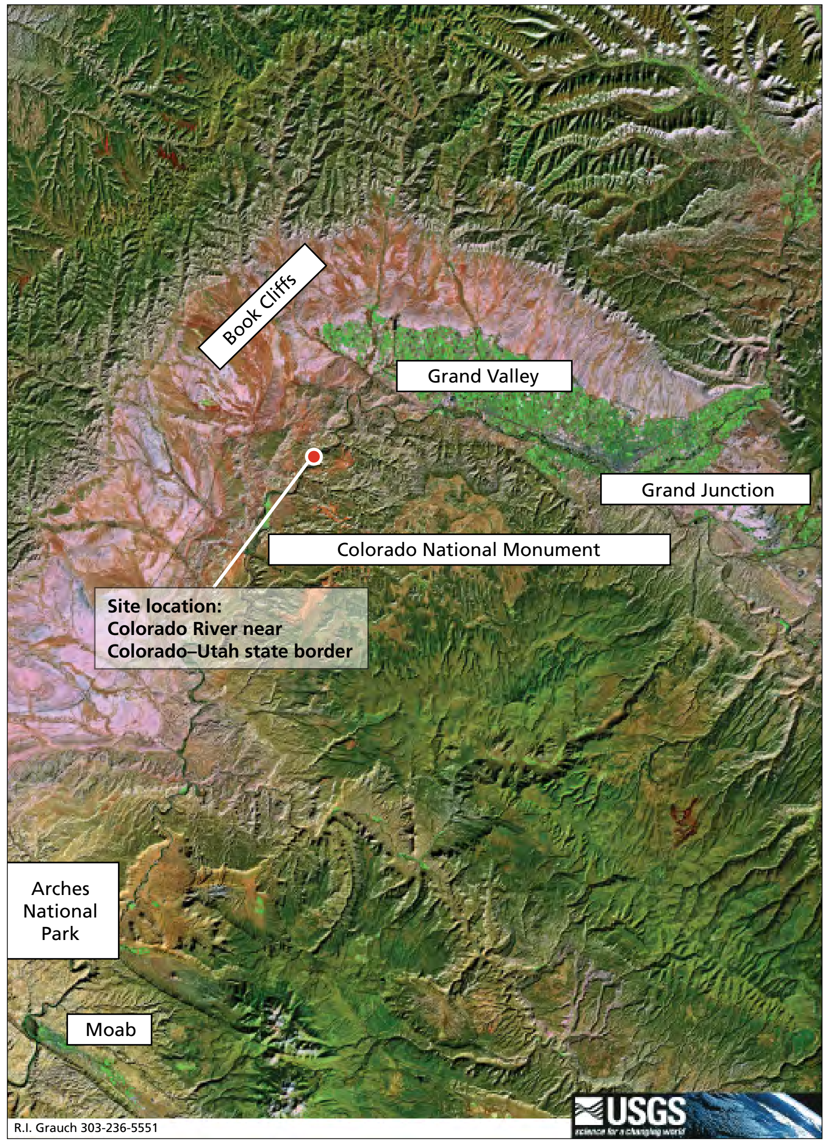


Figure 3-4. Geographic extent of Mancos Shale deposit (light pink) in western Colorado and eastern Utah.

The majority of *E. coli* exceedances at Upper Courthouse Wash occurred after high-discharge events. Because *E. coli* exceedances were infrequent and episodic storm events were related to the observed elevated *E. coli* concentrations, management concern is not warranted at this time. Preventive measures, such as ensuring that fences are properly maintained, could help minimize cattle trespass as a potential source of future *E. coli* contamination.

3.1.3.6 Temperature

Temperatures at Upper Courthouse Wash exceeded the warm-water game fish standard of 27°C on two occasions. On August 9, 2010, the water temperature was 27.8°C and on May 25, 2011, the temperature was 29.5°C. Water temperatures were measured in the afternoon, when air temperatures were also high. Because low-flow conditions, combined with hot summer air temperatures, cause periodic surface water-temperature exceedances, these exceedances do not warrant immediate concern. However, water temperatures are expected to rise due to higher air temperatures and reduced instream flows predicted by climate change models. Continued monitoring is recommended to detect and assess the frequency of long-term temperature exceedances at these sites.

3.1.4 Management implications

Many of the water quality exceedances in Arches NP were likely due to naturally occurring conditions, and resulted from the application of use designations that were intended to protect the Colorado River and its tributaries. Because many monitoring sites in Arches NP are low-flow, intermittent, or ephemeral tributaries to the Colorado River, the applicable use designations, specifically 3B (warm-water game fish), do not necessarily account for their biogeochemical nature. Additionally, the presence of salt-bearing geologic layers near the surface results in conditions that may be cause for exemption or re-classification of the total dissolved solids standard for Salt Wash. In fact, the UDWQ is reviewing water bodies across the state that may need to be re-classified as a result of natural conditions, such as salt-bearing geologic layers, that cause elevated TDS concentrations.

Most of the monitoring sites in Arches NP are candidates for use-attainability assessments because of their geologic setting. The geologic conditions of small springs with large groundwater components, and predominantly intermittent streams that may episodically contribute naturally elevated constituent loads, distinguish them from other perennial tributaries to the Colorado River. After over a decade of water quality monitoring, the Southeast Utah Group is evaluating its site-selection criteria and moving toward monitoring sites that are more perennial in nature (see story, next page).

The Evolution of Water Quality Monitoring in Southeast Utah Group Parks

The Southeast Utah Group (SEUG) of national parks (Arches and Canyonlands national parks and Hovenweep and Natural Bridges national monuments) is a strong—and vital—partner in NCPN water quality monitoring. SEUG has maintained an active, multi-faceted water monitoring program since the 1980s, and with recent changes, SEUG water monitoring is becoming smarter, more efficient, and more targeted to the effects of climate change, as well as to the individual needs and threats of specific sites.

SEUG water monitoring has evolved over the years due to changing understanding, technology, priorities, and management needs, as well as the group's partnership with the NCPN, begun in 2005. In 2012, the SEUG Resource Stewardship and Science Division (SEUG-RSS), in cooperation with the NCPN, reassessed the group's water monitoring program.

The first element of the review was to evaluate existing water quality site data and site threats. While water quality is generally good in SEUG parks, exceedances of some standards do occur at some sites, most commonly due to natural erosion of various sedimentary rock layers or the mismatch between water quality standards and site-specific conditions at intermittent desert streams and springs. But at a few sites, human-caused impacts nearby or upstream, or a combination of natural and human causes, are suspected. The SEUG-RSS review identified sites with continued perceived threats or significant records of exceeding certain water quality standards.

The second goal of the 2012 review was to choose sites for more targeted water quantity, or flow, monitoring. SEUG-RSS reviewed both former water quality monitoring sites and potential new sites using site-selection criteria specific to the NCPN Seeps and Springs monitoring protocol, which emphasizes high-quality flow monitoring but also includes measurement of field water quality parameters and assessments of human impacts, geomorphology, and vegetation. The review produced a list of SEUG sites appropriate for the Seeps and Springs protocol, and monitoring of some of these sites began in 2012. In addition, SEUG monitoring of four springs in western Arches NP, visited monthly since 2001, has been adapted to follow this protocol.

In all, five river-monitoring sites (Canyonlands NP), two spring sites at Hovenweep NM, and three intermittent stream sites at Arches NP will continue to be monitored within the SEUG–NCPN water quality monitoring program. The other former water quality sites have been discontinued, but could be reinstated should future threats arise. After over 25 years of monitoring at some of these springs and small stream sites, many of them have well-established water quality data baselines. The baseline information will be valuable for comparison should threats arise in the future.

—Mary Moran,
Biological Technician, SEUG

NATIONAL PARK SERVICE

3.2 Black Canyon of the Gunnison National Park

3.2.1 Water quality summary

A total of 1,076 designated beneficial-use evaluations were completed for water quality results obtained at three sites in Black Canyon of the Gunnison NP between October 1, 2009 and September 30, 2012. Of those 1,076 evaluations, 40 (3.7%) exceeded water quality standards or criteria (Figure 3-5). Water quality standards were exceeded for three constituent categories: metals, nutrients, and *E. coli* (Figure 3-6).

3.2.2 Reportable exceedances

The Gunnison River below the Gunnison Tunnel had no water quality exceedances or indications of impairment, based upon 369 total evaluations. Two of the three sites sampled had exceedances of surface water quality standards for the State of Colorado (Figure 3-7, Table 3-2). The following discussion focuses only on sites that had exceedances.

Red Rock Canyon at mouth near Montrose, Colorado. This site exceeded selenium standards for aquatic life warm-water class 2. Both the acute (18.4 µg/L) and chronic (4.6 µg/L) aquatic life warm-water class 2 standards were exceeded for 100% of evaluations.

Red Rock Canyon near the NPS boundary near Montrose, Colorado. This site had exceedances for total phosphorus, selenium, and *E. coli*. Total phosphorus levels exceeded the interim standard for aquatic life warm-water class 2 for 25% of evaluations. Dissolved selenium concentrations exceeded the acute (18.4 µg/L) and chronic (4.6 µg/L) standards for aquatic life warm-water class 2 for 60% and 93% of evaluations, respectively. *E. coli* levels exceeded the existing primary-contact recreation standard for 43% of evaluations.

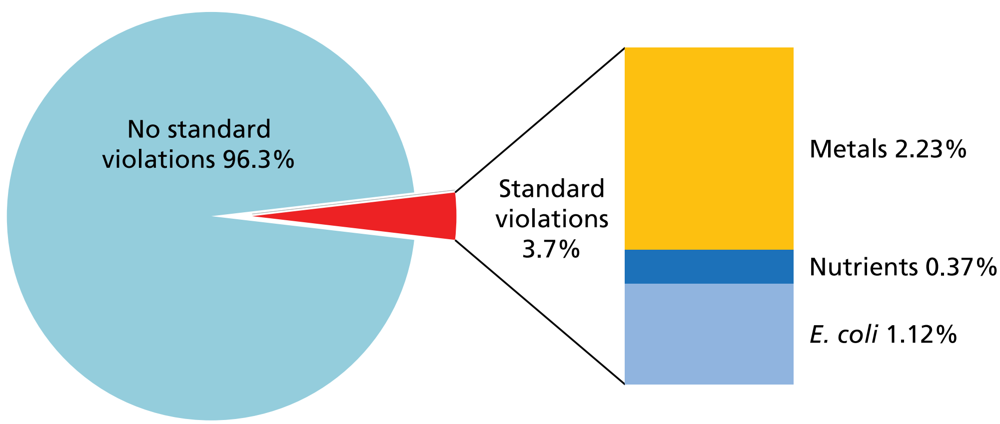


Figure 3-5. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Black Canyon of the Gunnison NP, October 1, 2009–September 30, 2012.

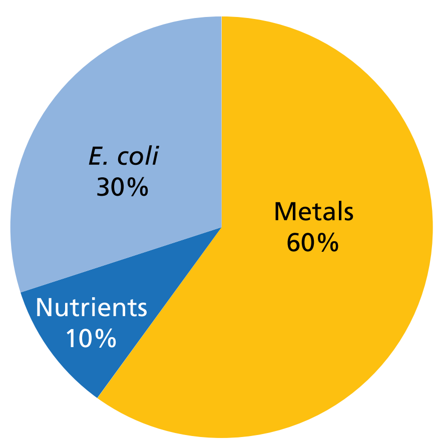


Figure 3-6. Most commonly exceeded water quality standards at Black Canyon of the Gunnison NP, October 1, 2009–September 30, 2012.

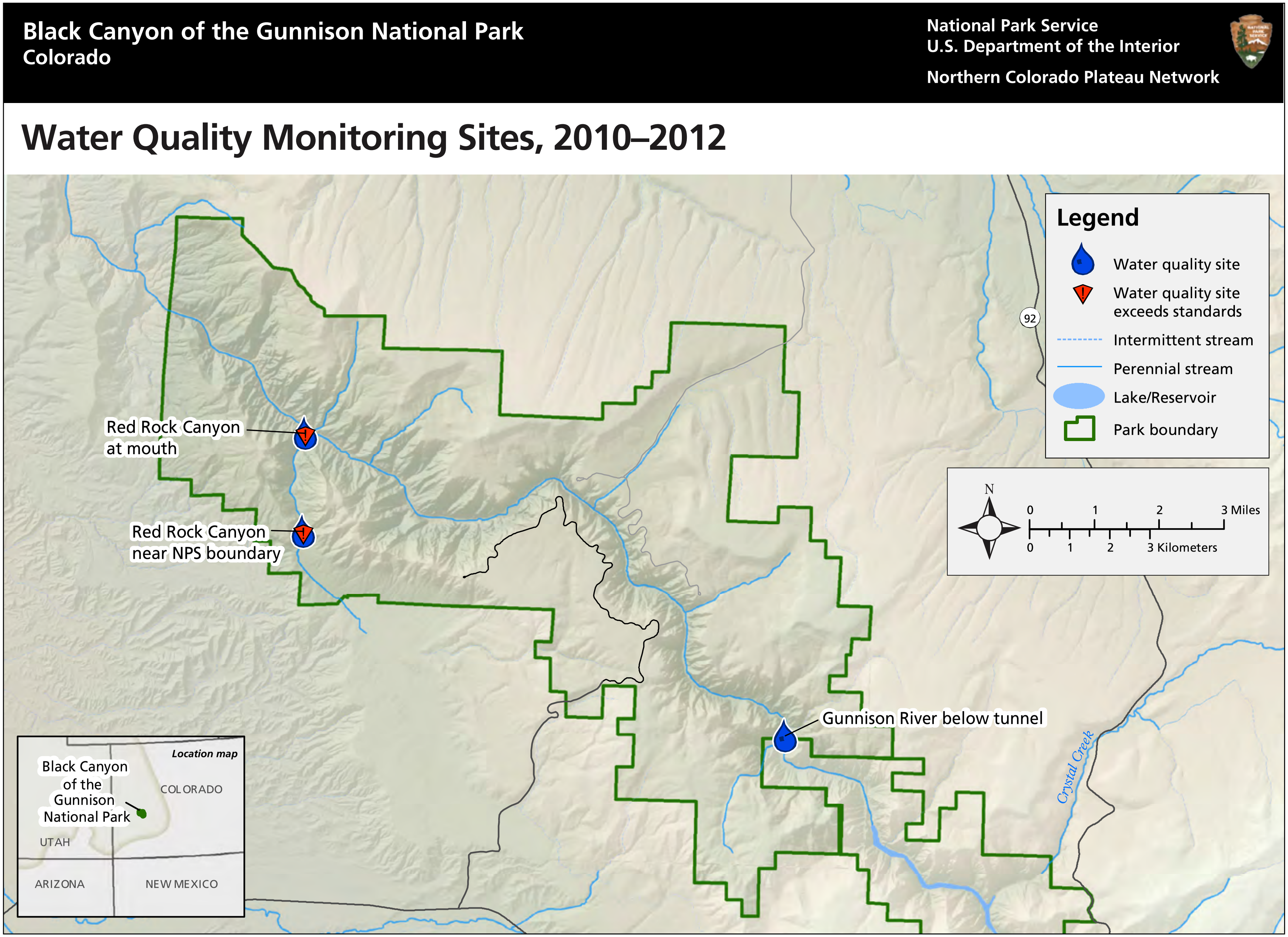


Figure 3-7. Water quality monitoring locations in Black Canyon of the Gunnison National Park. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-2. Exceedances of surface water quality standards for sites sampled in or near Black Canyon of the Gunnison NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Red Rock Canyon at mouth near Montrose, CO	ALWW2	Selenium, Dissolved	4.6	µg/L	10	100
Red Rock Canyon near NPS Boundary near Montrose, CO	RecE	*E. coli*	126	cfu/100ml	23	43
	ALWW2	Phosphorus, Total	0.17	mg/L	16	25
	ALWW2	Selenium, Dissolved	4.6	µg/L	15	93

Use codes: ALWW2 = aquatic life warm-water class 2; RecE = existing primary-contact recreation

3.2.3 Discussion and management implications

3.2.3.1 Metals

A brief discussion about elevated selenium concentrations found throughout western Colorado and eastern Utah can be found in Section 3.1.3.4. The Mancos Shale deposit, found in the Book Cliffs range and discussed in that section, is also present in the Red Rock Canyon watershed. Natural weathering of the Mancos Shale deposit generates elevated selenium and TDS levels in surface water bodies. However, accelerated erosion of the Mancos Shale deposit from certain land-use practices, such as irrigation and OHV recreation, are known to exacerbate selenium and TDS levels.

Selenium exceedances in Red Rock Canyon have been documented extensively, and the tributary was previously included on the 303(d) list of impaired waters in Colorado. In 2011, an assessment for total maximum daily load (TMDL) was completed for selenium for the Gunnison River and tributaries, including Red Rock Creek. The TMDL indicated that non-point sources in Red Rock Creek will need to be reduced by over 90% in order to meet state selenium standards (CDPHE 2011). Although selenium weathers naturally from bedrock and soils in the Red Rock Creek drainage, statewide debate exists about the impact of irrigation on this weathering. The majority of Red Rock Creek's discharge is return flow from an upstream irrigation headgate.

3.2.3.2 *E. coli*

The existing primary-contact recreation standard for *E. coli* was exceeded at Red Rock Canyon near the NPS boundary near Montrose, Colorado. Possible sources of *E. coli* contamination could be domestic animals, humans, wildlife, or a combination thereof.

During high-discharge events, runoff from the watershed contributes large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli*, are carried into streams, along with the silts and sands being eroded during overland flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies, and is able to survive for prolonged periods of time when attached to sediments (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during high-turbidity discharge events. However, if elevated concentrations occur in clear water conditions, then a persistent source may exist.

The majority of *E. coli* exceedances in Black Canyon of the Gunnison NP occurred during average flow and clear water conditions. In some cases, there were insufficient data available to correlate some of the *E. coli* exceedances with flow and turbidity. Because episodic storm events were not related to the observed *E. coli* exceedances, a continuous source may exist upstream. The majority of *E. coli* exceedances occurred during the summer months, when recreational activity in Red Rock Canyon is at its peak. Cooperation with the State of Colorado may be needed to determine the source or sources of bacteria in the area.

3.2.3.3 Nutrients

In June 2012, the Colorado Water Quality

Control Commission adopted regulations to address current and potential future nutrient pollution of Colorado surface waters. Interim numerical values for nutrients, including phosphorus, nitrogen, and chlorophyll a, were established at levels to protect designated uses of Colorado waters. These would initially be applied only to streams and lakes above dischargers (any building, structure, facility, or installation from which there is or may be a discharge of pollutants) and to protect municipal water supplies sourced directly from lakes or reservoirs.

The total phosphorus interim standard for Colorado warm-water rivers and streams, scheduled to be implemented in 2022, is analyzed as an annual median value of 0.17 mg/L (CDPHE 2012). For the purpose of this report, any individual total phosphorus value for Colorado warm-water rivers or streams that exceeded 0.17 mg/L was included as an indicator of a potential problem. Four evaluations at Red Rock Canyon near the NPS boundary exceeded this value. Elevated total phosphorus values in Red Rock Canyon are consistent with 10 years of data collected from 1996 to 2006 (Brown and Thoma 2012). Natural sources of phosphorus likely occur within Red Rock Canyon and the surrounding area. However, in conjunction with the high *E. coli* numbers noted above, it would be prudent for park managers to work with the State of Colorado to begin more intensive sampling of the area to determine if anthropogenic sources are contributing to phosphorus and coliform exceedances.

3.3 Bryce Canyon National Park

3.3.1 Water quality summary

A total of 1,122 designated beneficial-use evaluations were completed for water quality results obtained at four sites in Bryce Canyon NP between October 1, 2009 and September 30, 2012. Of those 1,122 evaluations, nine (0.8%) exceeded water quality standards or criteria (Figure 3-8). Water quality standards were exceeded for three constituent categories: nutrients, total dissolved solids, and *E. coli* (Figure 3-9).

3.3.2 Reportable exceedances

Tropic Ditch did not have any exceedances based upon 114 evaluations. The only parameters measured at Tropic Ditch were pH, dissolved oxygen, temperature, and *E. coli*. Sheep Creek had exceedances for *E. coli* and total dissolved solids during less than 10% of site visits. Mossy Cave Spring exceeded the indication of impairment for total phosphorus during less than 10% of site visits, while Sheep Creek and Yellow Creek exceeded the indication of impairment for total phosphorus for warm-water game fish for 10% and 13% of site visits, respectively (Figure 3-10, Table 3-3).

3.3.3 Discussion and management implications

3.3.3.1 Total dissolved solids

In part, Sheep and Yellow creeks are included in NCPN monitoring because they contribute flow to segments of the Paria River, which is on the State of Utah's 303(d) list of impaired water bodies for total dissolved solids and water temperature. Although TDS exceedances are common on these streams below the park boundary (Judd and Adams 2006), there were only two exceedances (7% of site visits) observed at the park boundary at Sheep Creek during the sampling period covered in this report.

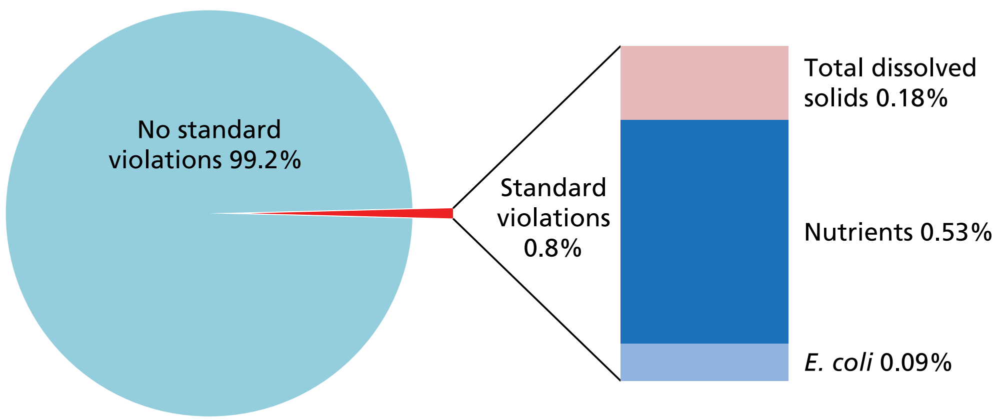


Figure 3-8. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Bryce Canyon NP, October 1, 2009–September 30, 2012.

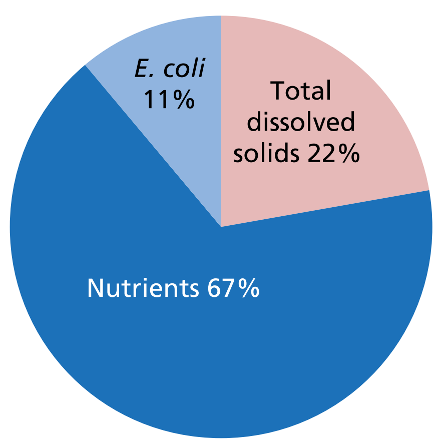


Figure 3-9. Most commonly exceeded water quality standards at Bryce Canyon NP, October 1, 2009–September 30, 2012.

Water Quality Monitoring Sites, 2010–2012

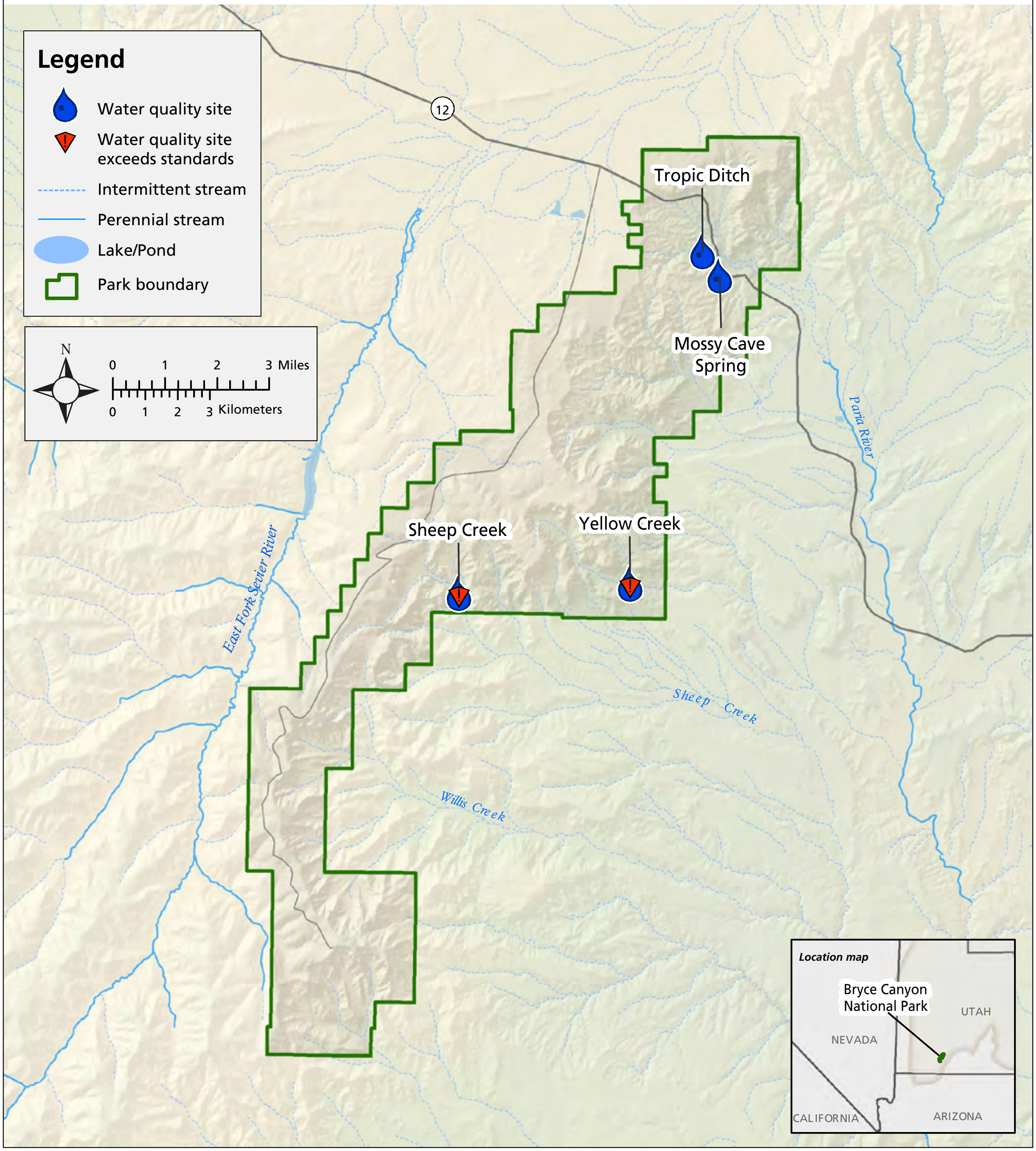


Figure 3-10. Water quality monitoring locations in Bryce Canyon National Park, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-3. Exceedances of surface water quality standards for sites sampled in or near Bryce Canyon NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Sheep Creek	2B	Phosphorus, Total	0.05	mg/L	31	10
Yellow Creek	2B	Phosphorus, Total	0.05	mg/L	16	13

Use codes: 2B = secondary-contact recreation

3.3.3.2 Nutrients

Total phosphorus exceedances may result from rock weathering, airborne deposition, or soil erosion. Phosphorus comes in several forms, including a form sorbed to soil particles that may be transported to water bodies where dissolution can occur, resulting in bioavailable phosphorus. Trespass cattle in and around Sheep and Yellow Creeks may contribute to soil erosion and increased total phosphorus levels. It is also possible that the phosphorus has a geologic origin and is naturally occurring at high levels due to weathering. A better understanding of phosphorus source, transport, and biological effect in these watersheds would help determine potential management actions for restoration, including the possibility of reclassifying or providing site-specific classifications for water bodies based on natural conditions.

3.3.3.3 *E. coli*

The infrequent *E. coli* exceedances that occurred during the study period do not warrant concern from a human-health perspective. Possible sources of contamination include wildlife, human use, and trespass cattle, which have been an infrequent but reoccurring issue in Bryce Canyon NP. During monthly monitoring visits, signs of cattle trespass were observed in the park along the riparian corridors of Sheep and Yellow creeks. Potential physical and biological damage to the riparian corridor and degradation of water quality from cattle trespass is not being measured, but may be a resource management concern.

There has been continued effort to maintain the boundary fences at Sheep Creek and Yellow creeks, but these fences are sometimes damaged by high water during the summer monsoon season and other factors. Maintaining these fences in good repair should minimize any potential impacts caused by trespass cattle in the riparian area along the stream.

3.4 Canyonlands National Park

3.4.1 Water quality summary

A total of 5,678 designated beneficial-use evaluations were completed for water quality results obtained at 15 sites in or near Canyonlands NP between October 1, 2009 and September 30, 2012. Of those 5,678 evaluations, 226 (4.0%) exceeded water quality standards or criteria (Figure 3-11). Water quality standards were exceeded for six constituent categories—most commonly, nutrients, dissolved oxygen, and metals (Figure 3-12).

3.4.2 Reportable exceedances

The Green River at Green River, Utah, did not have any exceedances or indications of impairment, based upon 168 total evaluations for the parameters tested, including temperature, pH, fluorides, and total dissolved solids. All other sites had exceedances of water quality standards for the State of Utah (Table 3-4, Figure 3-13). The following discussion focuses only on sites that had exceedances.

3.4.2.1 Rivers

Colorado River at Potash boat ramp. This site exceeded the indication for impairment for total phosphorus and the selenium standard for 79% and 16% of evaluations, respectively. The total phosphorus exceedances were greater than the indication for impairment for primary-contact recreation and warm-water game fish. The selenium concentrations exceeded the chronic standard for warm-water game fish but did not exceed the acute standard (18.6 µg/L).

Colorado River above the confluence with the Green River. This site exceeded the indication of impairment for total phosphorus, the standard for selenium, and the standard for temperature. Total phosphorus concentrations were greater than the indication of

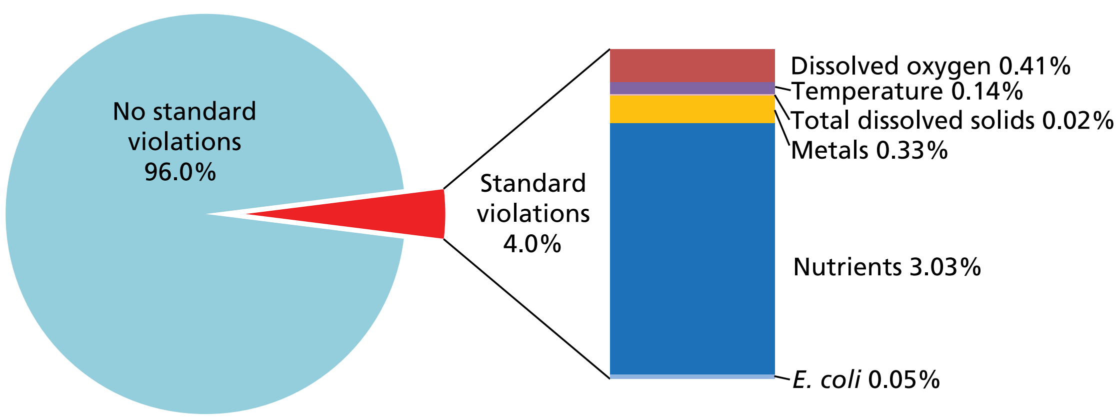


Figure 3-11. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Canyonlands NP, October 1, 2009–September 30, 2012.

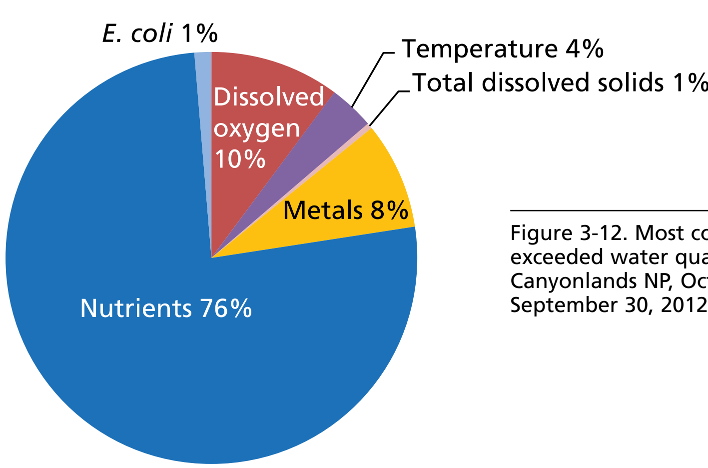


Figure 3-12. Most commonly exceeded water quality standards at Canyonlands NP, October 1, 2009–September 30, 2012.

Canyonlands National Park
Utah

National Park Service
U.S. Department of the Interior
Northern Colorado Plateau Network

Water Quality Monitoring Sites, 2010–2012

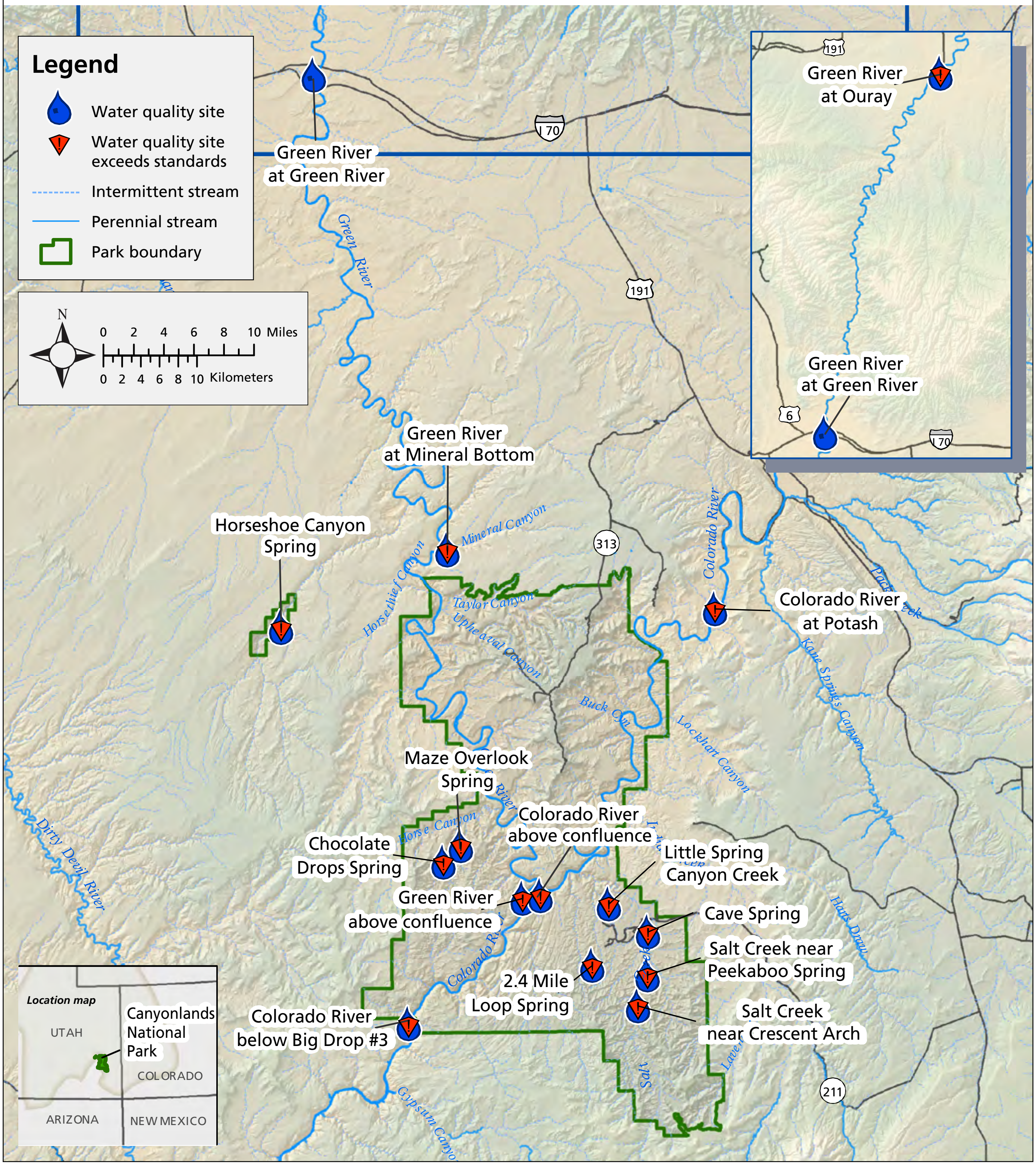


Figure 3-13. Water quality monitoring locations in and near Canyonlands National Park, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-4. Exceedances of surface water quality standards for sites sampled in or near Canyonlands NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Cave Spring	3B	Dissolved oxygen	5.5	mg/L	5	40
	2A, 3B	Phosphorus, Total	0.05	mg/L	11	36
Chocolate Drops Spring (0.5 mi S of Maze Overlook)	1C	Arsenic, Dissolved	10	µg/L	3	33
	3B	Dissolved oxygen	5.5	mg/L	7	43
Colorado River above confluence with Green River	2A, 3B	Phosphorus, Total	0.05	mg/L	21	86
	3B	Selenium, Dissolved	4.6	µg/L	21	24
	3B	Temperature, water	27	°C	20	15
Colorado River at Potash boat ramp	2A, 3B	Phosphorus, Total	0.05	mg/L	19	79
	3B	Selenium, Dissolved	4.6	µg/L	19	16
Colorado River below Big Drop #3 Rapids	2A, 3B	Phosphorus, Total	0.05	mg/L	20	85
	3B	Temperature, water	27	°C	19	11
Green River above confluence with Colorado River	2A, 3B	Phosphorus, Total	0.05	mg/L	21	95
	3B	Temperature, water	27	°C	19	11
Green River at Mineral Bottom	3B	Aluminum, Dissolved	87	µg/L	7	14
	2A, 3B	Phosphorus, Total	0.05	mg/L	7	100
Green River at Ouray, UT	3B	Mercury, Dissolved	0.012	µg/L	8	13
Horseshoe Canyon Spring (0.3 mi above confluence with Water Canyon)	1C	Arsenic, Dissolved	10	µg/L	3	33
	3B	Dissolved oxygen	5.5	mg/L	7	57
	2A	*E. coli*	126	MPN/100ml	5	20
Little Spring Canyon Creek	3B	Selenium, Dissolved	4.6	µg/L	4	100
Maze Overlook Spring (0.25 mi SE of Maze Overlook)	3B	Dissolved oxygen	5.5	mg/L	7	14
Salt Creek near Crescent Arch	3B	Dissolved oxygen	5.5	mg/L	18	39
	1C	Mercury, Dissolved	2	µg/L	9	11
	3B	Mercury, Dissolved	0.012	µg/L	9	11
	2A, 3B	Phosphorus, Total	0.05	mg/L	26	19
Salt Creek near Peekaboo Spring	3B	Temperature, water	27	°C	10	10
2.4 Mile Loop Spring	3B	Dissolved oxygen	5.5	mg/L	7	86

Use codes: 2A = primary-contact recreation; 3B = warm-water game fish; 1C = drinking water impairment for the warm-water game fish standard and the primary-contact recreation standard for 86% of evaluations. Selenium concentrations exceeded the chronic standard for warm-water game fish for 24% of evaluations, but did not exceed the acute selenium standard (18.6 μg/L). Temperatures exceeded the standard for warm-water game fish for 15% of evaluations.

Colorado River below Big Drop #3. This site exceeded the indication of impairment for total phosphorus concentration for primary-contact recreation and warm-water game fish for 79% of evaluations. Temperatures exceeded the standard for warm-water game fish for 11% of evaluations.

Green River at Ouray, Utah. This site exceeded the mercury standard for warm-water game fish for 13% of evaluations.

Green River at Mineral Bottom. This site exceeded the indication of impairment for total phosphorus for 100% of evaluations. The total phosphorus concentrations exceeded the indication of impairment for primary-contact recreation and warm-water game fish. Aluminum concentrations exceeded the chronic standard (87 μg/L) for warm-water game fish for 14% of evaluations.

Green River above confluence with Colorado River. This site exceeded the indication of impairment for total phosphorus for 95% of evaluations. The total phosphorus concentrations exceeded the indication of impairment for primary-contact recreation and warm-water game fish. Temperatures exceeded the standard for warm-water game fish for 11% of evaluations.

3.4.2.2 Intermittent streams

Horseshoe Canyon. Horseshoe Canyon exceeded the standards for arsenic, dissolved oxygen, and *E. coli*. Dissolved-oxygen concentrations failed to meet the chronic and acute standards for warm-water game fish for 57% and 29% of evaluations, respectively. One of five evaluations resulted in an *E. coli* exceedance for the chronic primary-contact recreation standard.

Salt Creek near Crescent Arch. This site exceeded the indication of impairment for total phosphorus, the standard for mercury, and the standard for dissolved oxygen. Total phosphorus concentrations were greater than the indication of impairment for the warm-water game fish standard and the primary-contact recreation standard for 19% of evaluations. Dissolved-oxygen concentrations were below the chronic and acute (3.0 mg/L) standard for warm-water game fish for 39% and 6% of evaluations, respectively. The warm-water game fish standard and drinking-water standard for mercury were exceeded for 11% of evaluations.

Salt Creek near Peekaboo Spring. This site exceeded the temperature standard for warm-water game fish for 10% of evaluations.

3.4.2.3 Springs

Cave Spring. Cave Spring exceeded the indication of impairment for total phosphorus and the dissolved-oxygen standard. Total phosphorus concentrations were greater than the indication of impairment for warm-water game fish and primary-contact recreation for 36% of evaluations. Dissolved-oxygen concentrations were less than the chronic (30-day average, 5.5 mg/L) and acute (3.0 mg/L) standards for warm-water game fish for 40% and 20% of evaluations, respectively.

Chocolate Drops Spring. This site had exceedances for dissolved arsenic and dissolved oxygen. One of three evaluations exceeded the arsenic standard for Utah drinking-water supply. Dissolved-oxygen concentrations were below the chronic and acute standard for warm-water game fish for 43% and 14% of evaluations, respectively.

Little Spring Canyon Creek. Little Spring Canyon Creek exceeded the chronic selenium standard for warm-water game fish for 100% of evaluations. There were only four results available for analysis from Little Spring Canyon Creek during the period covered in this report, none of which exceeded the acute standard for selenium.

Maze Overlook Spring (0.25 miles SE of Maze Overlook). One of seven evaluations (14%) for dissolved oxygen at Maze Overlook Spring failed to meet the chronic standard for warm-water game fish.

2.4 Mile Loop Spring. Dissolved-oxygen concentrations were below the chronic (5.5 mg/L) and acute (3.0 mg/L) standard for warm-water game fish for 86% and 29% of evaluations, respectively.

3.4.3 Discussion

3.4.3.1 Dissolved oxygen

The results from this monitoring period are consistent with the results from over 10 years of sampling in Canyonlands NP, as described by Schelz and Moran (2005a) and Van Grinsven and others (2010). Both the hydrologic setting and low-flow conditions typically found in intermittent streams, such as Horseshoe Canyon and Salt Creek, contribute to low dissolved-oxygen concentrations. During low-flow conditions, when water temperatures are high and surface flow is low, stagnant pools form. The combination of elevated temperatures and organic matter decomposition in stagnant or low-flow conditions causes the reduction and depletion of dissolved oxygen. In addition, these intermittent streams often have unshaded reaches in which water temperatures are elevated, even in free-flowing environments.

Groundwater-fed springs, such as Cave Spring, Chocolate Drops Spring, Maze Overlook Spring, and 2.4 Mile Loop Spring, also have low dissolved-oxygen concentrations. Spring sites, which are predominantly recharged by groundwater, tend to have low dissolved-oxygen concentrations because of underground biological activity that reduces the amount of oxygen present in emergent groundwater.

3.4.3.2 Nutrients

Total phosphorus exceedances in perennial and intermittent streams may result from rock weathering, airborne deposition, or soil erosion. Phosphorus comes in several forms, including a form sorbed to soil particles that may be transported to water bodies where dissolution can occur, resulting in bioavailable phosphorus.

In the headwaters areas of Canyonlands NP stream basins, soil erosion on uplands may have been accelerated due to grazing, and may continue at an accelerated pace if soil-surface crusts have not stabilized despite the absence of grazing for many years (Reynolds et al. 2005). Although speculative, this scenario may have important management implications. It is also possible that the phosphorus has a geologic origin and is naturally occurring at high levels due to weathering (Reynolds et al. 2001). Elevated total phosphorus concentrations at sites in or near Canyonlands NP are consistent with 11–29 years of data (1977–2006), depending on the site (Brown and Thoma 2012). A better understanding of phosphorus source, transport, and biological effect in these watersheds would help determine potential management actions for restoration, including the possibility of reclassifying or providing site-specific classifications for water bodies based on natural conditions.

3.4.3.3 Metals

Erosion of the Mancos Shale formation causes naturally elevated selenium concentrations in surface water bodies throughout the Northern Colorado Plateau, as discussed in Section 3.1.3.4. Water quality monitoring sites located on the Colorado River are no exception, as a large contributing area of the watershed includes a Mancos Shale component. The Colorado River, from its confluence with the Green River upstream to Moab, was added to Utah's 303(d) list in 2006, for selenium impairment.

Little Spring Canyon Creek's selenium exceedances have been documented for many years (Schelz and Moran 2005a; Van Grinsven et al. 2010) and may result from naturally derived sources. A geochemical investigation of the Cedar Mesa Sandstone and Elephant Canyon Formation could verify the likelihood of a naturally derived selenium source. Because the watershed lies entirely within Canyonlands NP, and open-range grazing near the Little Spring Canyon Creek headwaters ceased a few years after the park's 1964 designation, erosion from the Little Spring Canyon Creek watershed has likely been mitigated with time. In addition, the majority of surface water present at the Little Spring Canyon Creek site is derived from groundwater seepage, and the available results were collected during low-flow, clear water conditions, indicating that the selenium source is likely derived from groundwater and not overland flow.

One of seven samples for dissolved aluminum at Green River at Mineral Bottom exceeded the standards for warm-water game fish. The elevated concentration is likely from eroding natural deposits. Elevated dissolved arsenic concentrations in Chocolate Drops Spring and Horseshoe Canyon Spring occurred in one of three samples. Dissolved arsenic concentrations exceeded the Utah drinking-water standard but most likely entered these systems from natural sources. One sample from the Green River at Ouray, Utah, and one sample at Salt Creek near Crescent Arch exceeded the standard for dissolved mercury for warm-water game fish. Elevated concentrations of mercury are likely naturally derived from the surrounding area. Exceedances for dissolved aluminum, arsenic, and mercury were infrequent and are not an immediate cause for concern.

3.4.3.4 Temperature

Temperatures exceeded the warm-water game fish standard at three river sites and one spring in or near Canyonlands NP. Temperature exceedances occurred during the summer months and were infrequent during the study period. However, continued monitoring is recommended to detect and assess the frequency of long-term temperature exceedances at these sites.

3.4.3.5 *E. coli*

One *E. coli* exceedance occurred at Horseshoe Canyon Spring, with a value of 129.6 MPN where the chronic primary-contact recreation standard is 126 MPN. The sample was collected after recent rain and the elevated *E. coli* value could be due to overland flow. While the exact cause of the exceedance is unknown, preventive measures, such as ensuring that fences are properly maintained, can minimize cattle trespass as a potential source of future *E. coli* contamination.

3.4.4 Management implications

The sources of phosphorus and metals could be further investigated through evaluation of geologic formations and current and past human land-use practices in the watersheds. If a likely source or sources cannot be identified in the current literature or via additional internal investigation, the NPS could advance a regional study by partnering with academic institutions or the USGS. When park managers understand the source and mechanisms of pollutant transport to water bodies—and their potential biological impact—then management actions can be developed in cases where the pollutant source is anthropogenic. If the source is outside the park, then managers can advocate for the resource when opportunities arise. Additionally, when investigations of the source and cause determine that the pollutants are naturally occurring, the NPS can work with the state to reclassify water bodies or develop site-specific classifications to better reflect natural conditions.

Bacterial water quality in small intermittent and spring sites can episodically degrade after large discharge events. Microorganisms present in fecal matter can survive for at least several days—and up to a few weeks—once exposed to the environment (Sampson et al. 2006). Surface water located in rain-catchment pools, stagnant sections of intermittent streams, and free-flowing streams can potentially contain elevated concentrations of *E. coli* following a precipitation event that causes overland flow. It is always recommended that visitors properly filter or treat surface water prior to consumption, but added caution should be taken if the pool is turbid or if an overland-flow event recently occurred. Even groundwater can potentially be contaminated with *E. coli*.

3.5 Capitol Reef National Park

3.5.1 Water quality summary

A total of 1,570 designated beneficial-use evaluations were completed for water quality results obtained at six sites in or near Capitol Reef NP between October 1, 2009 and September 30, 2012. Of those 1,570 evaluations, 95 (6.1%) exceeded water quality standards or criteria (Figure 3-14). Water quality standards were exceeded for five constituent categories, most commonly for nutrients, total dissolved solids, and *E. coli* (Figure 3-15). Several sites along the Fremont River that are sampled by the State of Utah did not have results available for analysis.

3.5.2 Reportable exceedances

The Fremont River near Caineville, Utah, did not have any exceedances or indications of impairment based upon 44 total evaluations. Only water temperature and pH were evaluated at this site. The other five sites sampled had water quality exceedances for the State of Utah (Figure 3-16, Table 3-5). The following discussion focuses only on sites that had exceedances.

Fremont River near Bicknell, Utah. Only four parameters were tested at this site, including temperature, pH, fluorides, and total dissolved solids. Water temperature at this site exceeded the standard for cold-water game fish for 11% of evaluations.

Oak Creek above Sandy Ranch Dam. This site exceeded the indication of impairment for total phosphorus for secondary-contact recreation for 25% of evaluations. Two of sixteen evaluations resulted in a pH exceedance for secondary-contact recreation, nongame fish, and agricultural-use standards.

Pleasant Creek South of Sleeping Rainbow Ranch. Pleasant Creek exceeded the chronic drinking-water and secondary-contact recreation standards for *E. coli* for 13% of evaluations. The water temperature standard for cold-water game fish was exceeded for 18% of evaluations. Total phosphorus exceeded

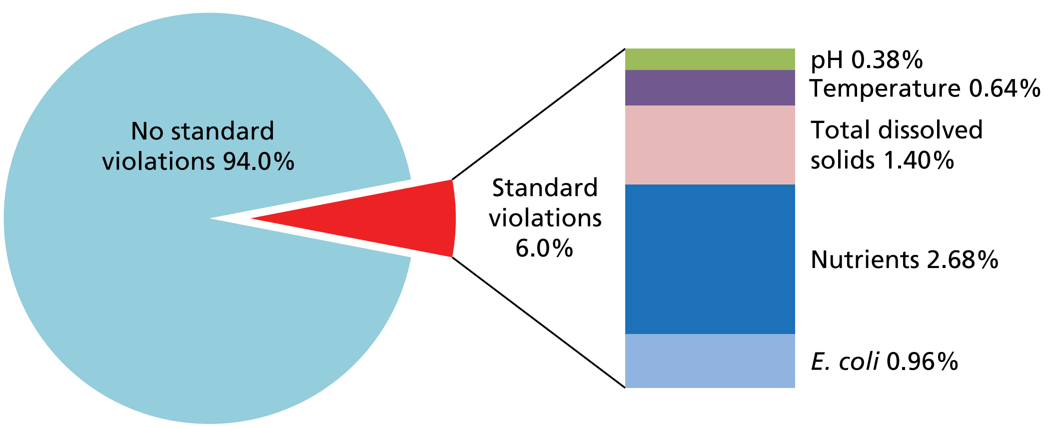


Figure 3-14. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Capitol Reef NP, October 1, 2009–September 30, 2012.

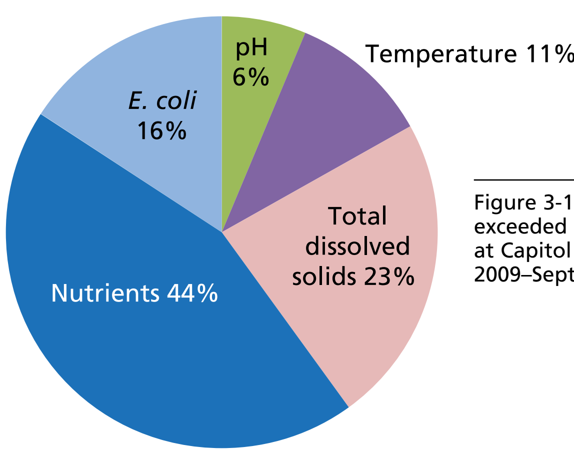


Figure 3-15. Most commonly exceeded water quality standards at Capitol Reef NP, October 1, 2009–September 30, 2012.

Capitol Reef National Park
Utah

National Park Service
U.S. Department of the Interior
Northern Colorado Plateau Network

Water Quality Monitoring Sites, 2010–2012

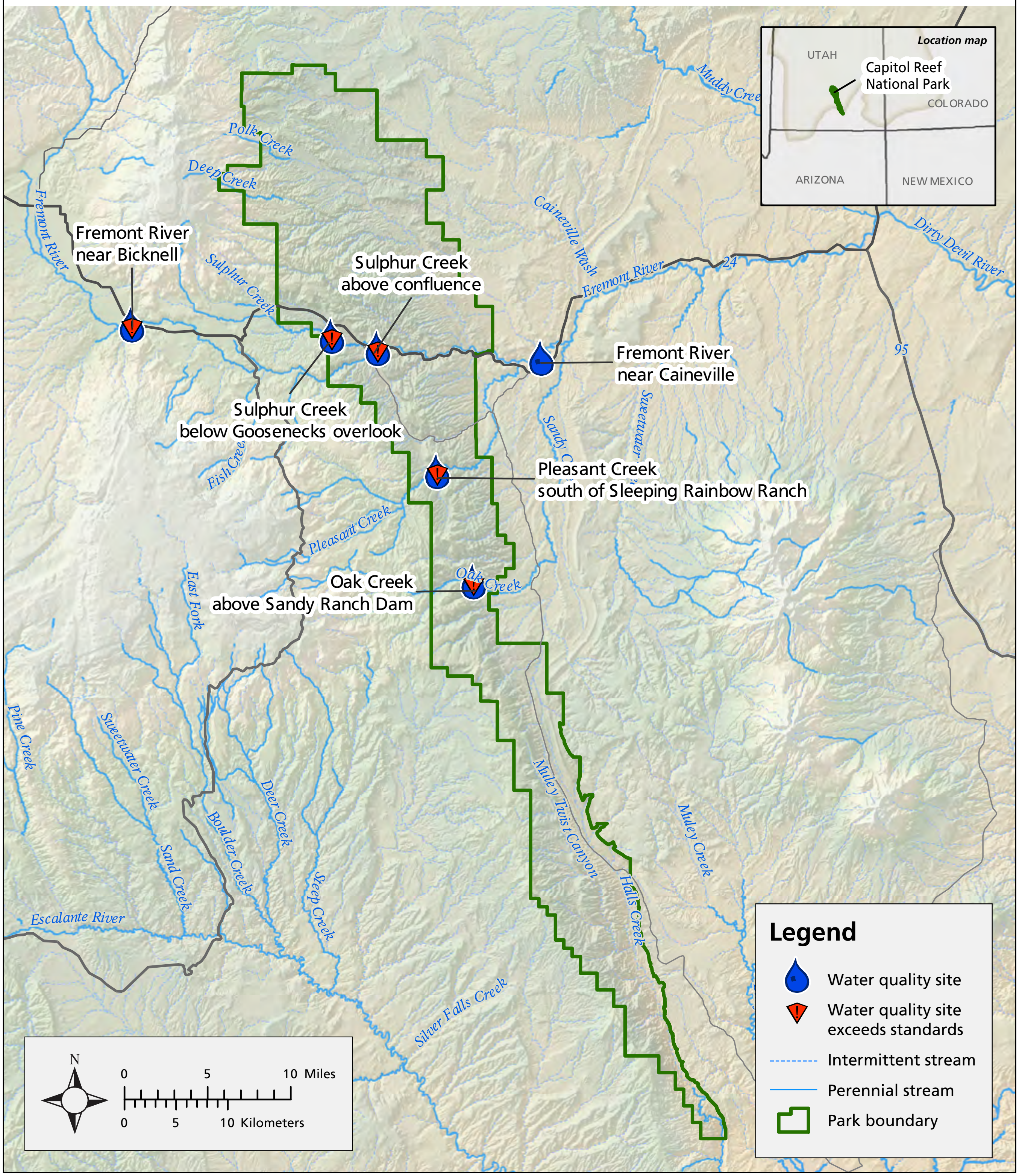


Figure 3-16. Water quality monitoring locations in and near Capitol Reef National Park, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-5. Exceedances of surface water quality standards for sites sampled in or near Capitol Reef NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Fremont River near Bicknell, UT	3A	Temperature, water	20	°C	19	11
Oak Creek above Sandy Ranch Dam	2B, 3C, 4	pH	9	none	16	13
	2B	Phosphorus, Total	0.05	mg/L	16	25
Pleasant Creek S of Sleeping Rainbow Ranch	1C, 2B	*E. coli*	206	MPN/100ml	8	13
	2B, 3A	Phosphorus, Total	0.05	mg/L	10	40
	3A	Temperature, water	20	°C	11	18
Sulphur Creek above confluence with Fremont River	2A	*E. coli*	126	MPN/100ml	8	25
	1C	*E. coli*	206	MPN/100ml	8	25
	2A	*E. coli*	409	MPN/100ml	8	13
	2A, 3A	Phosphorus, Total	0.05	mg/L	12	42
	3A	Temperature, water	20	°C	11	18
	4	Total Dissolved Solids	1200	mg/L	12	75
Sulphur Creek below road to Goosenecks Overlook	2A	*E. coli*	126	MPN/100ml	19	21
	1C	*E. coli*	206	MPN/100ml	19	16
	2A, 3A	Phosphorus, Total	0.05	mg/L	30	33
	3A	Temperature, water	20	°C	29	10
	4	Total Dissolved Solids	1200	mg/L	30	43

Use codes: 2A = primary-contact recreation; 2B = secondary-contact recreation; 3A = cold-water game fish; 3B = warm-water game fish; 1C = drinking water; 4 = agricultural use

the indication of impairment criteria for secondary-contact recreation and cold-water game fish for 40% of evaluations.

Sulphur Creek below road to Goosenecks Overlook. This site exceeded the chronic standard for *E. coli* for primary-contact recreation (126 MPN) and drinking water (206 MPN) for 25% of evaluations and exceeded the acute *E. coli* standard for primary-contact recreation (409 MPN) for 13% of evaluations. The water temperature standard for cold-water game fish was exceeded for 18% of evaluations. Total phosphorus exceeded the indication of impairment criteria for primary-contact recreation and cold-water game fish for 42% of evaluations. Total dissolved solids exceeded the agricultural-use standard for 75% of evaluations.

Sulphur Creek above confluence with Fremont River. This site exceeded the chronic standard for *E. coli* for primary-contact recreation (126 MPN) for 21% of evaluations and drinking water (206 MPN) for 16% of evaluations. The water temperature standard for cold-water game fish was exceeded for 10% of evaluations. Total phosphorus exceeded the indication of impairment criteria for primary-contact recreation and cold-water game fish for 33% of evaluations. Total dissolved solids exceeded the agricultural-use standard for 43% of evaluations.

3.5.3 Discussion and management implications

3.5.3.1 Nutrients

Four sites within Capitol Reef NP exceeded the indication of impairment for total phosphorus. Rocks of volcanic origin are known to have naturally high levels of phosphorus (Brown and Thoma 2012) and are common in the upper watersheds of these streams, and a geologic source for these exceedances is likely. Anthropogenic activities, such as pasture irrigation, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations are likely natural or anthropogenic in origin. If the observed total phosphorus exceedances are strongly correlated with low dissolved-oxygen conditions, then management action could be warranted. At these sites, elevated total phosphorus concentrations did not coincide with low dissolved-oxygen concentrations, indicating a low likelihood of eutrophication.

3.5.3.2 *E. coli*

During high-discharge events, runoff from the watershed contributes large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli*, are carried into streams, along with the silts and sands being eroded during overland flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies, and is able to survive for prolonged periods of time when attached to sediments (Sampson et al. 2006). The majority of *E. coli* exceedances in Pleasant and Sulphur creeks were associated with elevated turbidity and flow, and most did not exceed the acute standards for primary-contact recreation (409 MPN). In July 2012, sampling occurred the day after a flooding event at Upper Sulphur Creek, and the *E. coli* result exceeded this acute standard.

3.5.3.3 Total dissolved solids

Both sites monitored on Sulphur Creek exceeded the agricultural-use standard for total dissolved solids. Sulphur Creek runs primarily through the Moenkopi Formation, which is known to contribute naturally high levels of dissolved solids (Doelling et al. 1989). A possible anthropogenic source of elevated TDS levels may be due to irrigation inflows and runoff from agricultural activities upstream from and within Capitol Reef NP. However, a comparison of same-day TDS readings upstream and downstream of the park developed area does not indicate a pattern of higher TDS downstream of the park orchards, campgrounds, and housing area (Figure 3-17).

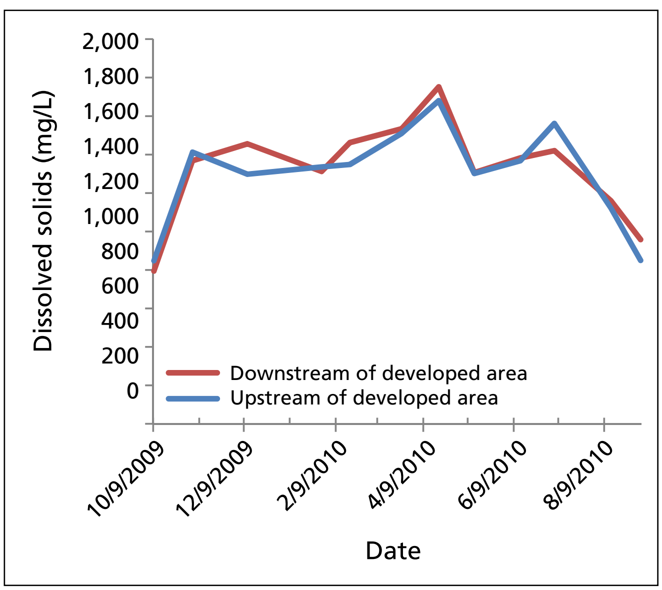


Figure 3-17. Comparison of total dissolved solids upstream and downstream of developed area at Capitol Reef NP.

3.5.3.4 Temperature

Elevated temperatures occurred at four sites within Capitol Reef National Park. Temperatures exceeded the State of Utah standard for cold-water game fish during the warmer summer months, usually from July through the beginning of September. Low-flow conditions, combined with hot summer air temperatures, cause periodic surface-water temperature exceedances at these sites.

3.5.3.5 pH

Oak Creek above Sandy Ranch Dam had two elevated pH readings that resulted in exceedances for three standards: secondary-contact recreation, non-game fish, and agricultural use. Notably, exceedances occurred on both occasions when Oak Creek was sampled during the afternoon in the summer. Other summer samples were taken in the morning, before air temperatures reached their peak. Elevated temperatures, in combination with available phosphorus, may have resulted in increased photosynthesis, which increases pH. Abundant algal growth was noted during site visits, but dissolved-oxygen levels did not indicate eutrophication in the stream.

The geochemical components of watersheds throughout the Northern Colorado Plateau naturally cause the pH of surface water to be slightly basic. However, the above-normal rate of photosynthesis during the summer months appears to cause alkalinization of water, resulting in periodic exceedances of State of Utah water quality standards for pH. Sampling in the afternoon during the summer months would help illustrate the frequency of pH exceedances.

3.6 Curecanti National Recreation Area

3.6.1 *Water quality summary*

A total of 8,470 designated beneficial-use evaluations were completed for water quality results obtained at 20 sites in and near Curecanti National Recreation Area (NRA) between October 1, 2009 and September 30, 2012. Of those 8,470 evaluations, 161 (1.9%) exceeded water quality standards or indications of impairment for the State of Colorado (Figure 3-18). Water quality standards were exceeded for four constituent categories, most commonly temperature, metals, *E. coli*, and dissolved oxygen (Figure 3-19).

Sites at Curecanti NRA consist of streams, rivers, and reservoirs. Blue Mesa, Morrow Point, and Crystal Reservoirs were not included in the previous exceedance reports.

3.6.2 *Reportable exceedances*

All sites sampled in Curecanti NRA had water quality exceedances for the State of Colorado. Seven of twenty sites had exceedances for less than 10% of evaluations: Curecanti Creek near Sapinero, Colorado (389 total evaluations), Lake Fork Gunnison River (528 total evaluations), Pine Creek at Hwy 50 near Sapinero, Colorado (544 total evaluations), Steuben Creek near Gunnison, Colorado (542 total evaluations), West Elk Creek near Sapinero, Colorado (339 total evaluations), Morrow Point Reservoir below Blue Creek (388 total evaluations), and Morrow Point Reservoir above Morrow Point Dam (388 total evaluations). The other 13 sites had exceedances for more than 10% of evaluations (Figure 3-20, Table 3-6). The following discussion focuses only on sites that had exceedances for more than 10% of evaluations.

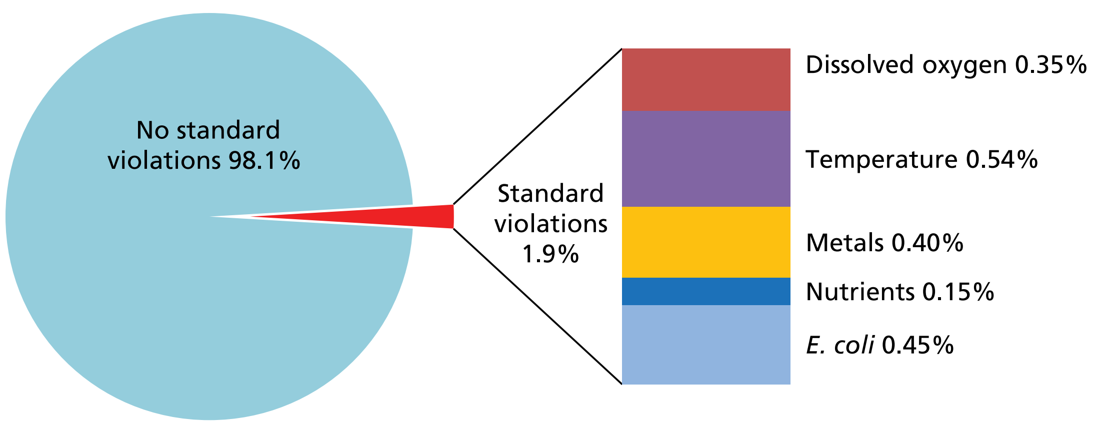


Figure 3-18. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Curecanti NRA, October 1, 2009–September 30, 2012.

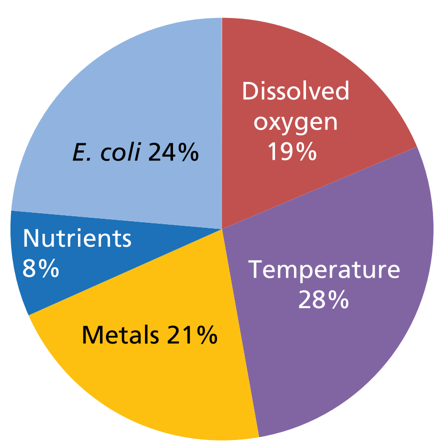


Figure 3-19. Most commonly exceeded water quality standards at Curecanti NRA, October 1, 2009–September 30, 2012.

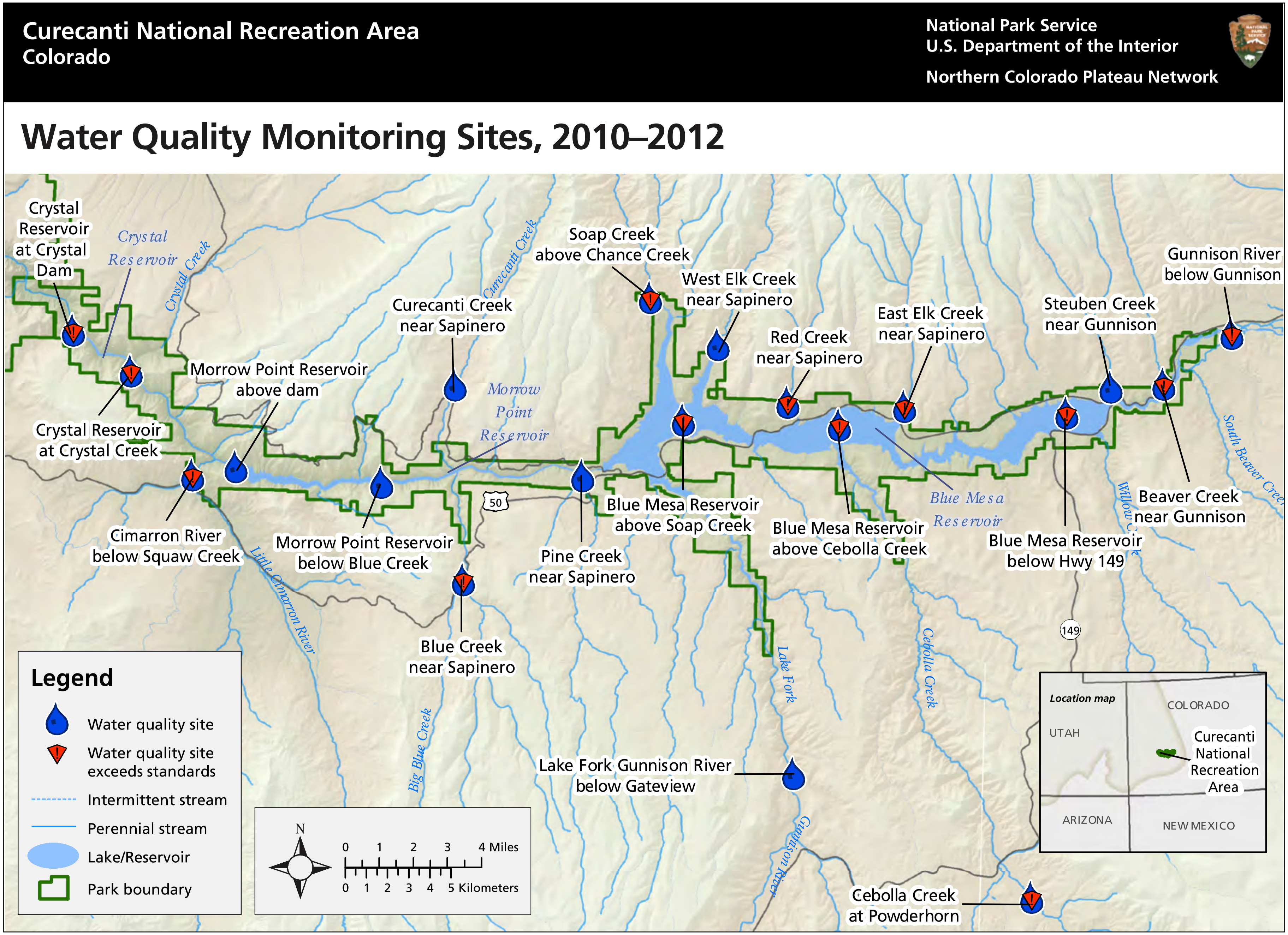


Figure 3-20. Water quality monitoring locations in and near Curecanti National Recreation Area, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-6. Exceedances of surface water quality standards for sites sampled in or near Curecanti NRA, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Beaver Creek at Hwy 50 near Gunnison, CO	ALCW1	Temperature, water	date dep.	°C	18	11
Blue Creek at Hwy 50 near Sapinero, CO	RecU, UG26	*E. coli*	126	cfu/100ml	23	22
	ALCW1	Temperature, water	date dep.	°C	16	13
Cebolla Creek at Powderhorn	ALCW1	Phosphorus, Total	0.11	mg/L	6	17
Cimarron River below Squaw Creek near Cimarron, CO	RecU, UG26	*E. coli*	126	cfu/100ml	26	27
	ALCW1	Temperature, water	date dep.	°C	18	28
East Elk Creek near mouth near Sapinero, CO	ALCW1	Dissolved Oxygen	7	mg/L	18	22
	DWS	Manganese, Dissolved	50	µg/L	18	50
	ALCW1	Silver, Dissolved	H. Dep.	µg/L	18	11
	ALCW1	Temperature, water	date dep.	°C	18	28
Gunnison River at County Rd 32 below Gunnison, CO	UG14	Temperature, water	date dep.	°C	6	17
Red Creek near mouth near Sapinero, CO	ALCW1	Dissolved Oxygen	7	mg/L	18	39
	DWS	Manganese, Dissolved	50	µg/L	18	61
	ALCW1	Temperature, water	date dep.	°C	18	50
Soap Creek above Chance Creek near Sapinero, CO	ALCW1	Temperature, water	date dep.	°C	15	13
Blue Mesa Reservoir above Cebolla Creek near Sapinero, CO	ALCW1	Dissolved Oxygen	7	mg/L	15	40
	DWS	Manganese, Dissolved	50	µg/L	16	13
	Res	Temperature, water	date dep.	°C	16	38
Blue Mesa Reservoir above Soap Creek near Sapinero, CO	ALCW1	Dissolved Oxygen	7	mg/L	14	50
	DWS	Manganese, Dissolved	50	µg/L	16	31
	Res	Temperature, water	date dep.	°C	15	27
Blue Mesa Reservoir below Hwy 149 near Gunnison, CO	ALCW1	Dissolved Oxygen	7	mg/L	15	20
	DWS	Manganese, Dissolved	50	µg/L	16	13
	Res	Phosphorus, Total	0.025	mg/L	16	50
	Res	Temperature, water	date dep.	°C	16	38
Crystal Reservoir at Crystal Creek near Cimarron, CO	DWS	Manganese, Dissolved	50	µg/L	10	10
	Res	Phosphorus, Total	0.025	mg/L	9	11
Crystal Reservoir at Crystal Dam near Cimarron, CO	Res	Phosphorus, Total	0.025	mg/L	9	22

Use codes: ALCW1 = aquatic life cold-water class 1; DWS = drinking-water supply; RecU = undetermined use recreation; Res = reservoir-specific aquatic life standard; UG14 = Upper Gunnison River basin segment 14 aquatic life standard; UG26 = Upper Gunnison River basin segment 26 aquatic life standard

3.6.3 Rivers and streams

Beaver Creek at Hwy 50 near Gunnison, Colorado. This site exceeded the aquatic life cold-water class 1 temperature standard for 11% of evaluations.

Blue Creek at Hwy 50 (near Sapinero). This site exceeded temperature and *E. coli* standards. Temperature exceeded the aquatic life cold-water class 1 standard for 13% of evaluations. *E. coli* exceeded the undetermined-use recreation standard and the State of Colorado Upper Gunnison segment-specific standard for 22% of evaluations.

Cebolla Creek at Powderhorn. This site exceeded the total phosphorus interim standard for aquatic life cold-water class 1 for 17% of evaluations.

Cimarron River below Squaw Creek near Cimarron, Colorado. This site exceeded the *E. coli* and temperature standards for 27% and 28% of evaluations, respectively. *E. coli* exceeded the undetermined-use recreation standard and the Upper Gunnison segment-specific standard. Temperature exceeded the aquatic life cold-water class 1 standard.

East Elk Creek near mouth near Sapinero, Colorado. This site exceeded the standards for dissolved oxygen, dissolved manganese, dissolved silver, and temperature. Dissolved-oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present, 7.0 mg/L) for 22% of evaluations, and one evaluation exceeded the standard for aquatic life cold-water class 1 (spawning absent, 6.0 mg/L). Dissolved manganese measurements exceeded the drinking-water standard for 50% of evaluations. There are no drinking-water supplies drawn from East Elk Creek within or outside Curecanti NRA. Dissolved silver concentrations exceeded the aquatic life cold-water class 1 standard for 11% of evaluations. Temperature standards were exceeded for aquatic life cold-water class 1 for 28% of evaluations.

Gunnison River at County Road 32 below Gunnison, Colorado. This site exceeded the Upper Gunnison segment-specific aquatic life cold-water standard for temperature for 17% of evaluations.

Red Creek near mouth near Sapinero, Colorado. At this site, exceedances were observed for dissolved oxygen, dissolved manganese, and temperature. Dissolved-oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present) for 39% of evaluations, and one evaluation exceeded the standard for aquatic life cold-water class 1 (spawning absent). Dissolved manganese concentrations exceeded the chronic standard for drinking-water supply for 61% of evaluations. There are no drinking-water supplies drawn from Red Creek within or outside Curecanti NRA. Temperature exceeded the aquatic life cold-water class 1 standard for 50% of evaluations.

Soap Creek above Chance Creek near Sapinero, Colorado. This site exceeded the aquatic life cold-water class 1 temperature standard for 13% of evaluations.

3.6.4 Reservoirs

Blue Mesa Reservoir above Cebolla Creek near Sapinero, Colorado. This site exceeded the standards for dissolved oxygen, dissolved manganese, and temperature. Dissolved-oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present) for 40% of evaluations, but never exceeded the standard for aquatic life cold-water class 1 (spawning absent). Dissolved manganese concentrations exceeded the drinking-water supply standard for 13% of evaluations. Temperature exceeded the State of Colorado reservoir-specific chronic standard for aquatic life cold-water for 38% of evaluations, but never exceeded the acute temperature standard (23.8°C).

Blue Mesa Reservoir above Soap Creek near Sapinero, Colorado. This site exceeded the standards for dissolved oxygen, dissolved manganese, and temperature. Dissolved-oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present) for 50% of evaluations, but never exceeded the standard for aquatic life cold-water class 1 (spawning absent). Dissolved manganese concentrations exceeded the drinking-water supply standard for 31% of evaluations. Temperature exceeded the State of Colorado reservoir-specific chronic standard for aquatic life cold-water for 27% of evaluations, but never exceeded the acute temperature standard (23.8°C).

Blue Mesa Reservoir below Hwy 149 near Gunnison, Colorado. This site exceeded the standards for dissolved oxygen, dissolved manganese, total phosphorus, and temperature. Dissolved-oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present) for 20% of evaluations, but never exceeded the standard for aquatic life cold-water class 1 (spawning absent). Dissolved manganese concentrations exceeded the drinking-water supply standard for 13% of evaluations. Total phosphorus exceeded the interim standard for aquatic life cold-water in Colorado reservoirs for 50% of evaluations. Temperature exceeded the State of Colorado reservoir-specific chronic standard for aquatic life cold-water for 38% of evaluations, but never exceeded the acute temperature standard (23.8°C).

Crystal Reservoir at Crystal Creek near Cimarron, Colorado. This site exceeded the standards for dissolved manganese and total phosphorus for 10% and 11% of evaluations, respectively. Dissolved manganese concentrations exceeded the drinking-water supply standard. Total phosphorus exceeded the interim standard for aquatic life cold-water in Colorado reservoirs.

Crystal Reservoir at Crystal Dam near Cimarron, Colorado. This site exceeded the interim standard for total phosphorus for aquatic life cold-water in Colorado reservoirs for 22% of evaluations.

3.6.5 Discussion

3.6.5.1 Metals

The chronic manganese standard for drinking-water supply was exceeded at East Elk Creek and Red Creek, and also at three sites at Blue Mesa Reservoir and one site at Crystal Reservoir. Exceedances on both the streams and reservoirs do not raise significant concerns because they have no direct drinking-water intakes. The tributaries drain areas of public land (including the West Elk Wilderness) that are minimally impacted by human activities, and it is likely that the source of manganese is natural weathering. It should also be noted that the concentration of manganese in these and other water bodies did not exceed criteria for aquatic life, and that the drinking-water standard of 50 µg/L is for odor, color, and staining, not human health.

It may be possible to request exemptions or site-specific manganese criteria if sufficient evidence exists to make a strong case for naturally occurring conditions that exceed criteria and no drinking-water source exists on the water bodies. Such a change would not improve water quality, but would make accounting for exceedances more straightforward, especially if these conditions are already recognized by the Colorado State Water Quality Control Commission.

The chronic and acute standards for dissolved silver for cold-water aquatic life are hardness-dependent. The chronic standard was exceeded at East Elk Creek for 2 of 18 evaluations and at Steuben Creek for 1 of 18 evaluations. Of note is that exceedances occurred when the USGS laboratory decreased the detection limit for dissolved silver from 0.01 µg/L to 0.005 µg/L. Dissolved silver is now being detected and reported in lower concentrations than ever before. All silver detections were well below the acute standard and management concern is not warranted at this time.

3.6.5.2 *E. coli*

The undetermined-use recreation standard and Upper Gunnison segment-specific aquatic life cold-water standard for *E. coli* were exceeded at Blue Creek and the Cimarron River below Squaw Creek. *E. coli* exceedances occurred for less than 10% of evaluations at five other sites in or near Curecanti NRA. Possible sources of *E. coli* contamination could be domestic animals, humans, wildlife, or a combination thereof.

During high-discharge events, runoff from the watershed and re-suspension of bedrock material contribute large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli,* are carried into nearby streams, along with the silts and sands being eroded and re-suspended during these events. *E. coli* readily binds to benthic and suspended sediment, and is able to survive for prolonged periods when so attached (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during turbid, high-discharge events. However, if elevated concentrations occur in clear water conditions, a persistent source may exist. The majority of *E. coli* exceedances in Curecanti NRA occurred during average flow and clear water conditions. In some cases, there were insufficient data available to correlate some of the *E. coli* exceedances with turbidity.

Because episodic storm events were not related to the observed *E. coli* exceedances, a persistent, seasonal bacterial source may exist upstream. Additionally, the majority of *E. coli* exceedances occurred during the summer months, when recreational activity in the park is at its peak. Because the risk of primary contact is greatest at the same time when the *E. coli* exceedances tend to occur, it is recommended that park resource staff warn visitors of potential bacterial contamination and increase the rate of sample collection if an exceedance is observed in the future.

3.6.5.3 Dissolved oxygen

Seasonal fluctuations in dissolved oxygen concentrations occur in all surface water bodies. During the summer, low-flow conditions and elevated water temperatures work in concert to reduce the amount of oxygen dissolved in surface water. The perennial streams of East Elk Creek and Red Creek failed to meet the standard for cold-water aquatic life class 1 (spawning present, 7.0 mg/L) on numerous occasions during the summer months, and both failed to meet the spawning-absent (6.0 mg/L) criterion on one occasion in August 2012. Exceedances in Blue Mesa reservoir occurred most often in the late summer months of August and September, and never exceeded the spawning-absent standard. Some dissolved-oxygen exceedances occurred when spawning was potentially present in streams and reservoirs, and dissolved-oxygen exceedances and water temperature exceedances tended to co-occur. No fish kills or other impacts have been noted during these episodes of low dissolved oxygen.

3.6.5.4 Temperature

Elevated temperatures occurred at 10 sites in Curecanti NRA. Temperatures exceeded the State of Colorado standard for cold-water aquatic life at seven stream and river sites and at three sites at Blue Mesa Reservoir. Most exceedances occurred during the warmer summer months, although there were also exceedances during the seasonal transition months of October and May, when the standard drops from 17°C (streams) or 18.3°C (reservoirs) to 9.0°C. At stream and river sites, low-flow conditions, combined with hot summer air temperatures, cause periodic surface-water temperature exceedances at these sites. At sites on Blue Mesa Reservoir, summer air temperatures can heat the water surface and result in water temperatures above the chronic standard for large reservoirs of 18.3°C. Reservoir data are based on samples collected at 1 m below surface, but other temperature data not assessed here show typical cold water refugia at depth.

As climate change continues to warm higher-elevation areas more rapidly than lower-elevation areas, continued stream temperature exceedances may threaten spawning habitat for fish. To reduce stress on game fish, managers at Yellowstone National Park have elected to close fisheries during periods of high water temperatures—a management option that may also be helpful for cold-water tributaries at Curecanti NRA.

3.6.5.5 Nutrients

In June 2012, the Colorado Water Quality Control Commission adopted regulations to address current and potential future nutrient pollution of Colorado surface waters. Interim numerical values for nutrients, including phosphorus, nitrogen, and chlorophyll a, were established at levels to protect designated uses of Colorado waters. These would initially be applied only to streams and lakes above dischargers and to protect municipal water supplies taken directly from lakes or reservoirs.

The total phosphorus interim standard for Colorado cold water rivers and streams, scheduled to be implemented in 2022, is analyzed as an annual median value of 0.11 mg/L (CDPHE 2012). For the purposes of this report, any individual total phosphorus value for Curecanti NRA rivers and streams that exceeded 0.11 mg/L was included as an indicator of a potential problem.

As with stream and rivers, there is an adopted interim standard for Colorado cold-water lakes and reservoirs. The interim total phosphorus value for Colorado cold-water lakes and reservoirs is analyzed as an average value of 0.025 mg/L for the summer months. Any individual total phosphorus value for Curecanti NRA reservoirs that exceeded 0.025 mg/L was included in this report.

Elevated phosphorus levels reported here are consistent with decades of data from streams in and near Curecanti NRA (Brown and Thoma 2012). Rocks of volcanic origin, which commonly occur around the park, are known to contain relatively high amounts of phosphorus. A recent trend analysis indicates that total phosphorus is not increasing or decreasing (Brown and Thoma 2012), and it is likely that elevated phosphorus is a naturally occurring phenomenon at Curecanti NRA.

3.6.6 Management implications

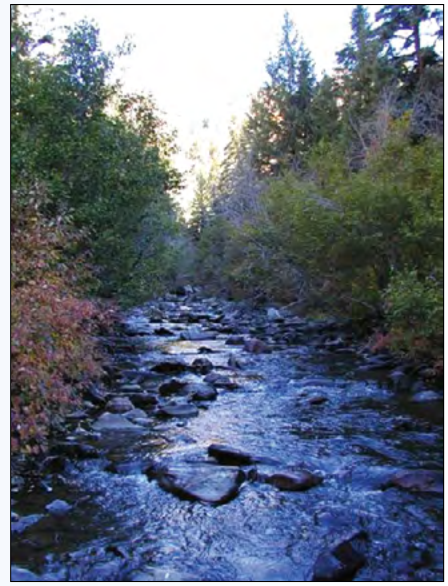
Generally, water quality of all streams in Curecanti NRA is excellent, with occasional exceedances due to naturally occurring conditions in the watersheds. A monitoring record of more than 10 years supports the findings in this report. In 2012, many tributaries that drain into the park from the north were given Outstanding National Resource Water designation, which recognizes the high quality of these waters and prevents any future point-source pollutant inputs (see story, next page).

Outstanding National Resource Waters at Curecanti National Recreation Area

It is the policy of the National Park Service to protect water resources as an integral component of park ecosystems and to avoid, whenever possible, the pollution of park waters from human activities occurring within and outside parks. To help fulfill this policy, Curecanti National Recreation Area recently petitioned the Colorado Water Quality Control Commission (the water quality rulemaking body in Colorado) for the highest protection of water quality possible under the Clean Water Act and state regulations. Outstanding Waters is a designation that preserves high-quality streams, rivers, and lakes at their current quality.

The staff of Curecanti NRA's aquatics program have maintained a rigorous water quality program for over 20 years and researched the possibility of an Outstanding Waters designation through data collection and analysis, outreach, and education. To support the petition effort, cutting-edge sample collection and analysis methods were used to assemble a high-quality dataset that specifically addressed the needs of the Water Quality Control Commission, and it was determined that the vast majority of rivers, streams, and reservoirs throughout the park met these criteria.

A significant, stepwise outreach and education process began 18 months prior to the hearing deadline. Participants in that process included federal, state, and local governments, water and ranching interests, and private landholders. The proposal, which was refined to meet the needs and concerns of these stakeholders throughout the process, was brought before the Water Quality Control Commission in September 2012, with support from numerous entities. Curecanti NRA Resource Stewardship and Science staff attended a day-long hearing and provided testimony.



Curecanti Creek, an Outstanding Water.

The Outstanding Waters designation extends from North Beaver Creek to Meyer's Gulch (except Steuben, Soap, and Willow Creeks), draining the West Elk Wilderness area to Blue Mesa and Morrow Point reservoirs (Figure 3-21). The designation doubled the area of non-Wilderness Outstanding Waters in the State of Colorado, and the Water Quality Control Commission commended National Park Service staff for the level of outreach and collaboration that was conducted to ensure a successful proposal. The Outstanding Waters designation will ensure that high-quality water will be perpetuated as an integral part of Curecanti National Recreation Area for the enjoyment of future generations.

—Matt Malick, Aquatic Ecologist, Curecanti National Recreation Area

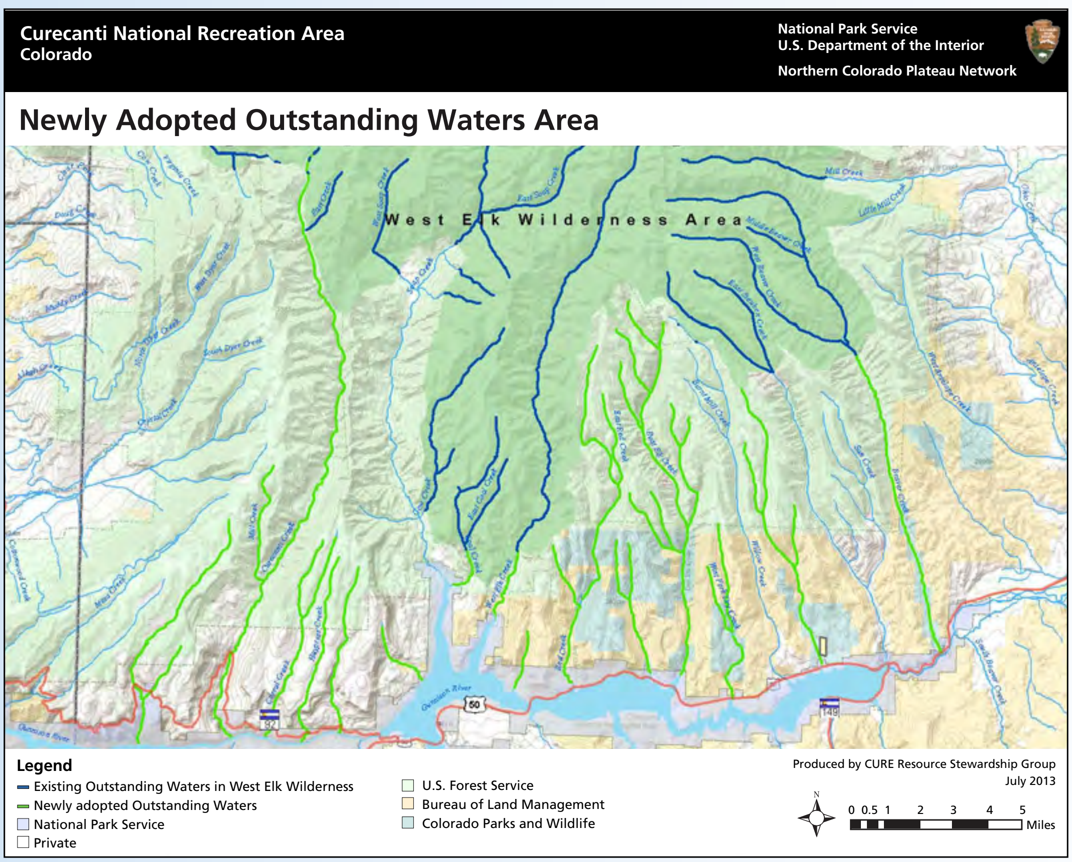


Figure 3-21. Newly adopted Outstanding Waters at Curecanti National Recreation Area

3.7 Dinosaur National Monument

3.7.1 Water quality summary

A total of 1,754 designated beneficial-use evaluations were completed for water quality results obtained at five sites in or near Dinosaur NM between October 1, 2009 and September 30, 2012. Of those 1,754 evaluations, 25 (1.4%) exceeded water quality standards or indications of impairment (Figure 3-22). Water quality standards were exceeded for five constituent categories—most commonly, nutrients, metals, and *E. coli.* (Figure 3-23). Dinosaur NM is the only park unit where sulfate was analyzed; exceedances occurred for less than 10% of evaluations.

3.7.2 Reportable exceedances

The Green River near Jensen, Utah, did not have any water quality exceedances based upon 219 total evaluations. The Yampa River near Maybell, Colorado, had only one exceedance for sulfate (6% of sulfate evaluations) based upon 270 total evaluations. The other three sites had exceedances for more than 10% of evaluations (Figure 3-24, Table 3-7). The following discussion focuses only on sites that had exceedances for more than 10% of evaluations.

Green River above Gates of Lodore. Temperatures at this site exceeded the Lower Yampa/Green River segment-specific standard for 17% of evaluations. This standard supercedes and augments the aquatic life warm-water class 1 standard and is date-dependent. The temperature standard is 18.3°C for April 1–October 31 and 9°C for November 1–March 31.

Yampa River below Craig, Colorado. This site exceeded the aquatic life warm-water

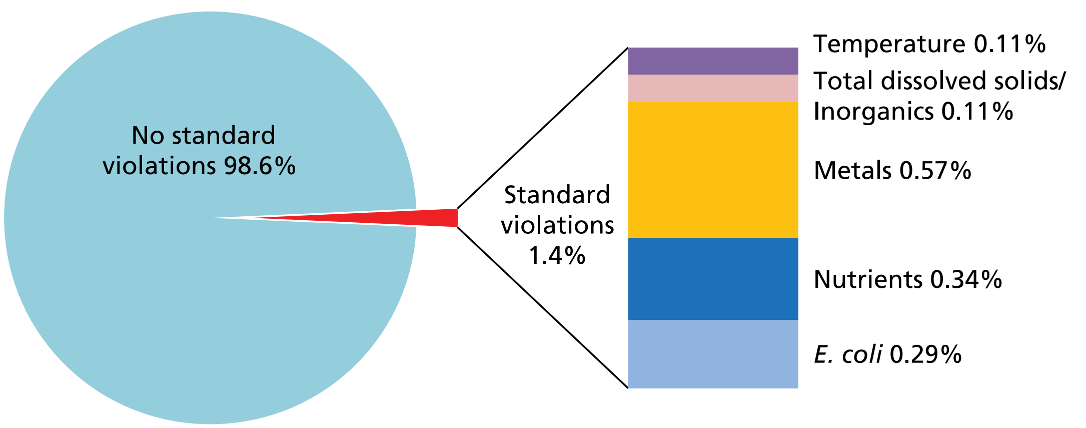


Figure 3-22. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Dinosaur NM, October 1, 2009–September 30, 2012.

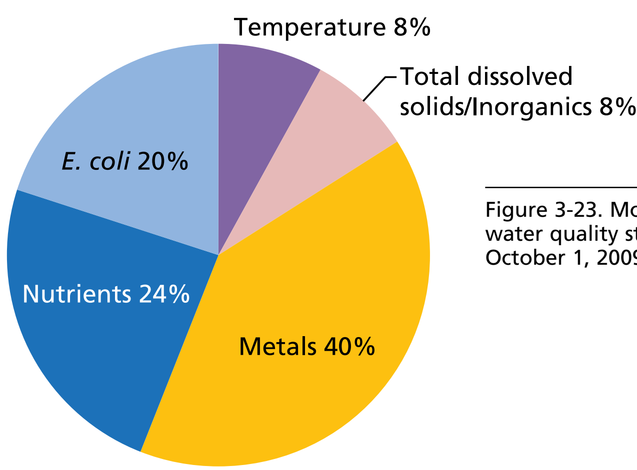


Figure 3-23. Most commonly exceeded water quality standards at Dinosaur NM, October 1, 2009–September 30, 2012.

Water Quality Monitoring Sites, 2010–2012

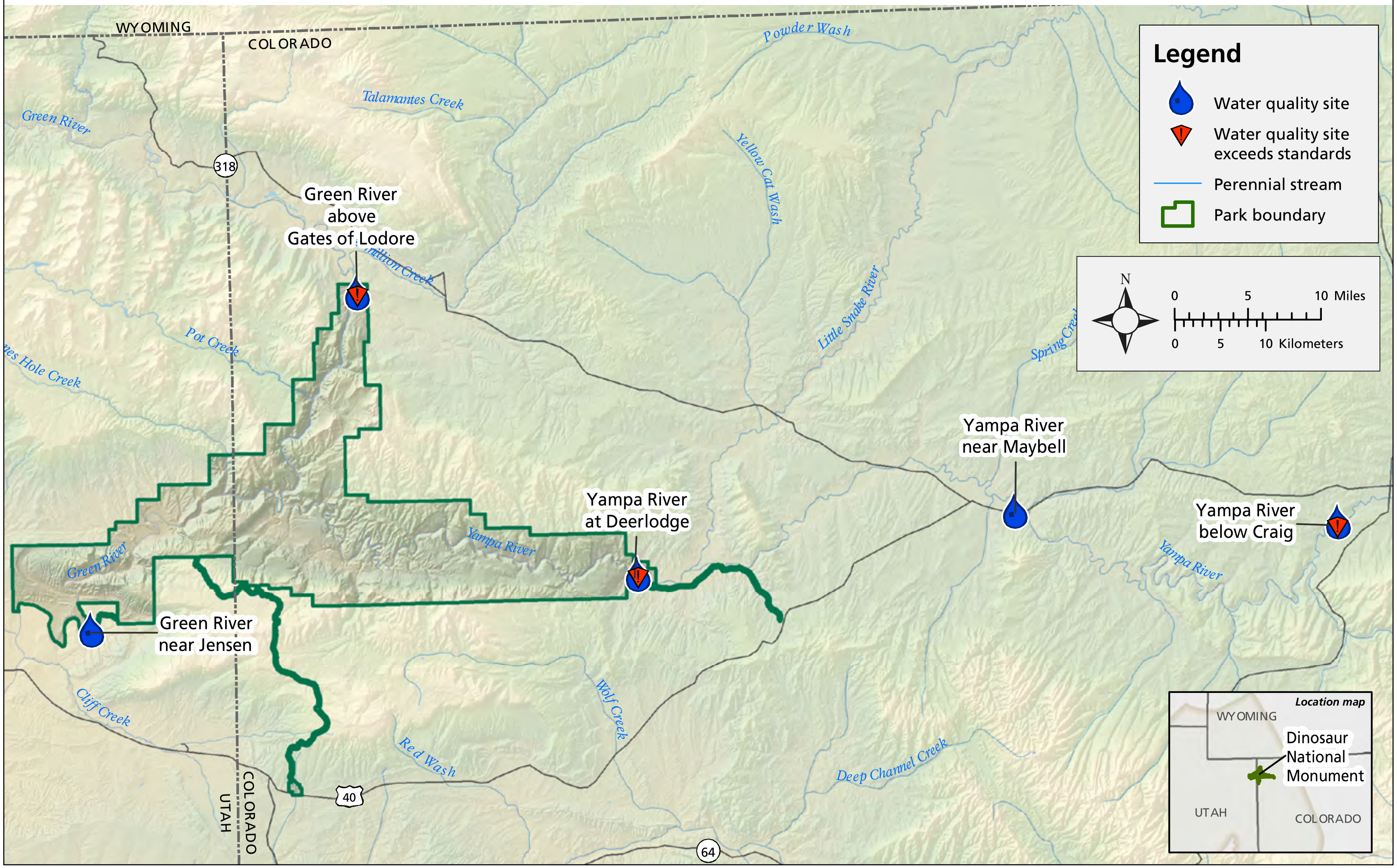


Figure 3-24. Water quality monitoring locations in and near Dinosaur National Monument, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-7. Exceedances of surface water quality standards for sites sampled in or near Dinosaur NM, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Green River above Gates of Lodore, CO	LYG19a	Temperature, water	Date Dep.	°C	12	17
Yampa River below Craig, CO	ALWW1	Iron, Total Recoverable	1000	µg/L	12	25
	ALWW1	Phosphorus, Total	0.17	mg/L	12	17
Yampa River at Deerlodge Park, CO	LYG2, RecE	*E. coli*	126	cfu/100ml	12	17
	ALWW1	Iron, Total Recoverable	1000	µg/L	8	38
	Ag	Manganese, Total Recoverable	200	µg/L	8	13
	DWS	Manganese, Dissolved	50	µg/L	8	13
	ALWW1	Phosphorus, Total	0.17	mg/L	11	36

Use codes: Ag = agricultural use; ALWW1 = aquatic life warm-water class 1; DWS = drinking-water supply; LYG2 = Lower Yampa/Green River basin segment 2 aquatic life standard; LYG19a = Lower Yampa/Green River basin segment 19a aquatic life standard; RecE = existing primary-contact recreation

class 1 standard for total recoverable iron for 25% of evaluations and total phosphorus for 17% of evaluations.

Yampa River at Deerlodge Park, Colorado. This site exceeded the existing primary-contact recreation standard and the Lower Yampa/Green River segment-specific aquatic life warm-water standard for *E. coli* for 17% of evaluations. Total recoverable iron concentrations exceeded the aquatic life warm-water class 1 standard for 38% of evaluations. Manganese concentrations exceeded the drinking-water standard and agricultural-use standard for 13% of evaluations. Total phosphorus levels exceeded the aquatic life warm-water class 1 interim standard for 36% of evaluations.

3.7.3 Discussion

3.7.3.1 Metals

Elevated iron and manganese concentrations in the Yampa River have been well documented (Roehm 2004; Harza 2002; Thoma et al. 2007). Naturally occurring mineralization of iron and manganese minerals is prevalent in the watershed. Elevated concentrations may also be a result of runoff from mining operations throughout the basin. Iron and manganese exceedances have been regularly observed in the past, are included in two State of Colorado watershed management plans, and are not unique to the lower portions of the Yampa River watershed. In 2010, the Yampa River from Elkhead Creek to its confluence with the Green River was added to Colorado's 303(d) list for iron exceedances. Total recoverable iron concentrations in the Yampa River at Deerlodge Park, Colorado, were consistently higher than concentrations observed at Craig, Colorado, indicating that there is a distinct source of iron located between these two sites.

The manganese criterion for drinking water is considered a secondary standard because it is designated for "welfare" impacts, such as color, odor, and staining, and not human health. Secondary standards for drinking water are based upon the 85th percentile value of relevant historic data since January 1, 2000 (CDPHE 2006). One exceedance for the secondary standard for manganese occurred at the Yampa River at Deerlodge Park (80.2 µg/L).

3.7.3.2 Nutrients

Two evaluations on the Yampa River below Craig, Colorado, and four evaluations on the Yampa River at Deerlodge Park exceeded the interim total phosphorus value. Elevated total phosphorus values are consistent with 27–33 years of data, and total phosphorus concentrations have not increased or decreased at these sites (Brown and Thoma 2012). Naturally elevated phosphorus conditions are common throughout the Northern Colorado

Plateau, and are suspected, in many cases, to be geologic in origin. Anthropogenic activities, such as logging, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations noted here are likely natural or anthropogenic in origin.

3.7.3.3 Temperature

Temperature exceedances observed at the Green River above Gates of Lodore were infrequent, and both exceedances occurred during the summer. Low-flow conditions, combined with hot summer air temperatures, cause periodic surface-water temperature exceedances.

3.7.3.4 *E. coli*

E. coli concentrations exceeded the existing primary-contact recreation standard and the aquatic life warm-water standard at the Yampa River at Deerlodge Park. Elevated *E. coli* concentrations occurred during turbid, high-discharge events. During high-discharge events, runoff from the watershed and re-suspension of bedrock material contribute large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli,* are carried into nearby streams, along with the silts and sands being eroded and re-suspended during these events. *E. coli* readily binds to benthic and suspended sediment, and is able to survive for prolonged periods when so attached (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during turbid, high-discharge events.

3.7.4 Management implications

Elevated iron concentrations on the Yampa River have been previously evaluated with respect to aquatic life (Roehm 2004; Harza 2002), and are used more as an indicator of sediment loading than of impacts on aquatic life, due to questions regarding toxicity (CDPHE 2008). Impacts associated with water depletions within the Yampa Basin, non-native and invasive aquatic organisms, and the cumulative effects of point and non-point source pollution throughout the watershed have tended to receive the greatest attention with respect to aquatic life (Roehm 2004; Harza 2002).

3.8 Golden Spike National Historic Site

3.8.1 Water quality summary

No data were reported for the single station located near Golden Spike National Historic Site between October 1, 2009 and September 30, 2012. This site, Blue Creek at County Road 504, is sampled by the State of Utah (see Section 1.5).

3.9 Hovenweep National Monument

3.9.1 Water quality summary

A total of 853 designated beneficial-use evaluations were determined for water quality results obtained at three sites in Hovenweep NM between October 1, 2009 and September 30, 2012. Of those 853 evaluations, 51 (6.0%) exceeded water quality standards or indications of impairment (Figure 3-25). Water quality standards were exceeded for five constituent categories—most commonly, nutrients, dissolved oxygen, and *E. coli* (Figure 3-26).

3.9.2 Reportable exceedances

All three sites sampled had water quality exceedances for the State of Utah (Figure 3-27, Table 3-8).

Square Tower Spring. Square Tower Spring had exceedances for dissolved oxygen and total dissolved solids and an indication of impairment for total phosphorus. Dissolved-oxygen concentrations failed to meet the chronic warm-water game fish standard for 36% of evaluations; 18% of visits also exceeded the acute warm-water game fish standard (3.0 mg/L). Total phosphorus concentrations exceeded the indication of impairment for primary-contact recreation and warm-water game fish standards for 27% of evaluations. Total dissolved solids exceeded the agricultural-use standard for 18% of evaluations.

Cajon Spring. Cajon Spring had exceedances for dissolved aluminum, dissolved oxygen, and *E. coli*, and an indication of impairment for total phosphorus. Dissolved-oxygen concentrations failed to meet the chronic warm-water game fish standard for 88% of evaluations; 75% of visits also exceeded the acute warm-water game fish standard (3.0 mg/L). This site exceeded the chronic warm-water game fish standard for dissolved aluminum concentrations for 33% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for the primary-

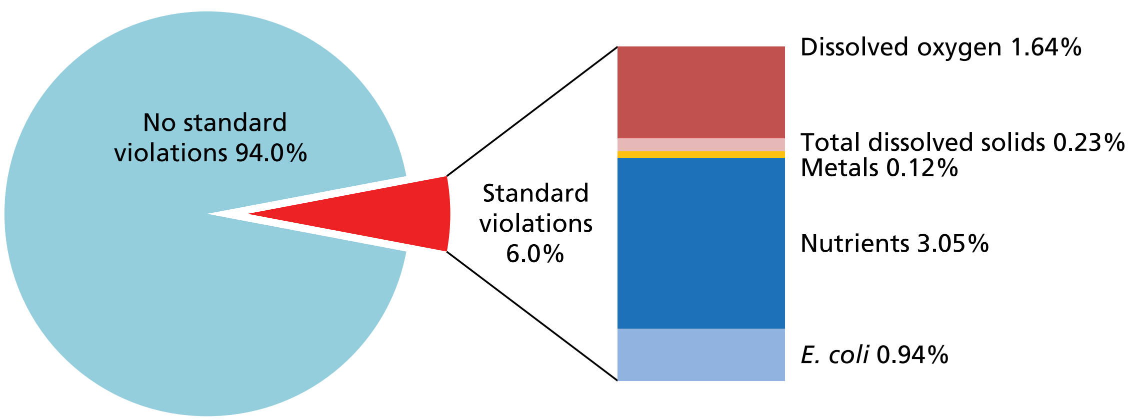


Figure 3-25. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Hovenweep NM, October 1, 2009–September 30, 2012.

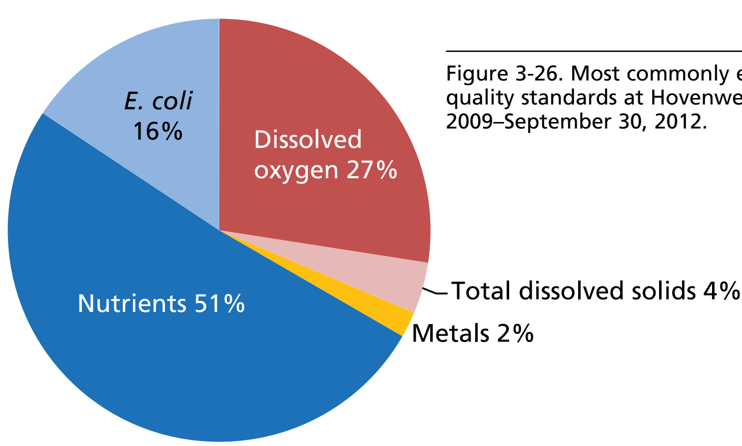


Figure 3-26. Most commonly exceeded water quality standards at Hovenweep NM, October 1, 2009–September 30, 2012.

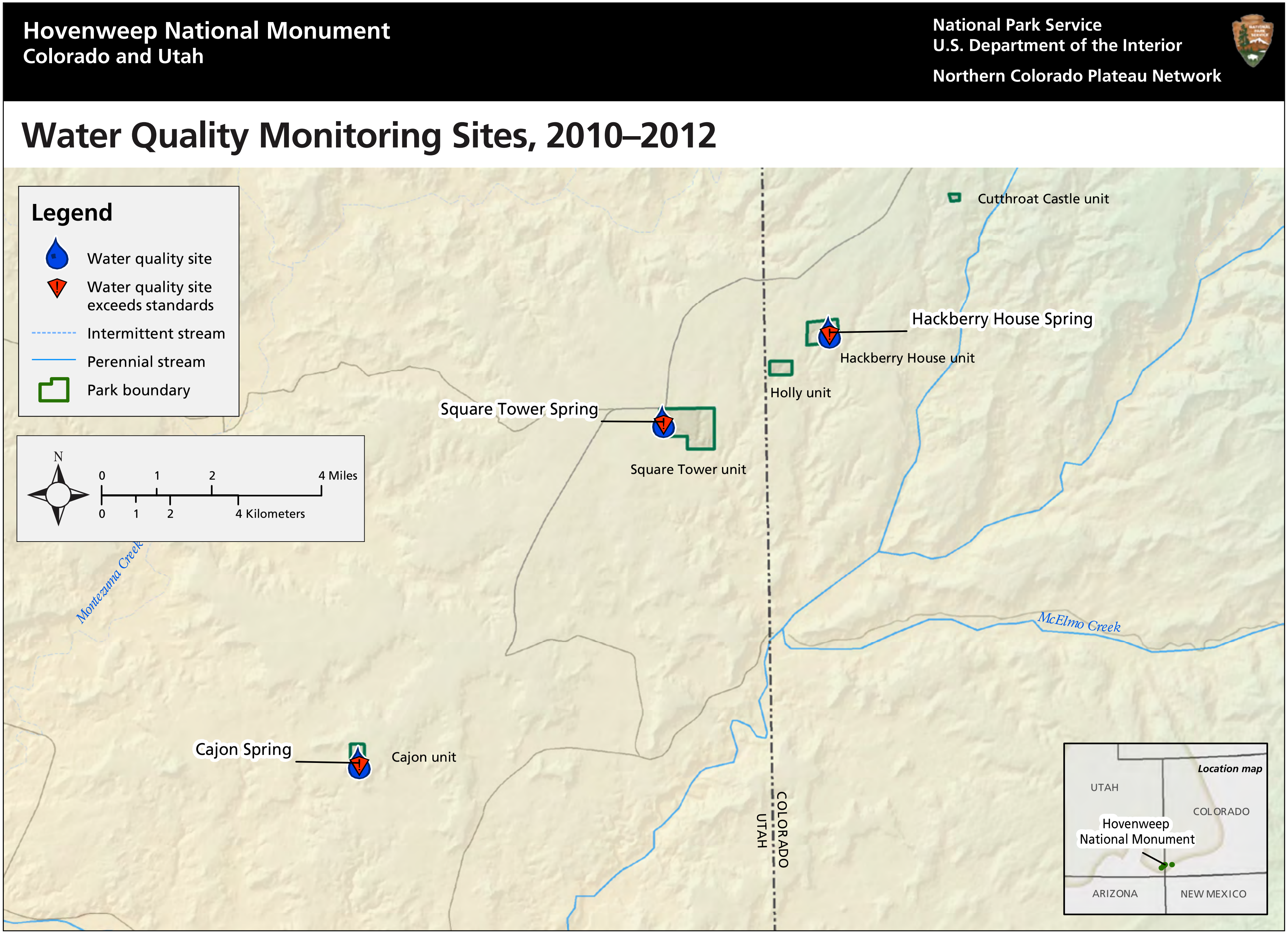


Figure 3-27. Water quality monitoring locations in Hovenweep National Monument, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-8. Exceedances of surface water quality standards for sites sampled in or near Hovenweep NM, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Cajon Spring	3B	Aluminum, Dissolved	87	µg/L	3	33
	3B	Dissolved oxygen	5.5	mg/L	8	88
	2A	*E. coli*	126	MPN/100ml	6	33
	1C	*E. coli*	206	MPN/100ml	6	17
	2A	*E. coli*	409	MPN/100ml	6	17
	2A, 3B	Phosphorus, Total	0.05	mg/L	8	88
Hackberry House Spring	3B	Dissolved oxygen	5.5	mg/L	10	30
	2A	*E. coli*	126	MPN/100ml	10	10
	1C	*E. coli*	206	MPN/100ml	10	10
	2A	*E. coli*	409	MPN/100ml	10	10
	1C	*E. coli*	668	MPN/100ml	10	10
	2A, 3B	Phosphorus, Total	0.05	mg/L	10	30
Square Tower Spring	3B	Dissolved oxygen	5.5	mg/L	11	36
	2A, 3B	Phosphorus, Total	0.05	mg/L	11	27
	4	Total Dissolved Solids	1200	mg/L	11	18

Use codes: 2A = primary-contact recreation; 3B = warm-water game fish; 1C = drinking water; 4 = agricultural use

contact recreation and warm-water game fish standards for 88% of evaluations. *E. coli* concentrations exceeded the chronic (126 MPN) and acute (409 MPN) standards for primary-contact recreation for 33% and 17% of evaluations, respectively. *E. coli* also exceeded the chronic drinking-water supply standard (206 MPN) for 17% of evaluations.

Hackberry House Spring. Hackberry House Spring had exceedances for dissolved oxygen and *E. coli*, and an indication of impairment for total phosphorus. One sample for *E. coli* exceeded the chronic (126 MPN) and acute (409 MPN) standards for primary-contact recreation and the chronic (206 MPN) and acute (668 MPN) drinking-water supply standards. Dissolved-oxygen concentrations failed to meet the chronic warm-water game fish standard for 30% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for the primary-contact recreation and warm-water game fish standards for 30% of evaluations.

3.9.3 Discussion

3.9.3.1 Dissolved oxygen

Cajon Spring has little-to-no actual spring input and is largely or completely a rain-catchment pool. Surface-water influx during precipitation and/or snowmelt events causes dissolved-oxygen concentrations to rise in the Cajon pool. After a rain event, the catchment, which is relatively deep, stagnates, and concurrent processes, such as elevated temperatures and increased microbial decomposition, cause dissolved-oxygen concentrations to decrease.

In contrast, Square Tower Spring and Hackberry House Spring are small, constant, spring-fed pools in the back of protected alcoves; they receive little direct influence from precipitation events. The oxygen-depleted groundwater discharged at these spring sites is a natural phenomenon, and indicates that the water has been underground long enough to achieve complete or significant biological reduction of oxygen.

3.9.3.2 Metals

One of three samples from Cajon Spring exceeded the chronic (87 µg/L) warm-water game fish standard for aluminum with a value of 87.5 µg/L. This site has a long history of aluminum exceedances (Schlez and Moran 2006).

3.9.3.3 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be geologic in origin. Anthropogenic activities, such as pasture irrigation, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Cajon Spring is the only site at Hovenweep NM likely to be affected by runoff events and has a history of more frequent and larger total phosphorus exceedances than other sites at the park (Schelz and Moran 2006). The same pattern occurred at these sites during the period covered in this report (Figure 3-28). Further investigation is warranted to determine if the observed total phosphorus concentrations are natural or anthropogenic in origin.

3.9.3.4 *E. coli*

Cajon Spring and Hackberry House Spring had *E. coli* exceedances. Cajon Spring is a rain-catchment pool and receives runoff from overland flow events. During high-discharge events, fecal matter and its microbial components, such as *E. coli*, are carried by runoff into drainages, along with the silts and sands being eroded during overland flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies, and is able to survive for prolonged periods of time when attached to sediments (Sampson et al. 2006). The exceedances at Cajon Spring coincided with high pool heights following precipitation. The exceedance at Hackberry House Spring occurred following a rain event that showed evidence of producing backflow up the channel and into the spring from the large, alcove-forming pourover. Additionally, heavy wildlife use has been noted at both sites, which may cause elevated *E. coli* concentrations.

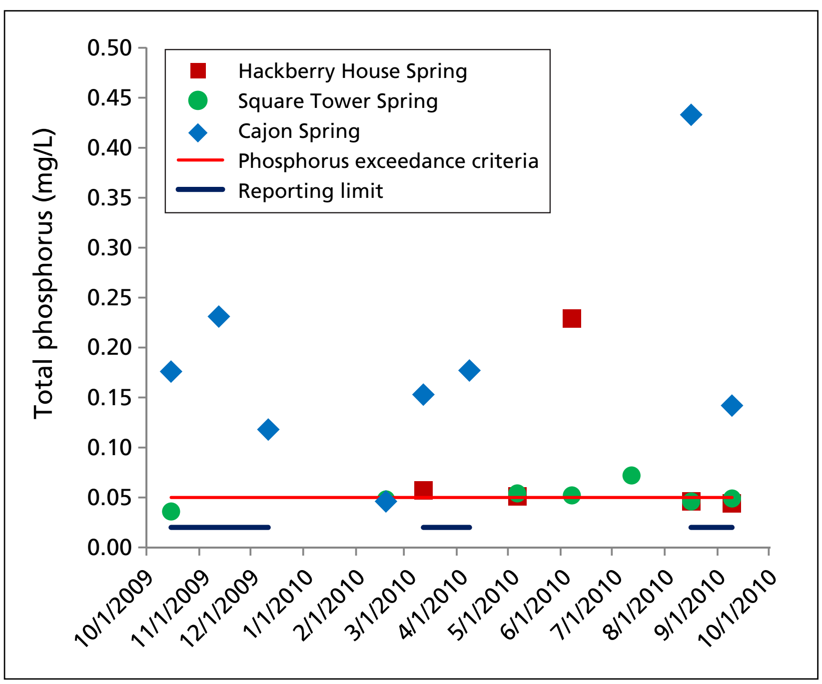


Table 3-28. Comparison of total phosphorus values at Hovenweep sites, October 15, 2009–November 15, 2010. Samples that fell below the reporting limit for phosphorus (0.02 mg/L) are indicated by a line.

3.9.3.5 Total dissolved solids

Square Tower Spring had two exceedances for total dissolved solids, in keeping with the data history of this site (Schelz and Moran 2006). The spring is situated in a well-protected alcove, and no direct anthropogenic influences are suspected at the site. The overlying Dakota Sandstone, which serves as a shallow aquifer for the spring, can have variable amounts of clays and silts, which can contribute to dissolved-solid concentrations in springs.

3.9.4 Management implications

All three sites in Hovenweep NM are protected for warm-water aquatic life; however, the isolated nature of these water bodies differentiates them from others nearby. The aquatic-life standards for Square Tower and Cajon springs were intended to protect the segment of the San Juan River and its tributaries between Lake Powell and the Colorado–Utah state line. Although these standards are applicable by law, the ephemeral and intermittent nature of these water bodies significantly differentiates them from the San Juan River. In fact, there are no known breeding populations of fish within Square Tower or Cajon springs, and all water that enters the San Juan River from the park is derived from episodic or seasonal-driven events that likely do not reflect long-term water quality conditions at these sites. Comparison of water quality results against long-term trends observed within these systems will better detect the timing and occurrence of degradation (if present) than comparison of these systems against water quality standards designed for large water bodies, such as the San Juan River.

3.10 Natural Bridges National Monument

3.10.1 *Water quality summary*

A total of 624 designated beneficial-use evaluations were completed for water quality results obtained at three sites at Natural Bridges NM between October 1, 2009 and September 30, 2011. (No sites were sampled at Natural Bridges NM during WY11–12, when the park was not in the sampling rotation.) Of the 624 evaluations, 35 (5.6%) exceeded water quality standards or indications of impairment (Figure 3-29). Water quality standards were exceeded for three constituent categories: nutrients, dissolved oxygen, and metals (Figure 3-30).

3.10.2 Reportable exceedances

All three sites sampled had water quality exceedances for the State of Utah (Figure 3-31, Table 3-9).

Armstrong Canyon near Kachina Natural Bridge. Armstrong Canyon Creek, one-half mile upstream of Kachina Bridge, exceeded the chronic and acute (3.0 mg/L) dissolved-oxygen standards for warm-water game fish for 33% of evaluations, and had an indication of impairment for total phosphorus for the secondary-contact recreation and warm-water game fish standards for 27% of evaluations. Dissolved aluminum and dissolved mercury concentrations exceeded the warm-water game fish standard for 25% of site visits.

Owachomo Bridge Spring at confluence of Armstrong and Tuwa canyons. Owachomo Bridge Spring exceeded the chronic warm-water game fish standard for dissolved aluminum concentrations for 25% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for the secondary-contact recreation and warm-water game fish standards for 36% of evaluations.

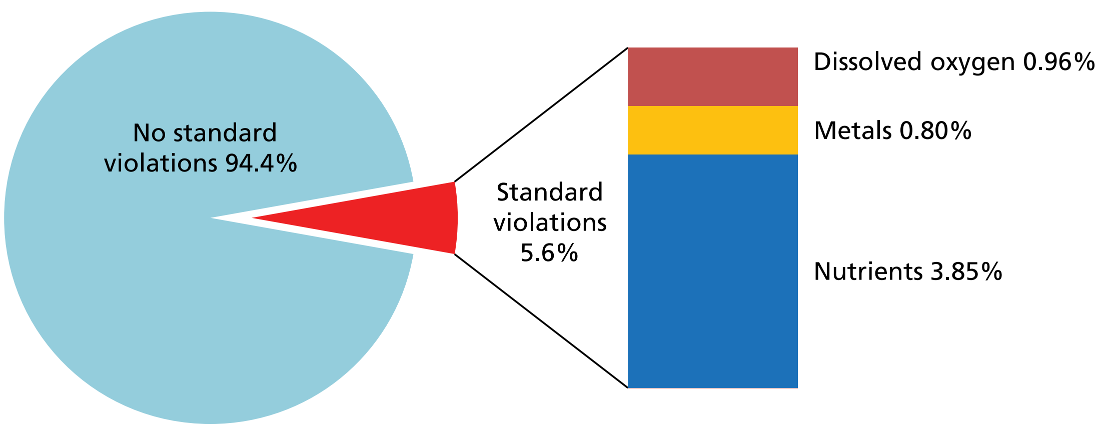


Figure 3-29. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Natural Bridges NM, October 1, 2009–September 30, 2012.

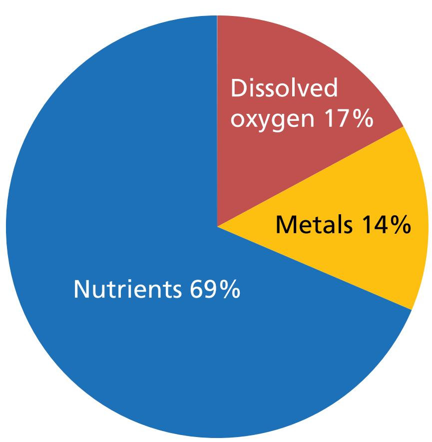


Figure 3-30. Most commonly exceeded water quality standards at Natural Bridges NM, October 1, 2009–September 30, 2012.

Water Quality Monitoring Sites, 2010–2012

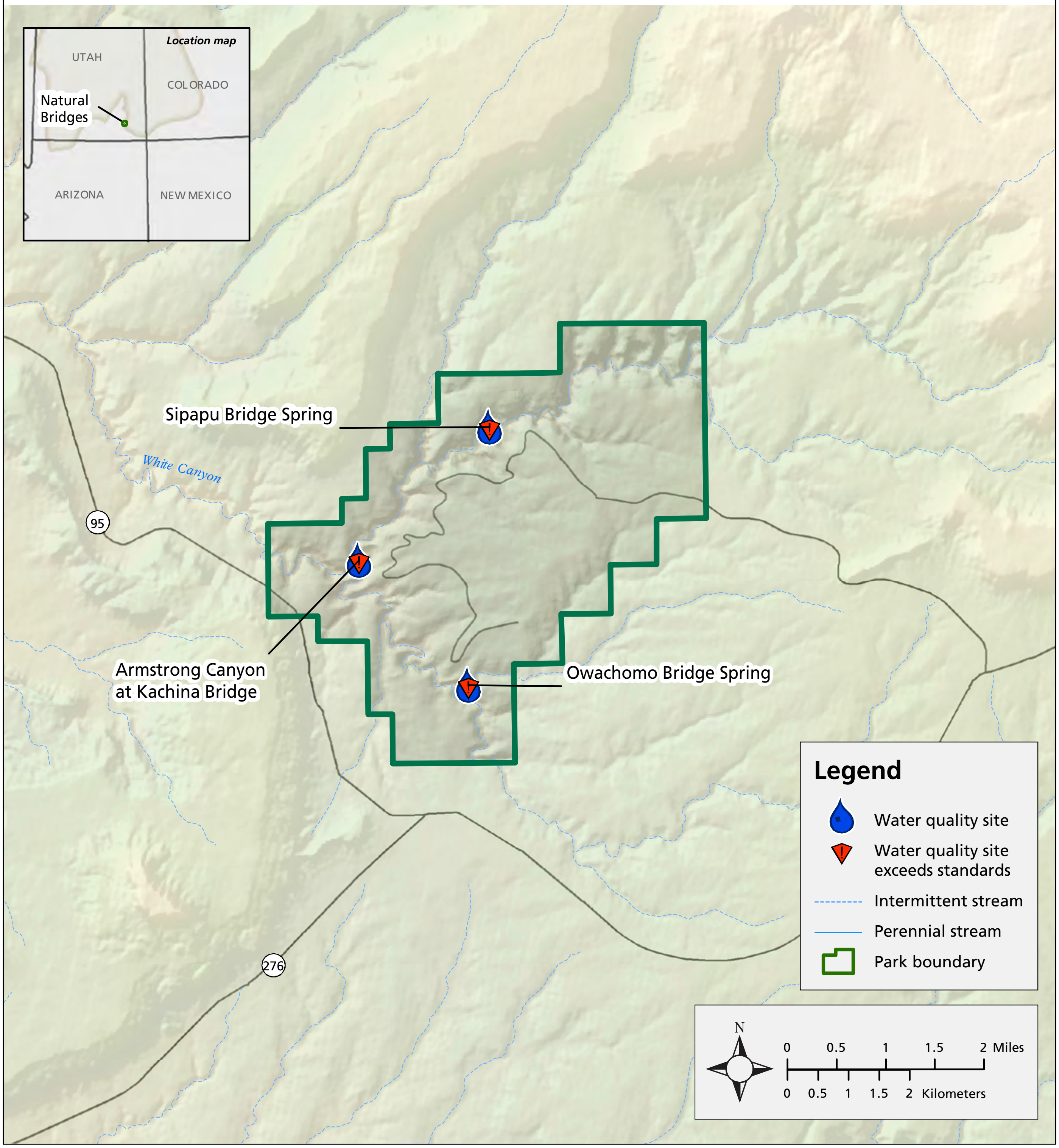


Figure 3-31. Water quality monitoring locations in Natural Bridges National Monument, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-9. Exceedances of surface water quality standards for sites sampled in or near Natural Bridges NM, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
Armstrong Canyon Creek	3B	Aluminum, Dissolved	87	µg/L	4	25
	3B	Dissolved oxygen	5.5	mg/L	9	33
	3B	Mercury, Dissolved	0.01	µg/L	4	25
	2B, 3B	Phosphorus, Total	0.05	mg/L	11	27
Owachomo Bridge Spring	3B	Aluminum, Dissolved	87	µg/L	4	25
	2B, 3B	Phosphorus, Total	0.05	mg/L	11	36
Sipapu Bridge Spring	3B	Aluminum, Dissolved	87	µg/L	3	67
	3B	Dissolved oxygen	5.5	mg/L	7	43
	2B, 3B	Phosphorus, Total	0.05	mg/L	9	56

Use codes: 2B = secondary-contact recreation; 3B = warm-water game fish

Sipapu Bridge Spring 0.25 mi above bridge. Sipapu Bridge Spring had exceedances for dissolved aluminum and dissolved oxygen and an indication of impairment for total phosphorus. Dissolved aluminum concentrations exceeded the chronic warm-water game fish standard for 67% of evaluations, but did not exceed the acute warm-water game fish standard (750 µg/L). Dissolved-oxygen concentrations failed to meet the chronic warm-water game fish standard for 43% of evaluations; 29% of visits also exceeded the acute warm-water game fish standard (3.0 mg/L). Total phosphorus concentrations exceeded the indication of impairment for the secondary-contact recreation and warm-water game fish standards for 56% of evaluations.

3.10.3 Discussion

3.10.3.1 Dissolved oxygen

Dissolved-oxygen exceedances of the warm-water game fish standard are likely the result of environmental conditions and hydrologic processes. These sites are canyon-bottom pools that probably receive groundwater flow at most times. They also receive seasonal surface flow from snowmelt and precipitation events. The Armstrong Canyon site is a large pool that receives both pool-bottom and back-wall groundwater seepage. Sipapu Bridge Spring is a much smaller pool than Owachomo Bridge Spring. Both are likely replenished, to some extent, via pool-bottom groundwater recharge, but recharge from overland flow events is likely the dominant source at these sites. The oxygen-depleted groundwater discharged at Armstrong Canyon—and possibly the Owachomo Bridge Spring and Sipapu Bridge Spring sites—is a natural phenomenon, indicating that the water has been underground for long enough to achieve complete or significant biological reduction of oxygen.

Dissolved-oxygen concentrations at all three sites undergo significant seasonal fluctuations. Environmental conditions deplete oxygen in surface water during summer low-flow periods, when solar heating of the unshaded pools increases temperatures and reduces the amount of oxygen that can be dissolved in water. Additionally, low-flow conditions produce stagnant pools that are poorly mixed. Microbes that decompose organic matter also consume oxygen, further decreasing dissolved oxygen in these warm pools.

3.10.3.2 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be geologic in origin. Elevated phosphorus levels have been noted for many years at Natural Bridges NM (Schelz and Moran 2005b; Van Grinsven et al. 2010; Brown and Thoma 2012). Anthropogenic activities, such as logging, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations noted here are likely natural or anthropogenic in origin.

3.10.3.3 Metals
One of four samples from Armstrong Canyon near Kachina Bridge and Owachomo Bridge Spring exceeded the chronic warm-water game fish standard for dissolved aluminum. One of four samples from Armstrong Canyon near Kachina Bridge exceeded the chronic warm-water game fish standard for dissolved mercury, and two of three samples from Sipapu Bridge Spring exceeded the chronic warm-water game fish standard for dissolved aluminum. Because these sites are predominantly groundwater-fed, natural sources of aluminum and mercury may be the cause of elevated concentrations. However, there were only 3–4 metals results available for analysis from each site, and further investigation is warranted to understand the nature of dissolved aluminum and mercury concentrations in Natural Bridges NM sampling sites.

3.10.4 Management implications

All three sites in Natural Bridges NM are protected for warm-water aquatic life; however, they are not expected to support all forms of aquatic life protected by their designated beneficial use (e.g., fish), due to intermittent flow and the application of standards intended to protect designated uses in Lake Powell. Although these standards are applicable by law, the ephemeral nature of these water bodies significantly differentiates them from Lake Powell and its major tributaries. In fact, there are no known breeding populations of fish within the park, and the vast majority of water that enters Lake Powell from Natural Bridges NM is derived from episodic or seasonally driven events that likely do not reflect the base-flow water quality conditions observed in these sites.

Comparing results from these sites against standards written for Lake Powell gives an incomplete understanding of their condition. Whereas comparison against standards for Lake Powell does provide an indication of contributing loads to Lake Powell, it may be better to evaluate conditions at these sites by other means. Comparison of any future observations against the range and trend of the existing data record would serve to better evaluate these water bodies than comparison against applicable state water quality standards. These sites are scheduled to be removed from Southeast Utah Group's long-term water quality monitoring rotation (see story, page 15).

3.11 Timpanogos Cave National Monument

3.11.1 Water quality summary

A total of 979 designated beneficial-use evaluations were completed for water quality results obtained for two sites at Timpanogos Cave NM between October 1, 2009 and September 30, 2012. Four of those evaluations (0.4%) exceeded the total phosphorus indication of impairment (Figure 3-32). At Hansen Cave Spring, total phosphorus exceeded the State of Utah indication of impairment for secondary-contact recreation and coldwater game fish on two occasions (7% of site visits). Hidden Lake had no exceedances (Figure 3-33), although total phosphorus was not analyzed at this site.

3.11.2 Discussion and management implications

Traditional parameters indicate that water quality at Timpanogos Cave NM is excellent.* Continued water quality monitoring is warranted for the purpose of long-term trend assessments. A trend assessment is likely a better method for evaluating condition than comparison against state water quality standards protective of the American Fork River and its tributaries, and will provide early detection of degradation if it occurs. It is unlikely that water from either site in the park supplies surface water recharge to the American Fork River.

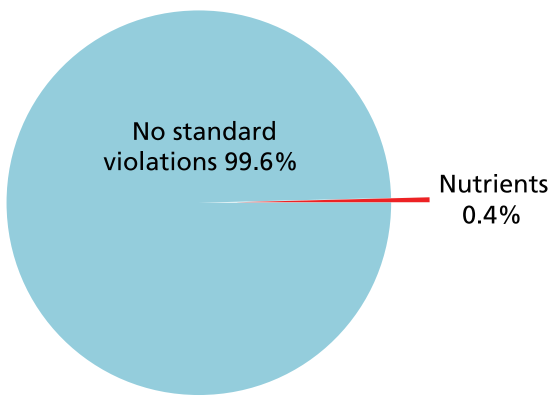


Figure 3-32. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Timpanogos Cave NM, October 1, 2009–September 30, 2012.

*Initial testing of contaminants of emerging concern (CECs), conducted separately from the water quality monitoring described in this report, suggest possible concerns (Weissinger et al. 2013). CECs—compounds such as pesticides, pharmaceuticals, personal care products, and wastewater indicators—are pollutants that have not traditionally been tested for during water quality sampling and may not be adequately cleansed by current wastewater treatment methods.

Water Quality Monitoring Sites, 2010–2012

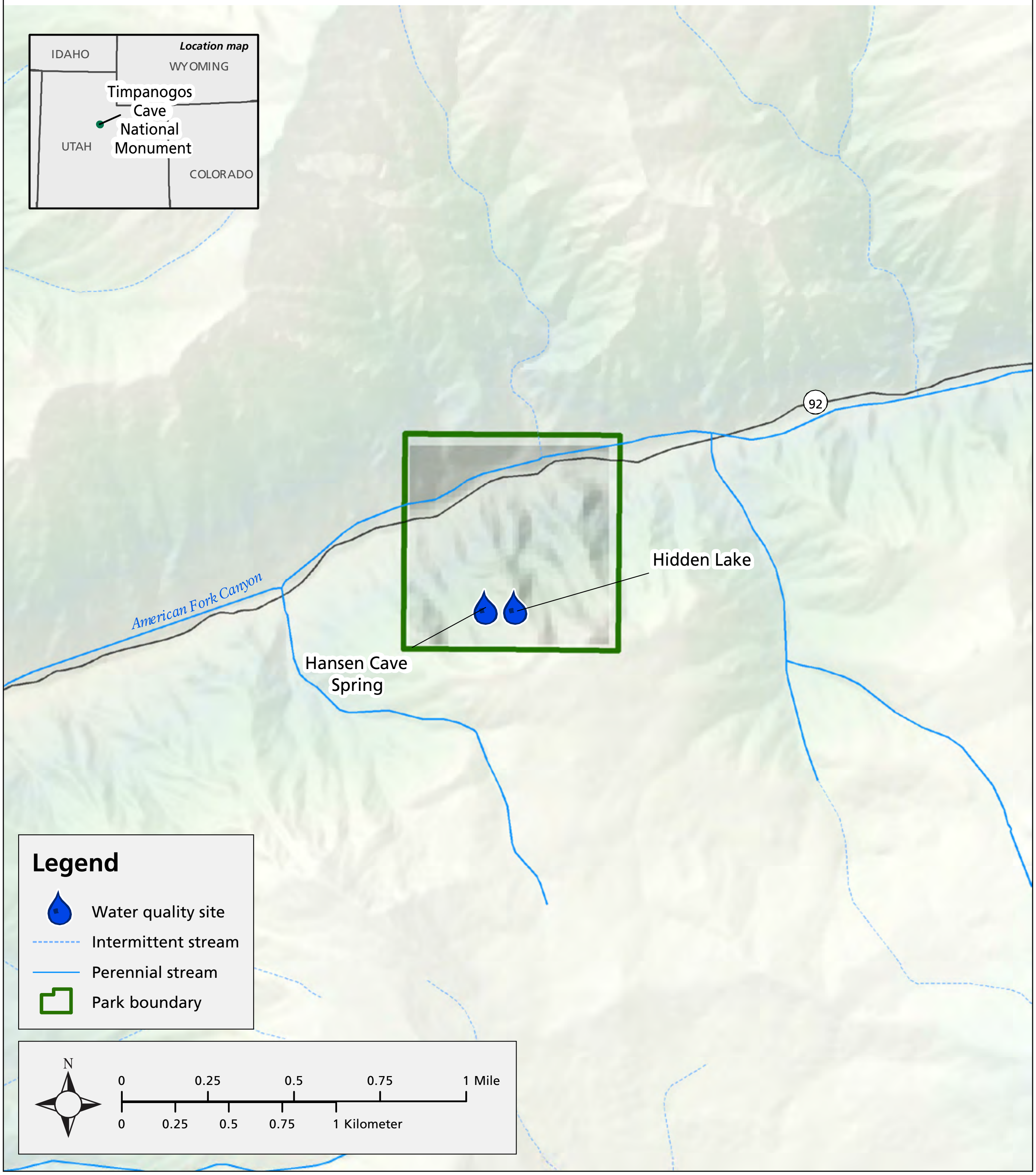


Figure 3-33. Water quality monitoring locations in Timpanogos Cave National Monument.

3.12 Zion National Park

3.12.1 Water quality summary

A total of 1,865 designated beneficial-use evaluations were completed for water quality results obtained at five sites in and around Zion NP between October 1, 2009 and September 30, 2012. Of those 1,865 evaluations, 83 (4.5%) exceeded water quality standards or indications of impairment (Figure 3-34). Water quality standards were exceeded for four constituent categories: pH, nutrients, *E. coli*, and temperature (Figure 3-35).

3.12.2 Reportable exceedances

Sites monitored by the Utah Department of Environmental Quality did not have data available in EPA STORET for the period covered in this report (see Section 1.5). These sites included North Creek above the confluence with the Virgin River, North Fork Virgin River above the confluence with East Fork Virgin River, East Fork Virgin River above the confluence with North Fork Virgin River, and La Verkin Creek at Utah Highway 17. One site previously sampled by the NCPN, the North Fork Virgin River at North Fork Virgin Road, was moved downstream to the North Fork Virgin River at the Bureau of Land Management Wilderness Study Area (BLM-WSA) boundary due to a planned development between the previous sampling location and the wilderness boundary.

Of the five sites reported for Zion NP for WY10–12, two did not have water quality exceedances for the State of Utah: the North Fork Virgin River near Springdale, Utah (23 total evaluations; water temperature only) and the Virgin River near Virgin, Utah (122 total evaluations). Three of five sites sampled had exceedances (Figure 3-36, Table 3-10). The following discussion focuses only on sites that had exceedances.

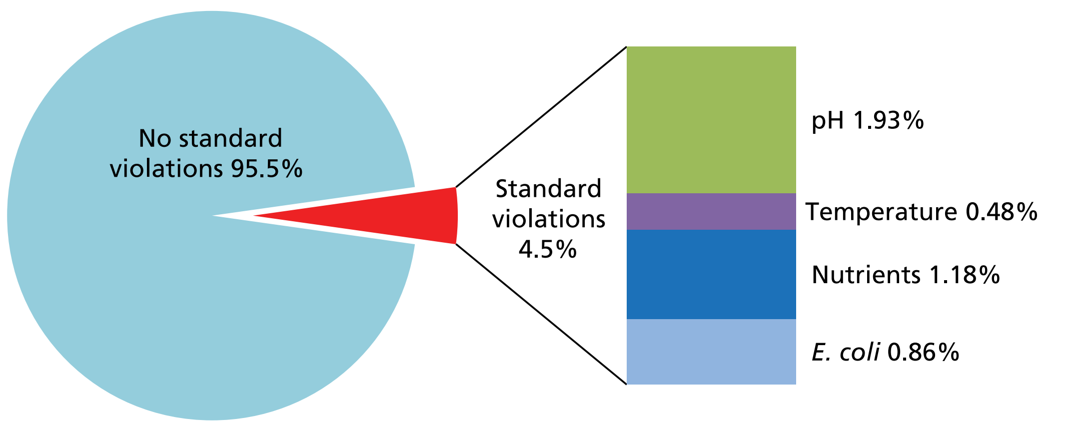


Figure 3-34. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Zion NP, October 1, 2009–September 30, 2012.

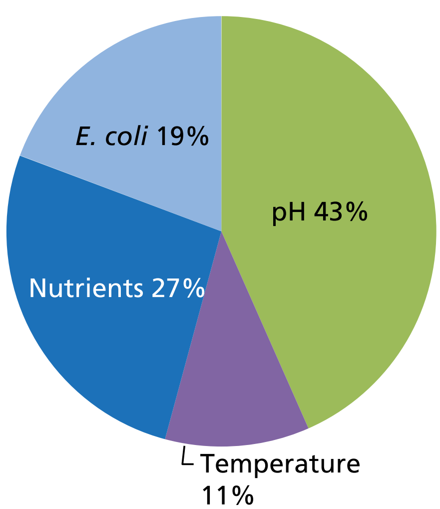


Figure 3-35. Most commonly exceeded water quality standards at Zion NP, October 1, 2009–September 30, 2012.

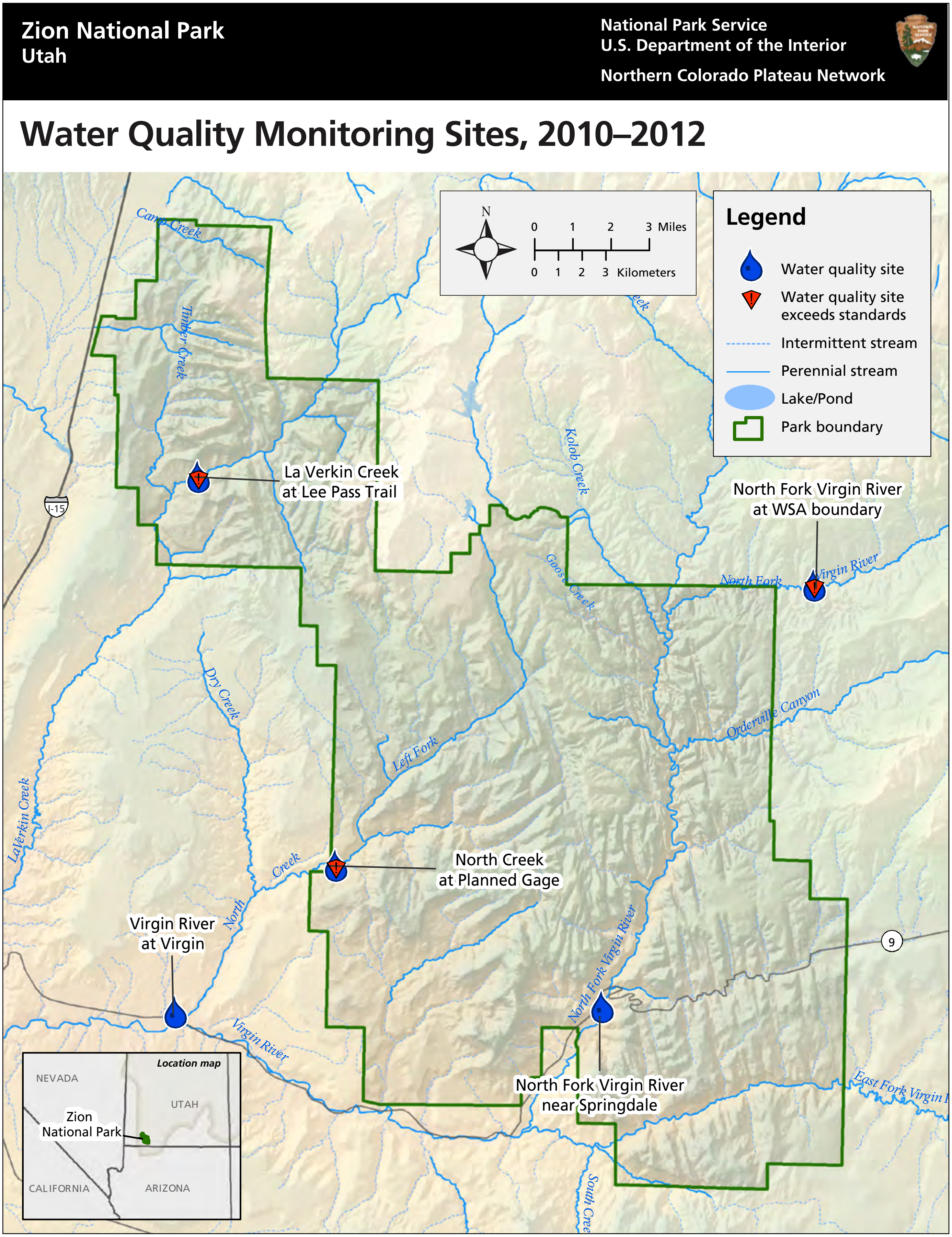


Figure 3-36. Water quality monitoring locations in and near Zion National Park, 2009–2012. Sites that exceeded standards for more than 10% of evaluations for one or more parameters are marked with a red symbol.

Table 3-10. Exceedances of surface water quality standards for sites sampled in or near Zion NP, October 1, 2009–September 30, 2012.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standards
La Verkin Creek at Lee Pass Trail	2B, 3B	Phosphorus, Total	0.05	mg/L	29	28
North Creek at planned gage in park	1C, 2B, 3C, 4	pH	9		30	30
	2B	Phosphorus, Total	0.05	mg/L	30	13
North Fork Virgin River at BLM-WSA Boundary	2A	*E. coli*	126	MPN/100ml	14	36
	1C	*E. coli*	206	MPN/100ml	14	36
	2A	*E. coli*	409	MPN/100ml	14	29
	1C	*E. coli*	668	MPN/100ml	14	14
	3A	Temperature, Water	20	°C	19	32

Use codes: 1C = drinking water; 2A = primary-contact recreation; 2B = secondary-contact recreation; 3A = cold-water game fish; 3B = warm-water game fish; 3C = non-game fish; 4 = agricultural use

La Verkin Creek at Lee Pass Trail. Total phosphorus concentrations at this site, in the Kolob Canyons area of the park, exceeded the State of Utah indication of impairment for secondary-contact recreation and warm-water game fish for 28% of site visits.

North Creek at planned gage in park. This site, which is near the park boundary, exceeded the State of Utah's pH standards for drinking water, secondary-contact recreation, non-game fish, and agricultural use for 30% of site visits. Total phosphorus exceeded the indication of impairment for secondary-contact recreation for 13% of visits. Cattle trespass occurs occasionally at this site, and recreational use occurs upstream in the park.

North Fork Virgin River at BLM-WSA boundary. This site exceeded the chronic and acute State of Utah *E. coli* standards for primary-contact recreation and drinking water. *E. coli* concentrations exceeded the chronic and acute (409 MPN) standards for primary-contact recreation for 36% and 29% of site visits, respectively. *E. coli* concentrations exceeded the chronic and acute (668 MPN) standards for drinking water for 36% and 14% of site visits, respectively. A combination of livestock grazing and flood-irrigation practices have resulted in chronic impairment of the site and 303(d) listing in 2010 (see story, page 60). This site also exceeded the cold-water game fish water temperature standard for 32% of site visits.

3.12.3 Discussion

3.12.3.1 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be caused by natural weathering of geologic strata containing phosphorus. Anthropogenic activities, such as pasture irrigation, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations are likely natural or anthropogenic in origin. If the observed total phosphorus exceedances are strongly correlated with low dissolved-oxygen conditions, then management action could be warranted.

High total phosphorus concentrations at La Verkin Creek tend to occur during spring runoff between January and April, and there appears to be a correlation between stream turbidity and total phosphorus (Figure 3-37). Upcoming trend analysis should evaluate this relationship to determine if soil erosion might be a significant factor in phosphorus loading at La Verkin Creek. Because dissolved-oxygen concentrations remain within acceptable limits, it is unlikely that the observed total phosphorus concentrations are causing eutrophication processes in La Verkin Creek that negatively impact aquatic ecological functions. Therefore, the observed

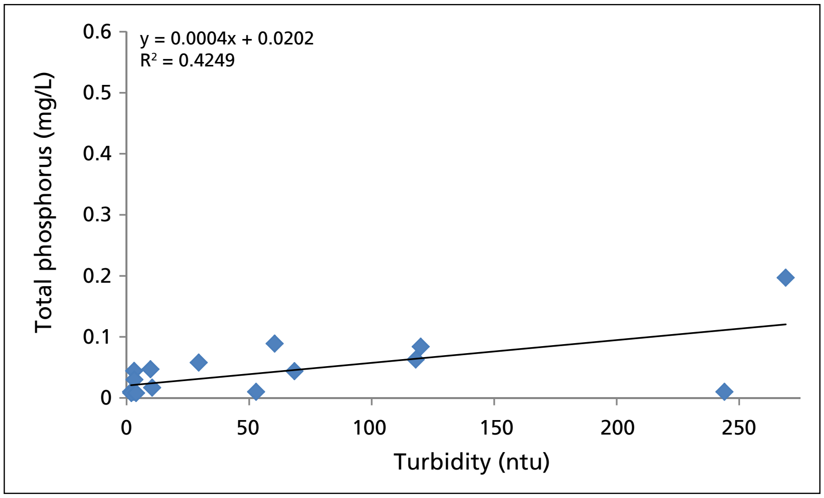


Figure 3-37.Total phosphorus appears to rise with turbidity at La Verkin Creek.

total phosphorus concentrations in La Verkin Creek do not currently warrant management concern.

Total phosphorus concentrations at North Creek also appear to correlate with turbidity, but were not as strongly seasonal as levels reported from La Verkin Creek. Visual observations indicated some degree of summertime eutrophication occurring during the period covered in this report. Algal blooms, elevated pH, and dissolved-oxygen concentrations continue to indicate nutrient enrichment (Van Grinsven et al. 2010). Drops in dissolved oxygen below aquatic life standards were not observed, perhaps due to the well-mixed conditions in this relatively high-velocity stream.

3.12.3.2 pH

In 2006, a wildfire along the Right Fork of North Creek removed the vegetation cover that provided shade protection to the river corridor and erosion control within the watershed. The associated increase in solar energy and influx of nutrients sorbed to sediments that resulted from this disturbance most likely increased the rate of photosynthetic activity within North Creek, which tends to cause a corresponding increase in pH. During warm summer months, pH levels still occasionally exceed applicable standards, as noted in previous reports (Van Grinsven et al. 2010) (Figure 3-38).

The geochemical components of watersheds throughout the Northern Colorado Plateau and, more specifically, in North Creek, naturally cause the pH of surface water to be

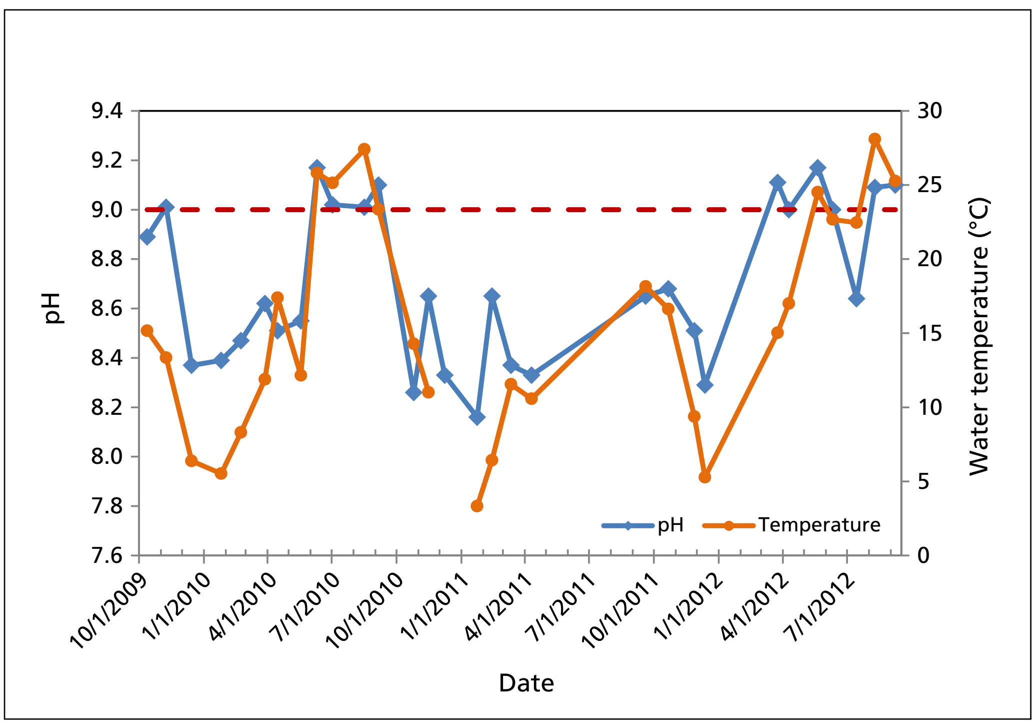


Figure 3-38. North Creek pH levels appear to show a correspondence with temperature, October 1, 2009–September 30, 2012. Red-dashed line = State of Utah exceedance criteria for pH.

slightly basic. However, the above-normal rate of photosynthesis during the summer months in North Creek appears to cause alkalinization of water, resulting in periodic State of Utah water quality exceedances for pH.

3.12.3.3 Temperature

Temperature exceedances in the North Fork Virgin River at the BLM-WSA boundary occurred during the summer months of May through September, and exceeded the State of Utah standard for cold-water game fish. Low-flow conditions, in concert with hot summer air temperatures, cause periodic surface-water temperature exceedances during the summer months at this site. Downstream of this site, the North Fork Virgin River, from its confluence with the East Fork to Kolob Creek, was added to the state 303(d) list of impaired waters in 2010 for water-temperature exceedances. The State of Utah is currently conducting continuous temperature monitoring in the North Fork Virgin River to evaluate exceedances. Due to its primarily desert setting, the river might be more appropriately classified as a warm-water game fishery.

3.12.3.4 *E. coli*

In summer months, *E. coli* contamination in the North Fork Virgin River upstream from the Narrows has been relatively consistent since the NCPN started monitoring efforts in 2006 (Van Grinsven et al. 2010). Zion NP staff noted exceedances above the Narrows in 2001 (D. Sharrow, Zion NP hydrologist, pers. comm.). The North Fork Virgin River, from its confluence with Deep Creek to its headwaters, was added to Utah's 303(d) list of impaired waters in 2010 because of *E. coli* contamination. Cooperative sampling between the State of Utah, the National Park Service, and the Bureau of Land Management continues to document chronic exceedances due to flood irrigation of riverside pastures grazed by livestock (see story, next page). The State of Utah is working with landowners and grazing permittees to improve water quality at this site.

Park managers are working with the UDWQ, BLM, and landowners to improve irrigation practices and reduce the contamination of the river. Park managers have entered into an agreement with the Utah Association of Conservation Districts to work with irrigators and design a system that improves efficiency. Funds for a pressurized sprinkler irrigation system have been provided by the state's non-point source pollution program and the park, with construction planned in 2014. To address another chronic hygiene problem, hiker waste at the Narrows trailhead on BLM lands, UDWQ provided funding for installation of a vault toilet there in 2011.

Intensive monitoring will continue through construction and into the future, until the state removes this site from the 303(d) list of non-compliant waters. At that time, the NCPN will resume regular monitoring and monitoring by the park and state may be reduced or cease.

Cooperative Efforts Identify Contamination Source: An Update

As was reported in the previous NCPN water quality report (Van Grinsven et al. 2010), a pattern of high *E. coli* measurements during the summer months became apparent shortly after the NCPN began monitoring the North Fork Virgin River upstream of the Zion Narrows in 2006. Park and network staff brought this to the attention of the Utah Division of Water Quality in 2009, and began intensive sampling for the remainder of that summer and in each following summer. Based on these data, the State of Utah placed the North Fork on the 303(d) list of noncompliant waters in 2010.

The NCPN, Zion NP, and the Utah Division of Water Quality combined resources to identify the source of the contamination—an effort that was complicated by several factors. The area of concern occurs where the North Fork Virgin River flows through pastures that are irrigated and grazed and into the place where hikers begin their trek through the Narrows. Land ownership in this area is mixed federal and private. Cattle graze pastures near the stream in summer, hundreds of visitors use the stream, and there are second homes, additional grazing, and wildlife use higher in the watershed.

In order to quantify the magnitude of the problem and identify the source, samples were collected from the river at several locations, and from irrigation return flows that spill back into the river. In the summers of 2009, 2010, 2011 and 2012, samples were collected on 10, 21, 11, and 8 days, respectively. Levels of *E. coli* exceeded the standard whenever both the fields were being irrigated and livestock were present (Figure 3-39).

NPS/M. NEIDIG

Zion Narrows.

The high intensity of monitoring and some fortuitous thunderstorms that washed out the irrigation ditches in the mid-summer of 2010 permitted the source to be identified with a high degree of certainty. Once irrigation began and livestock were present, every sample from the river exceeded the chronic standard for full-body contact recreation—whereas after a flood washed out the ditches and stopped the irrigation, every sample met the standard, even with the cattle still present.

This implicated the practice of poorly controlled flood irrigation, when combined with livestock grazing, as the primary source of *E. coli* loading to the stream. The presence of cattle alone contributed much less contamination, even when they had direct access to the stream.

—Dave Sharrow,
Hydrologist, Zion National Park

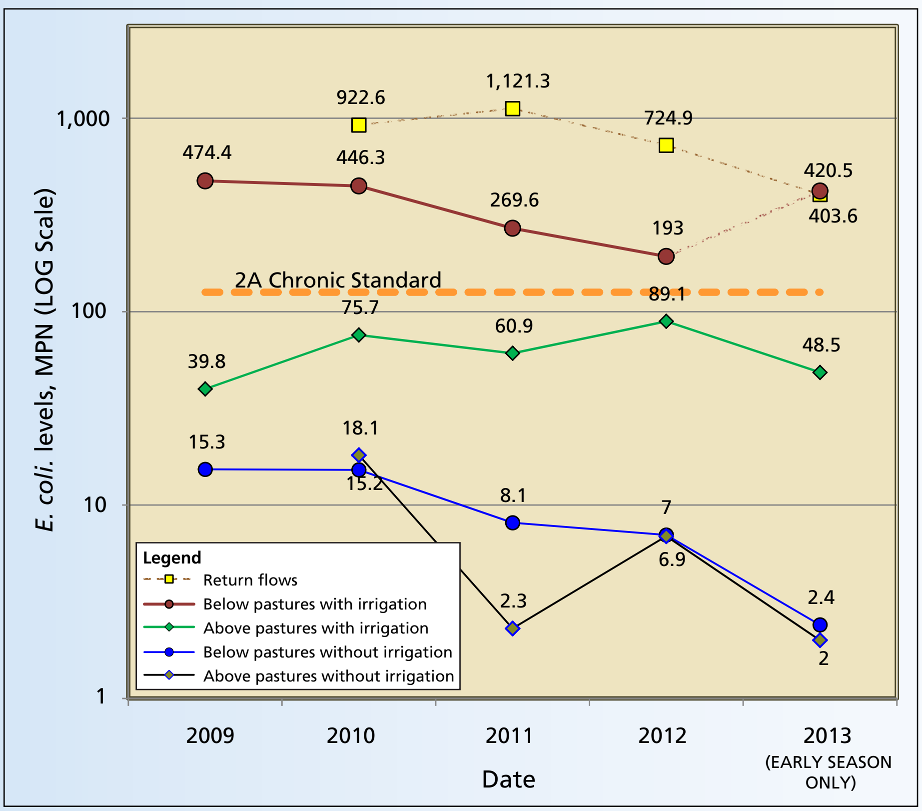


Figure 3-39. Fecal coliform exceedances occur when livestock grazing and flood irrigation practices coincide on pastures adjacent to the North Fork of the Virgin River.

4 Literature Cited

American Public Health Association, American Water Works Association, and Water Environment Federation (APHA). 1998. Standard methods for the examination of water and wastewater. Twentieth edition. Washington, D.C.: American Public Health Association.

Baars, D., and H. Doelling. 1987. Moab salt-intruded anticline, east-central Utah. Geological Society of America Centennial Field Guide—Rocky Mountain Section.

Brown, J. B., and Thoma, D. P. 2012. Assessment of total nitrogen and total phosphorus in selected surface water of the National Park Service Northern Colorado Plateau Network, Colorado, Utah, and Wyoming, from 1972 through 2007. U.S. Geological Survey Scientific Investigations Report 2012–5043.

Chaffin, T. 2002. Effects of the Paradox Valley unit on the dissolved-solids load of the Dolores River Basin, 1988–2001. USGS Water Resources Investigation Report 2002-4275.

Colorado Department of Public Health and Environment (CDPHE). 2006. Water Quality Control Commission regulation no. 37. Classifications and numeric standards for the Lower Colorado River Basin (5 CCR 1002-37). http://www.cdphe.state.co.us/regulations/wqccregs/100237wqcclowercoloradoriverbasin.pdf. Last accessed August 25, 2010.

——. 2008. Water Quality Control Commission regulation no. 31. The basic standards and methodologies for surface water (5 CCR 1002-31). http://www.cdphe.state.co.us/regulations/wqccregs/100231wqccbasicstandardsforsurfacewater.pdf. Last accessed August 25, 2010.

——. 2011. Total maximum daily load assessment, Gunnison River and tributaries, Uncompahgre River and tributaries, Delta/Mesa/Montrose counties, Colorado. http://www.epa.gov/waters/tmdldocs/GunnisonTMDL_Final_Final.pdf. Accessed 7/25/2013.

Doelling, H., F. Davis, and C. Brandt. 1989. The geology of Kane County, Utah. Utah Geological Survey, Bulletin 124.

Harza, M. 2002. Yampa Basin watershed plan. Colorado Department of Public Health and Environment: Water Quality Control Division.

Judd, H. A., and C. Adams. 2006. Paria River watershed water quality management plan. Prepared for Utah Department of Environmental Quality, Division of Water Quality, by Millennium Science & Engineering, Inc., Salt Lake City, Utah.

National Park Service (NPS). 2006. NPS management policies. http://www.nps.gov/policy/mp/policies.html#_Toc157232681. Last accessed April 12, 2010.

O'Dell, T. E., S. L. Garman, A. Evenden, M. Beer, E. Nance, A. Wight, M. Powell, D. Perry, R. DenBleyker, et al. 2005. Northern Colorado Plateau Inventory and Monitoring Network vital signs monitoring plan. National Park Service, Moab, Utah.

Reynolds, R., J. Belnap, M. Reheis, and P. Lamothe. 2001. Aeolian dust in Colorado Plateau soils: Nutrient inputs and recent change in source. Proceedings of National Academy of Science 98:13.

Reynolds, R., J. Neff, M. Reheis, and P. Lamothe. 2005. Atmospheric dust in modern soil on aeolian sandstone, Colorado Plateau (USA): Variation with landscape position and contribution to potential plant nutrients. Geoderma 130:108–123.

Roehm, G. 2004. Management plan for endangered fishes in the Yampa River Basin and environmental assesment. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6) Denver, Colorado.

Sampson, R.W., S. A. Swiatnicki, V. L. Osinga, J. L. Supita, C. M. McDermott, and G. T. Kleinheinz. 2006. Effects of temperature and sand on *E. coli* survival in a northern lake water microcosm. Journal of Water and Health 4(3):389–393.

Schelz, C., and M. Moran. 2006. Water quality monitoring, Hovenweep National Monument, 1999–2005. General Technical Report SEUG-001-2006. National Park Service, Southeast Utah Group, Moab, Utah.

——. 2005a. Water quality monitoring, Canyonlands National Park, 1994–2004. General Technical Report SEUG-003-2005. National Park Service, Southeast Utah Group, Moab, Utah.

——. 2005b. Water quality monitoring, Natural Bridges National Monument, 1994–2004. General Technical Report SEUG-002-2005. National Park Service, Southeast Utah Group, Moab, Utah.

——. 2004. Water quality monitoring, Arches National Park, 1994–2004. General Technical Report SEUG-004-2004. National Park Service, Southeast Utah Group, Moab, Utah.

Smith, R. P., G. A. Paiba, and J. Ellis-Iversen. 2008. Short communication: Turbidity as an indicator of Escherichia coli presence in water troughs on cattle farms. Journal of Dairy Science 91:2082–2085.

Stacey, P. B., A. L. Jones, J. C. Catlin, D. A. Duff, L. E. Stevens, and C. Gourley. 2007. User's guide for the rapid assessment of the functional condition of stream-riparian ecosystems in the American Southwest. Wild Utah Project, Salt Lake City, Utah.

Thoma, D., D. Sharrow, K. Wynn, J. Brown, M. Beer, and H. Thomas. 2007. Water quality vital signs monitoring protocol for park units in the Northern Colorado Plateau Network (ver. 1). National Park Service, Moab, Utah.

Tuttle, M., and R. Grauch. 2009. Salinization of the Upper Colorado River: Fingerprinting geologic salt sources. USGS Scientific Investigations Report 2009-5072.

U.S. Environmental Protection Agency (EPA). 2006. Clean Water Act. http://www.epa.gov/r5water/cwa.htm. Last accessed July 7, 2010.

U.S. Geological Survey (USGS). Western U.S. phosphate project. http://minerals.usgs.gov/west/projects/phos.htm. Last accessed August 3, 2010.

Utah Division of Water Quality (UDWQ). 2002. Fremont River watershed water quality management plan. Utah Division of Water Quality, Salt Lake City, Utah.

——. 2007. Matt Warner and Calder Reservoir water quality study and TMDL. Utah Division of Water Quality, Salt Lake City, Utah.

Van Grinsven, M., D. Thoma, M. Malick, and M. Moran. 2010. Water quality in the Northern Colorado Plateau Network, 2006–2009. Natural Resource Technical Report NPS/NCPN/NRTR—2010/358. National Park Service, Fort Collins, Colorado.

Weissinger, R., D. Thoma, K. Dahlin, and K. Keteles. 2013. Screening for contaminants of emerging concern in the Northern Colorado Plateau Network, 2010 and 2012. Natural Resource Technical Report NPS/NCPN/NRTR—2013/802. National Park Service, Fort Collins, Colorado.

Appendix A. Water Quality Sites Reported, WY 2010–2012

StationID	Station name	Latitude	Longitude	Designated beneficial uses
Arches National Park				
09163500	Colorado R nr Colorado-Utah state line	39.133	-109.027	Ag, ALWW1, RecE, LC3
09180000	Dolores R nr Cisco, UT	38.797	-109.195	2B, 3C, 4
09180500	Colorado R nr Cisco, UT	38.811	-109.293	1C, 2A, 3B, 4
5995200	Freshwater Spg in Salt Wash .5 mi ab rd xing SW-1	38.744	-109.525	1C, 2A, 3B, 4
5995220	Salt Wash at Wolfe Ranch rd xing SW-3	38.735	-109.519	1C, 2A, 3B, 4
5995240	Courthouse Wash .5 mi ab Colorado R at USGS CW-1	38.613	-109.579	1C, 2A, 3B, 4
5995245	Upper Courthouse Wash @ NPS bndy	38.687	-109.636	1C, 2A, 3B, 4
5995250	Sleepy Hollow Spg in Upper Courthouse Wash SH-1	38.671	-109.639	1C, 2A, 3B, 4
5995270	Willow Spg WS-1	38.700	-109.628	1C, 2A, 3B, 4
Black Canyon of the Gunnison National Park				
09128000	Gunnison R bl Gunnison Tunnel, CO	38.529	-107.649	Ag, ALCW1, DWS, RecE, LG1
383418107471401	Red Rock Canyon nr NPS boundary nr Montrose,CO	38.572	-107.788	Ag, ALWW2, DWS, RecE, LG4c
383537107471500	Red Rock Canyon at mouth nr Montrose, CO	38.594	-107.788	Ag, ALWW2, DWS, RecE, LG4c
Bryce Canyon National Park				
4951855	Sheep Ck bl Spg in Bryce Cyn NP	37.571	-112.201	2B, 3C, 4
4951857	Yellow Ck bl Spg in Bryce Cyn NP	37.574	-112.141	2B, 3C, 4
4951915	Mossy Cave Spg NW of Tropic	37.665	-112.115	2B, 3C, 4
N/A	Tropic Ditch	37.665	-112.115	2B, 3C, 4
Canyonlands National Park				
09272400	Green R at Ouray, Utah	40.085	-109.677	1C, 2A, 3B, 4
09315000	Green R at Green R, UT	38.896	-110.151	1C, 2A, 3B, 4
4930010	Green R ab cnfl / Colorado R	38.190	-109.889	1C, 2A, 3B, 4
4930150	Green R at Mineral Bottom	38.527	-109.993	1C, 2A, 3B, 4
4952380	Colorado R. bl Big Drop #3 rapids	38.071	-110.046	1C, 2A, 3B, 4
4952400	Colorado R ab cnfl / Green R	38.193	-109.884	1C, 2A, 3B, 4
4956290	Colorado R at Potash Boat Ramp	38.467	-109.666	1C, 2A, 3B, 4
5995020	2.4 Mile Loop Spg BS-2	38.125	-109.822	1C, 2A, 3B, 4
5995050	Cave Spg SQ-3	38.157	-109.753	1C, 2A, 3B, 4
5995120	Little Spg Canyon Creek LS2	38.184	-109.801	1C, 2A, 3B, 4
5995150	Salt Ck nr Crescent Arch SC-10	38.085	-109.766	1C, 2A, 3B, 4
5995160	Salt Creek nr Peekaboo Spg SC-12	38.115	-109.750	1C, 2A, 3B, 4
5995420	Chocolate Drops Spg .5 mi S of Maze Overlook SF-4	38.226	-110.002	1C, 2A, 3B, 4
5995500	Maze Overlook Spg .25 mi SE of Maze Overlook SF-2	38.229	-109.998	1C, 2A, 3B, 4
5995540	Horseshoe Cyn Spg .3 mi ab cnfl / Water Cyn lower HSC-2	38.454	-110.198	1C, 2A, 3B, 4

Appendix A. Water Quality Sites Reported, WY 2010–2012, cont.

StationID	Station name	Latitude	Longitude	Designated beneficial uses
Capitol Reef National Park				
09330000	Fremont R nr Bicknell, UT	38.307	-111.517	1C, 2A, 3A, 4
09330230	Fremont R nr Caineville, UT	38.279	-111.066	1C, 2B, 3C, 4
4954770	Sulphur Ck ab cnfl / Fremont R in picnic area	38.287	-111.247	1C, 2A, 3A, 4
4954775	Sulphur Ck bl road to Goosenecks Overlook in CRNP	38.307	-111.315	1C, 2A, 3A, 4
4954780	Pleasant Ck S of Sleeping Rainbow Ranch	38.180	-111.181	1C, 2B, 3A
4954795	Oak Creek ab Sands Ranch Dam	38.084	-111.140	2B, 3C, 4
Curecanti National Recreation Area				
09125000	Curecanti Creek nr Sapinero, CO	38.488	-107.415	Ag, ALCW1, DWS, RecU, UG26
09127000	Cimarron R bl Squaw Creek, nr Cimarron, CO	38.446	-107.556	Ag, ALCW1, DWS, RecU, UG26
381633107054700	Cebolla Creek at Powderhorn, CO	38.276	-107.097	Ag, ALCW1, DWS, RecU, UG29b
381934107133500	Lake Fork Gunnison R bl Gateview, CO	38.326	-107.227	Ag, ALCW1, DWS, RecE, UG29b
382418107242600	Blue Creek at HWY 50 nr Sapinero, CO	38.405	-107.408	Ag, ALCW1, DWS, RecU, UG26
382702107203900	Pine Creek at HWY 50 nr Sapinero, CO	38.451	-107.345	Ag, ALCW1, DWS, RecU, UG26
382900107101600	East Elk Creek nr mouth nr Sapinero, CO	38.483	-107.172	Ag, ALCW1, DWS, RecU, UG26
382902107140400	Red Creek nr mouth nr Sapinero, CO	38.484	-107.235	Ag, ALCW1, DWS, RecU, UG26
382937107033500	Steuben Creek nr mouth nr Gunnison, CO	38.494	-107.060	Ag, ALCW1, DWS, RecU, UG26
382943107015300	Beaver Creek at HWY 50 nr Gunnison, CO	38.495	-107.032	Ag, ALCW1, DWS, RecU, UG26
383028107162200	West Elk Cr bl forest boundary nr Sapinero, CO	38.508	-107.273	Ag, ALCW1, DWS, RecU, UG26
383103106594200	Gunnison R at Cnty Rd 32 bl Gunnison, CO	38.517	-106.996	Ag, ALCW1, DWS, RecE, UG14
383137107183600	Soap Creek ab Chance Creek nr Sapinero, CO	38.527	-107.311	Ag, ALCW1, DWS, RecU, UG26
382644107271000	Morrow Pt Reservoir bl Blue Cr nr Sapinero, CO	38.446	-107.453	Ag, ALCW1, DWS, RecE, Reservoir
382702107315400	Morrow Pt Res ab Morrow Pt Dam nr Cimarron, CO	38.451	-107.532	Ag, ALCW1, DWS, RecE, Reservoir
382829107122200	Blue Mesa Res ab Cebolla Cr nr Sapinero, CO	38.475	-107.207	Ag, ALCW1, DWS, RecE, Reservoir
382831107172600	Blue Mesa Reservoir ab Soap Cr nr Sapinero, CO	38.475	-107.291	Ag, ALCW1, DWS, RecE, Reservoir
382856107050000	Blue Mesa Res bl HWY 149 nr Gunnison, CO	38.482	-107.084	Ag, ALCW1, DWS, RecE, Reservoir
382924107352300	Crystal Reservoir at Crystal Creek nr Cimarron, CO	38.490	-107.590	Ag, ALCW1, DWS, RecE, Reservoir
383024107371800	Crystal Reservoir at Crystal Dam nr Cimarron, CO	38.507	-107.622	Ag, ALCW1, DWS, RecE, Reservoir
Dinosaur National Monument				
09247600	Yampa R bl Craig, CO	40.481	-107.614	Ag, ALWW1, DWS, RecE, LYG2
09251000	Yampa R nr Maybell, CO	40.503	-108.033	Ag, ALWW1, DWS, RecE, LYG2
09260050	Yampa R at Deerlodge Park, CO	40.452	-108.525	Ag, ALWW1, DWS, RecE, LYG2
09261000	Green R nr Jensen, UT	40.409	-109.235	1C, 2A, 3B, 4
404417108524900	Green R ab Gates Of Lodore, CO	40.738	-108.880	Ag, ALCW1, DWS, RecE, LYG19a

Appendix A. Water Quality Sites Reported, WY 2010–2012, cont.

StationID	Station name	Latitude	Longitude	Designated beneficial uses
Hovenweep National Monument				
5995700	Square Tower Spg	37.386	-109.081	1C, 2A, 3B, 4
5995710	Cajon Spg	37.297	-109.183	1C, 2A, 3B, 4
5995720	Hackberry House Spg	37.408	-109.025	1C, 2A, 3B, 4
Natural Bridges National Monument				
5995310	Armstrong Canyon Ck at Kachina Natural Bridge KB-1	37.600	-110.030	2B, 3B, 4
5995320	Owachomo Bridge Spg in Tuwa Cyn ab cnfl OB-1	37.582	-110.010	2B, 3B, 4
5995330	Sipapu Bridge Spg .25 mi ab Bridge SB-1	37.620	-110.006	2B, 3B, 4
Timpanogos Cave National Monument				
4994970	Hansen Cave Spg in Timpanogos Cave NM	40.438	-111.711	2B, 3A, 4
N/A	Hidden Lake at Timpanogos Cave	40.438	-111.709	2B, 3A, 4
Zion National Park				
09405500	North Fork Virgin R nr Spgdale, UT	37.210	-112.979	1C, 2A, 3A, 4
09406000	Virgin R at Virgin, UT	37.204	-113.181	1C, 2B, 3C, 4
4950800	La Verkin Ck at Lee Pass Trail	37.407	-113.176	2B, 3B, 4
4950920	North Ck at Planned Gage in Park	37.261	-113.106	1C, 2B, 3C, 4, NoCrk
4951265	N Fk Virgin R at WSA bndry	37.371	-112.882	1C, 2A, 3A, 4

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