



Water Quality in the Northern Colorado Plateau Network

Water Years 2019–2022



Pleasant Creek at Capitol Reef National Park.
NPS/CAROLYN HACKBARTH

Water quality in the Northern Colorado Plateau Network: Water years 2019–2022

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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 Division, individual park units, the U.S. Geological Survey, and the Utah Department of Environmental Quality. This report evaluates water quality data from site visits at 42 different locations within and around eight park units in Utah and Colorado from October 1, 2018 through September 30, 2022. Data are compared to state water quality standards for the purpose of providing information to park managers about potential water quality problems. Parks included for evaluation are Arches National Park (NP), Bryce Canyon NP, Canyonlands NP, Capitol Reef NP, Dinosaur National Monument (NM), Hovenweep NM, Timpanogos Cave NM, and Zion NP.

Evaluation of water quality parameters relative to state water quality standards indicated that 21,644 (96.8%) of the 22,356 total designated beneficial-use evaluations completed for the period covered in this report met state water quality standards. The most common parameters that did not meet a standard include fecal indicator bacteria (*Escherichia coli*), water temperature, and total dissolved solids (TDS). While TDS can be an indicator of pollution, in NCPN parks, it mostly occurs downstream of rock outcrops that naturally increase TDS in streams. Phosphorus concentrations were often greater than acceptable thresholds but were rarely associated with indicators of impairment such as algal blooms, fish kills, or low dissolved oxygen.

Sites monitored in Arches NP, Bryce Canyon NP, Capitol Reef NP, Dinosaur NM, Hovenweep NM, and Zion NP all had occurrences when fecal indicator bacteria concentrations were greater than associated state standards. State-coordinated plans to reduce waste contamination are in place for the North Fork Virgin River (Zion NP) and the Fremont River (Capitol Reef NP). The plans have resulted in a decrease in the number of chronic and acute standard violations at Zion. Elevated water temperatures occurred at sites in Canyonlands NP, Capitol Reef NP, and Zion NP. Water temperature is strongly correlated with air temperature in surface waters across the Colorado Plateau. Additional issues of management concern include low dissolved oxygen in Salt Wash at Wolfe Ranch (Arches NP) and Square Tower Spring (Hovenweep NM), as well as selenium in the Colorado River (Arches NP and Canyonlands NP). State-coordinated plans to reduce selenium concentrations in the Upper Colorado River basin are in place.

Acronyms, abbreviations, and codes

Park acronyms

ARCH: Arches National Park

BRCA: Bryce Canyon National Park

CANY: Canyonlands National Park

CARE: Capitol Reef National Park

DINO: Dinosaur National Monument

HOVE: Hovenweep 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

cfu: colony-forming units

CO: Colorado

E. coli: *Escherichia coli* bacteria

EPA: U.S. Environmental Protection Agency

HD: hardness-dependent

mg/L: milligrams per liter

MPN: most probable number

NPS: National Park Service

NCPN: Northern Colorado Plateau Network

NM: national monument

NP: national park

NWQL: National Water Quality Laboratory

OHV: off-highway vehicle

SEUG: Southeast Utah Group

SOP: standard operating procedure

TDS: total dissolved solids

TMDL: total maximum daily load

µg/L: micrograms per liter

UT: Utah

UDEQ: Utah Department of Environmental Quality

UPHL: Utah Public Health Laboratory

USGS: U.S. Geological Survey

WSA: Wilderness Study Area

Colorado designated beneficial use codes

Ag: Agricultural use

ALCW1: Aquatic life cold-water class 1

ALWW1: Aquatic life warm-water class 1

DWS: Domestic-water supply

RecE: Existing primary-contact recreation

Standards for assessed Colorado stream segments within Colorado park units

LC3: Lower Colorado River basin segment 3 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

Utah designated beneficial use codes

1C: Domestic-water supply

2A: Frequent primary-contact recreation

2B: Infrequent primary-contact recreation and secondary-contact recreation

3A: Cold-water aquatic life and game fish

3B: Warm-water aquatic life and game fish

3C: Non-game fish

4: Agricultural use

NoCrk: Zion National Park North Creek total dissolved solids standard

Executive Summary

The purpose of this report is to evaluate water quality data collected at 42 locations within and around eight national park units in Colorado and Utah and compare the data to state water quality standards. Parks with sites included for evaluation are Arches National Park (NP), Bryce Canyon NP, Canyonlands NP, Capitol Reef NP, Dinosaur National Monument (NM), Hovenweep NM, Timpanogos Cave NM, and Zion NP. Data from Black Canyon of the Gunnison NP, Curecanti National Recreation Area, and Golden Spike National Historical Park were not available to be included in this report. Water quality data are collected by individual park units and the Northern Colorado Plateau Network (NCPN) of the National Park Service (NPS), the Utah Department of Environmental Quality (UDEQ), and the US Geological Survey (USGS). The data are compared to state water quality standards for the purpose of providing information to park managers about potential water quality problems. The NPS does not determine the regulatory status of surface waters; state water quality agencies determine whether waters comply with the Clean Water Act.

The number of parameters evaluated for each site ranged from 1 to 22, depending on the available data. Over 96% of beneficial-use evaluations met state water quality standards (21,644 of 22,356). Trace elements such as aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc met standards for all or almost all the evaluations when data were available. Evaluations for ammonia, nitrate, pH, chloride, fluoride, and sulfate also met standards for all evaluations. However, half of the sites (21 of 42) had one or more parameters that did not meet at least one standard for 10% or more of the evaluations. The most common parameters that did not meet a standard include fecal indicator bacteria (*Escherichia coli*, 9 of 20 sites evaluated), water temperature (8 of 42 sites evaluated), and total dissolved solids (TDS, 7 of 31 sites evaluated). While TDS can be an indicator of pollution, in NCPN parks, it mostly occurs downstream of rock outcrops that naturally increase TDS in streams.

Sites monitored in Arches NP, Bryce Canyon NP, Capitol Reef NP, Dinosaur NM, Hovenweep NM, and Zion NP all had occurrences when fecal indicator bacteria concentrations were greater than associated state standards. *Escherichia coli* (*E. coli*) are found in the waste of mammals including wildlife, livestock, and humans. Reducing *E. coli* concentrations requires site-specific evaluations to determine the sources of waste contamination. At NCPN parks, these evaluations have identified sources such as flood irrigation over livestock-grazed pastures located upstream of park boundaries (Zion NP, Capitol Reef NP), high-density livestock operations outside of park boundaries (Capitol Reef NP), and the presence of trespass livestock within park boundaries (Bryce Canyon NP). Follow-up actions can include maintaining boundary fences to prevent livestock access, installing and maintaining toilets in high visitor use areas, and working with states and upstream landowners to improve watershed livestock management and septic systems. State-coordinated plans to reduce waste contamination are in place for the North Fork Virgin River (Zion NP) and the Fremont River (Capitol Reef NP). The plans have resulted in a decrease in the number of chronic and acute standard violations at Zion. Continued coordination between the NPS, state agencies, and local landowners will be necessary to reduce *E. coli* concentrations and, in turn, improve public health and safety in these streams.

Elevated water temperatures occurred in the Colorado River (Canyonlands NP), the Fremont River and three of its tributary streams (Capitol Reef NP), and the North Fork Virgin River and one of its tributary streams (Zion NP). Water temperature is strongly correlated with air temperature in surface waters across the Colorado Plateau. Water temperatures are expected to continue to rise as air temperatures increase. Management options to promote cooler water temperatures include maintaining shade cover along streams in higher elevation forested watersheds; prioritizing watersheds for proactive fire risk reduction; working with states to protect instream flows from new or excessive upstream diversions; and working with states to protect associated groundwater aquifers from additional withdrawals. Long-term strategies to reduce water temperatures will require individual and global action to address anthropogenic climate change.

Phosphorus concentrations were often greater than thresholds that trigger additional investigation (20 of 32 sites evaluated); however, they were rarely associated with indicators of impairment such as algal blooms, fish kills, or low dissolved oxygen. Harmful algal blooms are an increasing concern but are not included in NCPN's water quality monitoring program. Harmful algal blooms occur when naturally occurring cyanobacteria in the water multiply very rapidly. Cyanobacteria can produce toxins that target the kidney, liver, and neurologic system. These toxins, known as cyanotoxins, were detected at concentrations above the public health threshold in three water bodies in Zion NP in 2020–2022. Zion NP and the State of Utah are working with researchers to better understand the causes of benthic algal blooms that release toxins. Blue Mesa Reservoir in Curecanti National Recreation Area experienced harmful algal blooms and associated fish kills in 2018, 2021, and 2022. The park is working with the USGS to understand the causes of the blooms and develop predictive tools to better manage public health advisories. Because phosphorus concentrations are often high in the absence of algal blooms, it is likely that other factors contribute to these blooms.

Additional issues of management concern include low dissolved oxygen in Salt Wash at Wolfe Ranch (Arches NP) and Square Tower Spring (Hovenweep NM), as well as selenium in the Colorado River (Arches NP and Canyonlands NP). State-coordinated plans to reduce selenium concentrations in the Upper Colorado River basin are in place. Evaluations for this four-year period closely match results from previous evaluations from 2006 to 2018.

Acknowledgements

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1 Introduction

The Northern Colorado Plateau Network (NCPN) consists of 16 park units in Utah, Colorado, Arizona, and Wyoming (Figure 1). The water-dependent ecosystems in these unique landscapes are protected by the National Park Service (NPS) Organic Act, NPS Management Policies (NPS 2006), and the Clean Water Act. 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).

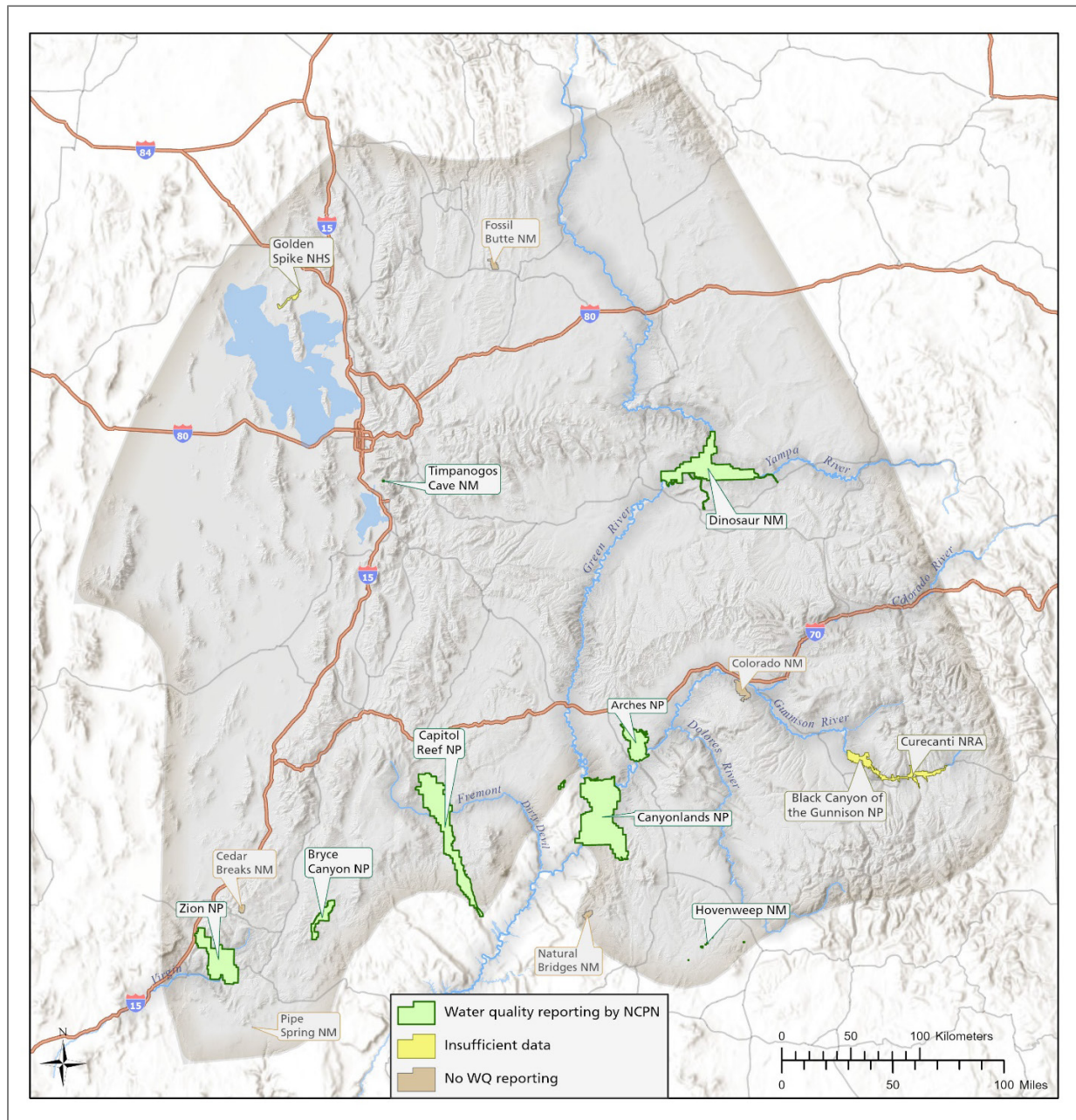


Figure 1. National Park Service units of the Northern Colorado Plateau Network. Parks where the NCPN monitors water quality are highlighted.

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

The NCPN compares available water quality data to applicable state water quality standards to report the recent condition of NCPN waters to park managers. The goal of NCPN monitoring is to provide information to park managers to allow them to identify issues of management concern, track responses to management actions, and demonstrate and maintain high-quality waters where they exist.

1.1 Report scope and objectives

This is the sixth report on activities and results of the NCPN water quality monitoring program (Thoma et al. 2008; Van Grinsven et al. 2010; Hackbarth and Weissinger 2013; Hackbarth and Weissinger 2016; Hackbarth and Weissinger 2020). In total, these six reports provide information on water years 2006–2022.

This report focuses on sites monitored by NCPN staff and by cooperating staff and agencies working in and near NCPN parks. Unlike previous reports, this report excludes results from water quality stations at Black Canyon of the Gunnison National Park and Curecanti National Recreation area, which are pending updated results from the National Water Quality Laboratory (NWQL). Although long-term data records exist for some of these sites, the period considered in this report is from October 1, 2018 through September 30, 2022 (water years 2019–2022).

The objectives of this report include the following:

- Compare data to state water quality standards.
- Identify and characterize potential sources of water quality contamination.
- Provide resource managers with timely information about these data.

2 Understanding this report

2.1 Methods

Data evaluated in this report are collected by individual parks, the NCPN, the Utah Department of Environmental Quality (UDEQ), and the U.S. Geological Survey (USGS). Sites supported by states and the USGS had a variety of parameters collected at differing time scales, depending on their program goals. Sites supported by other entities are included in this report if more than ten samples were collected over the course of the four-year period of record. Data were accessed via the [Water Quality Portal](https://www.waterqualitydata.us) (<https://www.waterqualitydata.us>, accessed April 2023).

For sites directly supported by NCPN, approximately 30 parameters were measured during monthly site visits for 10 months each year. 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 of trace elements, nutrients, major ions and total dissolved solids (TDS), and fecal indicator bacteria. Some sites are sampled each year, while others are sampled for two years and then rested for two years.

Field methods used by NCPN to collect data for this report are outlined in the NCPN Standard Operating Procedures (SOPs) for Water Quality (Thoma et al. 2017). 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. 2017). The NCPN ensures comparability of the laboratory data created by this monitoring program by using the USGS 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 the USGS NWQL and the Utah Public Health Laboratory are provided in SOP 7, Appendices A and B (Thoma et al. 2017).

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 to build a dataset 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.

Additional information on methods and data quality can be found in Appendix A.

2.2 Water quality and standards

NCPN evaluates water quality using the standards set for by the states of Colorado and Utah, depending on where each site is located (Appendices B and C). 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 aquatic life (beneficial-use designation) is 4.6 µg/L (numeric criterion). A parameter may be subject to more than one designated beneficial use, each with its own criterion. Typical beneficial-use designations include domestic water source, agricultural, aquatic life, and recreation uses. When warranted, states may also develop site- or reach-

specific criteria to better reflect the natural conditions at a site. Site- and reach-specific criteria supersede the more general criteria when they exist. The beneficial-use designations for each site evaluated in this report are listed in Appendix D.

One site visit can yield approximately 30 water quality parameter measurements or results. Each result is then evaluated against a water quality standard when one is available; 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. 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.

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 20 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.

2.2.1 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 (months) and acute exposure over a short period (hours or days). Permitted levels are much lower for chronic exposure than for acute exposure.

Parameter results are compared against the more stringent chronic criteria, and if the standard is not met, it is meant to inform managers of potential problems rather than conform to a regulatory definition. From a resource-conservation standpoint, instantaneous grab-sample data, when compared against more stringent criteria, can provide a means of early warning and an indication of a problem that may require more attention. In addition, if an evaluation did not meet the acute criterion, it is documented in the results section for that individual site.

2.2.2 Frequency of standards not met

To minimize reporting of short-duration changes in water chemistry that may result from natural variability associated with weather events, results are only reported if the parameter had at least ten samples and the standard was not met for 10% or more of the evaluations.

The 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 standards comparisons. 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.

2.2.3 Regulatory authority

This report does not determine whether sites meet the regulatory definition of impairment. The National Park Service does not have regulatory authority to establish water quality standards or assign beneficial-use designations over waters in the U.S. Those designations are left to the states in their 305(b) reports to Congress. States may have access to additional data they use to determine the regulatory status of a water body that is not included in this report. In addition, the methods used in this report align with but are not identical in every respect to how the states of Colorado and Utah evaluate data. The findings in this report may not match the states' findings in their 305(b) reports.

3 Results and discussion

3.1 Overview

This report evaluates water quality data collected from 42 locations within or around eight national park units in Colorado and Utah from October 1, 2018 through September 30, 2022, and compares the data to state water quality standards. Parks with sites included for evaluation are Arches National Park (NP), Bryce Canyon NP, Canyonlands NP, Capitol Reef NP, Dinosaur National Monument (NM), Hovenweep NM, Timpanogos Cave NM, and Zion NP. Data from Black Canyon of the Gunnison NP, Curecanti National Recreation Area, and Golden Spike National Historical Park were not available to be included in this report.

The number of parameters evaluated for each site ranged from 1 to 22, depending on the available data. Over 96% of beneficial-use evaluations met state water quality standards (21,644 of 22,356). Trace elements such as aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc met standards for all or almost all the evaluations when data were available. Evaluations for ammonia, nitrate, pH, chloride, fluoride, and sulfate also met standards for all evaluations. However, half of the sites (21 of 42) had one or more parameters that did not meet at least one standard for 10% or more of the evaluations. The most common parameters that did not meet a standard include fecal indicator bacteria (*Escherichia coli*, 9 of 20 sites evaluated), water temperature (8 of 42 sites evaluated), and TDS (7 of 31 sites evaluated) (Table 1). Phosphorus concentrations were often greater than criteria that trigger additional investigation (20 of 32 sites evaluated); however, they were rarely associated with indicators of impairment such as algal blooms, fish kills, or low dissolved oxygen. Measured levels of inorganic nitrogen in the form of nitrite, nitrate, and ammonia were low (Table 2). Trace elements such as metals were rarely at concerning levels (Table 3).

Table 1. Number of sites evaluated and not meeting standards for core parameters, *Escherichia coli*, and major ions for 10% or more of the evaluations.

Parameter	Sites evaluated	Number of sites not meeting standard	Percentage of sites evaluated not meeting standard
Chloride	4	0	0
Dissolved oxygen	35	2	6
<i>Escherichia coli</i>	20	9	45
pH	36	0	0
Sulfate	4	0	0
Total dissolved solids (TDS)	31	7	23
Water temperature	42	8	19

Table 2. Number of sites evaluated and not meeting nutrient standards or criteria for additional investigation for 10% or more of the evaluations.

Parameter	Sites evaluated	Number of sites not meeting standard	Percentage of sites evaluated not meeting standard
Ammonia	34	0	0
Nitrite	5	1	20
Nitrate	5	0	0
Phosphorus	32	20	62

Table 3. Number of sites evaluated and not meeting standards for trace elements for 10% or more of the evaluations.

Parameter	Sites evaluated	Number of sites not meeting standard	Percentage of sites evaluated not meeting standard
Aluminum	20	0	0
Arsenic	21	0	0
Barium	14	0	0
Beryllium	12	0	0
Boron	21	0	0
Cadmium	24	0	0
Chromium	20	0	0
Copper	24	0	0
Fluoride	6	0	0
Iron	24	3	13
Lead	24	0	0
Manganese	8	1	13
Mercury	14	0	0
Nickel	20	0	0
Selenium	25	1	4
Silver	24	0	0
Zinc	24	0	0

3.1.1 *Escherichia coli*

Escherichia coli (*E. coli*) is a fecal indicator bacteria found in the waste of humans, livestock, and wildlife. Potential sources of contamination in surface waters can be both natural and related to human activities. Sites monitored in Arches NP, Bryce Canyon NP, Capitol Reef NP, Dinosaur NM, Hovenweep NM, and Zion NP all had occurrences when *E. coli* concentrations were greater than associated state standards (Figure 2).

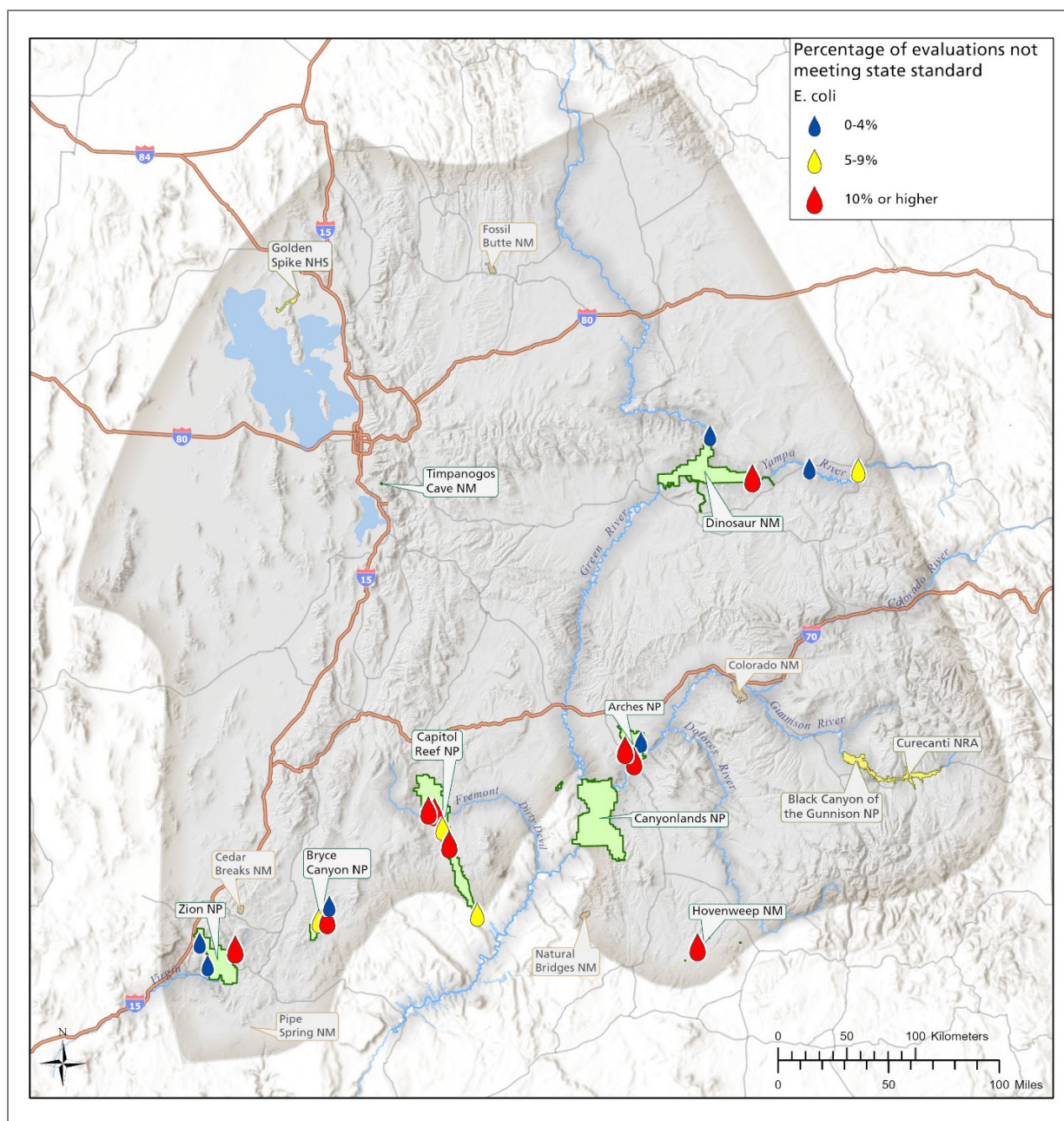


Figure 2. Sites evaluated for *E. coli* concentrations, with the percentage of evaluations not meeting state standards.

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 silts and sands eroded during overland-flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies and can survive for prolonged periods when attached to sediments (Sampson et al. 2006). Elevated *E. coli* concentrations are more likely to occur during turbid, high-discharge events. However, while some of these *E. coli* exceedances occurred

during higher flows and turbid water, many of the exceedances were associated with low to normal flows and clear water.

Reducing *E. coli* concentrations requires site-specific evaluations to determine the sources of waste contamination. At NCPN parks, these evaluations have identified likely sources such as flood irrigation over livestock-grazed pastures upstream of park boundaries (Zion NP and Capitol Reef NP; Dickey and Adams 2017; UDEQ 2020), high-density livestock operations adjacent to water bodies outside park boundaries (Capitol Reef NP; UDEQ 2002), and the presence of trespass livestock within park boundaries (Bryce Canyon NP; Weissinger 2022). Follow-up actions can include maintaining boundary fences to prevent livestock access, installing and maintaining toilets in high visitor use areas, and working with states and upstream landowners to improve watershed livestock management and domestic septic systems. State-coordinated plans to reduce waste contamination are in place for the North Fork Virgin River (Zion NP) and the Fremont River (Capitol Reef NP). Continued coordination between the NPS, state agencies, and local landowners will be necessary to reduce *E. coli* concentrations and, in turn, improve public health and safety in these streams. *E. coli* are discussed further in park-specific results sections.

3.1.2 Water temperature

Sites monitored in Canyonlands NP, Capitol Reef NP, and Zion NP had water temperatures that did not meet state standards for more than 10% of the evaluations from water years 2019 to 2022 (Figure 3). Some of these sites, particularly at Capitol Reef NP and Zion NP, are currently assigned to a cold-water aquatic life standard that is designed for higher elevation headwaters. These sites are small streams at lower elevations that may warrant a warm-water aquatic life designation. The State of Utah is investigating whether several of these stream reaches should be updated to the warm-water aquatic life standard.

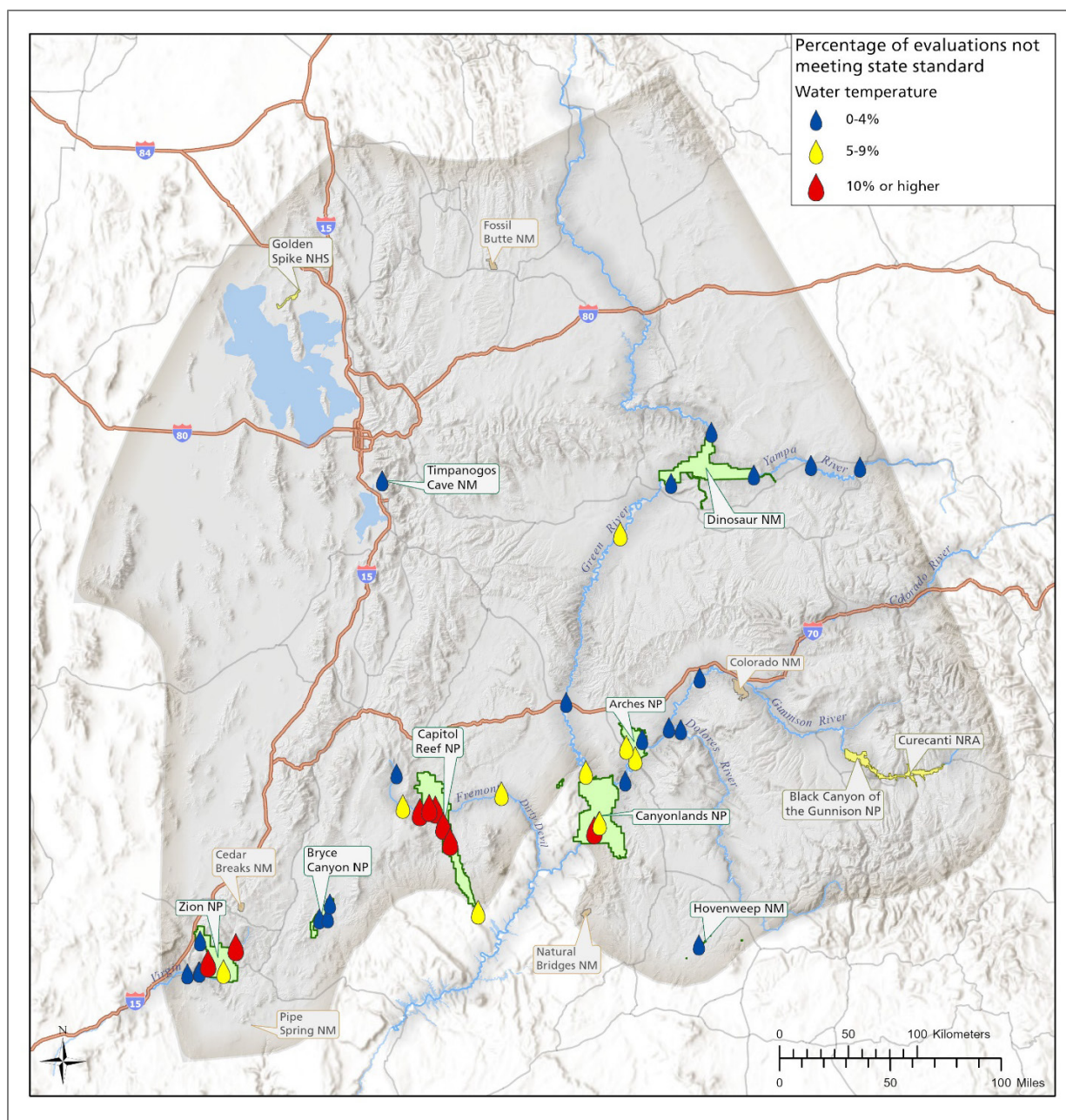


Figure 3. Sites evaluated for water temperature, with the percentage of evaluations not meeting state standards.

Elevated water temperatures can have direct negative effects on aquatic life and can contribute to low levels of dissolved oxygen and the development of harmful algal blooms. Water temperature is strongly related to air temperature in almost all surface water sites included in the NCPN monitoring program (Figure 4). Low-flow conditions, combined with hot summer air temperatures, cause periodic surface-water temperature exceedances at these sites. Water temperatures are expected to increase as climate change increases air temperatures and decreases surface water flows in the

southwestern United States (Seager et al. 2012). High water temperatures and their associated effects are likely to be increasingly common in NCPN waters.

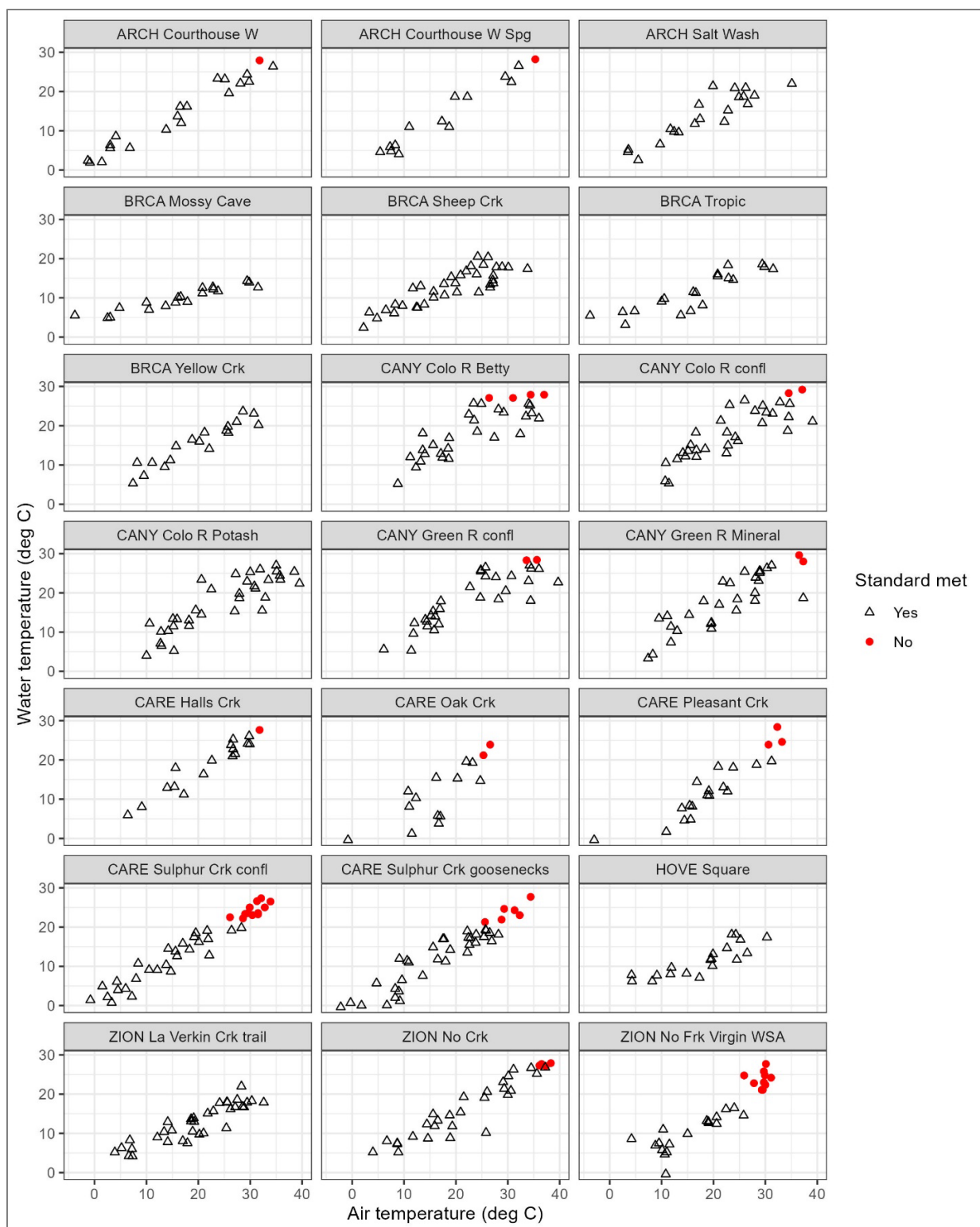


Figure 4. Water temperature related to air temperature at NCPN-relevant surface water sites with at least ten co-measurements from water years 2019 to 2022. Samples not meeting the relevant state water quality standard are shown as red dots.

Management options to promote cooler water temperatures include maintaining shade cover along streams in higher elevation forested watersheds; prioritizing watersheds for proactive fire risk reduction; working with states to protect instream flows from new or excessive upstream diversions; and working with states to protect associated groundwater aquifers from additional withdrawals. Long-term strategies to reduce water temperatures will require individual and global action to address anthropogenic climate change.

3.1.3 Total dissolved solids

Total dissolved solids concentrations greater than state standards were reported at sites in Arches NP, Capitol Reef NP, and Hovenweep NM (Figure 5). While TDS can be an indicator of pollution, in NCPN parks, it mostly occurs downstream of rock outcrops that naturally increase TDS in streams. Elevated TDS concentrations are associated with geologic outcrops with greater salt content, such as the Paradox Formation, Mancos and Morrison shales, the Moenkopi Formation, and the Burro Canyon Formation. While some sites may have associated upstream land uses, such as agricultural irrigation, that can increase TDS, it is likely that increased concentrations are primarily natural at these sites. The State of Utah has developed a site-specific criterion for North Creek at Zion NP and is investigating whether other sites should also have site-specific criteria for determining impairment. Occurrences of TDS greater than state standards are discussed further in the park-specific results sections.

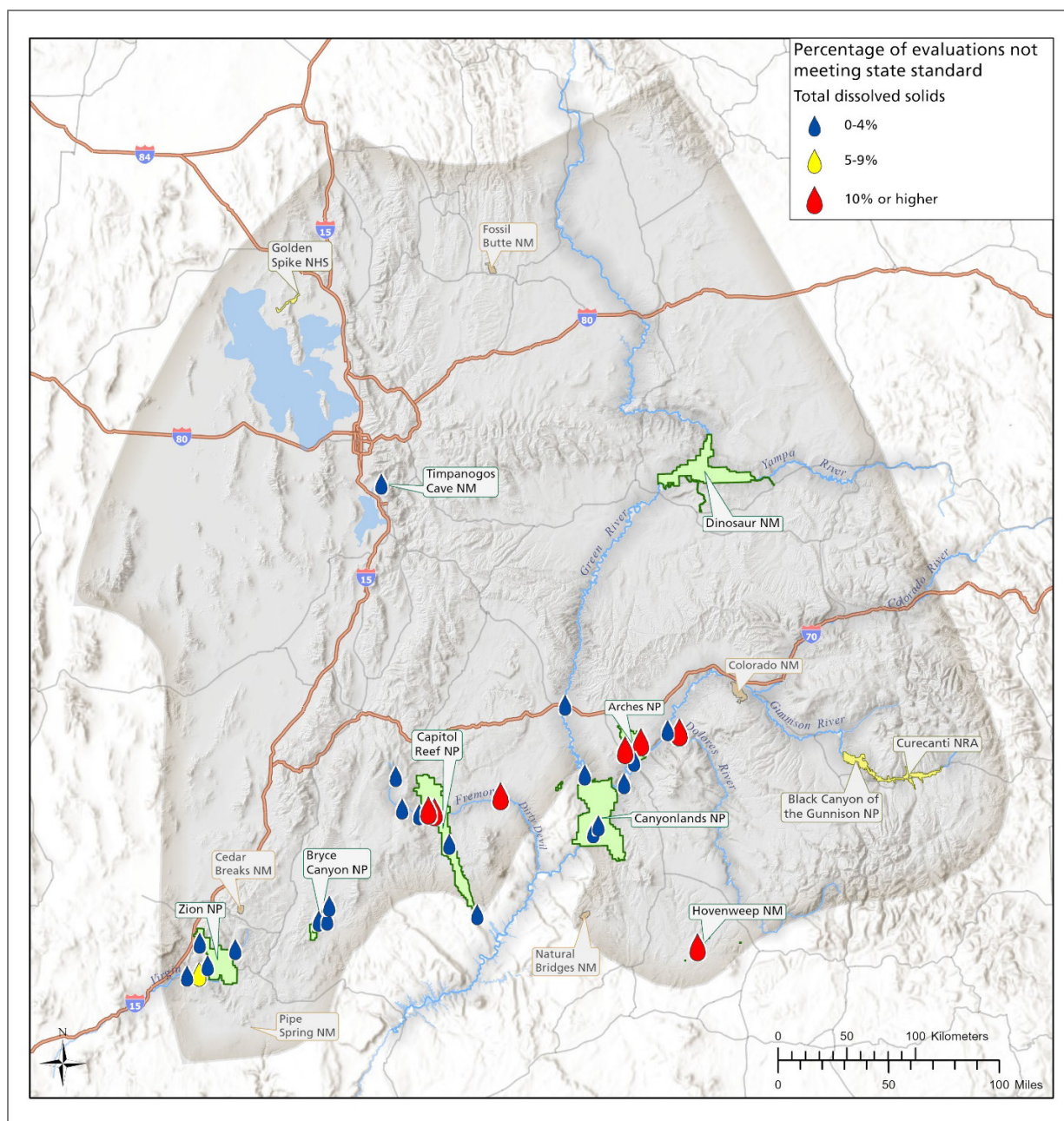


Figure 5. Sites evaluated for total dissolved solids, with the percentage of evaluations not meeting state standards.

3.1.4 Phosphorus

Elevated phosphorus concentrations were reported at sites in Arches NP, Canyonlands NP, Capitol Reef NP, Dinosaur NM, Hovenweep NM, and Zion NP (Figure 6). The states of Colorado and Utah use phosphorus standards and interim values as criteria to determine whether additional evaluation for impairment is needed. Corroborating evidence may include other chemical parameters associated with eutrophication—such as elevated nitrogen concentrations or low dissolved oxygen concentrations—and bioassessments, including algal blooms and fish kills.

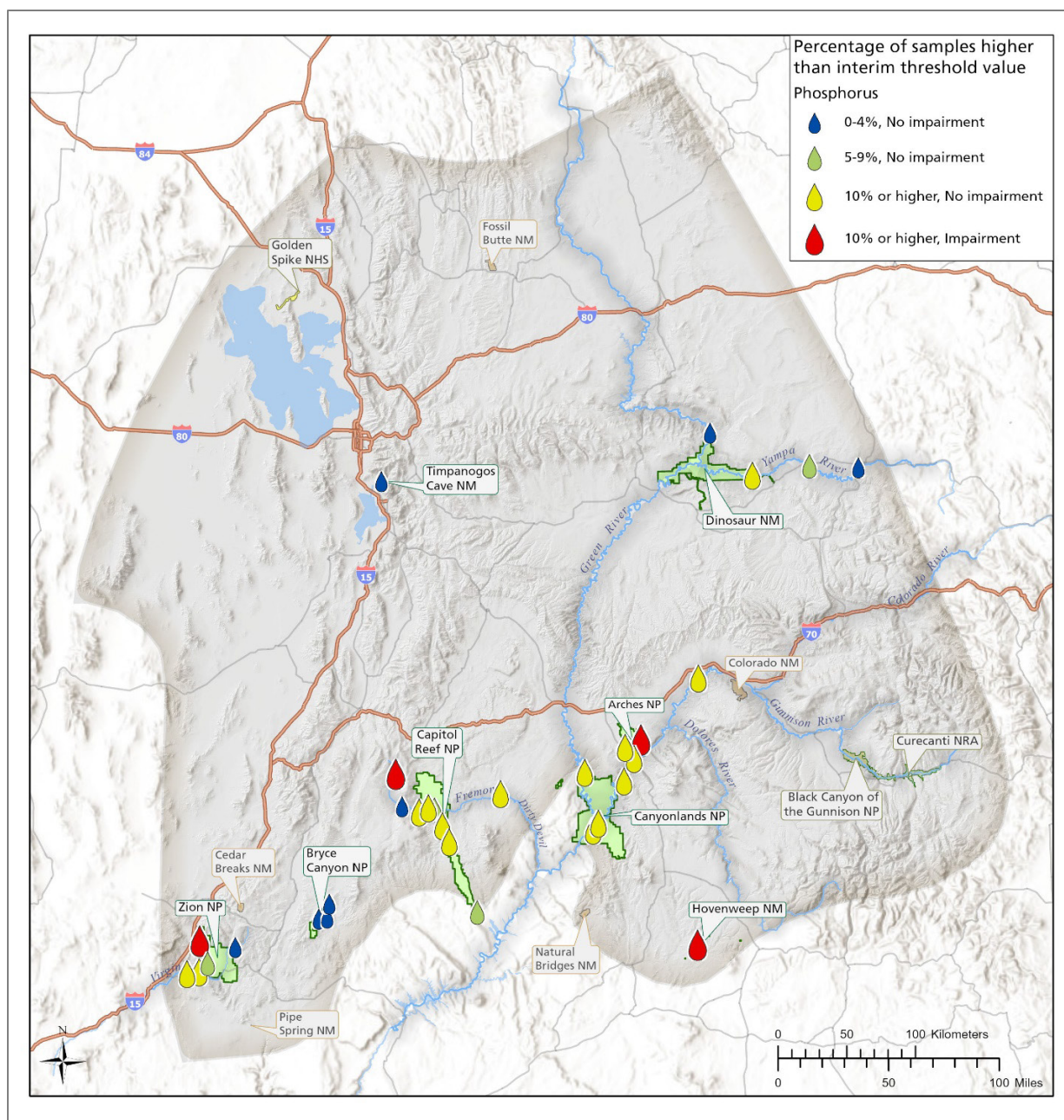


Figure 6. Sites evaluated for total phosphorus, with the percentage of samples higher than the interim threshold value and status of impairment. Only a few sites had additional indicators of impairment, such as low dissolved oxygen or harmful algal blooms.

Total phosphorus concentrations in water stem from rock weathering, airborne deposition, and soil erosion, and anthropogenic inputs such as fish hatcheries, high-density livestock operations, and fertilizers. Phosphorus comes in several forms, including a form attached to soil particles that may be transported to water bodies where dissolution can occur, resulting in bioavailable phosphorus. In many instances, phosphorus has a geologic origin and is naturally occurring at elevated levels due to weathering (Reynolds et al. 2001). Soil erosion on uplands may also contribute to phosphorus

loading and can be exacerbated by land uses including livestock grazing (Reynolds et al. 2005). A better understanding of phosphorus source, transport, and biological effect in NCPN watersheds could help determine potential management actions for restoration, including the possibility of reclassifying or providing site-specific classifications for water bodies based on natural conditions.

It is likely that many of the elevated phosphorus concentrations in NCPN waters are primarily natural in origin or augmented by non-point land uses that increase erosion. High phosphorus concentrations are discussed further in park results sections only if there are additional indicators of impairment in a water body, such as low dissolved oxygen levels or the presence of harmful algal blooms. High phosphorus concentrations alone are not sufficient to indicate impairment.

Harmful algal blooms are an increasing concern but are not included in NCPN's water quality monitoring program. Harmful algal blooms have been detected at Zion NP and Curecanti National Recreation Area and are discussed in the park results sections. Because phosphorus concentrations are often high in the absence of algal blooms, it is likely that other factors contribute to these blooms.

3.1.5 Trace elements

Trace elements in NCPN waters do not pose a widespread problem. Individual instances of sites not meeting standards are discussed in the park results sections. Additional discussion of selenium in the Colorado River is included in the Canyonlands NP results section.

3.2 Arches National Park

Water quality data evaluated at six sites in or near Arches NP indicated that 2,174 (94%) of the 2,304 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

Five of the six sites had at least one parameter that did not meet standards for 10% or greater of the evaluations or were greater than threshold values for additional investigation, with 2–10 parameters evaluated per site (Figure 7; Table 4). The most common parameters of concern are *E. coli* and TDS (Table 5). Phosphorus regularly surpassed interim criteria for additional evaluation, but indicators of impairment such as low dissolved oxygen were only observed at one site.

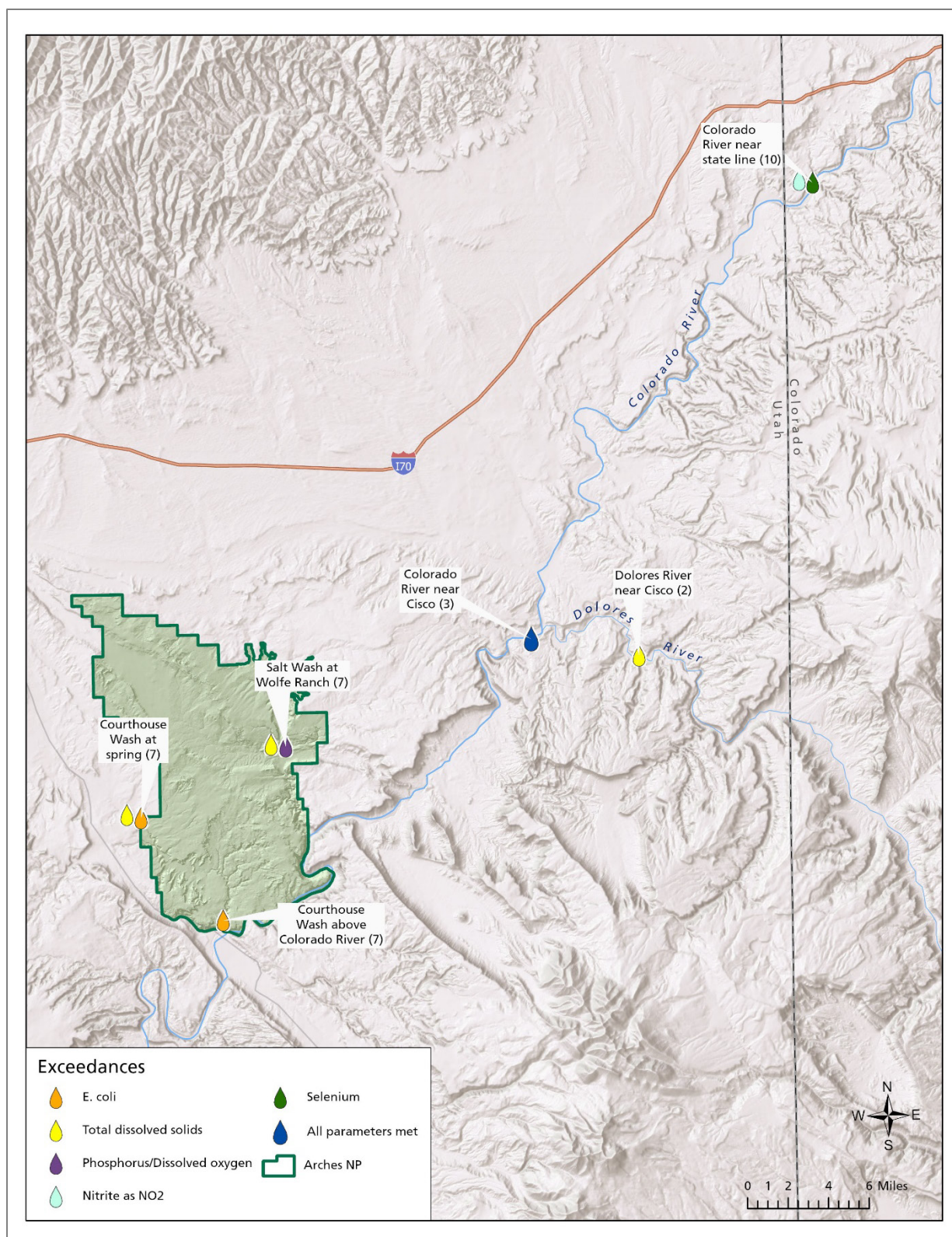


Figure 7. Water quality monitoring locations in and near Arches National Park evaluated in this report, with number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 4. Stations evaluated in and near Arches NP with number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Colorado River near state line	10	2	20
Dolores River near Cisco	2	1	50
Colorado River near Cisco	3	0	0
Salt Wash at Wolfe Ranch	7	3	43
Courthouse Wash at spring	7	2	29
Courthouse Wash above Colorado River	7	1	14

Table 5. Stations evaluated in and near Arches NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Colorado River near state line	Selenium (d) (ug/L)	CO_ALWW1	4.6	58	14	24
Colorado River near state line	Nitrite as NO2 (d) (mg/L)	CO_LC3	0.05	63	6	10
Dolores River near Cisco	Total dissolved solids (mg/L)	UT_4	1200	32	14	44
Salt Wash at Wolfe Ranch	Total dissolved solids (mg/L)	UT_4	1200	20	19	95
Salt Wash at Wolfe Ranch	Dissolved oxygen (mg/L)	UT_3B	5.5	20	4	20
Salt Wash at Wolfe Ranch	Phosphorus (mg/L)	UT_2A, UT_3B	0.05	20	4	20
Courthouse Wash at spring	Total dissolved solids (mg/L)	UT_4	1200	13	5	38
Courthouse Wash at spring	Escherichia coli (MPN/100 mL)	UT_1C chronic	206	13	2	15
Courthouse Wash at spring	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	13	2	15
Courthouse Wash above Colorado River	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	19	3	16
Courthouse Wash above Colorado River	Escherichia coli (MPN/100 mL)	UT_1C chronic	206	19	2	11

3.2.1 Colorado River near Colorado-Utah state line

This site is located in the state of Colorado and is evaluated against Colorado state water quality standards. Dissolved oxygen, pH, water temperature, ammonia, nitrate, arsenic, and boron met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

Selenium is a long-standing issue in the Colorado River and is subject to state-coordinated plans for reductions (CDPHE 2011; UDEQ 2014; Henneberg 2016). Concentrations of selenium above the Colorado standard for warm-water aquatic species occurred during the irrigation season when flows were lower than about 3900 cfs (Figures 8 and 9). This is consistent with findings that high selenium concentrations are attributable to irrigation return flows through selenium-rich soils in Colorado. Selenium concentrations are decreasing at this site and in the Colorado River basin and contributing tributaries in Colorado (Mayo and Leib 2012; Henneberg 2016; Miller et al. 2021). For additional discussion about selenium concentrations in the Colorado River, see the Canyonlands NP section of this report.

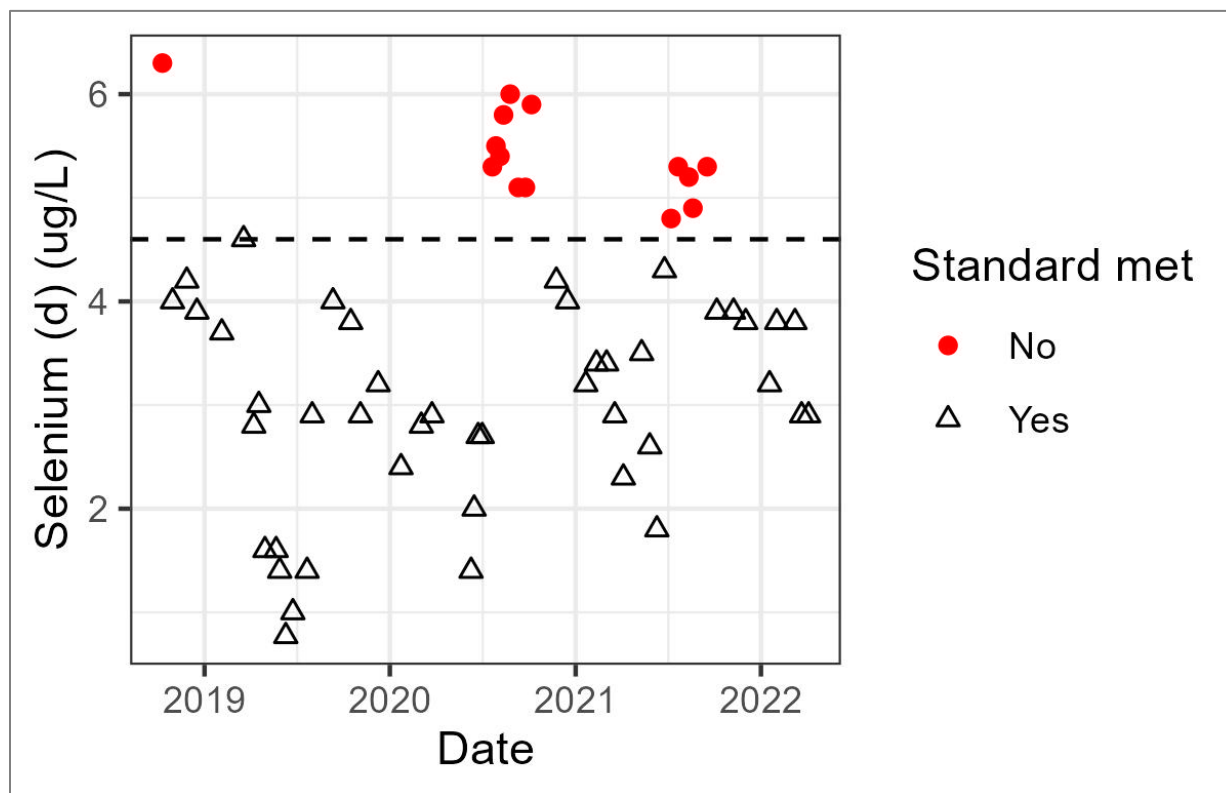
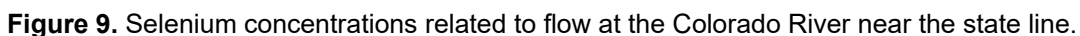
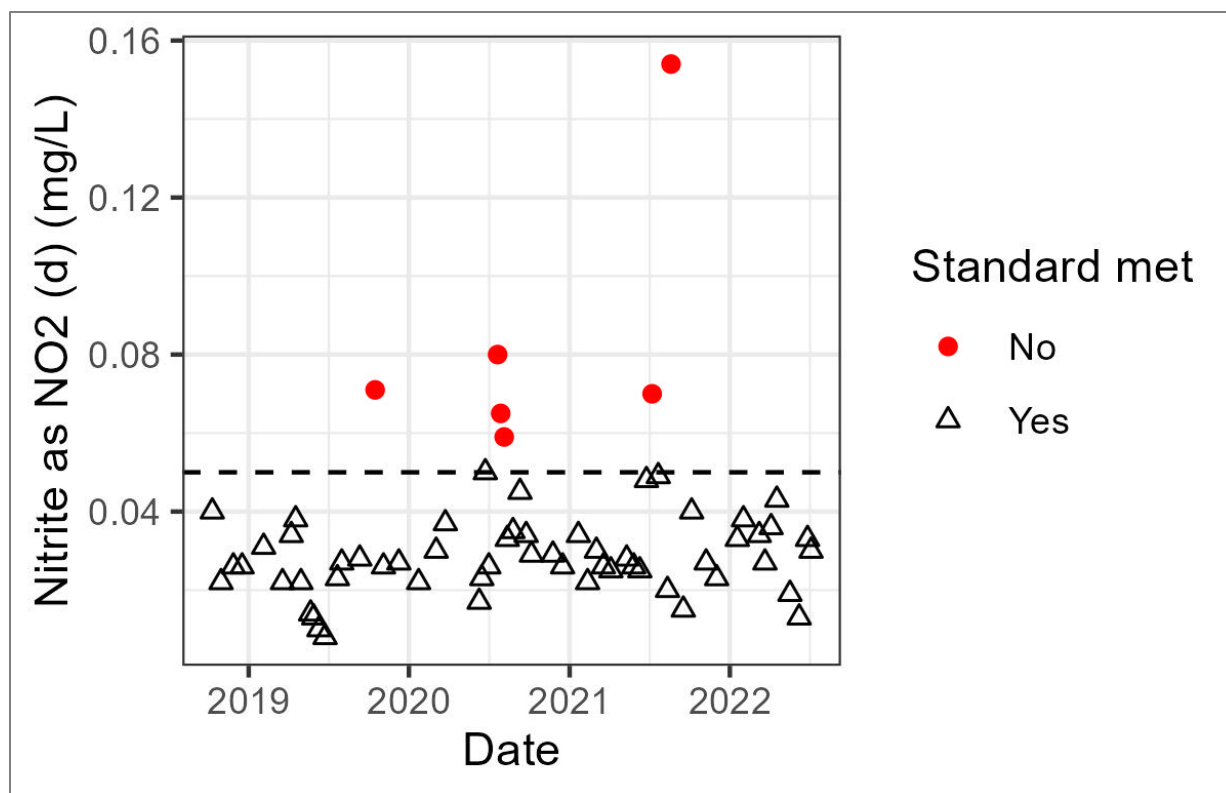


Figure 8. Selenium concentrations from water years 2019 to 2022 at the Colorado River near the state line. The dashed line indicates the Colorado warm-water aquatic life standard of 4.6 $\mu\text{g/L}$.



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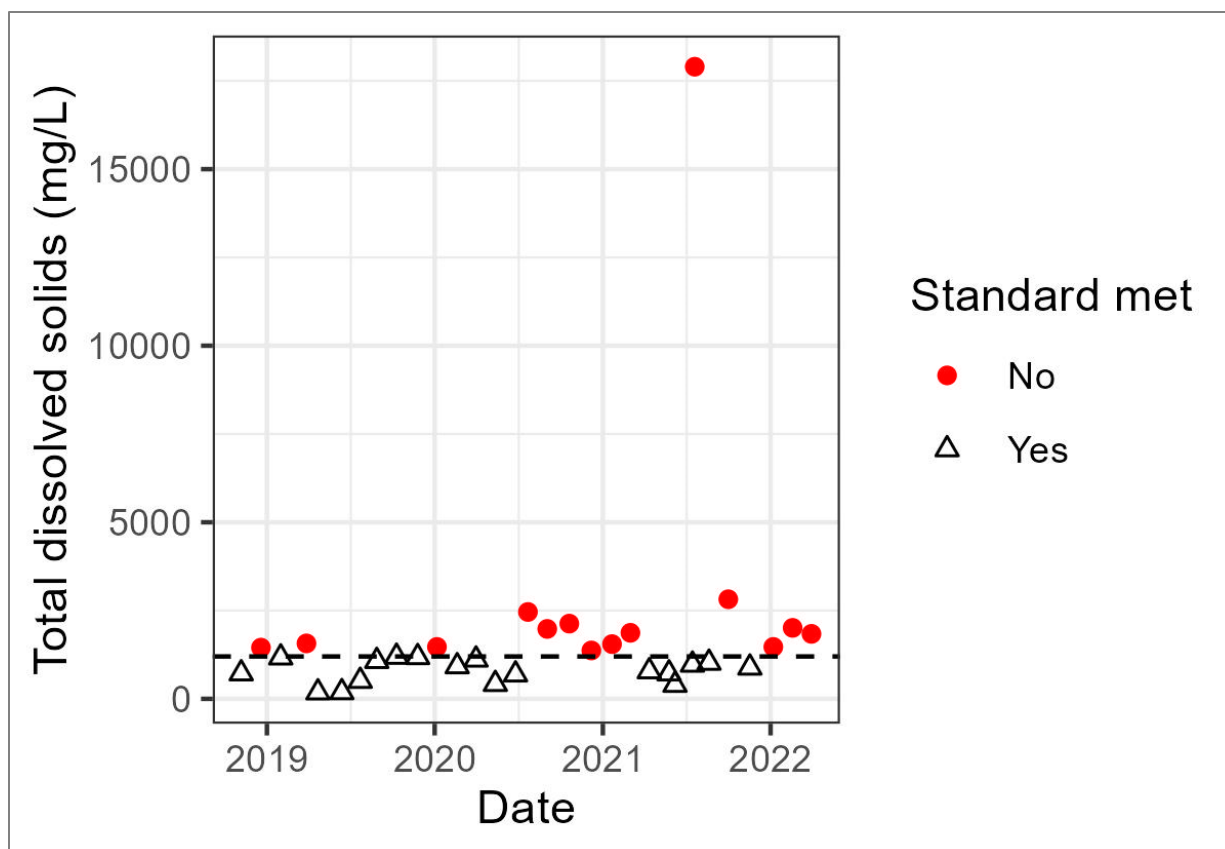


Figure 11. Total dissolved solids concentrations from water years 2019 to 2022 at the Dolores River near Cisco. The dashed line indicates the Utah agricultural standard of 1200 mg/L.

3.2.3 Colorado River near Cisco, Utah

At this site, the only parameters available for evaluation are water temperature, fluoride, and TDS. All three parameters met state water quality standards.

3.2.4 Salt Wash at Wolfe Ranch

The water temperature, *E. coli*, pH, and ammonia met state water quality standards. Samples for trace elements were only collected eight times during the period of record, and all the samples met state water quality standards. Low dissolved oxygen concentrations in Salt Wash at Wolfe Ranch occurred more often with elevated water temperatures (Figure 12) and were not related to phosphorus concentrations (Figure 13). High phosphorus concentrations were not associated with evidence of impairment.

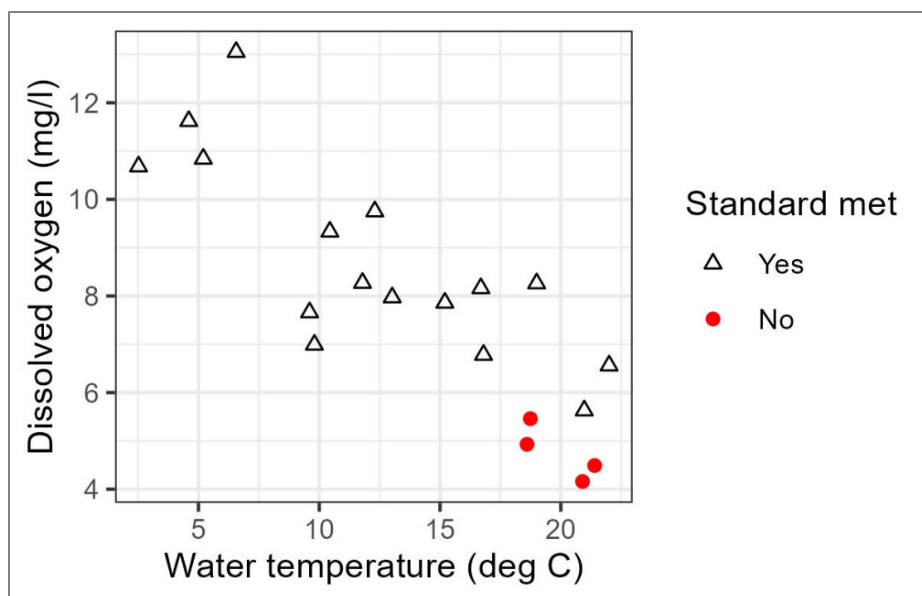


Figure 12. Dissolved oxygen concentrations related to water temperature in Salt Wash at Wolfe Ranch. Low dissolved oxygen occurs more often at higher water temperatures. Samples below the standard of 5.5 mg/L are shown as red dots.

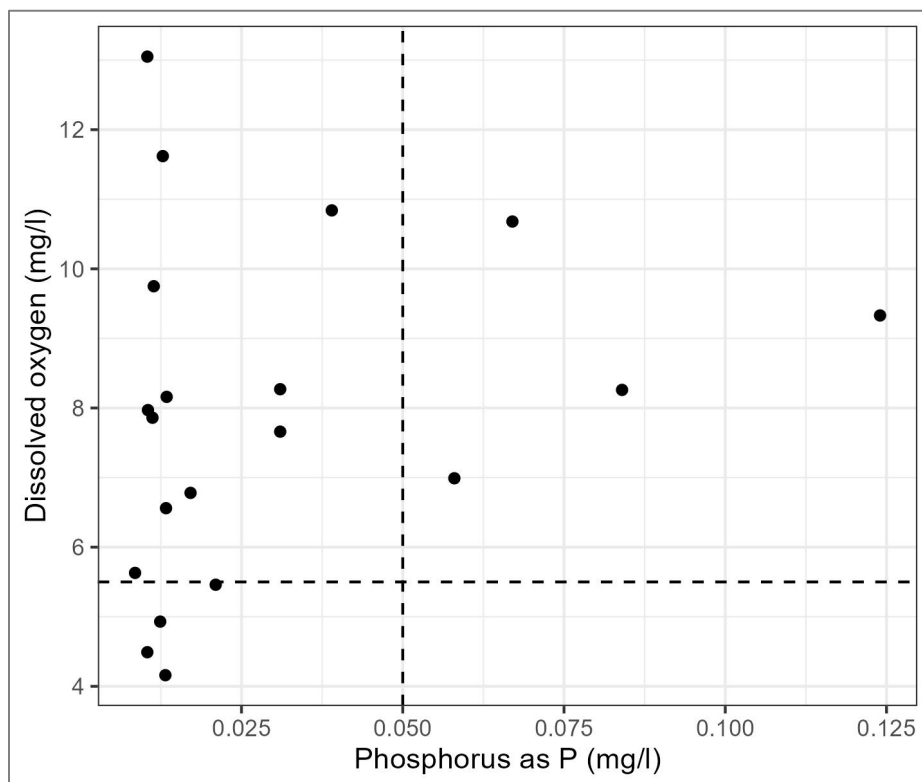


Figure 13. Dissolved oxygen concentrations related to phosphorus concentrations in Salt Wash at Wolfe Ranch. Low dissolved oxygen concentrations (lower left quadrant) did not correspond to high phosphorus concentrations (upper right quadrant). The horizontal dashed line indicates the dissolved oxygen standard (5.5 mg/L), and the vertical dashed line indicates the phosphorus standard (0.05 mg/L).

The TDS concentrations in Salt Wash at Wolfe Ranch likely have a geologic origin, as there are few human activities near Salt Wash that could contribute to such elevated TDS levels. Elevated TDS concentrations in surface water and groundwater in the Moab area result from the underground weathering of a near sub-surface salt dome (Baars and Doelling 1987). Mineral-rich clay and shale deposits of the Morrison and Mancos formations exposed near the sample site may also contribute TDS to Salt Wash.

3.2.5 Courthouse Wash at spring

Data collection at this site was suspended in 2022 because sedimentation in the wash had reduced the sampling location to a small bedrock pool. This site will not be included in future reports unless conditions at the site change. Dissolved oxygen, pH, water temperature, and ammonia met state water quality standards. Samples for trace elements were only collected six times during the period of record, and all the samples met state water quality standards except for one arsenic concentration. High phosphorus concentrations were not associated with evidence of impairment.

The chronic standards for *E. coli* for frequent primary-contact recreation (e.g., swimming) and domestic water supply were not met on two separate occasions. One of these instances involved *E. coli* numbers that surpassed the maximum detectable limit and failed to meet the acute standard. This site is located at the western boundary of Arches NP and is adjacent to public land that allows for off-highway vehicle (OHV) and cattle grazing. Even though the site is located within the park boundary, the fence to keep OHV travel and cattle out of the park is downstream of the site; therefore, cattle frequently visit this small spring-fed pool and OHVs drive directly through the site. Possible sources of *E. coli* contamination could be from wildlife, domestic animals, humans, or a combination thereof. At the time of each of the exceedances at this site, it was noted that cow manure was present in and around the site and could be a reasonable cause of standards not being met.

Mineral-rich clay and shale deposits of the Morrison formation are exposed directly upstream of the sample site and likely contribute to the occurrences with elevated TDS concentrations.

3.2.6 Courthouse Wash above the Colorado River

Dissolved oxygen, pH, water temperature, TDS, and ammonia met state water quality standards. Samples for trace elements were only collected eight times during the period of record, and all the samples met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

The chronic *E. coli* standard for frequent primary-contact recreation was not met on three occasions. Two of the three *E. coli* concentrations were also above the chronic standard for domestic water supply. During each of these occurrences, the acute standard was met. The two sites located in Courthouse Wash are in the same drainage, but they are usually not connected by flowing water. Elevated *E. coli* concentrations were noted in May and June 2022 under normal flow and clear water conditions (Figure 14). In August 2022, elevated concentrations corresponded to turbid water following a flash flood event, which can naturally elevate coliform concentrations in water. Trespass cattle have not been noted at Courthouse Wash above the Colorado River. The cause of elevated *E. coli* concentrations under clear water and normal flow conditions is unknown.

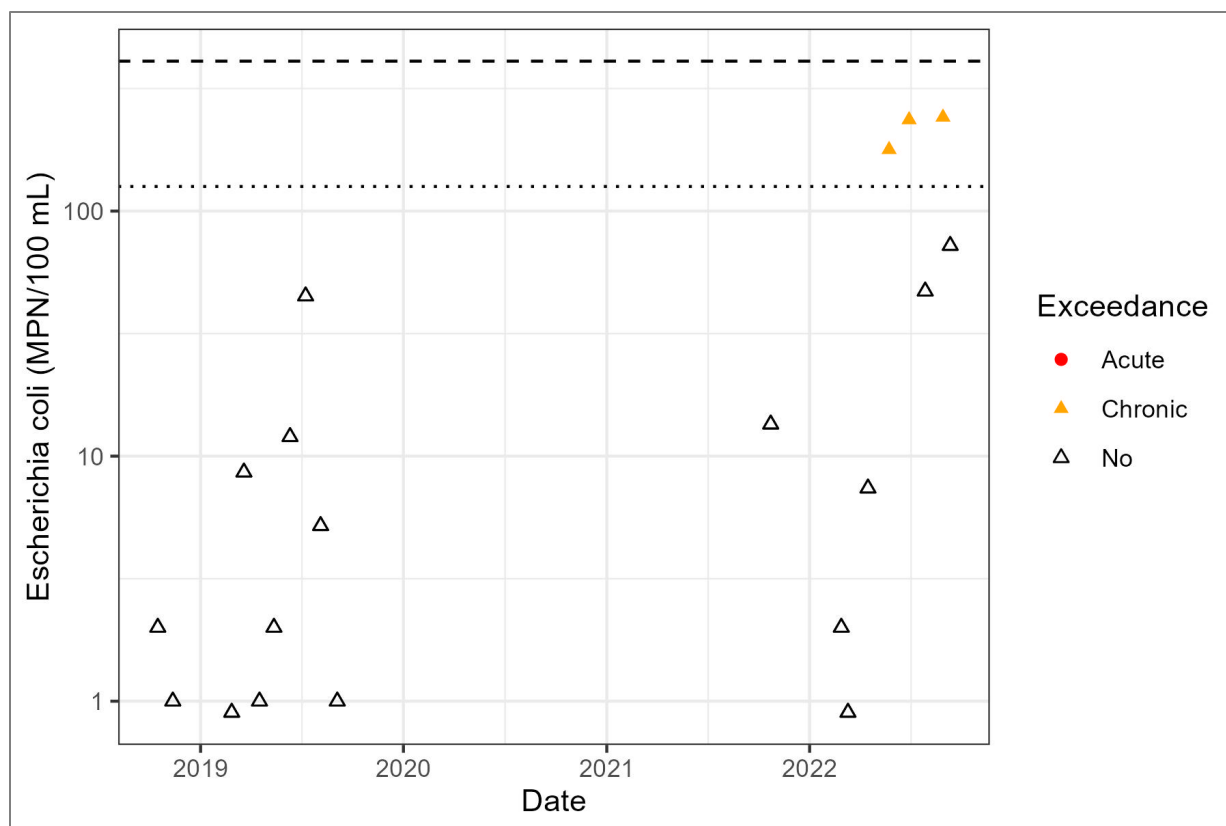


Figure 14. *E. coli* concentrations in Courthouse Wash above the Colorado River from water years 2019 to 2022. The dashed lines indicate the chronic standard (126 MPN/100mL) and the acute standard (409 MPN/100 mL) for frequent primary-contact recreation.

3.3 Bryce Canyon National Park

Water quality data evaluated at four sites in Bryce Canyon NP indicated that 1,361 (99%) of the 1,371 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

One of the four sites had a parameter that did not meet standards for 10% or greater of the evaluations, with 4–20 parameters evaluated per site (Figure 15, Table 6). At Yellow Creek, *E. coli* did not meet infrequent primary-contact recreation criteria (e.g., wading, fishing) on two occasions, one of which was also greater than the acute criterion (Table 7).

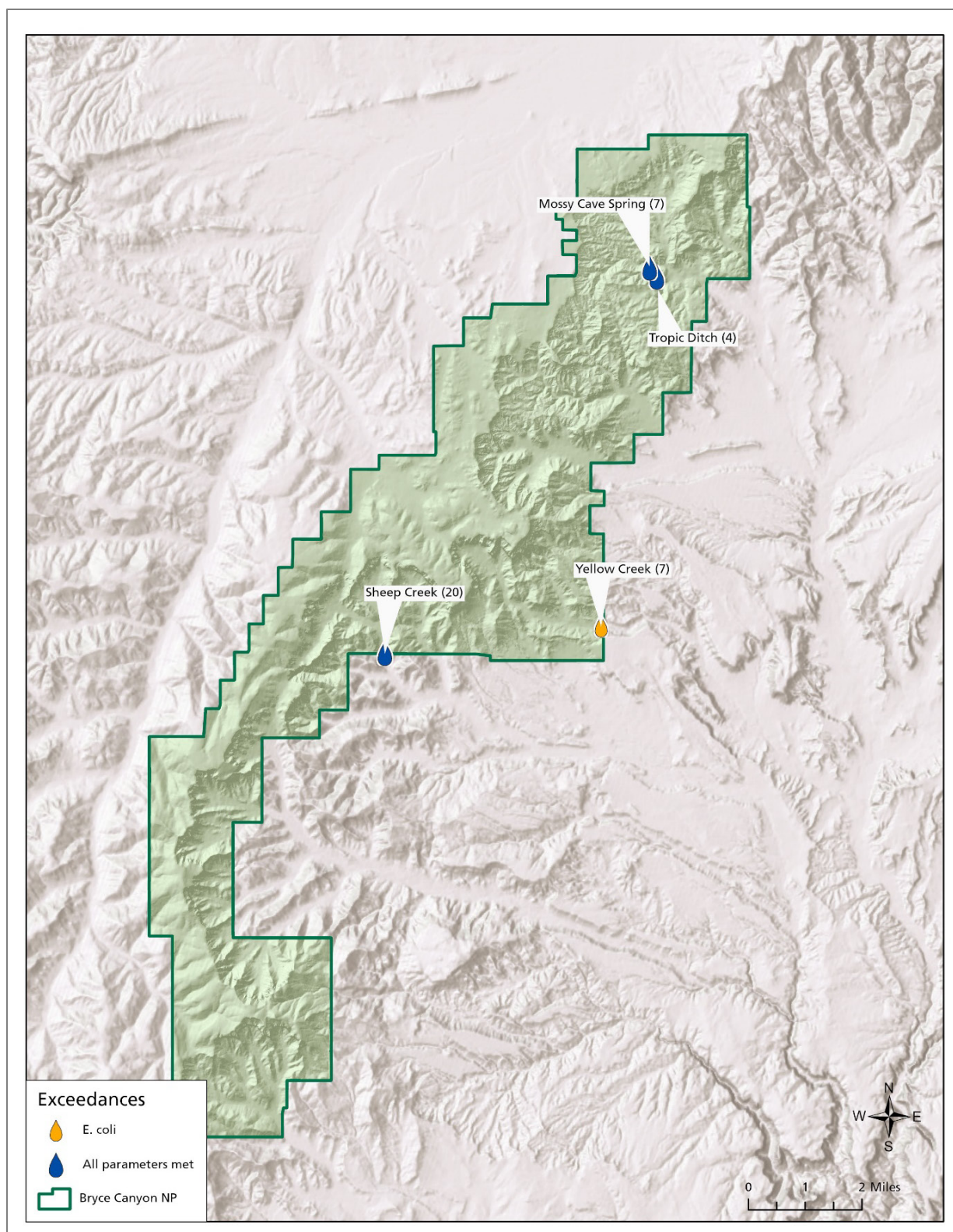


Figure 15. Water quality monitoring locations in Bryce Canyon National Park evaluated in this report, with number of parameters evaluated per station in parentheses and standards not met >10% of the time listed in the legend.

Table 6. Stations evaluated in Bryce Canyon NP with number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Mossy Cave Spring	7	0	0
Tropic Ditch	4	0	0
Sheep Creek	20	0	0
Yellow Creek	7	1	14

Table 7. Stations evaluated in Bryce Canyon NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Yellow Creek	<i>Escherichia coli</i> (MPN/100 mL)	UT_2B chronic	206	18	2	11

3.3.1 Mossy Cave Spring

Dissolved oxygen, *E. coli*, pH, water temperature, TDS, ammonia, and phosphorus met state water quality standards. Samples for trace elements were only collected seven times during the period of record, and all the samples met state water quality standards.

3.3.2 Tropic Ditch

Dissolved oxygen, *E. coli*, pH, and water temperature met state water quality standards. This site is located within Water Canyon, which serves as an irrigation canal to bring water to the valley below, and sampling at this site was suspended in 2022 after analysis suggested it was not relevant to sampling at a nearby spring (Weissinger 2022). This site will not be included in future reports.

3.3.3 Sheep Creek

All evaluated parameters met state water quality standards. Evaluated parameters include dissolved oxygen, *E. coli*, pH, water temperature, TDS, ammonia, phosphorus, and 13 trace elements.

3.3.4 Yellow Creek

Dissolved oxygen, pH, water temperature, TDS, ammonia, and phosphorus met state water quality standards. Samples for trace elements were only collected seven times during the period of record, and all the samples met state water quality standards. Two of the eighteen samples at Yellow Creek did not meet the chronic *E. coli* standard for infrequent primary-contact recreation. One of the samples also did not meet the acute standard (Figure 16). It was noted on each of these visits, in June 2021 and June 2022, that there were cattle tracks and fresh cattle manure at the site, although the park boundary fence was intact. Manure was also noted in the stream in July 2021, but *E. coli* concentrations met standards during that visit. 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.

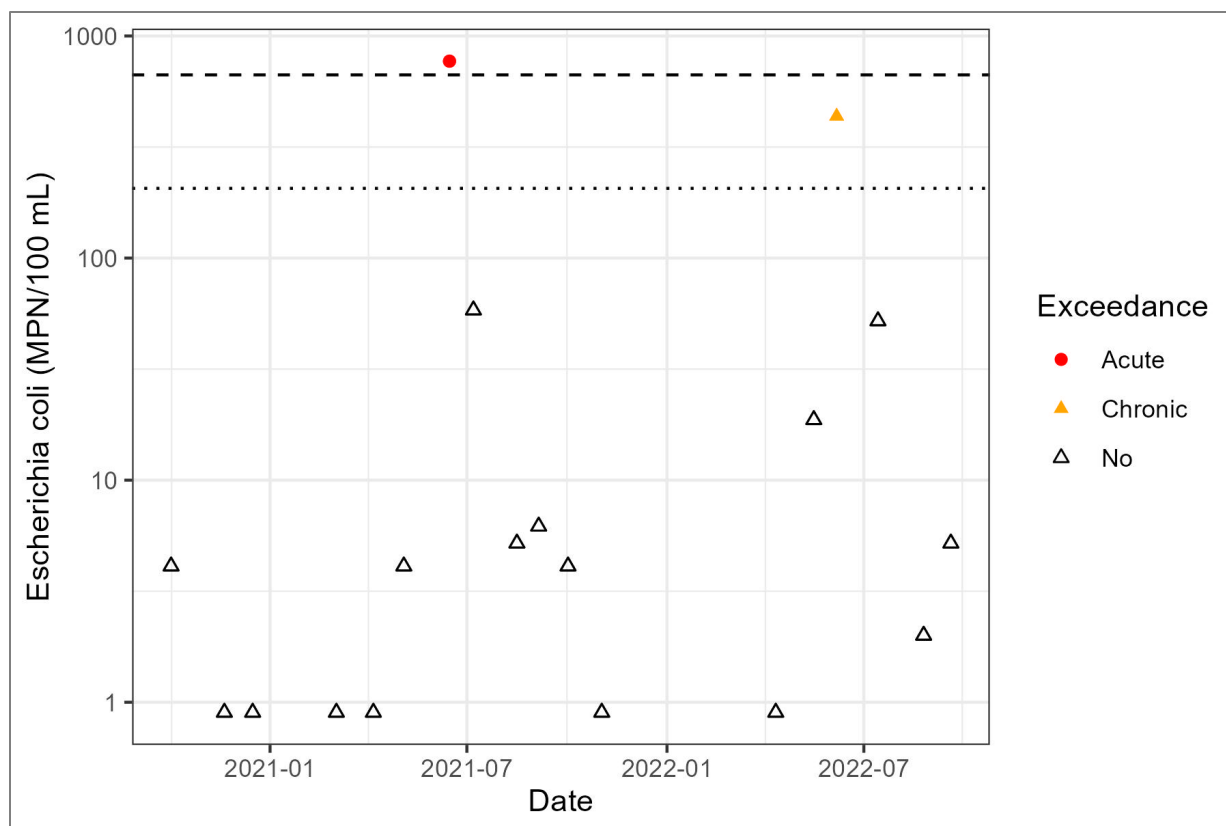


Figure 16. *E. coli* concentrations in Yellow Creek from water years 2021–2022. Site was not sampled during water years 2019–2020. The dashed lines indicate the chronic standard (206 MPN/100 mL) and the acute standard (668 MPN/100 mL) for infrequent primary-contact recreation.

3.4 Canyonlands National Park

Water quality data evaluated at seven sites in or near Canyonlands NP indicated that 5,478 (96%) of the 5,733 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

One of the seven sites had one parameter that did not meet standards for 10% or greater of the evaluations, with 1–21 parameters evaluated per site (Figure 17, Table 8). The only parameter of concern is water temperature at the Colorado River below Brown Betty Rapid (Table 9). Phosphorus regularly exceeded interim criteria for additional evaluation, but indicators of impairment such as low dissolved oxygen and algal blooms were not observed. Selenium met Utah water quality standards, but selenium results are not consistent with upstream sites sampled by the USGS. Selenium remains a concern in the Colorado River basin because of its effects on long-lived native fish species, many of which are endangered.

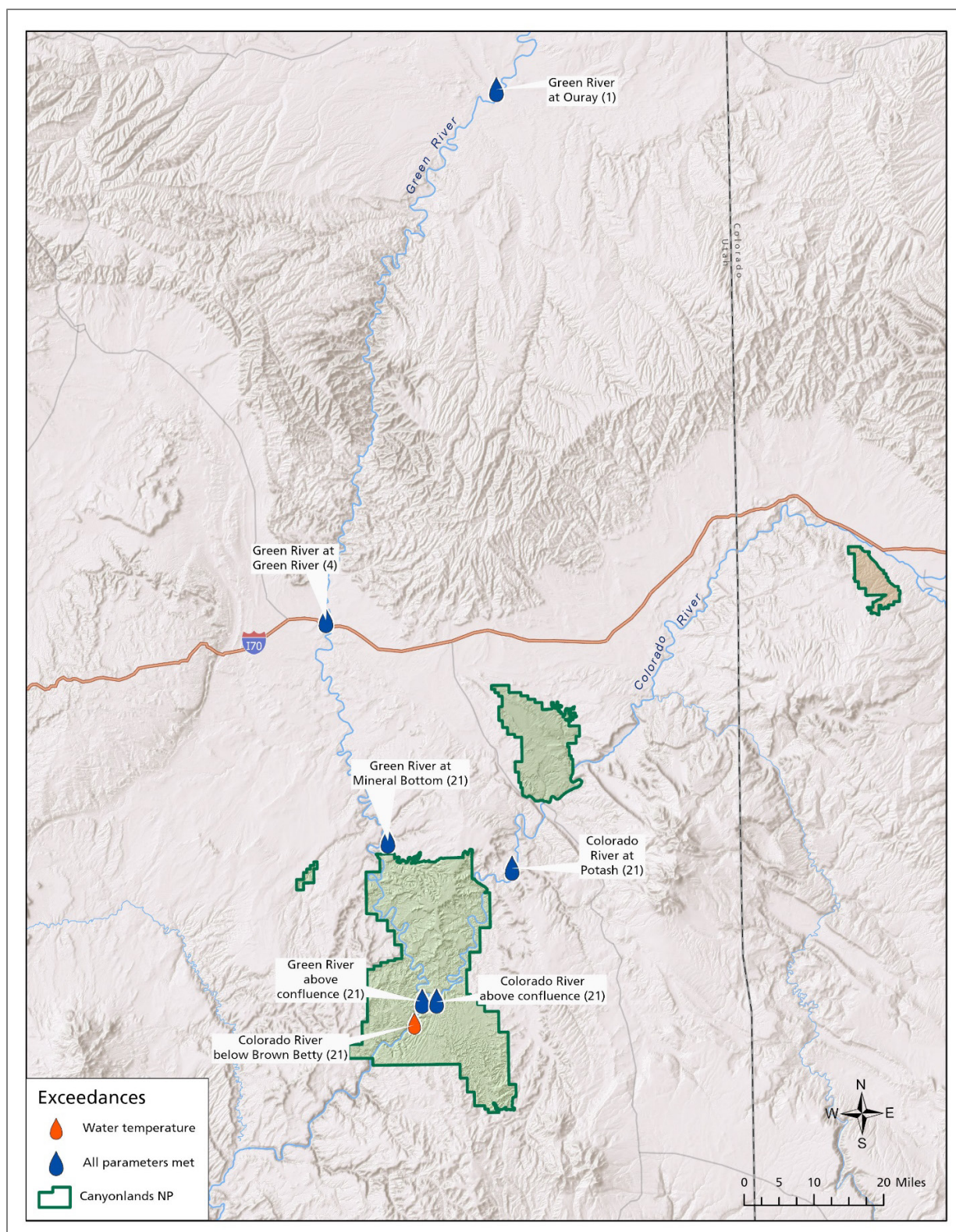


Figure 17. Water quality monitoring locations in and near Canyonlands NP evaluated in this report, with number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 8. Stations evaluated in and near Canyonlands NP with number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Colorado River at Potash	21	0	0
Colorado River above confluence	21	0	0
Green River at Ouray	1	0	0
Green River at Green River	4	0	0
Green River at Mineral Bottom	21	0	0
Green River above confluence	21	0	0
Colorado River below Brown Betty Rapid	21	1	5

Table 9. Stations evaluated in and near Canyonlands NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Colorado River below Brown Betty Rapid	Water temperature (deg C)	UT_3B	27	32	4	12

3.4.1 Colorado River at Potash

Trace elements, ammonia, dissolved oxygen, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.4.2 Colorado River above the confluence with the Green River

Trace elements, ammonia, dissolved oxygen, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.4.3 Green River at Ouray

Water temperature, the only parameter available for evaluation, met state water quality standards.

3.4.4 Green River at Green River

Fluoride, TDS, pH, and water temperature met state water quality standards.

3.4.5 Green River at Mineral Bottom

Trace elements, ammonia, dissolved oxygen, pH, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.4.6 Green River above the confluence with the Colorado River

Trace elements, ammonia, dissolved oxygen, pH, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.4.7 Colorado River below Brown Betty Rapid

Trace elements, ammonia, dissolved oxygen, pH, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment. The water temperature was greater than the Utah warm-water aquatic life criteria in 4 of 32 occasions. The water temperature in the Colorado River generally increases from upstream to downstream sites (Figure 18). Water temperatures are likely to increase further as air temperatures rise due to climate change.

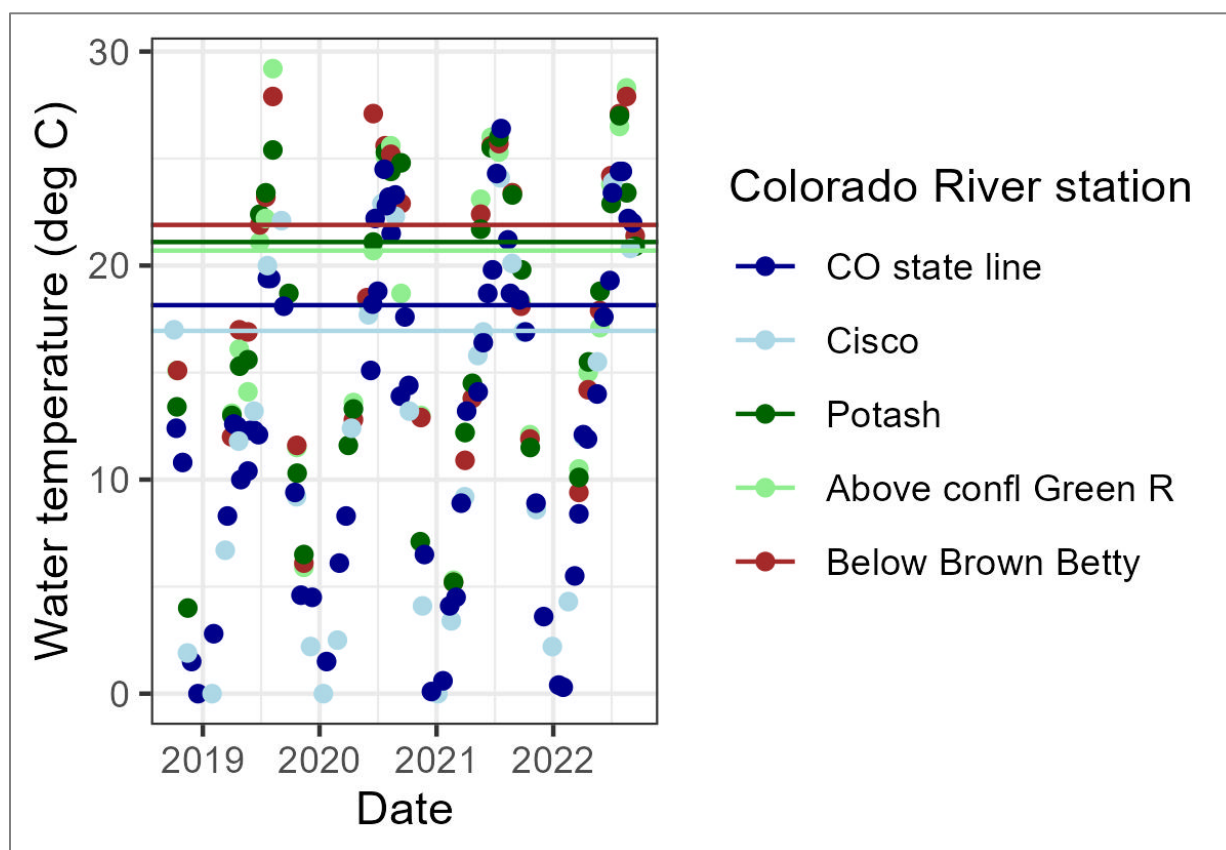


Figure 18. Colorado River water quality stations from the Colorado state line through Canyonlands NP with the median April – October water temperature for each site marked as a line of the corresponding color.

3.4.8 Selenium in the Colorado River from the Colorado-Utah state line through Canyonlands NP

Selenium concentrations in the Colorado River have been of concern for several decades. The Colorado River in Utah, from the Colorado state border to the confluence with the Green River within Canyonlands NP, was listed as impaired for selenium in 2006 under the Clean Water Act (UDEQ 2014). This listing was based in part on water chemistry samples collected by the NPS at two sites: the Colorado River at Potash and the Colorado River above the confluence with the Green River. From 2000 to 2010, 40 of 149 samples collected at four locations in the affected reach exceeded the state water quality standard of 4.6 $\mu\text{g/L}$ (UDEQ 2014).

All stations within Canyonlands NP reported selenium concentrations below analytical reporting limits from water years 2018 to 2022. However, a comparison of reported concentrations over time shows unexpected variation (Figure 19). An upstream location at the Colorado-Utah state line, sampled by the USGS and processed at the NWQL, has remained relatively consistent over time, with a median concentration of 4.0 $\mu\text{g/L}$ from water years 2000 to 2012 and 2.9 $\mu\text{g/L}$ from water years 2013 to 2021 (see Arches NP section of this report). The Canyonlands NP stations, collected by NPS staff, and processed at the Utah Public Health Laboratory (UPHL), had similar medians during water years 2000–2012, with slight decreases as one proceeds downstream. Concentrations from 2006 to 2012 were regularly above the 4.6 $\mu\text{g/L}$ standard for aquatic life at the Colorado River at Potash and the Colorado River above the confluence sites (Van Grinsven et al. 2010; Hackbarth and Weissinger 2013). However, beginning in water year 2013, NPS sites are comprised of almost entirely non-detectable concentrations below the reporting limit of 1.0 $\mu\text{g/L}$, while reported concentrations at the upstream USGS site do not show a similar decrease. The change in reported concentrations from the UPHL corresponded to a laboratory method change, which is detailed in Appendix E.

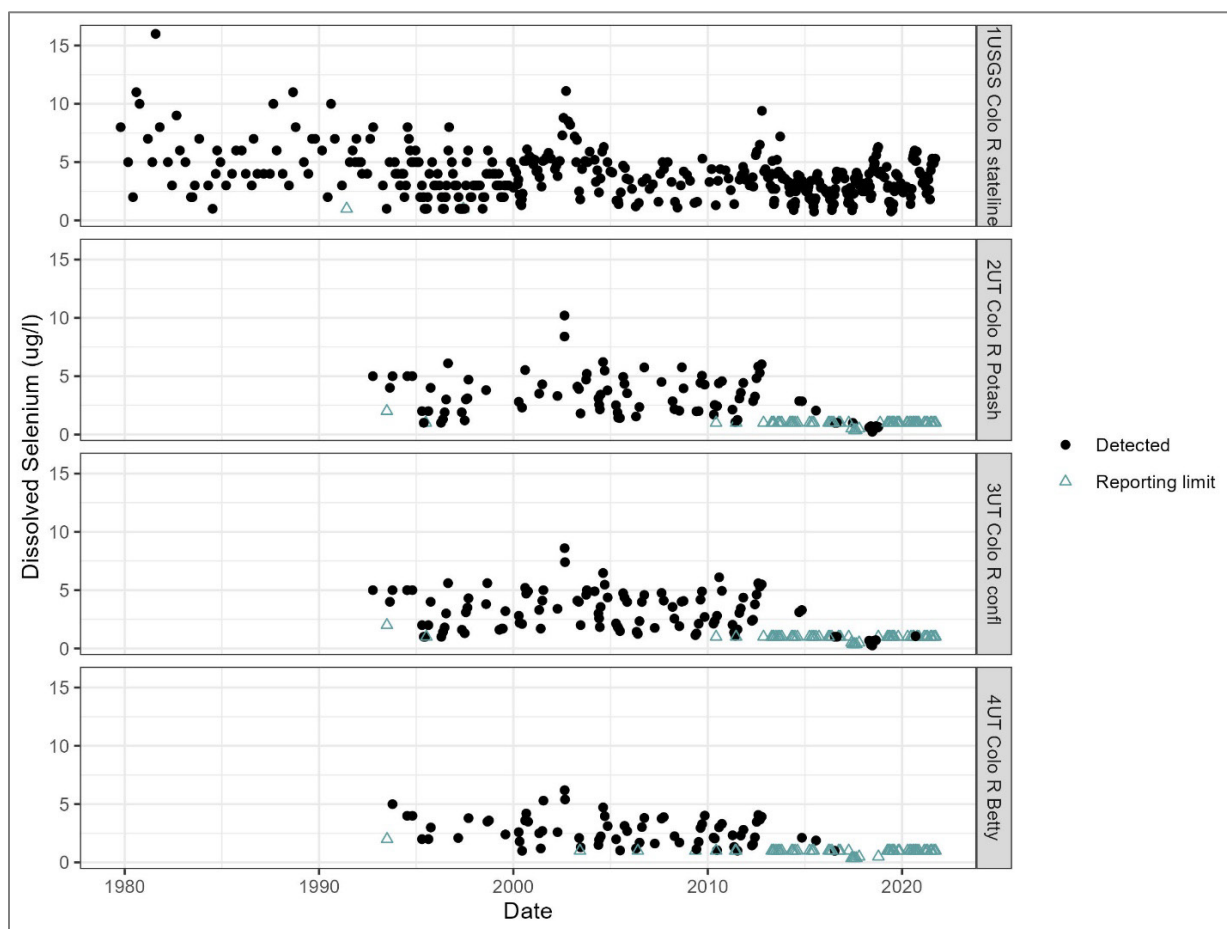


Figure 19. Reported concentrations of selenium at four water quality stations on the Colorado River, from upstream (top) to downstream (bottom). Concentrations reported below the reporting limit are plotted as hollow triangles at the reporting limit.

Resolving discrepancies between the UPHL and NWQL, as well as between two analytical methods used by the UPHL, is beyond the scope of this report. Given the available evidence, it is likely that the abrupt change to non-detectable concentrations at Canyonlands NP stations is a result of analytical method modifications rather than a true change in the condition in the Colorado River. The concentration of selenium in the Colorado River is subject to analytical uncertainty.

Based on other investigations, it is very likely that selenium concentrations have decreased over time in the Colorado River through Canyonlands NP. The primary source of added selenium in this river segment is agricultural irrigation in soils derived from the Mancos Shale, particularly in the Grand Valley and Gunnison River basin, both located upstream in the state of Colorado. The Dolores River, which joins the Colorado River near Dewey Bridge, also contributes excess selenium to the system (UDEQ 2014). Evidence from upstream of Canyonlands NP suggests that selenium concentrations are decreasing over time. From water years 1980 to 2017, dissolved selenium concentration at the Colorado River near the state line decreased by 3.8 µg/L, a 56% decrease (Miller et al. 2021). The downward trend was consistent across the seasons and was also observed in selenium loading. Downward trends in selenium loads have also been recorded further upstream in both the Colorado and Gunnison Rivers (Mayo and Leib 2012; Henneberg 2016).

In a 50-year retrospective analysis of fish tissue from the upper Colorado River basin, most (37 of 42) species and almost half of the individuals (827 of 1720), including endangered species such as the Colorado pikeminnow and the razorback sucker, exceeded selenium benchmarks (Day et al. 2020). Similarly, downstream of Canyonlands NP, invertebrates and fish throughout the Grand Canyon segment of the Colorado River regularly exceeded exposure risk thresholds (Walters et al. 2015). Because endangered fish in the system are long-lived and roam over large areas, selenium concentrations in the Colorado River should remain a concern for park managers. The states of Colorado and Utah have reduction plans in place.

3.5 Capitol Reef National Park

Water quality data evaluated at nine sites in or near Capitol Reef NP indicated that 4,784 (97%) of the 4,953 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

Seven of the nine sites had at least one parameter that did not meet standards for 10% or greater of the evaluations or were higher than threshold values for additional investigation, with 6–22 parameters evaluated per site (Figure 20, Table 10). The most common parameters of concern are *E. coli*, water temperature, and TDS (Table 11). Phosphorus regularly exceeded interim criteria for additional evaluation, but indicators of impairment such as low dissolved oxygen and algal blooms were only observed in Mill Meadow Reservoir in the upper Fremont River watershed. Reduction plans are in place for the Fremont River for phosphorus upstream of Capitol Reef NP (UDEQ 2002), *E. coli* upstream and within Capitol Reef NP (UDEQ 2020), and TDS downstream of Capitol Reef NP (UDEQ 2002).

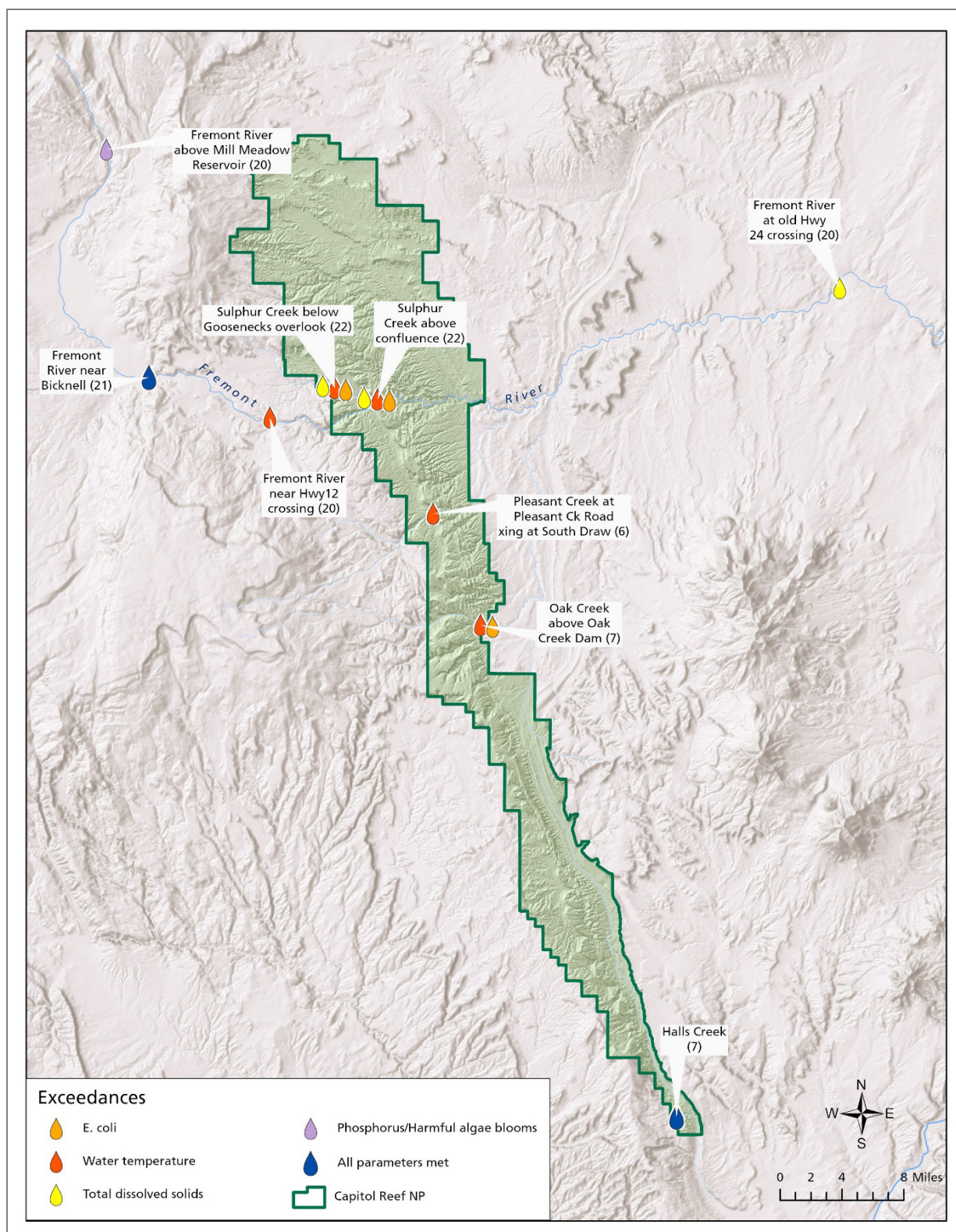


Figure 20. Water quality monitoring locations in and near Capitol Reef National Park evaluated in this report, with the number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 10. Stations evaluated in and near Capitol Reef NP with number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Fremont River above Mill Meadow Reservoir	20	1	5
Fremont River at Highway 12 crossing	20	1	5
Fremont River near Bicknell	21	0	0
Fremont River at old Highway 24 crossing	20	1	5
Sulphur Creek below Goosenecks overlook	22	3	14
Sulphur Creek above confluence	22	3	14
Pleasant Creek at Pleasant Creek Road crossing at South Draw	6	1	17
Oak Creek above Oak Creek Dam	7	2	29
Halls Creek	7	0	0

Table 11. Stations evaluated in and near Capitol Reef NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Fremont River above Mill Meadow Reservoir	Phosphorus (mg/L)	UT_2A, UT_3A	0.05	13	3	23
Fremont River at Highway 12 crossing	Water temperature (deg C)	UT_3A	20	14	2	14
Fremont River at old Highway 24 crossing	Total dissolved solids (mg/L)	UT_4	1200	12	5	42
Sulphur Creek below Goosenecks overlook	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	39	7	18
Sulphur Creek below Goosenecks overlook	Escherichia coli (MPN/100 mL)	UT_1C chronic	206	39	4	10
Sulphur Creek below Goosenecks overlook	Total dissolved solids (mg/L)	UT_4	1200	39	11	28
Sulphur Creek below Goosenecks overlook	Water temperature (deg C)	UT_3A	20	39	6	15
Sulphur Creek above confluence	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	39	4	10
Sulphur Creek above confluence	Total dissolved solids (mg/L)	UT_4	1200	39	11	28
Sulphur Creek above confluence	Water temperature (deg C)	UT_3A	20	39	12	31

Table 11 (continued). Stations evaluated in and near Capitol Reef NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Pleasant Creek at Pleasant Creek Road crossing at South Draw	Water temperature (deg C)	UT_3A	20	20	3	15
Oak Creek above Oak Creek Dam	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	15	3	20
Oak Creek above Oak Creek Dam	Escherichia coli (MPN/100 mL)	UT_1C chronic	206	15	2	13
Oak Creek above Oak Creek Dam	Water temperature (deg C)	UT_3A	20	15	2	13

3.5.1 Fremont River above Mill Meadow Reservoir

Trace elements, ammonia, dissolved oxygen, pH, water temperature, and TDS met state water quality standards. This site exceeded the frequent primary-contact recreation and cold-water aquatic life threshold for additional investigation for phosphorus in 23% of the evaluations. This section of river and the reservoir immediately downstream, Mill Meadow Reservoir, were listed as impaired for phosphorus in 1998 (UDEQ 2002). Dissolved oxygen at the site met standards on all evaluations, but harmful algal blooms were noted in Mill Meadow Reservoir in 2018 and 2019. The state reduction plan for Mill Meadow Reservoir identified fish hatcheries and livestock grazing, particularly manure in the low water zone that is submerged by snowmelt in spring, as likely sources of excess anthropogenic inputs of phosphorus into the system (UDEQ 2002). Sections of the Fremont River are dewatered between Mill Meadow Reservoir and the town of Bicknell and therefore water quality problems in the upper Fremont River watershed most likely do not affect water quality conditions downstream and within the park.

3.5.2 Fremont River at Highway 12 crossing and Fremont River near Bicknell

The Fremont River at the Highway 12 crossing met state water quality standards for trace elements, ammonia, dissolved oxygen, pH, and TDS. This site did not meet the cold-water aquatic life water temperature criteria for 14% of the evaluations. High phosphorus concentrations were not associated with additional indicators of impairment. The Fremont River near Bicknell met all water quality standards for trace elements, nutrients, dissolved oxygen, pH, water temperature, and TDS.

The Fremont River at the Highway 12 crossing and the Fremont River near Bicknell are located upstream of Capitol Reef NP and are adjacent to rural and agricultural land uses. Neither site met the threshold for 10 sampling events within the four-year period, but they are part of the UDEQ monitoring for fecal indicator bacteria (*E. coli*) concentrations in the Fremont River. *E. coli* was sampled nine times at the Fremont River at the Highway 12 crossing and eight times at the Fremont River near Bicknell. *E. coli* concentrations at these two sites regularly did not meet the chronic standard for frequent primary-contact recreation from water years 2019 to 2022 (Figure 21). In

addition, *E. coli* concentrations exceeded the acute criterion for frequent primary-contact recreation for two of the nine visits at the Highway 12 site.

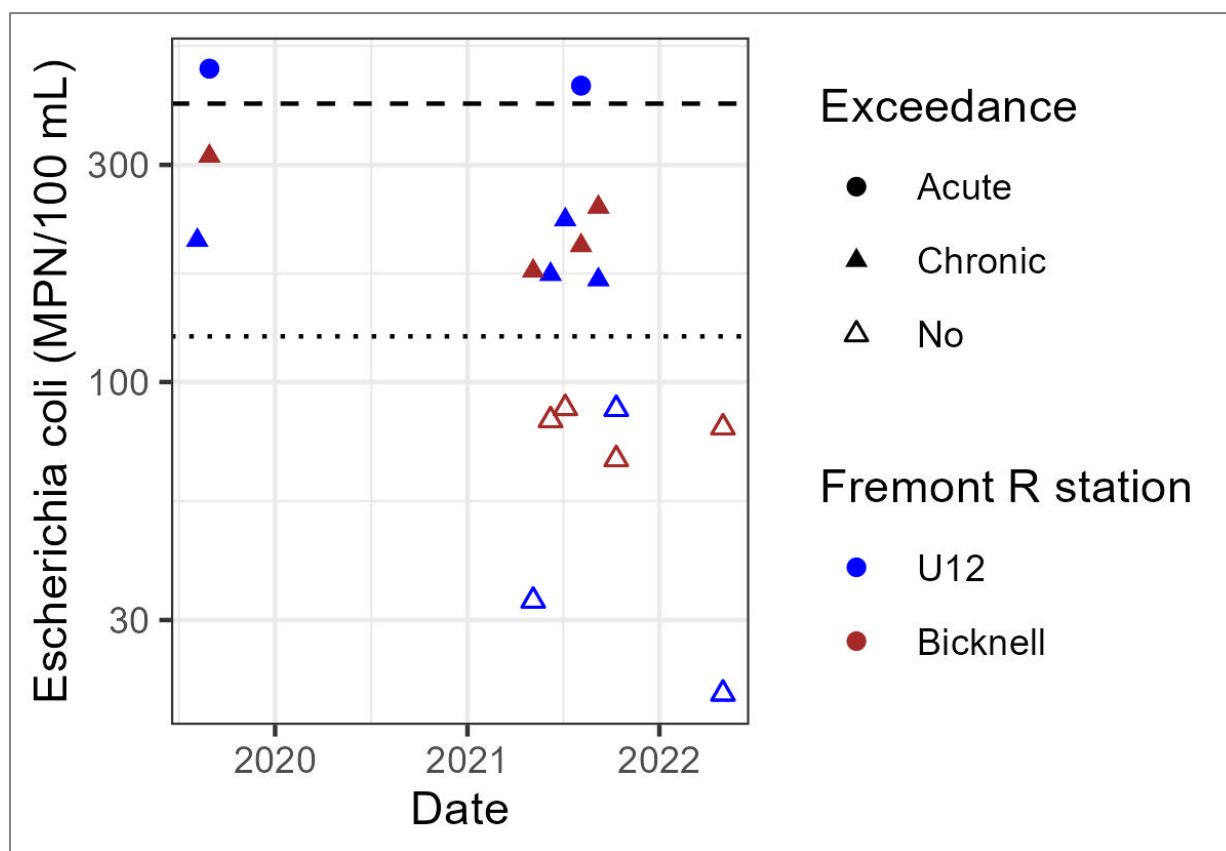


Figure 21. Geometric mean of *E. coli* concentrations at two stations upstream of Capitol Reef NP on the Fremont River from water years 2019 to 2022. The dashed lines indicate the chronic standard (126 MPN/100 mL) and the acute standard (409 MPN/100 mL) for frequent primary-contact recreation.

Investigations by the UDEQ found that exceedances of the frequent primary-contact recreation standard for *E. coli* are common during the recreation season months, specifically July and August, and are driven primarily by grazing of livestock (74% of load) and wildlife (25% of load) in close proximity to the river (UDEQ 2020). The UDEQ identified sources such as animal feedlots, overgrazed pastureland, and irrigation return flows as resource concerns. A plan to reduce *E. coli* loading to the Fremont River was implemented in 2020. The state employs a voluntary adaptive management approach to address all anthropogenic sources of *E. coli* loading, with a focus on improvements to failing septic systems and grazing and irrigation management.

3.5.3 Fremont River at old Highway 24 crossing

This station is located well downstream of Capitol Reef NP. Trace elements, ammonia, dissolved oxygen, pH, and water temperature met water quality standards. High phosphorus concentrations were not associated with additional indicators of impairment. The agricultural standard for TDS was not met for 42% of the evaluations. In the lower Fremont River, TDS can be primarily attributed to

high concentrations of salts within the units of the Mancos Shale and the Carmel formation (UDEQ 2002). A state reduction plan is in place that focuses on capping artesian wells from high-salinity aquifers and lining irrigation ditches (UDEQ 2002). Because of intervening geology, land uses, and distance, water quality conditions at this site are likely not representative of water quality conditions within the park.

3.5.4 Sulphur Creek

Sulphur Creek is monitored at two locations within the park including an upper site near the park boundary and a lower site in the park developed area. These stations were established to help determine whether park infrastructure and activities could be contributing to water quality issues in the creek. Trace elements, ammonia, dissolved oxygen, and pH met water quality standards. High phosphorus concentrations were not associated with additional indicators of impairment. These sites did not meet the standards for *E. coli*, water temperature, and TDS.

As reported in previous results (Hackbarth and Weissinger 2018), *E. coli* concentrations in Sulphur Creek tended to be higher during the recreation season and were not necessarily associated with high flow or high turbidity events. Sites were sampled on the same day and had similar concentrations (Figure 22), suggesting that park infrastructure and activities do not substantially increase *E. coli* loading in Sulphur Creek. Orchards in the park are flood irrigated with water diverted from the Fremont River. The irrigation water that passes over the orchards has the potential to carry fecal bacteria, including *E. coli*, into Sulphur Creek (UDEQ 2020).

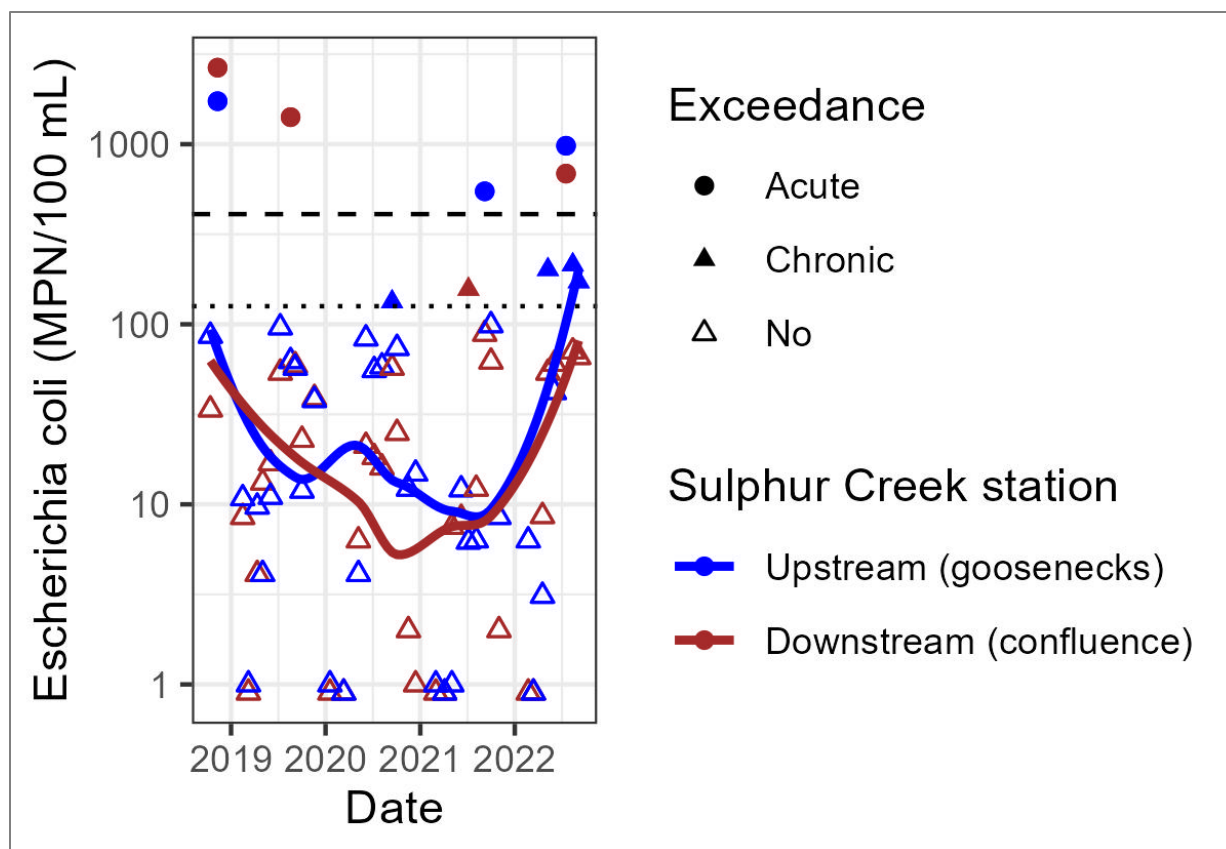


Figure 22. *E. coli* concentrations at two stations on Sulphur Creek from water years 2019 to 2022. The dashed lines indicate the chronic standard (126 MPN/100 mL) and the acute standard (409 MPN/100 mL) for frequent primary-contact recreation. Solid curves are LOESS smooths for each site in their corresponding color.

Both sites did not meet the agricultural use standard for TDS. Exceedances for TDS at Sulphur Creek are consistent with past data (e.g., Hackbarth and Weissinger 2020). Sulphur Creek runs predominantly through the Moenkopi Formation, which is known to contribute naturally high levels of dissolved solids (Doelling et al. 1989). Irrigation inflows and runoff from agricultural activities upstream from and within Capitol Reef NP are a possible anthropogenic source of elevated TDS concentrations. The two sites on Sulphur Creek tended to have very similar TDS concentrations (Figure 23), suggesting park activities do not substantially increase TDS in Sulphur Creek.

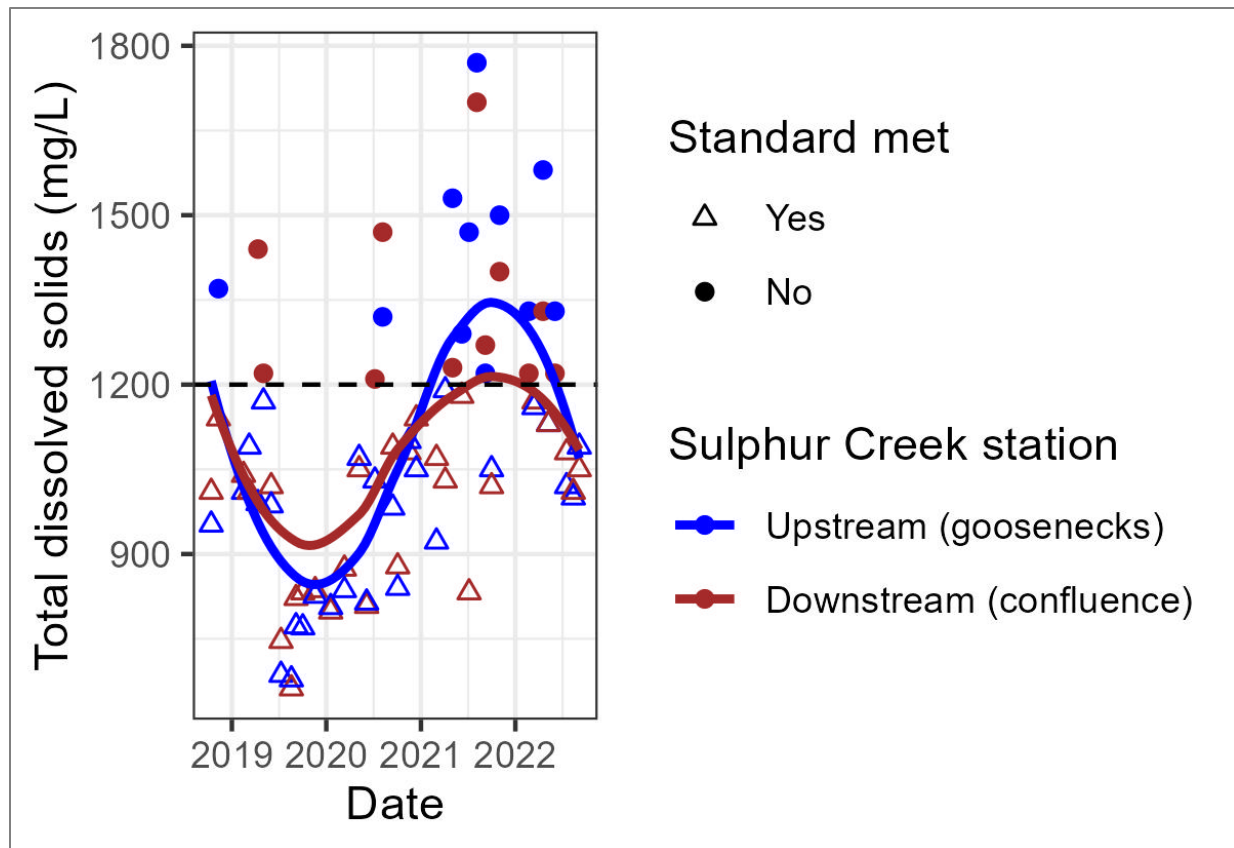


Figure 23. Total dissolved solids concentrations at two stations on Sulphur Creek from water years 2019 to 2022. The dashed line indicates the agricultural standard of 1200 mg/L. Solid curves are LOESS smooths for each site in their corresponding color.

Water temperatures tended to be higher at the downstream location on Sulphur Creek (Figure 24). Shallow irrigation ditches and return flows could contribute to warmer water temperatures, while instream flow also warms from exposure to warm air temperatures as it travels farther downstream from groundwater inflows.

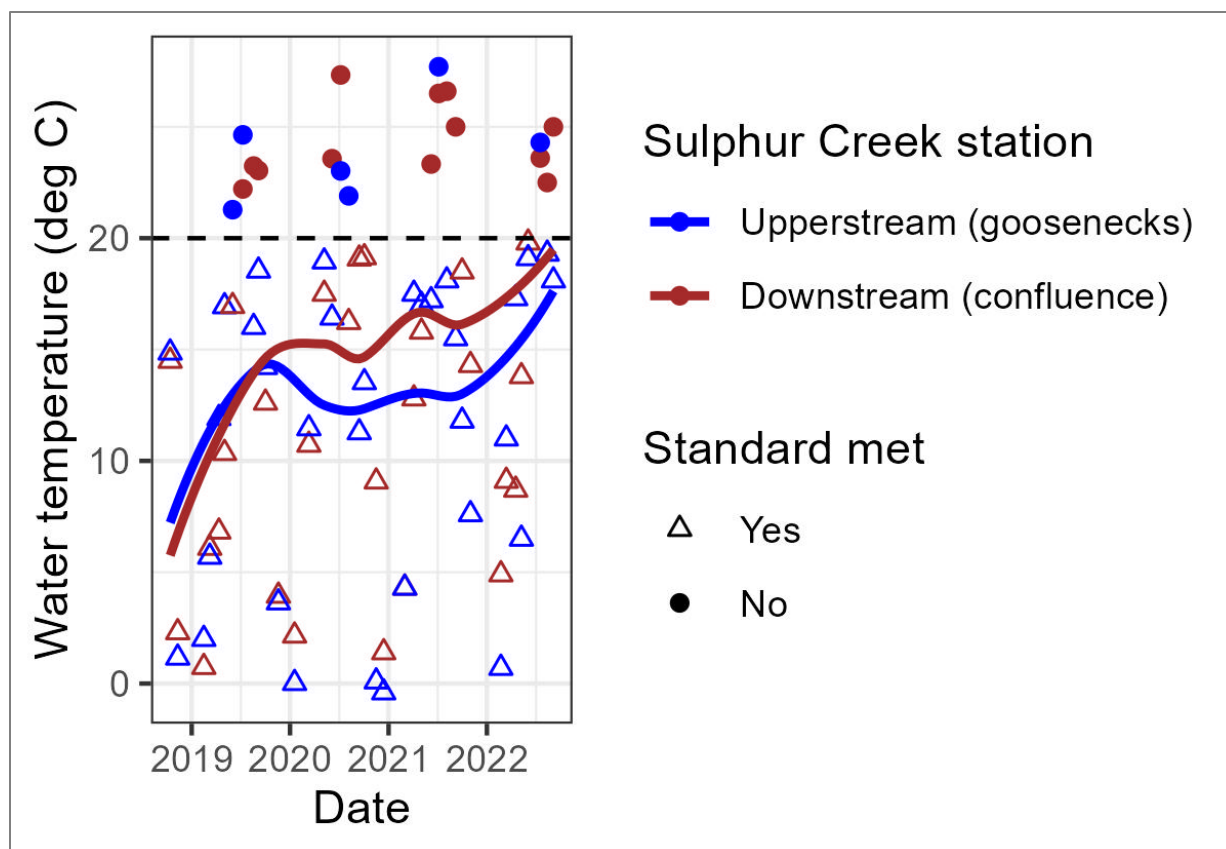


Figure 24. Water temperature at two stations on Sulphur Creek from water years 2019 to 2022. The dashed line indicates the cold-water aquatic life standard of 20°C. Solid curves are LOESS smooths for each site in their corresponding color.

3.5.5 Pleasant Creek at Pleasant Creek Road crossing at South Draw

Ammonia, dissolved oxygen, *E. coli*, and pH met state water quality standards. Samples for trace elements were only collected eight times during the period of record, and all the samples met state standards. High phosphorus concentrations did not coincide with additional indicators of impairment. Water temperature did not meet the cold-water aquatic life criteria on three occasions over a two-year period. This station is located at an elevation of approximately 1,801 m (5,910 ft), well downslope of the headwaters of Pleasant Creek on Boulder Mountain. This semi-arid location may be more appropriately classified as a warm water reach.

3.5.6 Oak Creek above Oak Creek Dam

Ammonia, dissolved oxygen, pH, and TDS met state water quality standards. Samples for trace elements were only collected six times during the period of record, and all the samples met state standards. High phosphorus concentrations did not coincide with additional indicators of impairment. Water temperature did not meet the cold-water aquatic life criteria on two occasions over a two-year period. This station is located at an elevation of approximately 1,774 m (5,820 ft), well downslope of the headwaters of Oak Creek on Boulder Mountain. This semi-arid location may be more appropriately classified as a warm water reach.

The chronic *E. coli* criteria for frequent primary-contact recreation was not met on three occasions. Two of the three *E. coli* concentrations were also above the chronic standard for domestic water supply (Figure 25). One sample also exceeded the acute criteria for these standards. Turbid conditions were noted during the acute exceedance, but other exceedances occurred during clear water and low flow conditions. Cattle are moved from lower elevation pastures and up through Oak Creek to pastures on Boulder Mountain in late spring. In the fall, cattle are trailed back through Oak Creek to return to lower elevations. Conditions after cattle trailing can cause damage to riparian areas and degrade water quality. Trespass cattle have been frequently noted along Oak Creek within the park outside of the permitted trailing times. Also, cattle grazing occurs from early June through mid-October on U.S. Forest Service lands upstream of the park.

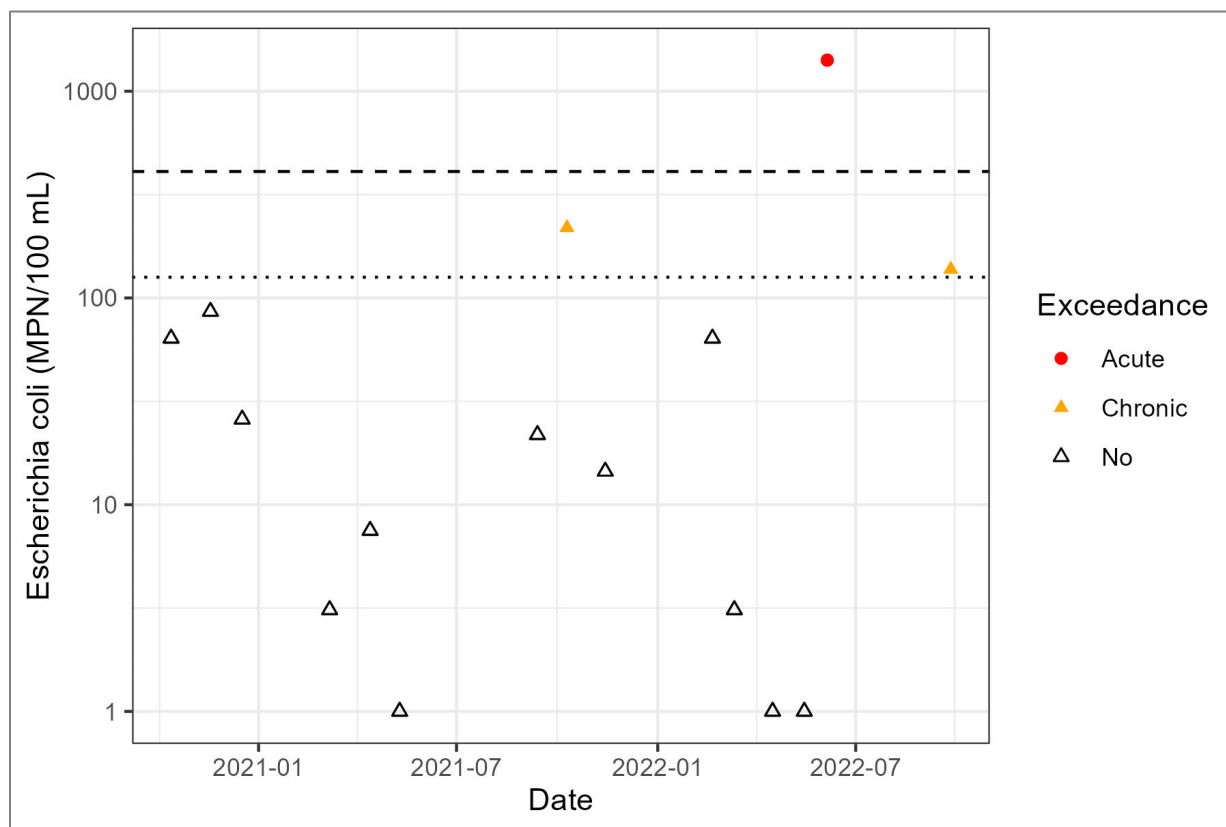


Figure 25. *E. coli* concentrations in Oak Creek above Oak Creek Dam from water years 2021 to 2022. Site was not sampled during water years 2019–2020. The dashed lines indicate the chronic standard (126 MPN/100 mL) and the acute standard (409 MPN/100 mL) for frequent primary-contact recreation.

3.5.7 Halls Creek

Nutrients, dissolved oxygen, *E. coli*, pH, water temperature, and TDS met state water quality standards. Samples for trace elements were only collected six times during the period of record, and all the samples met state standards.

3.6 Dinosaur National Monument

Water quality data evaluated at five sites in or near Dinosaur NM indicated that 2,450 (99%) of the 2,485 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

Three of the five sites had at least one parameter that did not meet standards for 10% or greater of the evaluations, with 1–20 parameters evaluated per site (Figure 26, Table 12). The most common parameter of concern is iron (Table 13).

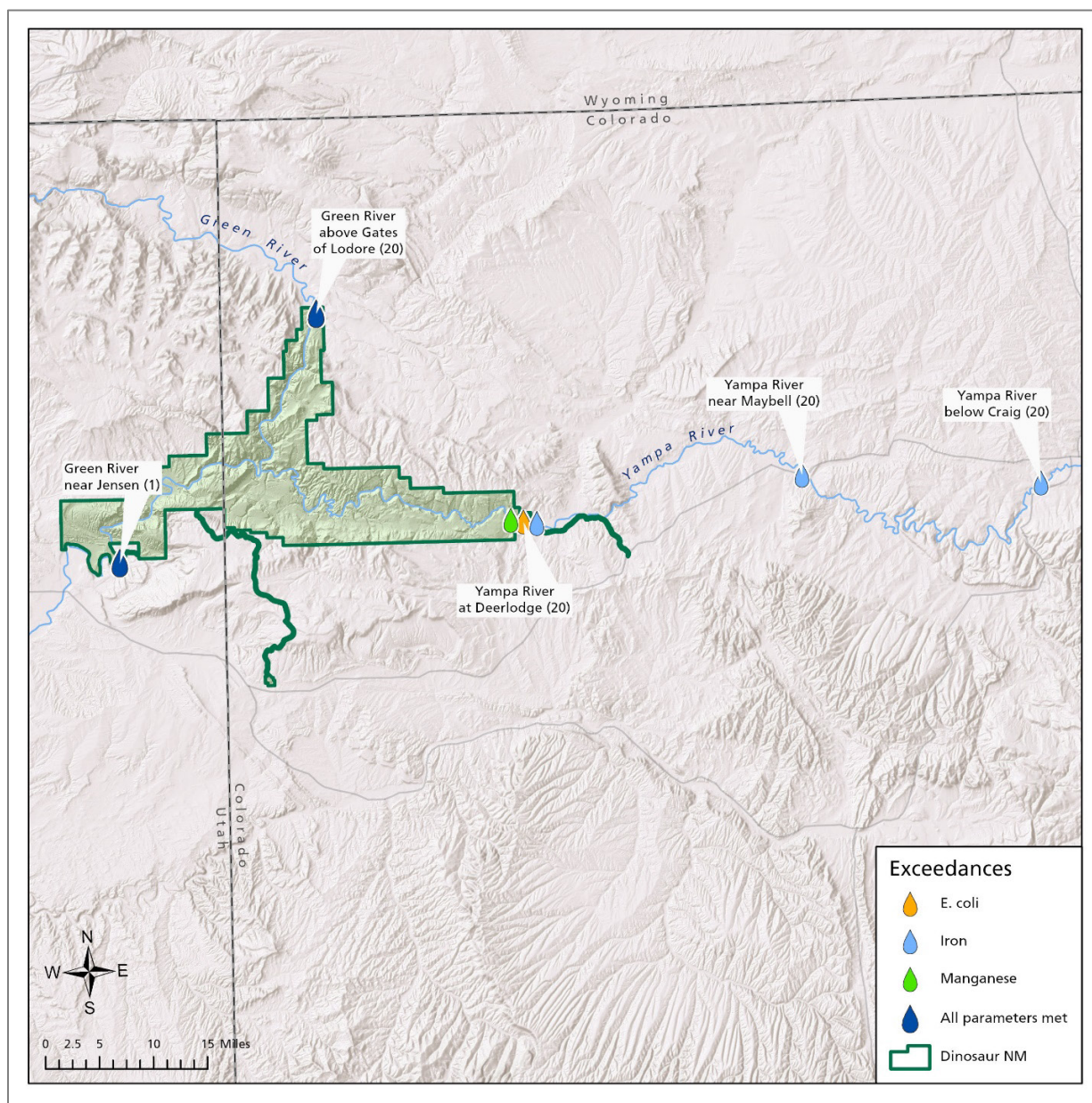


Figure 26. Water quality monitoring locations in and near Dinosaur National Monument evaluated in this report, with the number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 12. Stations evaluated in and near Dinosaur NM with the number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Green River above Gates of Lodore	20	0	0
Yampa River below Craig	20	1	5
Yampa River near Maybell	20	1	5
Yampa River at Deerlodge Park	20	3	15
Green River near Jensen	1	0	0

Table 13. Stations evaluated in and near Dinosaur NM with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Yampa River below Craig	Iron (Trec) (ug/L)	CO_ALWW1	1000	15	2	13
Yampa River near Maybell	Iron (Trec) (ug/L)	CO_ALWW1	1000	22	3	14
Yampa River at Deerlodge Park	Iron (Trec) (ug/L)	CO_ALWW1	1000	14	6	43
Yampa River at Deerlodge Park	Escherichia coli (cfu/100 mL)	CO_RecE	126	15	3	20
Yampa River at Deerlodge Park	Manganese (Trec) (ug/L)	CO_Ag	200	14	2	14

3.6.1 Green River above Gates of Lodore

Trace elements, nutrients, dissolved oxygen, *E. coli*, pH, water temperature, chloride, fluoride, and sulfate met state water quality standards.

3.6.2 Yampa River

Cadmium, copper, lead, selenium, silver, and zinc met state water quality standards. Ammonia, nitrate, and nitrite also met state standards. High phosphorus concentrations were not associated with additional indicators of impairment. Dissolved oxygen, pH, water temperature, chloride, fluoride, and sulfate met state water quality standards. *E. coli* met state standards at sampling locations in Craig and Maybell, Colorado.

All three stations on the Yampa River upstream of Dinosaur NM did not meet the warm-water aquatic life standard for total recoverable iron on 13%, 14%, and 43% of the evaluations as one moves downstream. The Yampa River at Deerlodge Park also did not meet the standard for total recoverable manganese in 14% of the evaluations.

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). 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, and they 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. As in past years, total recoverable iron concentrations in the Yampa River at Deerlodge Park were consistently greater than concentrations observed upstream at Craig, Colorado, indicating that there is a source of iron located between these two sites (Figure 27).

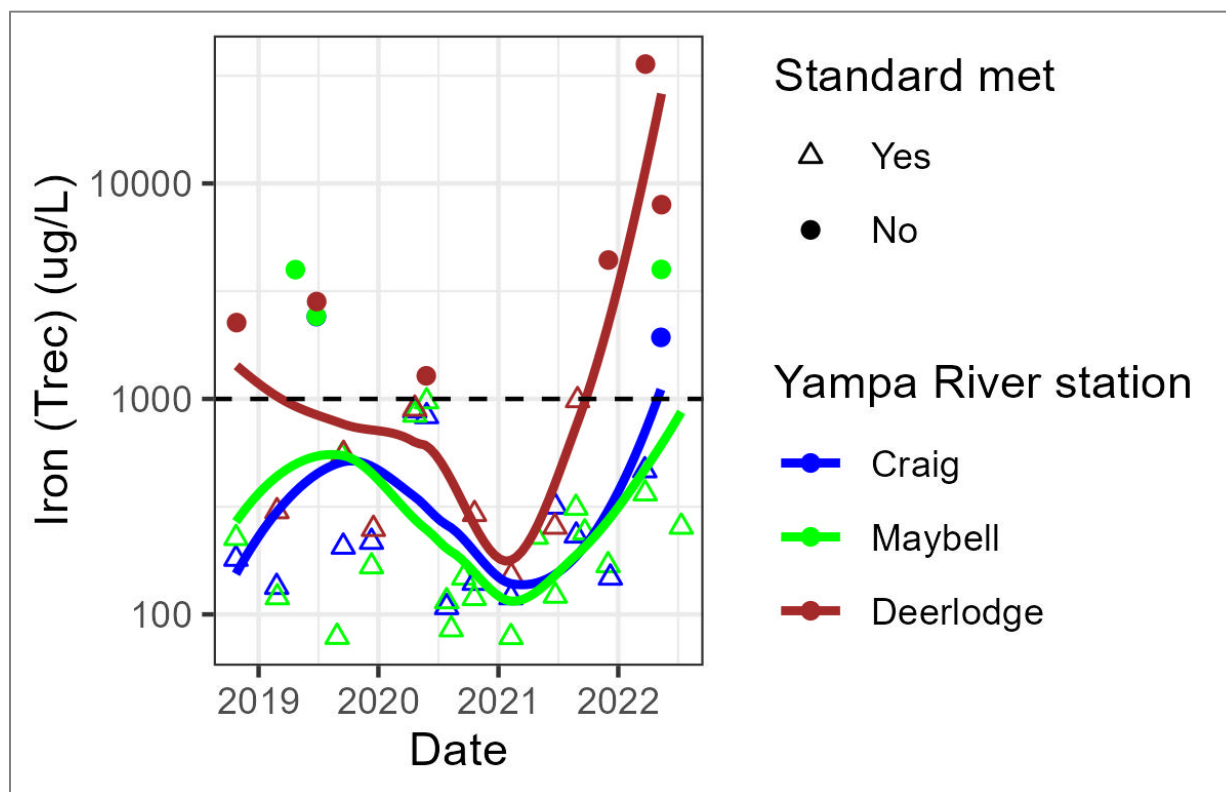


Figure 27. Total recoverable iron concentrations at three stations on the Yampa River. The dashed line indicates Colorado warm-water aquatic life standard of 1000 ug/L. Solid curves are LOESS smooths for each site in their corresponding color. The most downstream station, the Yampa River at Deerlodge Park, had higher concentrations than the two upstream stations.

Fecal indicator bacteria (*E. coli*) did not meet the Colorado primary-contact recreation standard at the Yampa River at Deerlodge Park in 20% of the evaluations (Figure 28). The cause of elevated *E. coli* concentrations at this location has not been investigated. This site includes a boat launch and campground and is located downstream of rural and agricultural land uses in the watershed.

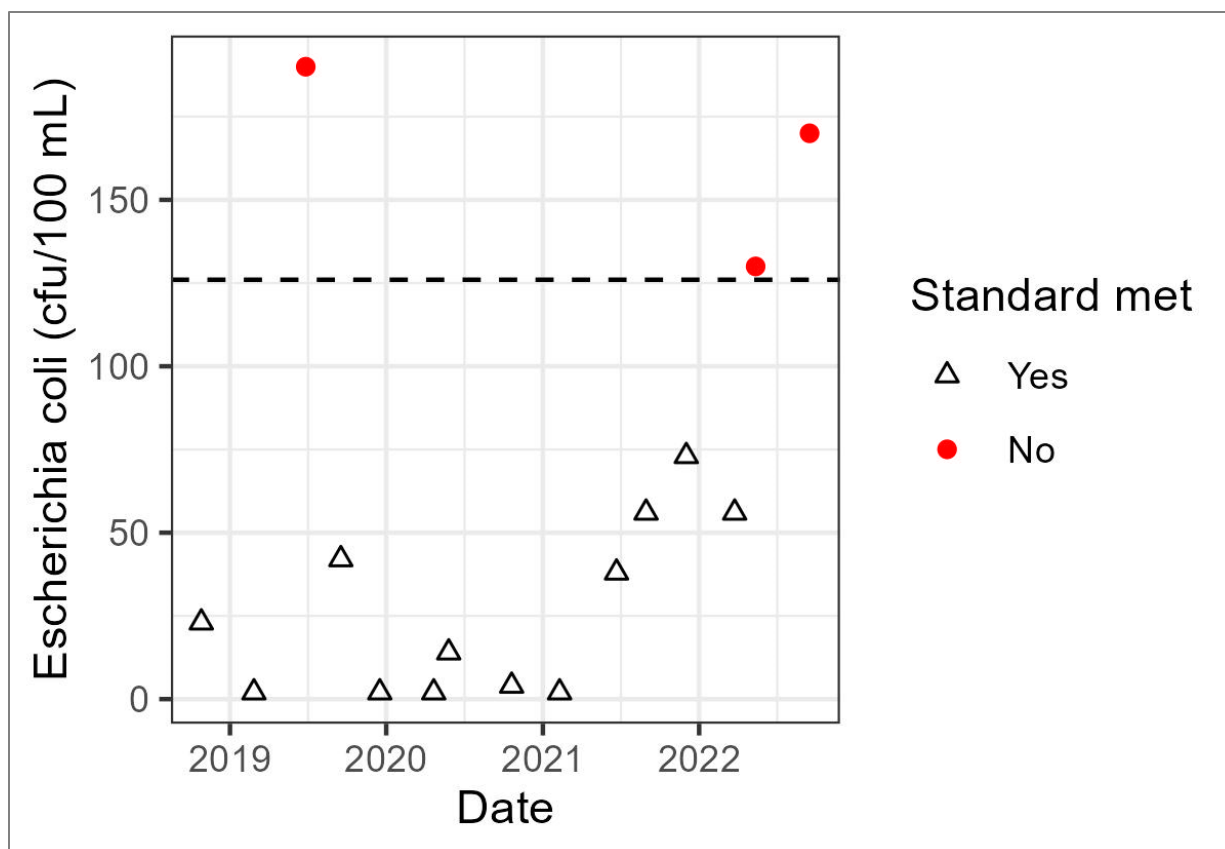


Figure 28. *E. coli* concentrations in the Yampa River at Deerlodge Park from water years 2019 to 2022. The dashed line indicates the Colorado primary-contact recreation standard of 126 cfu/100mL.

3.6.3 Green River near Jensen, Utah

Water temperature, the only parameter available for evaluation, met state water quality standards.

3.7 Hovenweep National Monument

Water quality data evaluated at one site in Hovenweep NM indicated that 289 (86%) of the 338 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

Four of the seven parameters evaluated at Square Tower Spring did not meet standards for 10% or greater of the evaluations or were greater than threshold values for additional investigation (Figure 29, Tables 14 and 15).

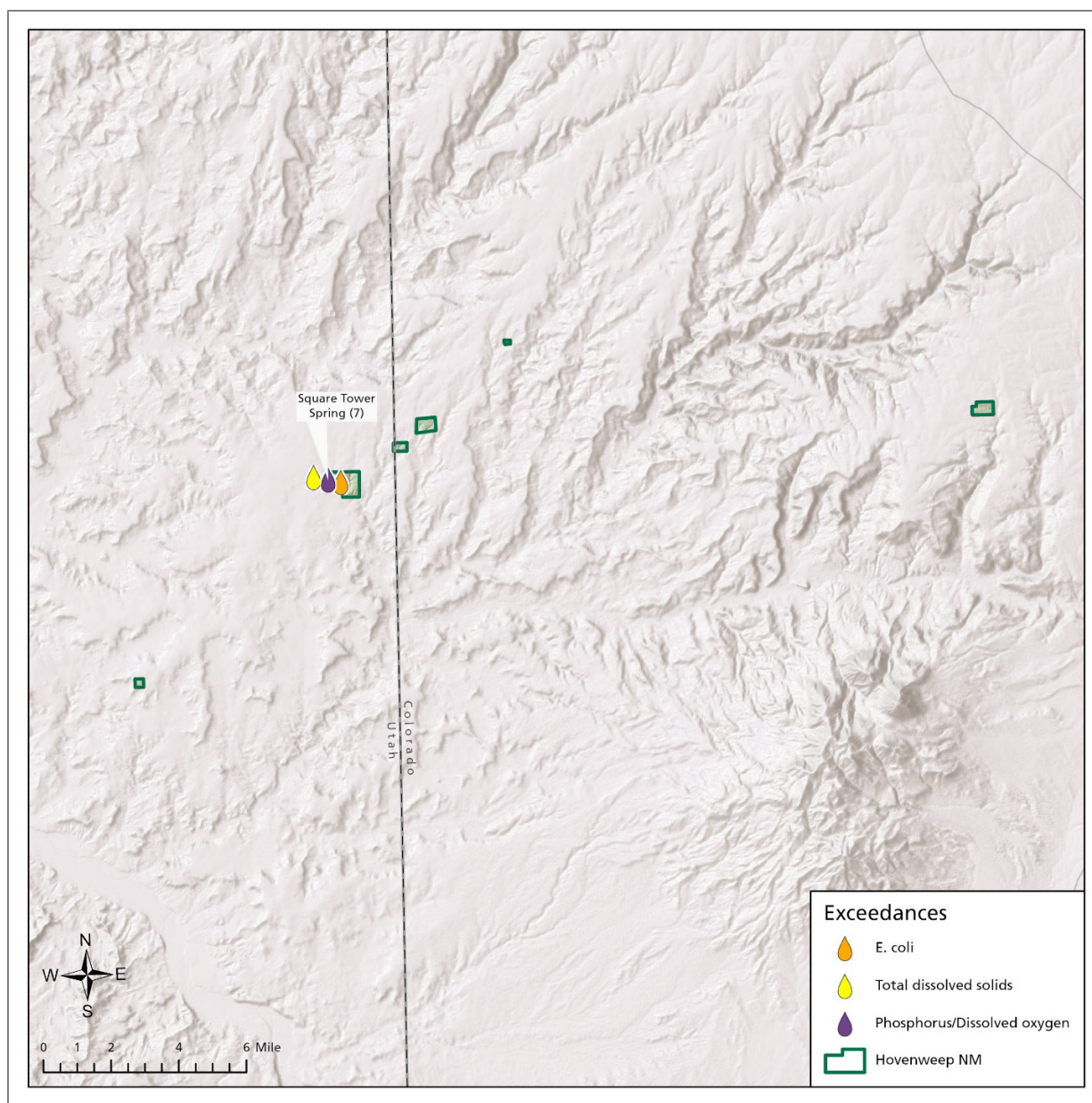


Figure 29. Water quality monitoring locations in Hovenweep National Monument evaluated in this report, with the number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 14. Station evaluated in Hovenweep NM with the number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Square Tower Spring	7	4	57

Table 15. Stations evaluated in Hovenweep NM with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
Square Tower Spring	Dissolved oxygen (mg/L)	UT_3B	5.5	19	15	79
Square Tower Spring	Total dissolved solids (mg/L)	UT_4	1200	19	13	68
Square Tower Spring	Phosphorus (mg/L)	UT_2A, UT_3B	0.05	19	8	42
Square Tower Spring	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	18	2	11

Ammonia, pH, and water temperature met water quality standards. Samples for trace elements were only collected seven times during the period of record, and all the samples met state water quality standards. Dissolved oxygen concentrations failed to meet the chronic standard for warm-water aquatic life in 79% of the evaluations. Two samples exceeded the chronic standard for *E. coli* for frequent primary-contact recreation (126 MPN/100 mL), and one of those samples also exceeded the acute standard. Total phosphorus exceeded the indication of impairment criteria for frequent primary-contact recreation and warm-water aquatic life in 42% of the evaluations. Total dissolved solids exceeded the agricultural use standard in 68% of the evaluations.

State water quality standards are designed to be applied to flowing waters of at least one kilometer in extent. Square Tower Spring is a small, spring-fed pool in the back of a protected alcove; the spring receives little direct influence from precipitation events. Comparisons to surface water quality standards are included because few groundwater standards exist, and groundwater standards do not include aquatic life criteria. A comprehensive trend analysis of water quality data at Hovenweep NM suggests conditions are persistently poor for aquatic life (Weissinger 2023).

Groundwater is naturally depleted in oxygen, and dissolved oxygen in Square Tower Spring is persistently low (Figure 30). Dissolved oxygen concentrations below the state standard occurred at both high and low concentrations of phosphorus (Figure 31) and at a range of water temperatures. Because of a lack of surface-water inputs, it is likely that phosphorus concentrations are primarily natural at the spring. Algal growth, decomposition of organic matter, and lack of flow likely exacerbate naturally low dissolved oxygen concentrations.

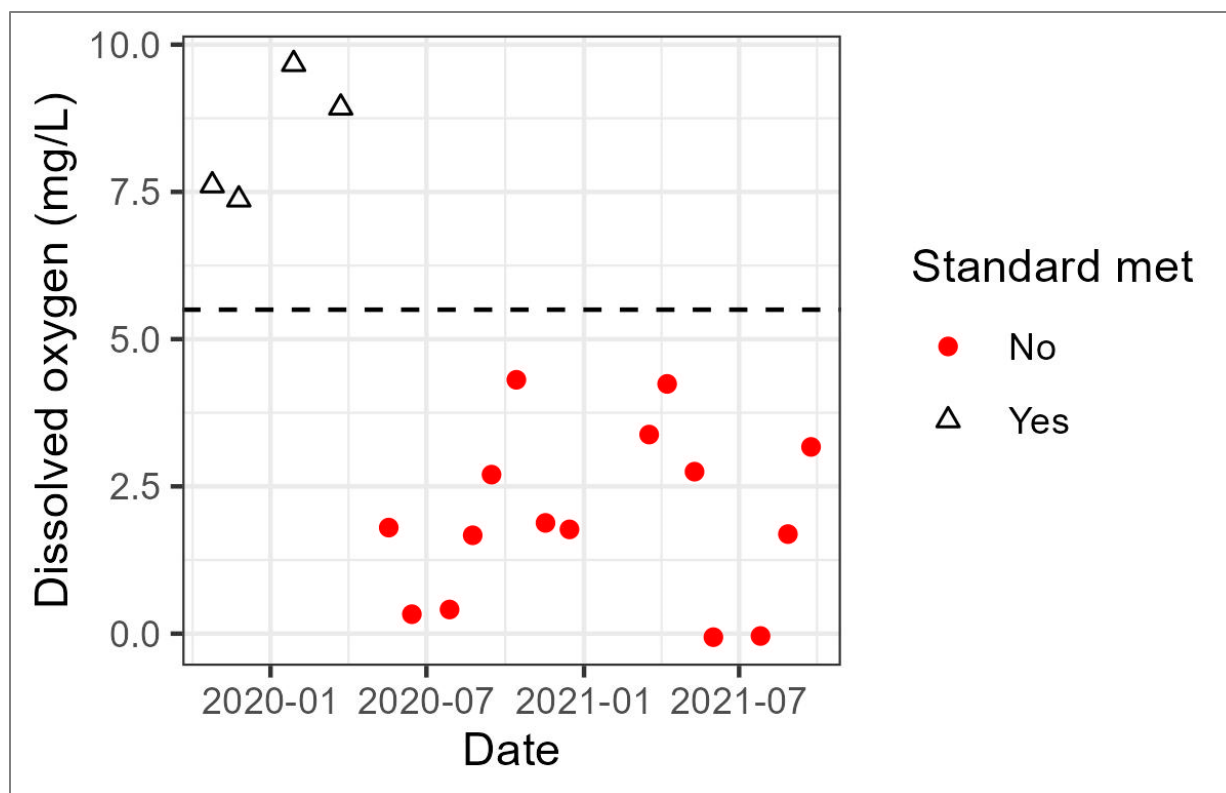


Figure 30. Dissolved oxygen at Square Tower Spring from water years 2020 to 2021. The dashed line indicates the warm-water aquatic life standard of 5.5 mg/L.

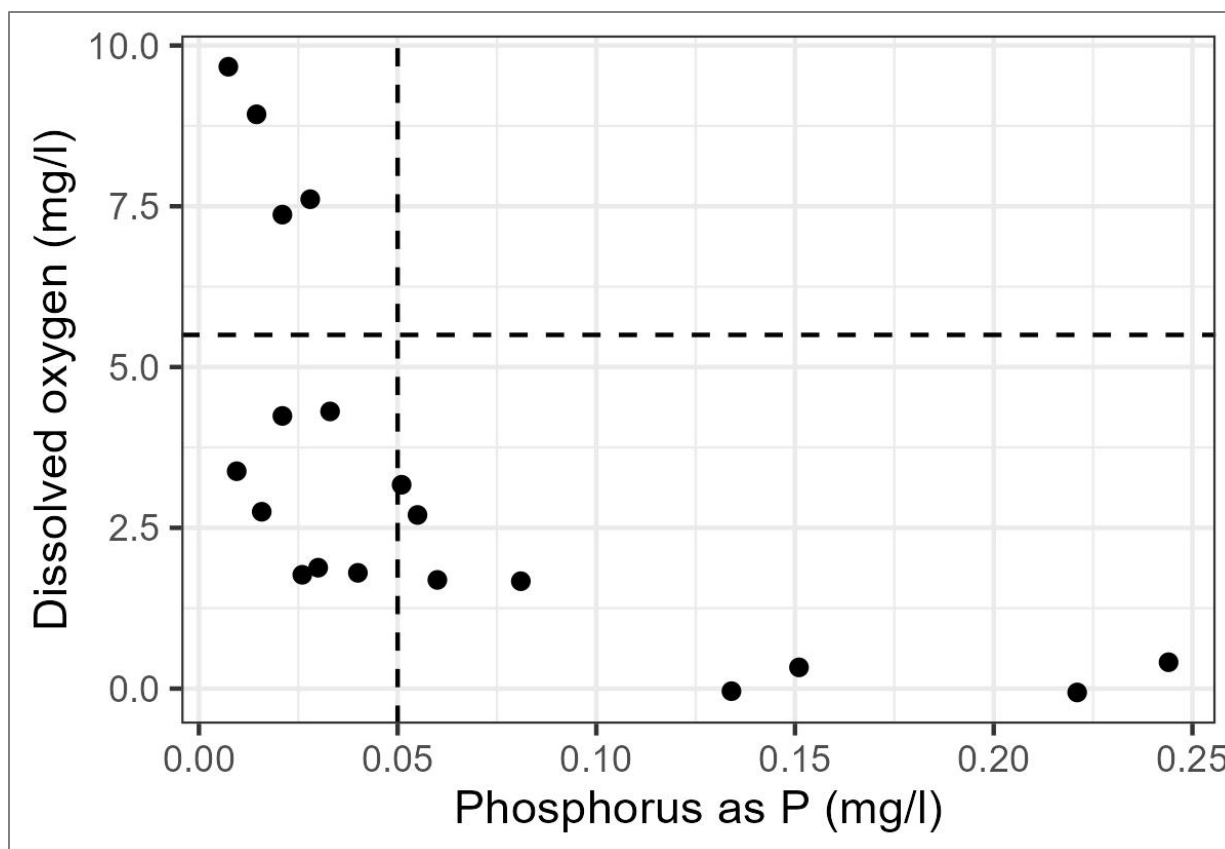


Figure 31. Low concentrations of dissolved oxygen (<5.5 mg/l) at Square Tower Spring occurred both above and below the 0.05 mg/l threshold for phosphorus concentrations.

Bird excrement was noted around the Square Tower Spring pool when high *E. coli* concentrations occurred, but no unusual potential sources were noted. One of the samples also did not meet the *E. coli* acute criterion for frequent primary-contact recreation. High TDS concentrations in Square Tower Spring has been attributed to groundwater contact with underlying gypsum (Avery 1986).

3.8 Timpanogos Cave National Monument

A total of 1,841 designated beneficial-use evaluations were completed for water quality results obtained at three sites in Timpanogos Cave NM between October 1, 2018 and September 30, 2022. All three sites met all water quality standards for trace elements, nutrients, dissolved oxygen, pH, water temperature, and TDS (Figure 32, Table 16).

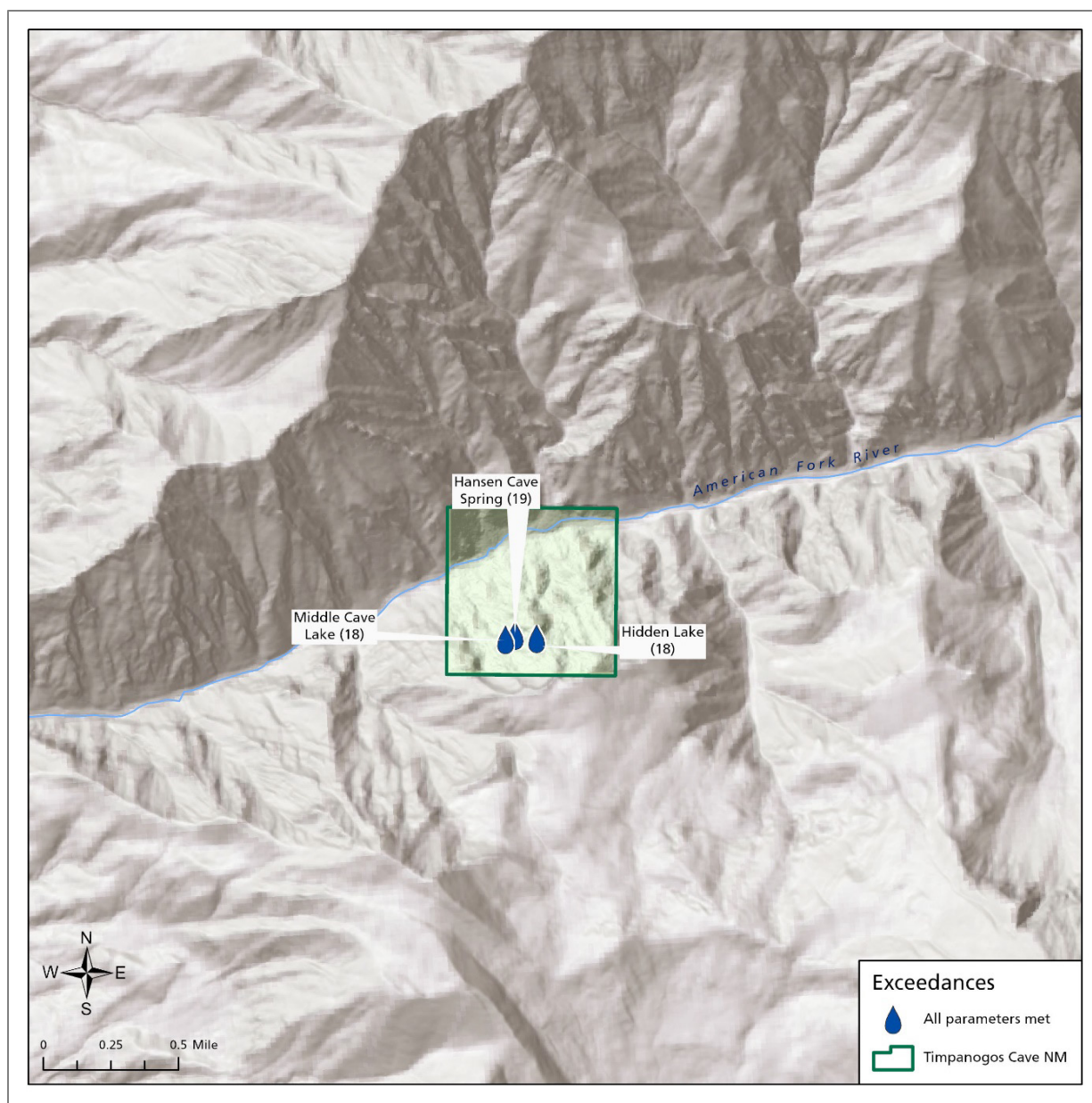


Figure 32. Water quality monitoring locations in Timpanogos Cave National Monument evaluated in this report, with the number of parameters evaluated per station in parentheses.

Table 16. Stations evaluated in Timpanogos Cave NM with the number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
Hansen Cave Spring	19	0	0
Middle Cave Lake	18	0	0
Hidden Lake	18	0	0

3.9 Zion National Park

Water quality data evaluated at seven sites in or near Zion NP indicated that 3,268 (98%) of the 3,331 total designated beneficial-use evaluations completed between October 1, 2018 and September 30, 2022 met state water quality standards.

Three of the seven sites had at least one parameter that did not meet standards for 10% or greater of the evaluations or were higher than threshold values for additional investigation, with 1–22 parameters evaluated per site (Figure 33, Table 17). The most common parameter of concern is water temperature (Table 18).

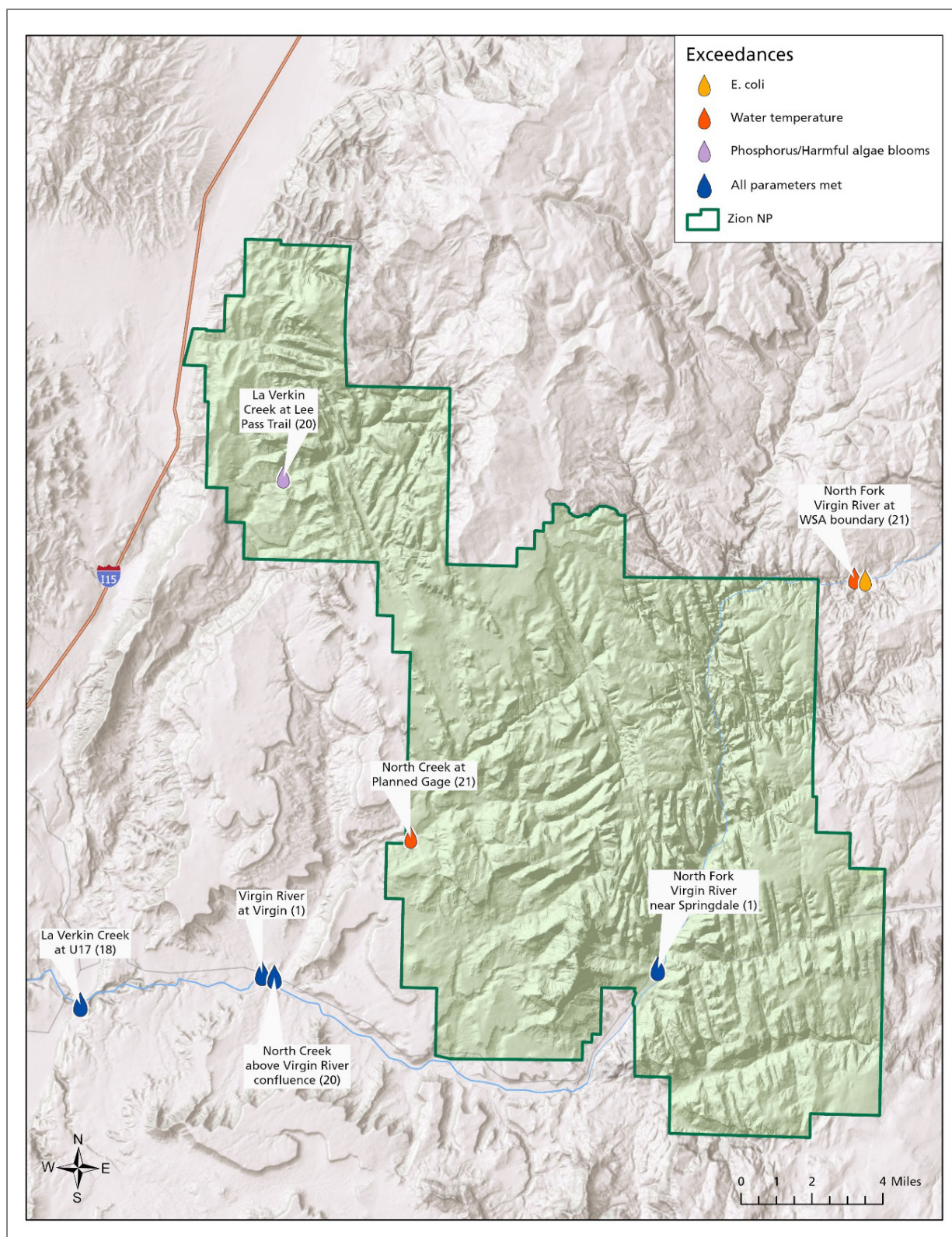


Figure 33. Water quality locations in and near Zion National Park evaluated in this report, with the number of parameters evaluated per station in parentheses, and standards not met >10% of the time listed in the legend.

Table 17. Stations evaluated in and near Zion NP with number of parameters evaluated and number and percentage of parameters not meeting a criterion at least 10% of the time.

Site	Parameters evaluated	Parameters not meeting standard	Percent not meeting standard
North Fork Virgin River at WSA boundary	21	2	10
North Fork Virgin River near Springdale	1	0	0
North Creek at Planned Gage	21	1	5
North Creek above Virgin River confluence	20	0	0
La Verkin Creek at Lee Pass Trail	20	1	5
La Verkin Creek at U17	18	0	0
Virgin River at Virgin	1	0	0

Table 18. Stations evaluated in and near Zion NP with associated parameters not meeting a criterion at least 10% of the time.

Site	Parameter	Use code	Standard	Total evaluations	Criterion not met	Percent not met
North Fork Virgin River at WSA boundary	Water temperature (deg C)	UT_3A	20	28	10	36
North Fork Virgin River at WSA boundary	Escherichia coli (MPN/100 mL)	UT_2A chronic	126	28	3	11
North Creek at Planned Gage	Water temperature (deg C)	UT_3C	27	34	5	15
La Verkin Creek at Lee Pass Trail	Phosphorus (mg/L)	UT_2B, UT_3B	0.05	35	7	20

3.9.1 North Fork Virgin River at Wilderness Study Area (WSA) boundary

Trace elements, nutrients, dissolved oxygen, pH, and TDS met state water quality standards. At this site, three samples (11%) did not meet the chronic *E. coli* standard (126 MPN/100 mL) for frequent primary-contact recreation during the four-year period (Figure 34). Water temperatures did not meet the standard for cold-water aquatic life for 36% of evaluations.

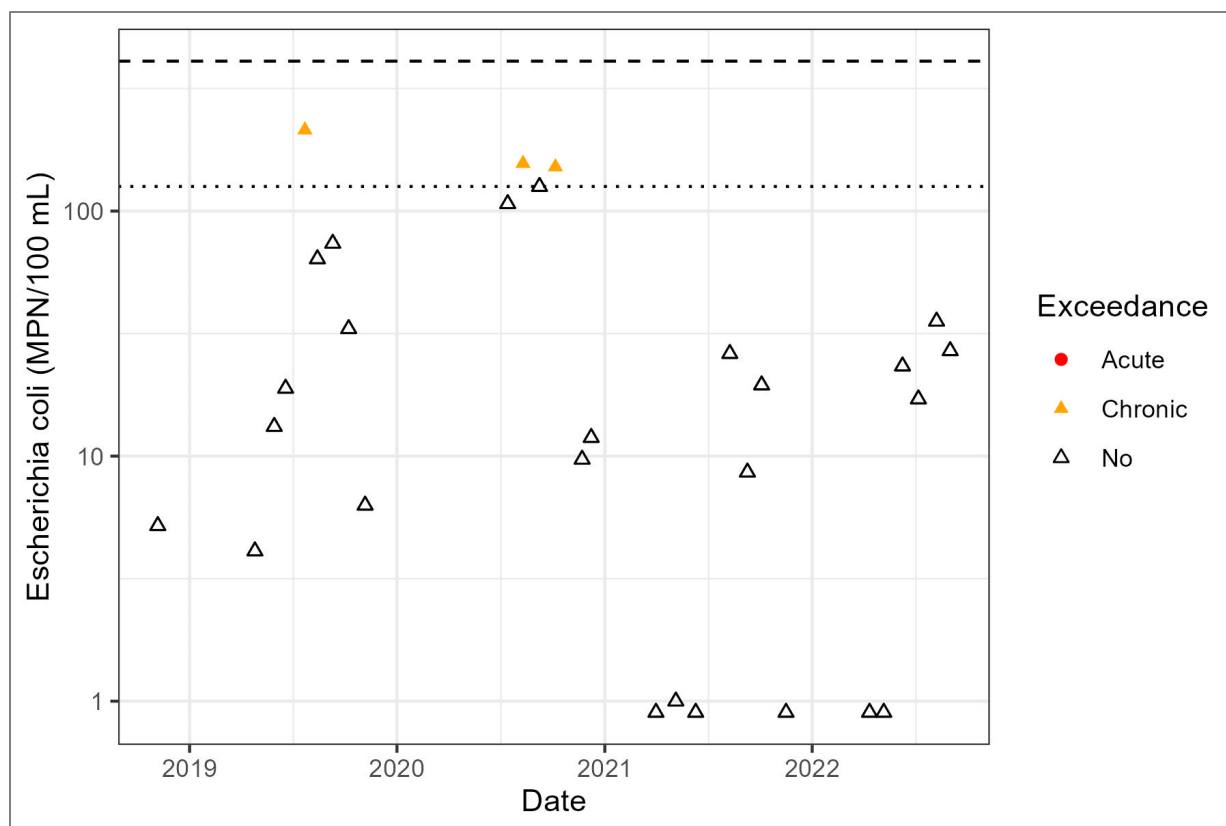


Figure 34. *E. coli* concentrations at the North Fork Virgin River at the Wilderness Study Area boundary from water years 2019 to 2022. The dashed lines indicate the chronic standard (126 MPN/100 mL) and the acute standard (409 MPN/100 mL) for frequent primary-contact recreation.

In summer months, *E. coli* contamination in the North Fork Virgin River upstream from the Zion Narrows has been relatively consistent since the NCPN started monitoring efforts in 2006 (Van Grinsven et al. 2010; Hackbarth and Weissinger 2013; Hackbarth and Weissinger 2016; Hackbarth and Weissinger 2020). Water quality concerns in the North Fork Virgin River were first identified in a previous study conducted by Zion NP staff that showed elevated fecal coliform levels in 2000. The North Fork of the Virgin River, from its confluence with Deep Creek to its headwaters, was added to Utah's 303(d) list of impaired waters because of *E. coli* contamination in 2010. Exceedances of the standard were primarily driven by return flows from flood-irrigated pastures grazed by cattle and wildlife (Dickey and Adams 2017). During the summer recreational season, *E. coli* has been intensively monitored through cooperative sampling between the State of Utah, the NPS, and the Bureau of Land Management.

Since 2011, the State of Utah has collaborated with agencies and landowners to improve water quality in this area. Between 2011 and 2017, recreational area improvements and best management practices were implemented, which included installing a vault toilet at the trailhead where the Zion Narrows top-down hike begins. In 2015, fences and gates along several pastures were improved to allow ease of hiker access while discouraging trespass cattle from grazing on pastures that were

being actively irrigated. In 2016, a control gate and flume were installed in one of the irrigation ditches to limit the amount of water irrigating the pastures.

Results from NCPN monthly sampling have shown that the number of *E. coli* exceedances decreased in the North Fork Virgin River at the WSA boundary site. Exceedances for the chronic *E. coli* standard for frequent primary-contact recreation occurred in 36% of samples during water years 2010–2012, 26% of samples during water years 2013–2015, and 13% of samples during water years 2016–2018. It should also be noted that *E. coli* levels have not exceeded the acute primary-contact recreation standard during water years 2016–2022 as compared to the five exceedances during water years 2010–2015. All *E. coli* levels in water year 2022 were below the chronic and acute standards. Overall, water quality seems to be improving in the area due to the implementation of the best management practices and recreational area improvements mentioned above. Intensive monitoring will continue 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 discontinued.

3.9.2 North Fork Virgin River near Springdale

Water temperature, the only parameter available for evaluation, met state water quality standards. Toxic benthic cyanobacteria were noted near this site in 2020–2022.

Toxic benthic cyanobacteria were first noted in the North Fork Virgin River in Zion NP in July 2020, after a dog developed symptoms of exposure to neurotoxins and died shortly after playing in the water. Unlike free-floating harmful algal blooms typical of reservoirs, benthic cyanobacteria blooms can occur in clear water and have not been widely detected in the United States. This was the first such event noted in Utah or in a national park unit. Follow-up sampling by the park and the State of Utah found high levels of anatoxin-a, a dangerous toxin that targets the nervous system, in several reaches of the North Fork Virgin River, East Fork Virgin River, North Creek, and La Verkin Creek within the park.

Cyanobacteria naturally occur in rivers and streams and are usually benign. Zion NP is working with the State of Utah and researchers to determine when and why these bacteria are spurred to produce cyanotoxins. They have developed a multi-pronged monitoring approach to detect cyanobacteria capable of producing toxins and passively sample for toxins in the water column. Toxins continued to be detected in the North Fork Virgin River and other streams from 2020 to 2022, triggering health watches and advisories based on the detected concentrations (<https://deq.utah.gov/health-advisory-panel/virgin-river-watershed-recreational-monitoring>, accessed July 3, 2023). The root causes of benthic cyanobacteria blooms are still under investigation.

3.9.3 North Creek at planned gage

Trace elements, nutrients, dissolved oxygen, *E. coli*, pH, and TDS met state water quality standards. Water temperature did not meet the warm-water aquatic life standard in 15% of the evaluations. This site had toxic benthic cyanobacteria noted in 2020–2022.

3.9.4 North Creek above Virgin River confluence

Trace elements, ammonia, dissolved oxygen, pH, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.9.5 La Verkin Creek at Lee Pass Trail

Trace elements, ammonia, dissolved oxygen, *E. coli*, pH, water temperature, and TDS met state water quality standards. Total phosphorus concentrations did not meet the State of Utah indication of impairment for infrequent primary-contact recreation and warm-water aquatic life in 20% of the evaluations. This site also had toxic benthic cyanobacteria noted in 2020–2022. Because high phosphorus concentrations have been documented prior to the first known occurrence of a benthic cyanobacteria bloom, it is likely that other factors contribute to these algal blooms.

3.9.6 La Verkin Creek at Utah Highway 17 crossing

Trace elements, ammonia, dissolved oxygen, pH, water temperature, and TDS met state water quality standards. High phosphorus concentrations were not associated with evidence of impairment.

3.9.7 Virgin River at Virgin, Utah

Water temperature, the only parameter available for evaluation, met state water quality standards.

4 Conclusion

Overall, water quality in NCPN meets water quality standards for most evaluations, and parks such as Bryce Canyon NP and Timpanogos Cave NM have relatively pristine water quality. Management concerns identified in this report are consistent with previous reports summarizing data collected from 2005 to 2018. Waste contamination, indicated by high fecal coliform (*E. coli*) concentrations, is the most common concern. Reducing *E. coli* concentrations requires site-specific evaluations to determine the likely sources of waste contamination, and park managers at Capitol Reef NP and Zion NP have had success working with states to identify and mitigate sources at several sites. Such a study could also be pursued at Dinosaur NM for the Yampa River at Deerlodge Park.

Water temperature is of increasing concern but likely can only be effectively addressed through widespread efforts to mitigate climate warming. NCPN monitoring will continue, and future reports will include sites at Black Canyon of the Gunnison NP, Curecanti National Recreation Area, and Golden Spike National Historical Park if data become available.

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Appendix A. Supplemental Material on Methods

Target Population

The target population for Northern Colorado Plateau Network (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. 2017).

Specific water sources were selected based on the following hierarchy:

1. **303(d)-listed waters**, where previous sampling indicated that one or more parameters regularly approached or exceeded criteria or recommended levels.
2. **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.
3. **Data gaps**: Waters identified as important, but where little or no water quality information existed.
4. **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.
5. **Other perennial waters** with no specific threat.

Perennial waters were preferentially selected over ephemeral or seasonal water sources because they support year-round aquatic ecological processes and functions and have established criteria that allow monitoring for compliance with the Clean Water Act.

Partnerships

The NCPN water quality monitoring program is a collaborative venture between the NCPN, Black Canyon of the Gunnison National Park (NP), Curecanti National Recreation Area, the Southeast Utah Group (SEUG), Timpanogos Cave National Monument (NM), the USGS, and the Utah Department of Environmental Quality (UDEQ). Personnel from the NCPN, SEUG, and Timpanogos Cave NM conduct field work and deliver samples to the Utah Public Health Laboratory according to a partnership agreement between the NPS and the UDEQ. Staff from Black Canyon of the Gunnison NP and Curecanti National Recreation Area conduct field work and have laboratory analysis conducted at the National Water Quality Laboratory (NWQL) in Lakewood, Colorado, via agreements with the USGS. Sites at Dinosaur NM are visited by USGS staff, who deliver samples to the NWQL for laboratory analysis. Other nearby sites (outside park boundaries) routinely monitored by the states of Colorado and Utah are also considered when they will help determine water quality flowing into or out of the park. Regardless of which entity performed the field work or laboratory analysis, the data were stewarded through the NPSTORET database v.2.2, which was used for the water quality standards evaluations. Graphs and summary statistics were completed in R (R Core Team 2023) using the *tidyverse* package (Wickham et al. 2019).

Data quality

Samples collected by staff from the USGS and the State of Utah are evaluated for data quality by those entities. Quality-control data for these sites are not included in this report. For sites sampled by NCPN and SEUG staff and analyzed by the Utah Public Health Laboratory (UPHL), up to 38 field blanks were submitted between October 1, 2018 and September 30, 2022. For the parameters evaluated in this report, concentrations were detected in 23 of 534 blank analyses (Table 19). All the detections were well below the assessment criteria and should not affect evaluations. Most of the detections were for phosphorus, which is currently reported by the UPHL at the method detection limit (0.003 mg/L) rather than the more conservative lower quantification limit (0.02 mg/L). Replicate samples for major constituents and nutrients were submitted 33 times. Replicate samples for trace elements were submitted 24 times. The median replicate percentage difference was 0% (interquartile range 0–2.9%, range 0–190%).

Table 19. Results of field blanks submitted by NCPN and SEUG to the UPHL for water years 2019–2022. ND = non-detectable; LQL = lower quantification limit; pH dep = standard is dependent on concurrently measured pH value.

Parameter	Number of blank samples	Number of non-detects	Number of detects	Maximum blank sample concentration	Minimum LQL	Maximum LQL	Minimum environmental sample concentration	Minimum Utah standard
Aluminum (d) (ug/L)	27	25	2	27	5	10	10.2	87
Arsenic (d) (ug/L)	27	27	0	ND	1	1	1	10
Barium (d) (ug/L)	27	27	0	ND	5	10	11.7	100
Beryllium (d) (ug/L)	26	26	0	ND	1	1	ND	4
Boron (d) (ug/L)	27	27	0	ND	30	30	30.5	750
Cadmium (d) (ug/L)	27	27	0	ND	0.1	0.1	0.198	0.72
Chromium (d) (ug/L)	27	27	0	ND	2	2	2.2	50
Copper (d) (ug/L)	27	25	2	1.84	1	1	1	9
Iron (d) (ug/L)	27	27	0	ND	30	30	30.4	1,000
Lead (d) (ug/L)	27	26	1	0.433	0.1	0.1	0.117	2.5
Mercury (d) (ug/L)	27	27	0	ND	0.2	0.2	ND	0.012
Nickel (d) (ug/L)	27	25	2	5.78	1	5	1	52
Ammonia as N (mg/L)	38	38	0	ND	0.05	0.05	0.081	pH dep
Phosphorus as P (mg/L)	38	22	16	0.029	0.003	0.02	0.003	0.05
Selenium (d) (ug/L)	27	27	0	ND	0.5	1	0.639	4.6
Silver (d) (ug/L)	27	27	0	ND	0.5	0.5	ND	1.6
Total dissolved solids (mg/L)	37	37	0	ND	20	20	106	1,200
Zinc (d) (ug/L)	27	27	0	ND	5	10	10.3	120

Appendix B. Colorado water quality standards

Table 20. Colorado water-quality standards with applicable designated beneficial uses. These are the relevant standards for parameters that were measured in the field and laboratory during water years 2019–2022. Ag = agricultural use; ALCW1 = aquatic life cold-water class 1; ALWW1 = aquatic life warm-water class 1; DWS = domestic-water supply; RecE = existing primary-contact recreation; pH dep = standard is dependent on concurrently measured pH value; HD = standard is dependent on concurrently measured hardness concentration.

Parameter	Ag	ALCW1	ALWW1	DWS	RecE
Dissolved oxygen (mg/L)	3.0	7.0	5.0	3.0	3.0
<i>Escherichia coli</i> (per 100 mL)	–	–	–	630	126
pH	–	6.5–9.0	6.5–9.0	5.0–9.0	6.5–9.0
Water temperature (°C), summer	–	18.3	27.5	–	–
Water temperature (°C), winter	–	9.0	13.8	–	–
Ammonia, dissolved (mg/L)	–	pH dep	pH dep	–	–
Boron, dissolved (mg/L)	0.75	–	–	–	–
Chloride, dissolved (mg/L)	–	–	–	250	–
Chlorophyll <i>a</i> (µg/L)	–	–	–	–	–
Fluoride, dissolved (mg/L)	–	–	–	2.0	–
Nitrate, dissolved (mg/L)	100	–	–	10	–
Nitrite, dissolved (mg/L)	10	0.05	0.05	1.0	–
Phosphorus, total (mg/L) (interim)	–	0.110	0.170	–	–
Sulfate, dissolved (mg/L)	–	–	–	250	–
Aluminum, total recoverable (µg/L)	–	HD	HD	–	–
Arsenic, dissolved (µg/L)	–	150	150	–	–
Barium, total recoverable (µg/L)	–	–	–	1000	–
Cadmium, dissolved (µg/L)	–	HD	HD	–	–
Copper, dissolved (µg/L)	–	HD	HD	–	–
Iron, dissolved (µg/L)	–	–	–	300	–
Lead, dissolved (µg/L)	–	HD	HD	–	–
Manganese, dissolved (µg/L)	–	HD	HD	50	–
Manganese, total recoverable (µg/L)	200	–	–	–	–
Mercury, total (µg/L)	–	0.01	0.01	–	–
Selenium, dissolved (µg/L)	–	4.6	4.6	–	–
Silver, dissolved (µg/L)	–	HD	HD	–	–
Zinc, dissolved (µg/L)	–	HD	HD	–	–

Appendix C. Utah water quality standards

Table 21. Utah water-quality standards with applicable designated beneficial uses. These are the relevant standards for parameters that were measured in the field and laboratory during water years 2019–2022. 1C = domestic-water supply; 2A = frequent primary-contact recreation; 2B = infrequent primary-contact and secondary-contact recreation; 3A = cold-water aquatic life; 3B = warm-water aquatic life; 3C = non-game fish; 4 = agricultural use; pH dep = standard is dependent on concurrently measured pH value; HD = standard is dependent on concurrently measured hardness concentration; NoCrk = Zion National Park North Creek TDS standard.

Parameter	1C	2A	2B	3A	3B	3C	4
Dissolved oxygen (mg/L) (minimum)	–	–	–	6.5	5.5	5.0	–
<i>Escherichia coli</i> (MPN/100 mL), acute	668	409	668	–	–	–	–
<i>Escherichia coli</i> (MPN/100 mL), chronic	206	126	206	–	–	–	–
pH	6.5–9	6.5–9	6.5–9	6.5–9	6.5–9	6.5–9	6.5–9
Water temperature (°C)	–	–	–	20	27	27	–
Total dissolved solids (mg/L)	–	–	–	–	–	–	1200 2035 (NoCrk)
Ammonia, total (mg/L)	–	–	–	pH dep	pH dep	pH dep	–
Boron, dissolved (µg/L)	–	–	–	–	–	–	750
Phosphorus, total (mg/L)	–	0.05	0.05	0.05	0.05	0.05	–
Aluminum, dissolved (µg/L)	–	–	–	87	87	87	–
Arsenic, dissolved (µg/L)	10	–	–	150	150	150	100
Barium, dissolved (µg/L)	1000	–	–	–	–	–	–
Beryllium, dissolved (µg/L)	4	–	–	–	–	–	–
Cadmium, dissolved (µg/L)	10	–	–	HD	HD	HD	10
Chromium, dissolved (µg/L)	50	–	–	HD	HD	HD	100
Copper, dissolved (µg/L)	–	–	–	HD	HD	HD	200
Iron, dissolved (µg/L)	–	–	–	1000	1000	1000	–
Lead, dissolved (µg/L)	15	–	–	HD	HD	HD	100
Mercury, dissolved (µg/L)	2	–	–	0.012	0.012	0.012	–
Nickel, dissolved (µg/L)	–	–	–	HD	HD	HD	–
Selenium, dissolved (µg/L)	50	–	–	4.6	4.6	4.6	50
Silver, dissolved (µg/L)	50	–	–	HD	HD	HD	–
Zinc, dissolved (µg/L)	–	–	–	HD	HD	HD	–

Appendix D. Water quality sites reported, water years 2019–2022

Table 22. Water quality sites reported, water years 2019–2022. See Acronyms and Abbreviations list for key to designated beneficial uses.

Park unit	Station ID	Station name	Latitude	Longitude	Beneficial use
Arches National Park	09180500	Colorado River near Cisco, UT	38.811	–109.293	1C, 2A, 3B, 4
	09163500	Colorado River near Colorado-Utah state line	39.133	–109.027	Ag, ALWW1, RecE, LC3
	5995240	Courthouse Wash above Colorado River	38.613	–109.579	1C, 2A, 3B, 4
	5995246	Courthouse Wash at spring inside Arches NP west boundary	38.687	–109.653	1C, 2A, 3B, 4
	09180000	Dolores R near Cisco, UT	38.797	–109.195	2B, 3C, 4
	5995220	Salt Wash at Wolfe Ranch	38.735	–109.519	1C, 2A, 3B, 4
Bryce Canyon National Park	4951915	Mossy Cave Spring northwest of Tropic	37.665	–112.115	2B, 3C, 4
	4951855	Sheep Creek below spring in Bryce Canyon NP	37.571	–112.201	2B, 3C, 4
	N/A	Tropic Ditch	37.665	–112.115	2B, 3C, 4
	4951857	Yellow Creek below spring in Bryce Canyon NP	37.574	–112.141	2B, 3C, 4
Canyonlands National Park	4952400	Colorado River above confluence with Green River	38.193	–109.884	1C, 2A, 3B, 4
	4952380	Colorado River below Brown Betty Rapid	38.147	–109.928	1C, 2A, 3B, 4
	4956290	Colorado River at Potash Boat Ramp	38.467	–109.666	1C, 2A, 3B, 4
	4930010	Green River above confluence with Colorado River	38.190	–109.889	1C, 2A, 3B, 4
	4930150	Green River at Mineral Bottom	38.527	–109.993	1C, 2A, 3B, 4
	09315000	Green River at Green River, UT	38.896	–110.151	1C, 2A, 3B, 4
	09272400	Green River at Ouray, UT	40.085	–109.677	1C, 2A, 3B, 4
Capitol Reef National Park	09330000, 4954380	Fremont River near Bicknell, UT	38.307	–111.517	1C, 2A, 3A, 4
	4954550	Fremont River above Mill Meadow Reservoir	38.520	–111.571	1C, 2A, 3A, 4
	4954390	Fremont River at Highway 12 crossing	38.270	–111.375	1C, 2A, 3A, 4
	4954330	Fremont River at old Highway 24 crossing	38.391	–110.697	1C, 2B, 3C, 4
	4954812	Halls Creek below Narrows	37.615	–110.892	2B, 3B, 4

Table 22 (continued). Water quality sites reported, water years 2019–2022. See Acronyms and Abbreviations list for key to designated beneficial uses.

Park unit	Station ID	Station name	Latitude	Longitude	Beneficial use
Capitol Reef National Park (continued)	4954795	Oak Creek above Oak Creek Dam	38.084	-111.140	1C, 2A, 3A, 4
	4954780	Pleasant Creek at Pleasant Creek Road crossing at South Draw	38.180	-111.181	1C, 2B, 3A
	4954770	Sulphur Creek above confluence with Fremont River	38.287	-111.247	1C, 2A, 3A, 4
	4954775	Sulphur Creek below road to Goosenecks Overlook	38.307	-111.315	1C, 2A, 3A, 4
Dinosaur National Monument	404417108524900	Green River above Gates of Lodore, CO	40.738	-108.880	Ag, ALCW1, DWS, RecE, LYG19a
	09261000	Green River near Jensen, UT	40.409	-109.235	1C, 2A, 3B, 4
	09260050	Yampa River at Deerlodge Park, CO	40.452	-108.525	Ag, ALWW1, DWS, RecE, LYG2
	09247600	Yampa River below Craig, CO	40.481	-107.614	Ag, ALWW1, DWS, RecE, LYG2
	09251000	Yampa River near Maybell, CO	40.503	-108.033	Ag, ALWW1, DWS, RecE, LYG2
Hovenweep National Monument	5995700	Square Tower Spring	37.386	-109.081	1C, 2A, 3B, 4
Timpanogos Cave National Monument	4994970	Hansen Cave Spring in Timpanogos Cave	40.438	-111.711	2B, 3A, 4
	N/A	Hidden Lake at Timpanogos Cave	40.438	-111.709	2B, 3A, 4
	N/A	Middle Cave Lake	40.438	-111.711	2B, 3A, 4
Zion National Park	4950800	La Verkin Creek at Lee Pass Trail	37.407	-113.176	2B, 3B, 4
	4950770	La Verkin Creek at Utah Highway 17 crossing	37.220	-113.275	2B, 3B, 4
	4950920	North Creek at planned gage in park	37.261	-113.106	1C, 2B, 3C, 4, NoCrk
	4950890	North Creek above confluence with Virgin River	37.203	-113.174	1C, 2B, 3C, 4, NoCrk
	4951265	North Fork Virgin River at WSA boundary	37.371	-112.882	1C, 2A, 3A, 4
	09405500	North Fork Virgin River near Springdale, UT	37.210	-112.979	1C, 2A, 3A, 4
	09406000	Virgin River at Virgin, UT	37.204	-113.181	1C, 2B, 3C, 4

Appendix E. Comparison of selenium analytical results

Selenium results in this report are processed through two different laboratories. For sites sampled by the NPS and UDEQ, samples are processed at the Utah Public Health Laboratory (UPHL). For sites sampled by the USGS, samples are processed at the National Water Quality Laboratory (NWQL).

Selenium concentrations at an upstream location on the Colorado River at the Colorado-Utah state line, sampled by the USGS and processed at the NWQL, have remained relatively consistent over time, with a median concentration of 4.0 µg/L from water years 2000 to 2012 and 2.9 µg/L from water years 2013 to 2021 (Table 20). The Canyonlands NP sites, collected by NPS staff and processed at the UPHL had similar medians during water years 2000–2012, with slight decreases as one proceeds downstream. However, beginning in water year 2013, NPS sites are comprised of almost entirely non-detectable concentrations below the reporting limit of 1.0 µg/L, while reported concentrations at the USGS site do not show a similar decrease. Although data are limited, for two sites sampled by UDEQ and processed at the UPHL, the pattern is similar to the Canyonlands NP sites, with summary statistics similar to the USGS site during the earlier period and non-detectable concentrations starting in water year 2013.

Table 23. Summary statistics of reported concentrations of selenium (ug/L) at the 10th, 50th, and 90th percentiles at water quality stations on the Colorado River from the Colorado-Utah state line through Canyonlands National Park, from upstream (top) to downstream (bottom), for periods of water years 2000–2012 and 2013–2021.

Sampled by	Lab	Station Name	Water Years	Number of samples	10 th	50 th	90 th
USGS	NWQL	Colorado River near Colorado-Utah state line	2000–2012	108	1.6	4.1	5.9
USGS	NWQL	Colorado River near Colorado-Utah state line	2013–2021	162	1.4	3.0	5.1
UDEQ	UPHL	Colorado River at Dewey Bridge	2000–2008	33	1.8	4.2	6.6
UDEQ	UPHL	Colorado River at Dewey Bridge	2013, 2019	22	<1.0	<1.0	<1.0
UDEQ	UPHL	Colorado River at Highway 191 crossing near Moab	2003, 2008	9	2.7	4.1	6.5
UDEQ	UPHL	Colorado River at Highway 191 crossing near Moab	2013, 2019	23	<1.0	<1.0	<1.0
NPS	UPHL	Colorado River at Potash boat ramp	2000–2012	59	1.5	3.4	5.6
NPS	UPHL	Colorado River at Potash boat ramp	2013–2021	66	<1.0	<1.0	<1.0
NPS	UPHL	Colorado River above confluence with Green River	2000–2012	72	1.4	3.4	5.2
NPS	UPHL	Colorado River above confluence with Green River	2013–2021	60	<1.0	<1.0	<1.0
NPS	UPHL	Colorado River below Brown Betty Rapid	2000–2012	61	<1.0	2.3	4.0
NPS	UPHL	Colorado River below Brown Betty Rapid	2013–2021	53	<1.0	<1.0	<1.0

In December 2012, the UPHL switched their primary dissolved selenium analysis from EPA Method 200.8 using inductively coupled plasma with mass spectrometry (ICP-MS; EPA 1994) to Standard Method (SM) 3114-C using atomic absorption spectroscopy after the conversion of selenium to selenium-hydride (HG-AAS; APHA 1992). In the early 2000s, UDEQ became aware that EPA Method 200.8 could overestimate selenium concentrations in waters with very high salinity (pers. comm. Toby Hooker, August 29, 2019). This is of particular importance to the State of Utah because many samples processed at the UPHL come from the Great Salt Lake. As a result, UDEQ requested that any sample with a detected concentration using EPA Method 200.8 be re-run using SM 3114-C, a method that is less affected by interference from dissolved salts.

However, this change in analytical method corresponded to an abrupt shift to non-detectable concentrations at sites that had previously reported detected concentrations of selenium at a range of locations sampled by parks, NCPN, and UDEQ (Figure 35). In a few cases in 2017–2018, results were reported for both methods, and in all those cases, EPA Method 200.8 results were detected concentration while SM 3114-C results were non-detectable concentrations. These datasets are from different parks and waterbodies and were sampled by different personnel using different equipment. It is unlikely that sample handling is responsible for the change in reported selenium concentrations.

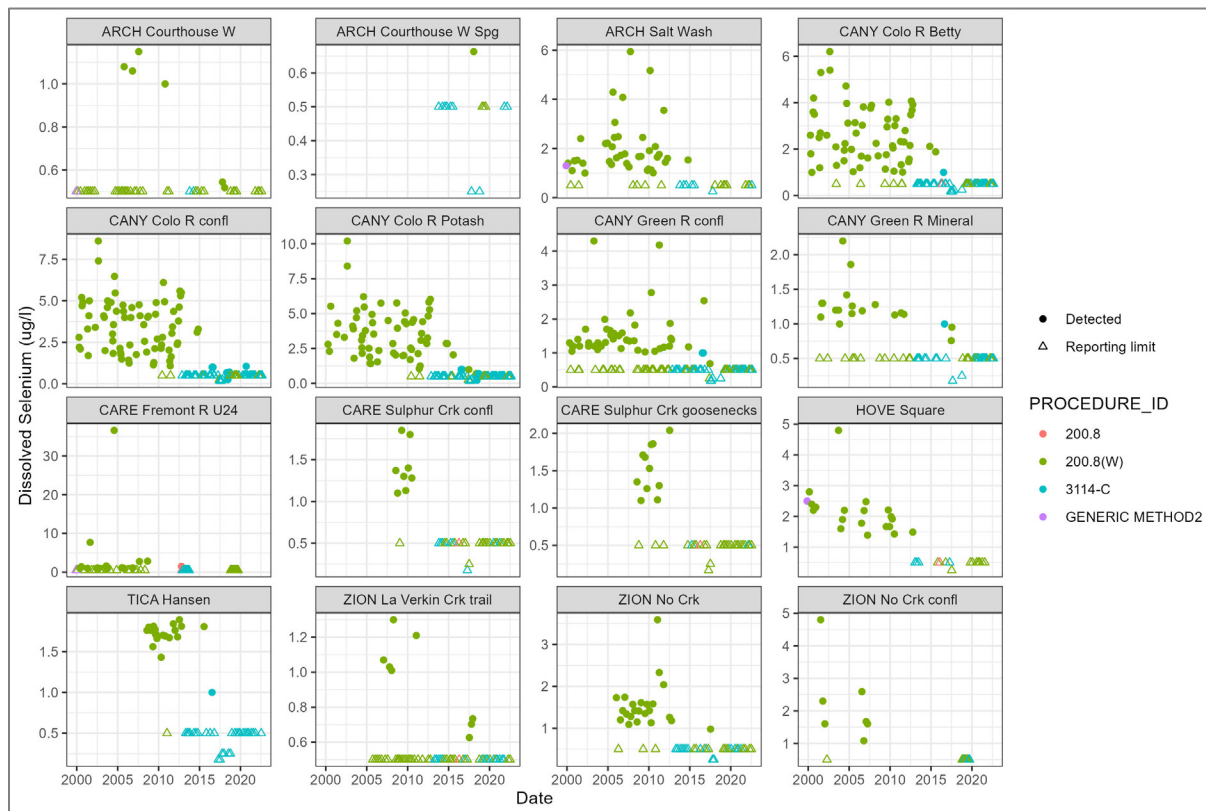


Figure 35. NCPN-relevant reported selenium concentrations from the Utah Public Health Laboratory from water years 2000 to 2021 at sites sampled by NCPN (5), parks (10), and UDEQ (1). Colors correspond to the analytical procedure used at the laboratory. Concentrations reported below the reporting limit are plotted as hollow triangles at the reporting limit. Sites with only non-detectable concentrations for the entire record are not presented in the figure.

NCPN first reported this discrepancy to UDEQ in 2019. In response, UDEQ reviewed recent available data and found that similar patterns could be observed at other sites (pers. comm. Toby Hooker, November 25, 2019). UDEQ then conducted a small-scale, direct method comparison of EPA Method 200.8 and SM 3114-C for selenium as analyzed by UPHL using samples from source waters spanning a range of dissolved solid concentrations. This study found good agreement between EPA Method 200.8 and SM 3114-C, particularly at lower salinity sites (pers. comm., Toby Hooker May 20, 2020). Samples spiked with known concentrations of selenium showed greater variability in reported concentrations using EPA Method 200.8 compared to SM 3114-C (pers. comm., Toby Hooker May 20, 2020).

The NWQL used ICP-MS to analyze for selenium over the period of record under a variety of procedure numbers including PLM 40 (Faires 1993), PLM 10, and I-2020-05 (Garbarino et al. 2006). In 2019, the USGS issued a technical memorandum indicating that deviations from the published protocol could result in a positive bias in reported selenium concentrations, with a median bias of 8.0% (Stetson et al. 2019). This bias was present across the range of reported concentrations and occurred from as early as 2005 through August 2015. In a report on trends in selenium from water years 1980 to 2017, Miller et al. (2021) estimated a positive bias of about 3.9% during the affected period for samples collected at the Colorado River near the Colorado-Utah state line. Correcting for this bias would not decrease the median of 2.9 µg/L below the UPHL reporting limit of 1.0 µg/L and cannot explain differences in reported concentrations between the upstream site sampled by USGS and downstream sites sampled by the NPS.

It is beyond the scope of this report to reconcile differences between the UPHL and NWQL and between two analytical methods from the UPHL. It is clear that ICP-MS results from the two labs are more similar to each other than to HG-AAS results from the UPHL. The change in results from the UPHL is seen across independent water bodies from independent samplers using independent equipment. Analytical uncertainty remains regarding low concentrations of selenium in NCPN water bodies.

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