



Water Quality Monitoring for Bright Angel, Garden, and Hermit Creeks in Grand Canyon National Park

2014 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2017/1135



ON THE COVER
Garden Creek in Grand Canyon National Park
Photography by SCPN

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

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

Water-related vital signs are fundamental components defining overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified water quality as one of seven key vital signs used to determine the condition and long-term status of aquatic ecosystems in park streams. This report summarizes water quality core parameter data and bacteria, nutrient, major element, and trace metal data for water quality samples collected from Bright Angel, Garden, and Hermit Creeks in Grand Canyon National Park in 2014. In addition, it reports data on Contaminants of Emerging Concern found in water quality samples for an agreement with the U.S. EPA. Data collected on Contaminants of Emerging Concern from Bright Angel and Garden Creeks are also reported. The data presented in this report represent a snapshot of the water quality in these systems in 2014.

1 Introduction

The National Park Service Inventory and Monitoring Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. Hydrologic vital signs are the fundamental components that define overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified 7 vital signs pertaining to riparian and spring ecosystems: 1) aquatic macroinvertebrates, 2) stream water quality, 3) stream flow and depth to groundwater, 4) spring water quality, 5) fluvial geomorphology, 6) riparian vegetation, composition, and structure, and 7) spring ecosystems. These vital signs are closely related and are all included in the Vital Signs Monitoring Plan for the Southern Colorado Plateau Network (Thomas et al. 2006). The context and ecological significance of these vital signs are further explained in Scott et al. (2005). In this report we focus on stream water quality.

Specific objectives for monitoring stream water quality in SCPN parks are

- Determine status and trends for selected core water quality parameters (water temperature, pH, specific conductance, dissolved oxygen, turbidity and discharge) at selected sites in priority streams within SCPN parks.
- Determine status and trends of selected water quality constituents, including bacteria, nutrients, major elements, and trace metals at selected sites in priority streams within SCPN parks.
- Compare water quality data against state standards for chronic exceedances. Multiple exceedances in a year typically indicate non-compliance.

1.1 Selecting potential water quality monitoring sites

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

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

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

Whenever possible, SCPN water quality monitoring sites are located where a history of water quality data collection exists, and co-located with SCPN aquatic macroinvertebrate monitoring sites.

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

1.2 Water quality monitoring at Grand Canyon National Park

Garden Creek is a perennial stream that originates from numerous springs surrounding Indian Gardens, a popular campground, day-hiking, and mule-riding destination located below the South Rim in Grand Canyon NP (GRCA). The campground and mule corral are located adjacent to the springs and Garden Creek. Just below Indian Gardens is a discharge pipe from the Trans-Canyon Pipeline, which transports water from Roaring Springs below the North Rim to a pumping station at Indian Gardens. From Indian Gardens, the water is pumped to the South Rim. When pumping is not occurring, the water is released into Garden Creek, roughly doubling its flow (Dyer et al. 2016). Bright Angel Trail, the most popular trail into Grand Canyon, follows Garden Creek along most of its extent. The lower portion of the creek crosses the trail multiple times before converging with Pipe Creek, which flows into the Colorado River. In addition to as many as 800 hikers per day, up to 10 mule trips per day can occur along the Bright Angel Trail.

Bright Angel Creek is a perennial stream that flows from Roaring Springs near the North Rim of GRCA and runs parallel to the North Kaibab Trail before draining into the Colorado River. The creek passes Phantom Ranch and the Bright Angel Campground, both extremely popular overnight destinations located at the bottom of Grand Canyon. Phantom Ranch is also the final destination for overnight mule rides into the canyon.

Hermit Creek is a perennial stream that flows from Grand Canyon's South Rim into the Colorado River at Hermit Rapids. The Hermit Fault acts as one of the main pathways for the flow of groundwater from the South Rim. Consequently, this creek is one of the larger streams in this section of the Grand Canyon. The creek flows past the Hermit Campground and along Hermit Trail before joining the Colorado River.

In 2013 SCPN implemented long-term water quality monitoring on Garden and Bright Angel Creeks in GRCA. Water samples are collected on a quarterly basis at the following sites (Figure 1):

- *Garden Creek below Tonto Trail* (GRCAGAR01), identified in this report as GAR01, is located 1 km downstream from Indian Gardens. GAR01 is co-located with a SCPN aquatic macroinvertebrate monitoring site. In addition to the four quarterly visits, SCPN crew collected 4 additional core parameter samples from 28–31 May.
- *Bright Angel Creek near Colorado River* (GRCABRI02), identified in this report as BRI02, is located below Phantom Ranch and the Bright Angel Campground and is 0.2 km upstream from the Colorado River.

In addition to the long-term water quality monitoring sites listed above, core parameter measurements are collected at two aquatic macroinvertebrate monitoring sites. These sites are visited once per year:

- *Hermit Creek below Tonto Trail*. (GRCAHER01), identified in this report as HER01, is located just downstream of the Hermit Creek Campground and the Tonto Trail crossing.
- *Bright Angel Creek below first foot bridge* (GRCABRI01), identified in this report as BRI01 is located approximately 4.5 km upstream from Phantom Ranch, and downstream from the first large steel footbridge on the North Kaibab Trail.

In 2014 SCPN continued a collaboration with the US EPA to sample at selected sites for Contaminants of Emerging Concern (CEC). The following sites were sampled as described.

- *Bright Angel Creek near Colorado River* (GRCABRI02) was sampled for CEC's during water quality monitoring visits on 24 April, 5 September, and 24 October 2014.
- *Garden Creek below Tonto Trail* (GRCAGAR01) was sampled for CECs during regular water quality monitoring visits on 5 September and 24 October.

SCPN collects core water quality data and water quality samples at regular intervals throughout the year. Water quality samples are analyzed by SCPN staff and by a qualified contract laboratory. In 2014, SCPN staff made four water quality monitoring site visits to BRI02 and GAR01. Additional data on Contaminants of Emerging Concern



Figure 1. Water quality and aquatic macroinvertebrate monitoring sites on Garden, Bright Angel and Hermit Creeks in Grand Canyon NP, 2014.

were collected at GAR01 during another visit to Garden Creek in May 2014 to make observations on a related but separate issue. This report documents all SCPN water quality monitoring activities at GRCA in 2014 and summarizes the data collected.

2 Methods

A brief description of water quality data collection and processing procedures followed by SCPN staff at GRCA during 2014 is presented here. Detailed descriptions of these procedures are available in Water Quality Monitoring Protocol for Streams and Springs in the Southern Colorado Plateau Network (Monroe et al. 2016).

2.1 Water quality core parameters

NPS core water quality parameters include water temperature, pH, specific conductance, dissolved oxygen, turbidity, and discharge. During each site visit, SCPN water resources field crew noted the hydrologic conditions and collected water quality core parameter data using the following methods:

- As soon as possible after arrival at the site a multiparameter sonde (Hydrolab-MS5; Hach Inc.) was calibrated and deployed in a well-mixed part of the stream channel, logging temperature, pH, specific conductance, and dissolved oxygen data at 5-second intervals. The sonde was left stationary in the stream for the duration of the site visit.
- Turbidity samples were kept on ice for no longer than 24 hours, and analyzed with a HACH 2100P Portable Turbidimeter (Hach Inc.).
- Discharge was measured using a Marsh-McBirney Flo-mate (Hach, Inc.), a Hach FH950, Baski Flume, or a Sontek Flowtracker ADV (Xylem, Inc.).

2.2 Water quality samples and analysis

In 2013 SCPN began collecting water quality samples on a quarterly basis at GRCA to analyze for bacteria, nutrients, major elements and trace metals. In 2014, samples from BRI02 taken on 24 April and 5 September were analyzed for total organic carbon, as well. Samples for contaminants of emerging concern and bacteria have been collected at GRCA since 2011.

Bacteria samples were collected by dipping a sample bottle into the center of flow. SCPN staff analyzed the sample for total coliforms and *E. coli* using the Quanti-Tray® 2000 system (IDEXX Inc.). Samples were collected to be tested for other analytes in a similar manner. Sample water was filtered and/or acid-treated (as required), kept on ice, and shipped to the contract laboratory. In 2014 SCPN continued an Interagency Agreement with the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analysis of water samples for selected water quality constituents (Table 1).

In 2014, SCPN collected samples at GRCA for a suite of contaminants of emerging concern (CECs), which include pharmaceuticals, personal care products, waste water indicators, and pesticides (Appendix C). The procedures described in NPS 2013 were followed, and the samples were analyzed by the EPA Region 8 laboratory. The purpose was to develop a baseline dataset documenting the occurrence of these contaminants within SCPN parks. Samples for these contaminants were collected at BRI02 and GAR01.

Table 1. USGS National Water Quality Laboratory and U.S. Environmental Protection Agency Laboratory sample analytes.

Analytical group	Analytes
Nutrients	ammonia, nitrite, nitrite + nitrate, orthophosphate
Major elements	calcium, chloride, fluoride, magnesium, potassium, silica, sodium, sulfate, acid neutralizing capacity (ANC; as CaCO ₃), total dissolved solids
Trace metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc
Total organic carbon	total organic carbon
Contaminants of emerging concern	pharmaceuticals, personal care products, waste water indicators, pesticides

2.3 Data handling and reporting

All water quality data are entered into SCPN's water quality database. All multiparameter sonde electronic data and discharge files are stored on the SCPN server. In this report, we include the median values of a subset of seven consecutive multiparameter sonde measurements. Similarly, only the median values for each set of turbidity samples are presented. For total coliforms and *E. coli* samples, most-probable numbers (MPN/100 mL) are reported; MPN is a statistical estimate of the number of bacteria per unit volume of a sample, determined by using a lookup table provided by the manufacturer of Quanti-Tray 2000, the method used by SCPN to analyze bacteria in stream samples (IDEXX Inc.). For *E. coli*, we compared our results against the Arizona water quality criteria for full body contact.

All results from the NWQL and EPA are presented as they were reported from the lab. In cases where analytes were not detected, we present the applicable laboratory reporting level, which is the lowest concentration that can be reliably quantified by a given analytical method. For the NWQL data, results which are below the laboratory reporting level but above the method detection level are flagged to indicate that the analyte was detected, but the concentration was not high enough to report.

We compared our results against Arizona water quality standards applicable to the monitoring sites in GRCA (ADEQ 2009), and noted any exceedances of these standards.

2.4 Understanding water quality data and standards

The NPS Natural Resource Challenge (NRC) provides funding for water quality monitoring in NPS park units. This funding is intended to advance NPS's long-term goals to protect pristine water quality and improve impaired water quality in parks by supporting Clean Water Act protections and provisions for designated unimpaired and impaired waters. Preliminary analysis of data available through the water quality data synthesis (Brown 2008), a Level 1 water quality inventory (Macy and Monroe 2006), and SCPN monitoring indicate that water quality conditions at many SCPN parks exceed established USEPA, State or Tribal standards.

The SCPN water quality monitoring program collects samples quarterly to document the range of hydrologic conditions that occur in network parks. Thus, rare and short-term events may not be captured. These 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.

The Arizona DEQ has developed water quality standards to meet requirements of the Federal Clean Water Act. This report includes water quality standards applicable to waters in Arizona that are not on tribal land (ADEQ 2009). A water quality standard refers to a specific parameter and its associated designated beneficial use, in conjunction with a criterion, which is the numeric component against which a result is compared. For example, the standard for chronic mercury (parameter) for warm water aquatic and wildlife (use designation) is 0.01 µg/L (numeric criterion).

All of SCPN's sample results are for the dissolved concentration, meaning the samples are filtered through a 0.45 µm filter to remove the particulate component of the sample before it is shipped for analysis of the dissolved fraction. Most Arizona aquatic life criteria for metals are based on the dissolved fraction. This method more accurately addresses the form of metals that is most toxic to aquatic life while excluding less toxic forms. However, not all Arizona water quality criteria are based on dissolved samples. Many are based on the total sample concentration, which includes the portion of the analyte bound to particulates. Because our samples exclude the particulate component, our data are not necessarily comparable to criteria based on the total sample. Therefore, only the criteria for dissolved parameters are listed in the Results section of this report. However, we note when dissolved concentrations exceed the criteria for total concentrations.

In this report results for each parameter are evaluated against applicable water quality standards as defined for each stream by the Arizona DEQ. There are three designated uses that apply to the SCPN water quality sites in

GRCA: aquatic and wildlife (warm water), full-body contact, and fish consumption. Each designated use may have different criteria for a particular parameter. Also, aquatic and wildlife criteria are often dependent upon water hardness, which varies at each site visit. In these cases, the criteria are expressed as a range encompassing the lowest and highest values for the year.

2.4.1 Chronic and acute standards

Numeric criteria for aquatic life water quality standards address potential effects of both chronic exposure to a parameter over an extended period of time (months) and acute exposure over a short period of time (hours or days). Acute standards apply to any single sample and are not to be exceeded at any time. Criteria are much lower for chronic exposure than for acute exposure and are not directly comparable to the results obtained from a single sample because chronic standards are based on the geometric mean of four samples collected at least 24 hours apart (ADEQ 2009). From a compliance standpoint, the acute instantaneous criteria afford the only direct comparison for such data because they apply to a single sample. However, from a resource conservation standpoint, instantaneous grab-sample data, when compared against more stringent chronic criteria, can provide a means of early warning and an indication of a problem that may require more attention. Therefore, we have identified when results are outside the chronic criteria in the Results section of this report.

2.4.2 Regulatory authority

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

3 Results

This section summarizes data collected by SCPN from Bright Angel, Garden, and Hermit Creeks in 2014 and in some cases, compares it with data collected in 2013. All data collected from these creeks, including dates and sample times, are in Appendix B.

3.1 Bright Angel Creek.

SCPN collects water quality core parameter measurements at two sites on Bright Angel Creek in GRCA. Each October, SCPN staff visit BRI01 to conduct aquatic macroinvertebrate monitoring. During these annual visits, water quality core parameter measurements are also collected. In 2014, this visit occurred on 23 October. Four times a year, SCPN takes core parameter measurements as well as samples for bacteria, nutrients, major elements, and trace metals at BRI02, a long-term water quality monitoring site. In 2014 these visits took place on 24 January, 24 April, 5 September, and 24 October.

3.1.1 Water quality core parameter data

Core parameter data measured at BRI01 and BRI02 are summarized in Table 2, along with the applicable Arizona water quality criteria. The data for the 2013 site visits are included for comparison. For BRI01, both the 2013 and 2014 site visits occurred in October.

At Bright Angel Creek, Arizona water quality criteria for aquatic life apply to both pH and dissolved oxygen. For the visit made to BRI01 in 2014, water temperature was 14.5°C; pH was 8.6, which met the Arizona water quality criteria (see Table 2), specific conductance was 340 µS/cm; and dissolved oxygen was 9.4 mg/L, which also met the water quality criterion; turbidity was 0.9 NTU; discharge was 16.9 cfs.

For the four quarterly measurements taken at BRI02, water temperature ranged from 6.5–18.0°C. Values for pH ranged from 8.3–8.7; specific conductance was similar between site visits, ranging from 343–358 µS/cm. Dissolved

Table 2. Water quality core parameter data from BRI01 and BRI02 on Bright Angel Creek in Grand Canyon NP, 2014. Data from 2013 are included for comparison, along with the applicable Arizona aquatic life criteria. For BRI01 in 2013 and 2014 the median will equal the value as only one sample was collected. An “nc” indicates that no criteria exist for a specific parameter; “na” indicates range is not applicable for a single value.

Core parameter	Site	n	2013		2014		AZ state aquatic life criteria
			Median	Range	Median	Range	
Water temperature (°C)	BRI01	1	11.3	na	14.5	na	nc
	BRI02	3	11.4	10.9–21.4	15.9	6.5–18.0	
pH	BRI01	1	8.7	na	8.6	na	6.5–9.0
	BRI02	3	8.5	8.4–8.7	8.4	8.3–8.7	
Specific conductance (µS/cm)	BRI01	1	351	na	340	na	nc
	BRI02	3	341	278–356	352	343–358	
Dissolved oxygen (mg/L)	BRI01	1	10.3	na	9.4	na	>6.0
	BRI02	3	9.1	7.9–10.4	9.0	8.3–12.3	
Dissolved oxygen (%)	BRI01	1	103	na	102	na	nc
	BRI02	3	97.9	90.3–103	98.7	96.3–107	
Turbidity (NTU)	BRI01	1	1.1	na	0.9	na	nc
	BRI02	4	2.5	1.0–3.8	2.0	0.9–4.7	
Discharge (cfs)	BRI01	1	24	na	16.9	na	nc
	BRI02	4	21.7	13.1–25.8	17	15.6–18.8	

oxygen ranged from 8.3–12.3 mg/L; both pH and dissolved oxygen were within the water quality criteria. Dissolved oxygen was near 100% saturation for all four site visits; turbidity was low, ranging from 0.9–4.7 NTU.

Figure 2 shows discharge recorded at 15-minute intervals during 2014 at the USGS streamflow gaging station located near BRI02, Bright Angel Creek near Grand Canyon, AZ (#09403000, USGS 2016). The gage did not record a prolonged snowmelt period this year. There were several pulses of higher flow during the monsoon season between July and September. The highest flow for the year occurred on August 27 and measured 343 cfs. The lowest flow was recorded on June 5 and measured 6.5 cfs. Discharge measured during the four quarterly SCPN site visits ranged from 15.6–18.8 cfs.

The USGS station also records air and water temperatures at 15-minute intervals at Bright Angel Creek. The daily maximum, average, and minimum temperatures for 2014 are presented in Figure 3 (USGS 2016). The average air temperature was 19.3°C. The lowest air temperature was 0.2°C on December 31, and the highest air temperature was 40.9°C on May 27. Water temperatures ranged from a high of 28.3°C on July 30 to a low of 3.2°C on December 31. The average water temperature was 14.6°C. There are no water quality criteria for temperature at Bright Angel Creek.

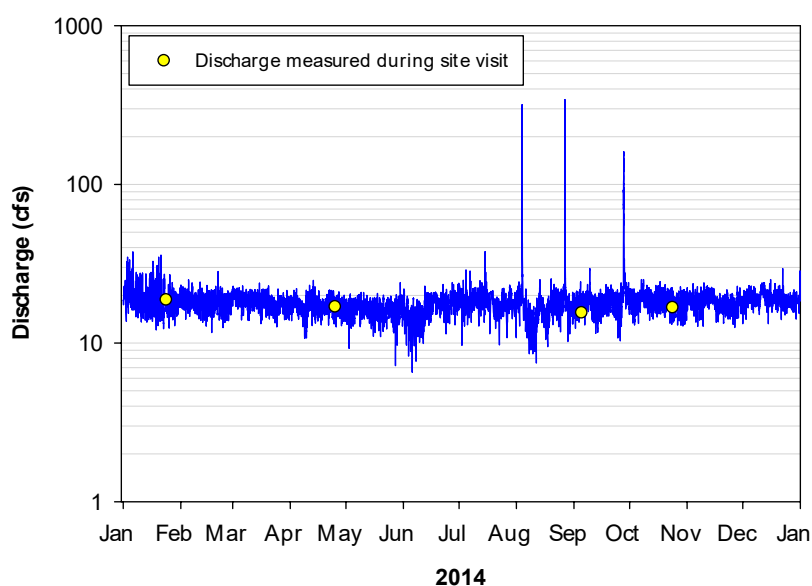


Figure 2. Discharge recorded at 15-minute intervals at Bright Angel Creek in 2014 from USGS streamflow gaging station #09403000 located near BRI02 in Grand Canyon NP.

3.1.2 Precipitation

Daily precipitation measurements for 2014 from the NOAA/NCDC monitoring station at Phantom Ranch are presented in Figure 4 (NOAA/NCDC 2016) with the dates of SCPN water quality site visits. Precipitation occurred primarily during the summer months, when monsoon thunderstorms tend to occur. The largest precipitation event, which was 2.2 cm, occurred on September 27. The September 5 water quality site visit occurred soon after rain and thunderstorms had occurred; the remaining three site visits occurred during dry periods. The total precipitation for the year was 14.1 cm.

3.1.3 Total coliforms and *E. coli*

Results for total coliforms and *E. coli* at BRI02 are presented in Figure 5 and listed in Appendix B. Bright Angel Creek is protected for full body contact (ADEQ 2009), meaning there is a high likelihood of complete submergence in the creek leading to ingestion of the water. The water quality criterion for *E. coli* is either a four-sample geometric mean of 126 MPN/100 mL or a single-sample maximum of 235 MPN/100 mL. *E. coli* results at BRI02 were low and well below the water quality criteria, ranging from <1–5 MPN/100 mL.

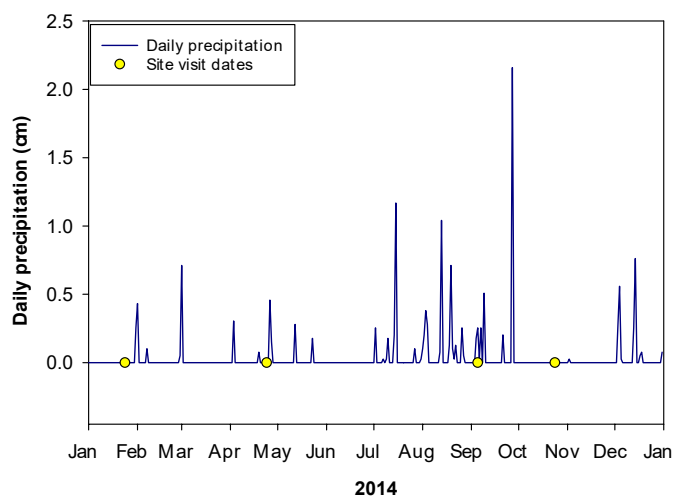
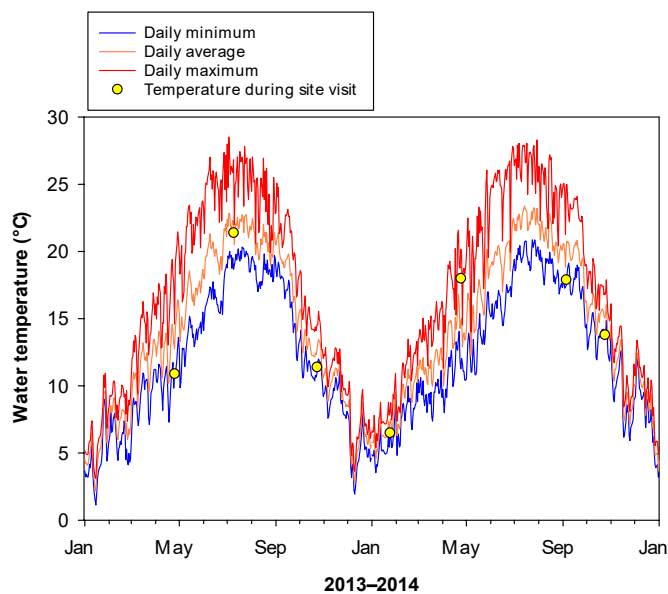
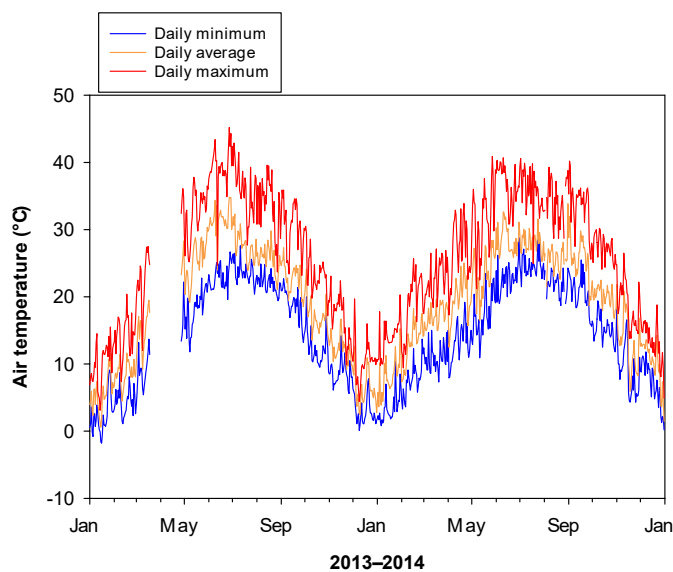


Figure 3. Daily minimum, maximum, and average air (top) and water (bottom) temperatures recorded at 15-minute intervals in 2014 by USGS station #09403000, located near BRI02 in Grand Canyon NP. Data from 2013 is included for comparison.

Figure 4. Total daily precipitation from the NOAA/ NCDC monitoring station (#026471) at Phantom Ranch in Grand Canyon NP, 2014.

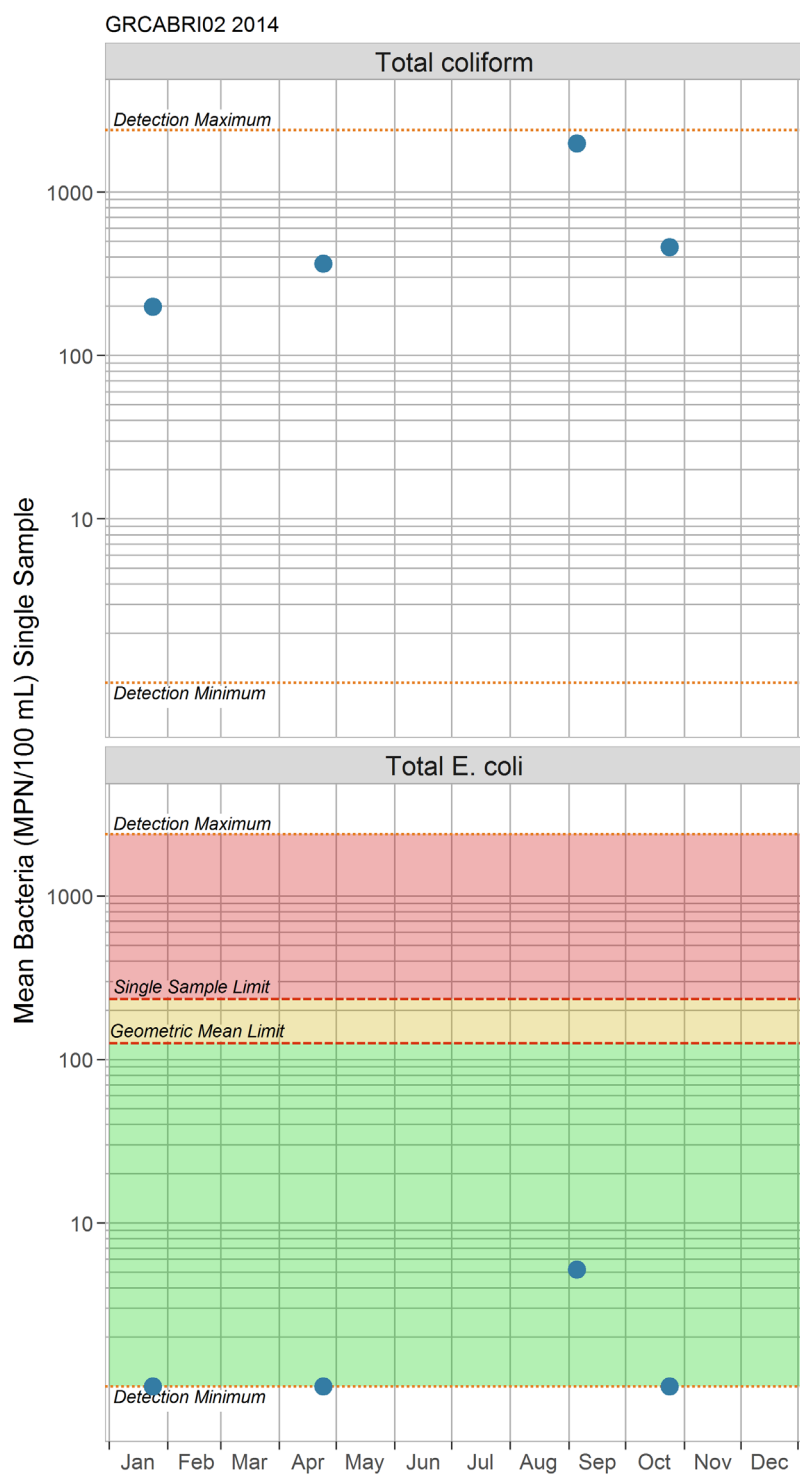


Figure 5. Total coliforms (top) and *E. coli* (bottom) results from samples collected at BRI02 in Grand Canyon NP, 2013–2014.

Total coliforms, which include *E. coli* and many other types of bacteria, are also included in the IDEXX analyses. They are indicators of the presence of all coliform groups of bacteria, both vegetative and fecal in origin. They are used in drinking water testing because their presence indicates contamination of a water supply by an outside source. There are no water quality standards for total coliforms in stream water. Results from BRI02 ranged from 200 to 2000 MPN/100 mL.

3.1.4 Water quality laboratory data

Nutrient, major element, and trace metal results from BRI02 are presented in Tables 3–5, along with the Arizona water quality standards applicable to this reach of Bright Angel Creek (ADEQ 2009). All results are for dissolved analytes except for acid neutralizing capacity and total organic carbon. Nutrient data are presented in Table 3. Ammonia, nitrite+nitrate, and nitrite were not detected above the laboratory reporting levels, which are 0.0200, 0.080, and 0.00200 mg/L, respectively. The water quality criterion for nitrate is 3733 mg/L, while the criterion for nitrite is 233 mg/L. Orthophosphate was detected in the January and April samples, but concentrations were low and near the 0.00800 mg/L reporting level. There are no water quality criteria for orthophosphate.

Major element data are presented in Table 4; there are no water quality standards for these analytes applicable to BRI02. Total dissolved solids ranged from 157–207 mg/L. Acid neutralizing capacity was similar in the four samples and ranged from 158–196 mg/L. Total organic carbon was analyzed in two samples but was only detected in one sample, at 0.97 mg/L. Silica concentrations ranged from 3.78–6.05 mg/L. Major ions are plotted relative to one another in terms of milliequivalents per liter in Figure 6. This plot shows that cation chemistry is dominated by calcium and magnesium, while anion chemistry is dominated by bicarbonate plus carbonate.

Table 3. Dissolved nutrient data from samples collected from BRI02 at Grand Canyon NP, AZ, 2014. Results that were lower than the National Water Quality Laboratory (NWQL) reporting levels are noted as “<[reporting level]”; “nc” indicates that there is no AZ criterion.

Nutrients (mg/L)	1/24/2014 10:15	4/24/2014 17:40	9/5/2014 9:20	10/24/2014 5:20	AZ Lowest dissolved criterion	# of exceed- ances	AZ Beneficial use
Ammonia as N	<0.0200	<0.0200 ^a	<0.0200	<0.0200	ndc	ndc	ndc
Nitrite + nitrate as N	<0.080 ^a	<0.080	<0.080	<0.080	3733 (NO ₃ as N)	0	FBC
Nitrite as N	<0.00200	<0.00200	<0.00200	<0.00200	233	0	FBC
Orthophosphate as P	0.0117	0.0106	<0.00800 ^a	<0.00800	nc	nc	nc

a Result is above the Method Detection Level and below the NWQL Reporting Level.

b FBC - beneficial use = Full body contact

Table 4. Major element data from BRI02 on Bright Angel Creek in Grand Canyon NP, 2014. All analytes are dissolved except for acid neutralizing capacity and organic carbon, which were measured in unfiltered samples. There are no Arizona water quality standards for these analytes. An “nd” indicates data is not available.

Major elements (mg/L)	1/24/2014 10:15	4/24/2014 17:40	9/5/2014 9:20	10/24/2014 5:20
Calcium	43.0	38.1	39.9	39.8
Chloride	3.64	3.53	3.58	3.60
Fluoride	0.065	0.059	0.054	0.059
Magnesium	22.4	21.1	21.9	22.2
Potassium	0.915	0.931	1.02	0.990
Silica	6.05	4.46	3.78	4.51
Sodium	3.65	3.51	3.25	3.41
Sulfate	5.90	5.70	5.20	5.65
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	196	170	158	180
Total dissolved solids	207	183	157	196
Total organic carbon (unfiltered)	nd	<0.70	0.97	nd

Major ion proportions were nearly identical in the four samples.

Trace metal data are presented in Table 5, along with the most stringent water quality criteria that apply to dissolved parameters. The data were evaluated against the Arizona water quality standards that apply to this reach of Bright Angel Creek: aquatic and wildlife (warm water), full-body contact, and fish consumption (ADEQ 2009). Of the 21 analytes, 9 were not detected above their laboratory reporting levels: aluminum, beryllium, cadmium, cobalt, copper, lead, mercury, silver, and zinc. The remaining metals were present in most samples but in low concentrations. None of the trace metals results exceed the water quality standards.

3.1.5 Contaminants of emerging concern

In 2014, three sets of samples were collected at BRI02 to be analyzed for contaminants of emerging concern, which fall in the following categories: pesticides, pharmaceuticals, personal care products, and waste indicators (Table 6; complete analyte list is in Appendix C). The samples were collected on 24 April, 5 September, and 24 October. Of the 265 analytes, four were detected at BRI02. No CECs were detected in the 24 April sample. The 5

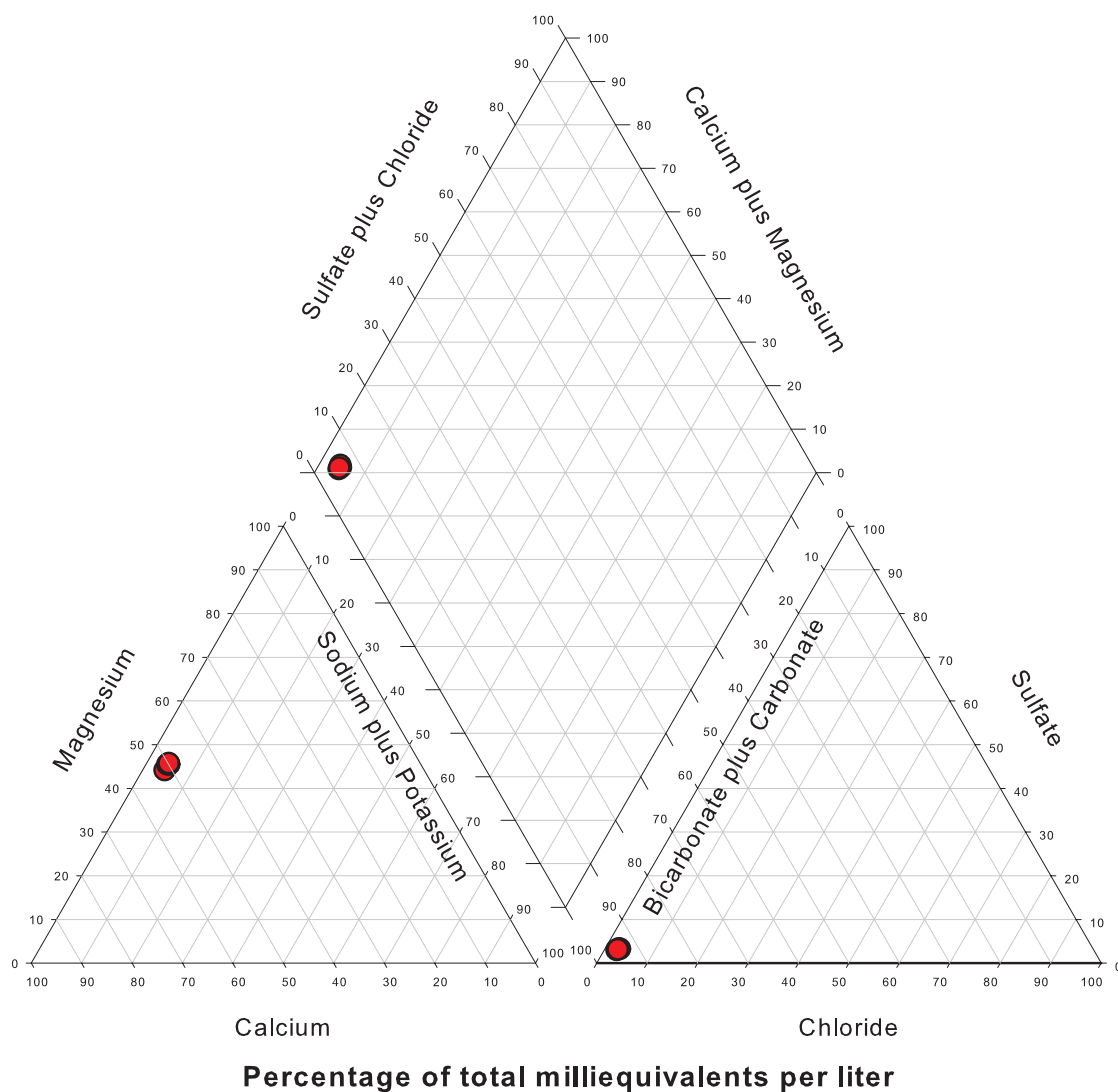


Figure 6. Major ion composition at BRI02 on Bright Angel Creek in Grand Canyon NP, 2014.

September sample contained caffeine and the flame retardant tri(dichloroisopropyl) phosphate. The 24 October sample contained the herbicide imazethapyr and bisphenol A (BPA). There are no Arizona water quality standards for these analytes.

3.2 Garden Creek

The following sections summarize data collected at Garden Creek in 2014 from four quarterly water quality monitoring site visits which took place on 24 January, 25 April, 5 September, and 24 October. Core parameter measurements and the results for bacteria, nutrients, major elements, trace metals, and contaminants of emerging concern are also presented.

3.2.1 Water quality core parameter data

Table 7 summarizes water quality core parameter data collected during all site visits to GAR01 in 2014. This includes the four quarterly water quality monitoring visits and four visits during a May 28–30 sampling event for another purpose. A summary of the 2013 data is included for comparison. Water temperature was recorded at

Table 5. Dissolved trace metal results from BRI02 on Bright Angel Creek in Grand Canyon NP, 2014, and number of times the samples were outside the applicable water quality criteria. An “nc” indicates that no criterion has been developed for a particular trace metal. An “ndc” indicates that there is no dissolved criterion for the trace metal. Results that were lower than the NWQL reporting levels are noted as “<[reporting level]”.

Trace metal (µg/L)	1/24/2014 10:15	4/24/2014 17:40	9/5/2014 9:20	10/24/2014 5:20	AZ Lowest dissolved criterion	# of exceedances	AZ Beneficial use ^a
Aluminum	<4.40	<4.40	<4.40	<6.00 ^{b,c}	nc	nc	nc
Antimony	<0.0540	0.0719	<0.0540	0.205	30 (chronic)	0	A&Ww
Arsenic	0.857	1.07	1.14	0.847	150 (chronic)	0	A&Ww
Barium	143	134	148	148	ndc	ndc	ndc
Beryllium	<0.040	<0.040	<0.040	<0.040	ndc	ndc	ndc
Boron	18.6	21.3	16.6	20.4	ndc	ndc	ndc
Cadmium	<0.060	<0.060	<0.060	<0.060	0.85–0.91 (chronic)	0	A&Ww
Chromium	0.86	0.65	<0.60 ^a	<0.60 ^a	Cr (III), 121–131; Cr (VI), 11 (chronic)	0	A&Ww
Cobalt	<0.100 ^a	<0.100 ^a	<0.100 ^a	0.708	nc	nc	nc
Copper	<1.60	<1.60 ^a	<1.60	<1.60 ^a	14.9–16.2 (chronic)	0	A&Ww
Iron	<8.00 ^a	<8.00 ^a	8.57	<8.00 ^a	1000 (chronic)	0	A&Ww
Lead	<0.080	<0.080	<0.080	<0.080	4.80–5.31 (chronic)	0	A&Ww
Manganese	1.22	1.25	3.51	2.70	ndc	ndc	ndc
Mercury	<0.010	<0.010	<0.010	<0.010	0.01 (chronic)	0	A&Ww
Molybdenum	0.163	0.170	0.182	0.171	nc	nc	nc
Nickel	0.727	0.633	<0.400	0.713	86.3–93.5 (chronic)	0	A&Ww
Selenium	0.323	0.374	0.231	0.240	2 (total, chronic)	0	A&Ww
Silver	<0.040	<0.040	<0.040	<0.040	9.01–10.6 (acute)	0	A&Ww
Uranium	0.635	0.560	0.563	0.540	ndc	ndc	ndc
Vanadium	0.773	0.995	0.738	0.670	nc	nc	nc
Zinc	<4.00	<4.00	<4.00	<4.00	195–211 (chronic)	0	A&Ww

a Beneficial use codes: A&WHbt - aquatic and wildlife habitat; AgWS - agricultural water supply; LW - livestock watering

b Result is above the Method Detection Level and below the NWQL Reporting Level.

c NWQL changed the Reporting Level to 6.00.

Table 6. Summary of detections of contaminants of emerging concern in samples collected at BRI02 on Bright Angel Creek in Grand Canyon NP, 2014.

Contaminant	Use	No. of detections
Pesticides		
Imazethapyr	herbicide	1
Pharmaceuticals and personal care products		
Waste indicators		
Caffeine	Stimulant drug	1
Tri(dichloroisopropyl) Phosphate	Flame retardant	1
Bisphenol A	Used in the production of polycarbonate plastics and epoxy resins (such as hard plastic bottles and metal food cans)	1 ^a

a Analyzed outside holding time; method blank spike yield was low

Table 7. Summary of water quality core parameter data from GAR01 on Garden Creek in Grand Canyon NP, 2014. Data from 2013 are included for comparison, along with the applicable Arizona aquatic life criteria. An “nc” indicates that no criteria exist for a specific parameter.

Core parameter	2013			2014			AZ state aquatic life criteria
	<i>n</i>	Median	Range	<i>n</i>	Median	Range	
Water temperature (°C)	6	17.9	15.2–19.0	8	16.6	11.2–21.3	nc
pH	6	8.3	7.9–8.6	8	8.3	8.2–8.5	>6.5 and <9.0
Specific conductance (µS/cm)	6	375	360–475	8	455	363–488	nc
Dissolved oxygen (mg/L)	6	7.7	7.6–8.6	8	8.3	7.7–8.6	>6.0
Dissolved oxygen (%)	6	94.1	91.5–97.4	8	97.4	87.8–100	nc
Turbidity (NTU)	7	1.6	0.3–6.3	8	0.5	0.4–3.7	nc
Discharge (cfs)	7	1.8	0.5–3.2	7	0.9	0.5–1.6	nc

15-minute intervals throughout 2014 at GAR01. The maximum water temperature was 24.4°C, which occurred on July 13. The minimum temperature was 8.3°C and occurred on January 6 and 8. The average temperature in 2014 was 15.2°C. There are no Arizona water quality criteria for temperature for Garden Creek.

Values for pH ranged from 8.2–8.5, and specific conductance ranged from 363–488 µS/cm; measurements for this parameter tended to fluctuate with the input of North Rim water (see below). Dissolved oxygen ranged from 7.7–8.6 mg/L (87.8–100% saturation) both dissolved oxygen and pH were within the warm water aquatic life criteria (see Table 7). Turbidity ranged from 0.4–3.7 NTU and discharge ranged from 0.5–1.6 cfs; discharge roughly doubles when the stream is receiving North Rim water.

3.2.2 Precipitation

Daily precipitation data for 2014 from the NADP/NTN AZ03 weather monitoring station (NADP 2016) at Hopi Point is presented in Figure 7, along with the dates of water quality site visits. Precipitation totaled 28.5 cm in 2014. Most of the precipitation this year occurred during the monsoonal months of July, August, and September. All eight precipitation events that exceeded 1 cm occurred during these months. The 5 September sample event occurred after a day of heavy rain; the remaining site visits occurred during dry periods.

3.2.3 Total coliforms and *E. coli*

Results for total coliforms and *E. coli* at GAR01 are presented in Figure 8 and listed in Appendix B. Total coliforms are indicators of the presence of all coliform groups of bacteria, both vegetative and fecal in origin. For drinking water, they are the standard diagnostic test because their presence indicates contamination of a water supply from an outside source, though there are no surface water quality criteria for these bacteria. Total coliforms at GAR01 ranged from 70– >2400 MPN/100 mL.

Arizona has two *E. coli* criteria applicable to Garden Creek. Those criteria are 235 MPN/100 mL for a single sample or 126 MPN/100 mL for the geometric mean of four samples collected in a 24-hour period. In all samples collected at GRCA in 2014, *E. coli* levels were very low and far below these criteria. *E. coli* at GAR01 ranged from <1–4 MPN/100 mL.

3.2.4 Water quality laboratory data

Results from four sets of samples from GAR01 analyzed for nutrients, major elements, and trace metals are presented in Tables 8–10. The lowest water quality criteria applicable to Garden Creek for dissolved nutrients and trace metals are also presented.

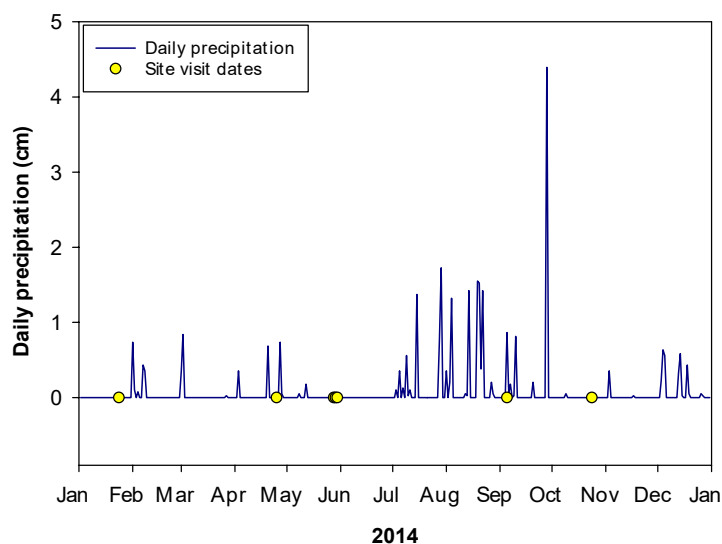


Figure 7. Daily precipitation from the NADP/NTN AZ03 monitoring station at Hopi Point in Grand Canyon NP in 2014, and sample dates for Garden Creek.

Dissolved nutrient levels were very low in all four samples and well below the applicable water quality criteria (Table 8). Ammonia and nitrite were not detected above their respective water quality criteria of 0.0200 and 0.00200 mg/L. Nitrite+nitrate was detected once, in the 24 January sample, at 0.152 mg/L. The remaining three samples were below 0.080 mg/L. Orthophosphate was detected twice, but levels were only slightly above the reporting level of 0.00800 mg/L.

Major element results are in Table 9; concentrations for these analytes were similar among the four samples. Silica concentrations ranged from 7.83–9.13 mg/L. Acid neutralizing capacity ranged from 195–232 mg/L. Total dissolved solids ranged from 200–261 mg/L. Major ions are plotted relative to one another in terms of milliequivalents per liter in Figure 9. This plot shows that water chemistry in Garden Creek is very similar to Bright Angel Creek. The cations are equally dominated by magnesium and calcium, while anions are almost entirely dominated by bicarbonate plus carbonate.

Dissolved trace metal results are provided in Table 10. The 25 April result for selenium was 2.53 µg/L, which is higher than the chronic warm water aquatic life criterion of 2 µg/L. However, this is a chronic criterion and requires the geometric mean of four samples, which was 1.82 µg/L for the four samples collected in 2014. While our sample results did not exceed the chronic selenium criterion, it is important to note that the selenium criterion is based on the total (unfiltered) sample concentration, and our result is for the dissolved (filtered) concentration. It is possible that the total concentration is higher than our results indicate.

Table 8. Dissolved nutrient data from GAR01 at Grand Canyon NP, 2014. An “nc” indicates that no water quality standards have been developed for a particular nutrient. Results that were lower than the National Water Quality Laboratory reporting levels are noted as “<[reporting level]”.

Nutrients (mg/L)	1/24/2014 14:00	4/25/2014 9:30	9/5/2014 12:41	10/24/2014 8:34	AZ Lowest dissolved criterion	# of exceedances	AZ Beneficial use
Ammonia as N	<0.0200	<0.0200 ^a	<0.0200	<0.0200	ndc	ndc	A&Ww
Nitrite + nitrate as N	0.152	<0.080 ^a	<0.080 ^a	<0.080	3733 (NO ₃ as N)	0	FBC
Nitrite as N	<0.00200	<0.00200 ^a	<0.00200	<0.00200 ^a	233	0	FBC
Orthophosphate as P	0.01800	0.00810	<0.00800 ^a	<0.00800	nc	nc	nc

a Result is above the Method Detection Level and below the NWQL Reporting Level.

b Beneficial use FBC= full body contact; A&Ww = Aquatic and wildlife (warm water)

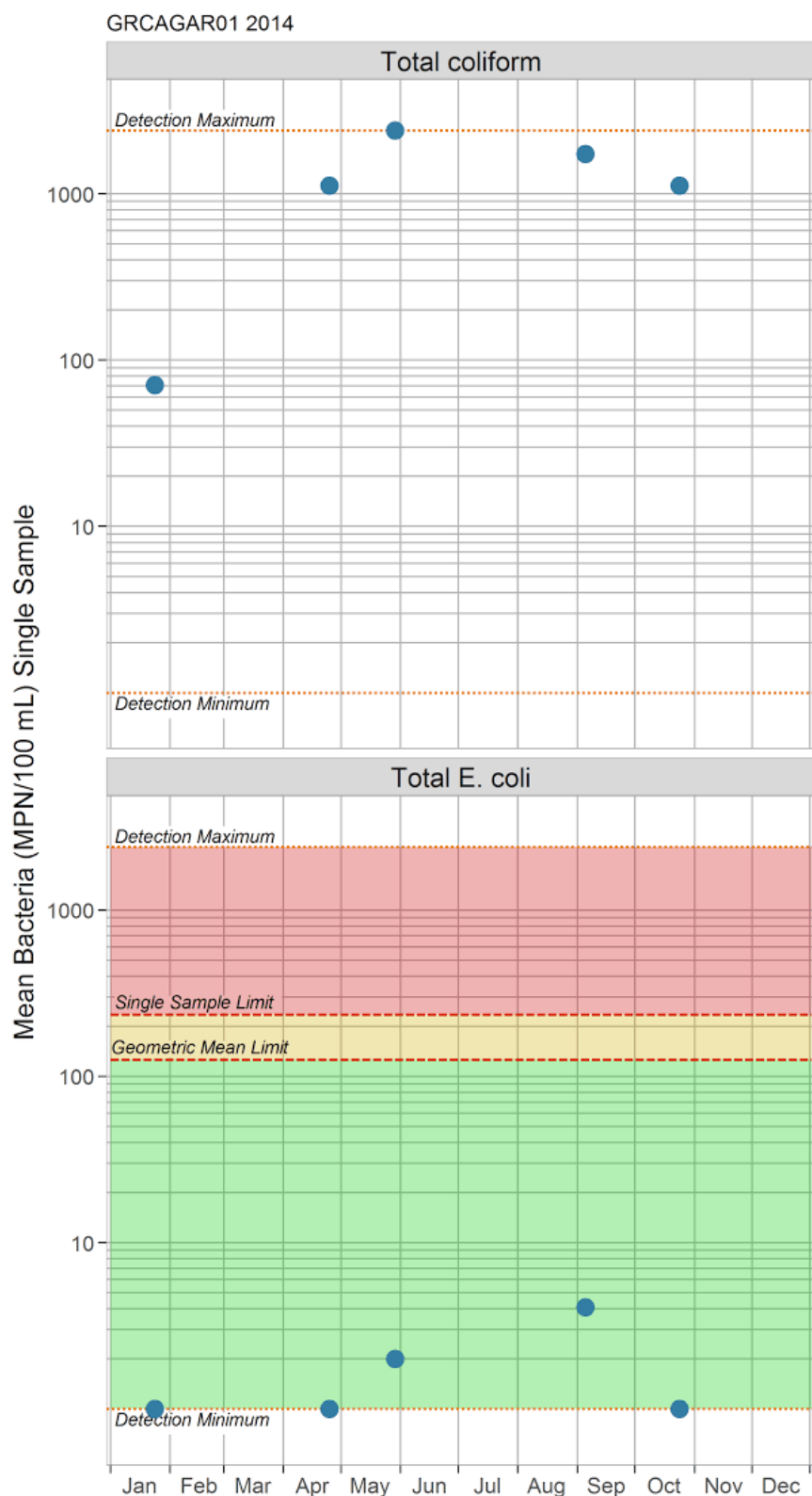


Figure 8. Total coliforms (top) and *E. coli* (bottom) results for samples collected from GAR01 at Garden Creek in Grand Canyon NP in 2014.

Results for seven metals—beryllium, cadmium, copper, lead, mercury, silver, and zinc—were below the laboratory reporting limits. Concentrations for the remaining trace metals were fairly similar between site visits. With the exception of selenium, concentrations for these metals were well below their water quality criteria.

3.2.5 Contaminants of emerging concern

The complete list of 265 analytes for contaminants of emerging concern is in Appendix C. Table 11 summarizes detections for contaminants of emerging concern at GAR01. CEC samples for GAR01 were collected six times in 2014. Complete CEC data are in Appendix B. Four samples for CEC analysis were collected from 28–30 May. The waste indicator sample was only collected twice. There were two detections in the waste indicator samples: the flame retardant and plasticizer tri(2-butoxyethyl) phosphate and bisphenol A, which is used in polycarbonate plastics and in metal food can coatings.

Table 9. Major element data from GAR01 on Garden Creek in Grand Canyon NP, 2014. All analytes are dissolved except for acid neutralizing capacity, which was measured in unfiltered samples. There are no Arizona water quality standards for these analytes.

Major elements (mg/L)	1/24/2014 14:00	4/25/2014 9:30	9/5/2014 12:41	10/24/2014 8:34
Calcium	43.1	49.8	51.5	50.0
Chloride	5.12	9.56	10.5	9.52
Fluoride	0.092	0.120	0.122	0.118
Magnesium	23.9	29.5	31.1	28.9
Potassium	1.03	1.24	1.36	1.18
Silica	7.83	9.13	9.05	9.11
Sodium	3.34	6.06	6.70	6.12
Sulfate	6.97	14.1	13.7	12.8
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	195	229	211	232
Total dissolved solids	200	261	229	261

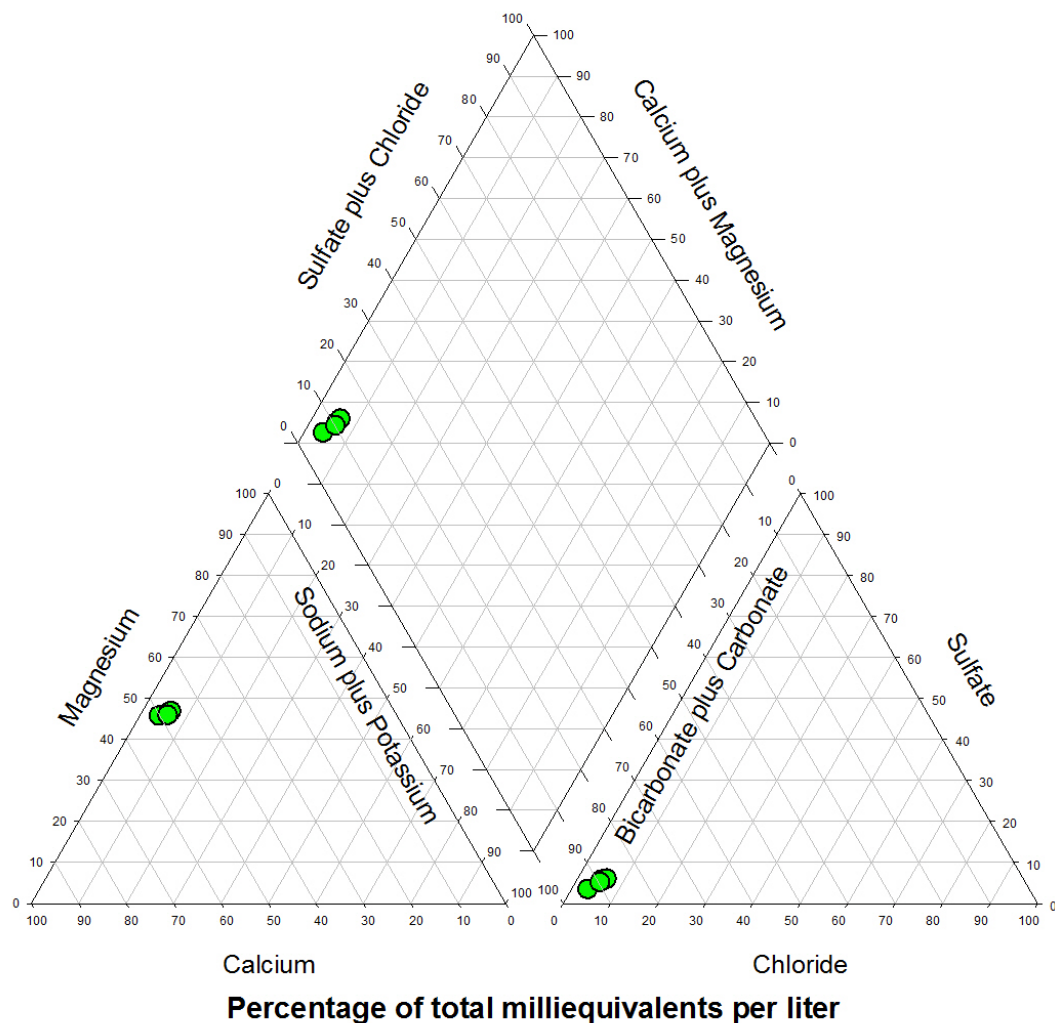


Figure 9. Major ion composition at GAR01 on Garden Creek in Grand Canyon NP, 2014.

Table 10. Dissolved trace metal results from GAR01 on Garden Creek in Grand Canyon NP, 2014, and number of times the samples were outside the applicable water quality criteria. An “nc” indicates that no criterion has been developed for a particular trace metal. An “ndc” indicates that there is no dissolved criterion for the trace metal. Results that were lower than the NWQL reporting levels are noted as “<[reporting level]”.

Trace metal (µg/L)	1/24/2014 14:00	4/25/2014 9:30	9/5/2014 12:41	10/24/2014 8:34	AZ Lowest dissolved criterion	# of exceedances	AZ Beneficial use ^a
Aluminum	9.57	<4.40	<4.40	<6.00 ^{b,c}	nc	nc	nc
Antimony	<0.0540	0.0669	<0.0540 ^a	0.205	30 (chronic)	0	A&Ww
Arsenic	1.27	1.61	1.73	1.35	150 (chronic)	0	A&Ww
Barium	196	276	317	276	ndc	ndc	ndc
Beryllium	<0.040	<0.040	<0.040	<0.040	ndc	ndc	ndc
Boron	16.9	28.2	25.3	26.5	ndc	ndc	ndc
Cadmium	<0.060	<0.060	<0.060	<0.060	0.93–1.08	0	A&Ww
Chromium	0.94	<0.60 ^a	<0.60	<0.60 ^a	Cr (III), 134–161; Cr (VI), 11 (chronic)	0	A&Ww
Cobalt	<0.100 ^a	<0.100 ^a	<0.100 ^a	0.616	nc	nc	nc
Copper	<1.60	<1.60	<1.60	<1.60	16.6–20.1 (chronic)	0	A&Ww
Iron	11.9	<8.00 ^a	14.5	15.6	1000 (chronic)	0	A&Ww
Lead	<0.080	<0.080 ^a	<0.080	<0.080 ^a	5.47–6.91 (chronic)	0	A&Ww
Manganese	2.10	2.82	3.90	4.48	ndc	ndc	ndc
Mercury	<0.010	<0.010	<0.010	<0.010	0.01 (chronic)	0	A&Ww
Molybdenum	0.364	0.607	0.706	0.570	nc	nc	nc
Nickel	0.759	0.781	<0.400	0.805	95.9–116 (chronic)	0	A&Ww
Selenium	1.47	2.53	1.66	1.76	2 (total)	1	A&Ww
Silver	<0.040	<0.040	<0.040	<0.040	11.2–16.3 (acute)	0	A&Ww
Uranium	0.919	1.43	1.46	1.25	ndc	ndc	ndc
Vanadium	1.05	0.876	0.865	0.790	nc	nc	nc
Zinc	<4.00	<4.00	<4.00	<4.00	216–261 (chronic)	0	A&Ww

a Beneficial use codes: A&Ww - aquatic and wildlife (warm water)

b Result is above the Method Detection Level and below the NWQL Reporting Level.

c NWQL changed the Reporting Level to 6.00.

Table 11. Summary of detections of contaminants of emerging concern in samples collected at GAR01 on Garden Creek in Grand Canyon NP, 2014.

Contaminant	Use	No. of detections
Pesticides		0
Pharmaceuticals and personal care products		0
Waste indicators ^a		
Bisphenol A	Used in the production of polycarbonate plastics and epoxy resins (such as hard plastic bottles and metal food cans)	1
Tri(dichloroisopropyl) Phosphate ^b	Flame retardant	2

a Waste indicators were not sampled on 4 of the 6 sampling days.

3.3 Hermit Creek

HER01 at Hermit Creek is visited annually for aquatic macroinvertebrate monitoring. Core parameter data are measured during these visits; the results for 2014 are displayed below in Table 12, with 2013 data included for comparison. None of the measurements exceeded the Arizona water quality criteria for aquatic life.

Table 12. Water quality core parameter data from HER01 on Hermit Creek in Grand Canyon NP, 2014, along with the applicable Arizona aquatic life criteria. An "nc" indicates that no criteria exist for a specific parameter.

Core parameter	4/18/2013 12:00	4/10/2014 12:00	AZ state aquatic life criteria
Water temperature (°C)	15.7	16.5	nc
pH	8.8	8.5	>6.5 and <9.0
Specific conductance	462	465	nc
Dissolved oxygen (mg/L)	9.1	8.8	>6.0
Dissolved oxygen (%)	101	99.3	nc
Turbidity (NTU)	2.2	1.6	nc
Discharge (cfs)	0.6	0.9	nc

4 Quality assurance/Quality control

SCPN crew followed the Quality Assurance/Quality Control procedures described in Monroe et al. (2016) and in National Park Service 2013. To assure accuracy of the instruments, we calibrated and performed maintenance on the multiparameter sondes in an indoor laboratory several times per year. Instruments were also calibrated in the field prior to measurements. We checked the current meters to ensure they were in working order following manufacturers recommendations, and calibrated the turbidimeter quarterly in the lab. The turbidimeter was also checked for drift in the field prior to each measurement. We collected five duplicate bacteria samples at several SCPN monitoring sites by filling two sample bottles in succession and comparing tray results after the incubation period. Two blank samples were processed using sterile water provided by IDEXX.

To verify the cleanliness of both the sampling equipment and the sample filtration process for nutrients, major elements, and trace metals, NWQL analyzed two sample sets of certified inorganic blank water, and results were compared to the 2014 reporting levels.

In reporting results for the Contaminants of Emerging Concern, SCPN collected one blank at GAR01. These sample results were considered, as well as the results provided by the EPA lab when making decisions to flag or to exclude data. The EPA lab includes results for laboratory method blanks, blank spikes, matrix spikes, and other QA/QC checks in their reports to SCPN; these results were also used to evaluate data quality.

5 Summary

This report summarizes water quality monitoring activities at Garden, Bright Angel, and Hermit Creeks in 2014 in GRCA, and compares the results to the Arizona water quality standards (ADEQ 2009).

NPS core parameter measurements for water temperature, pH, specific conductance, dissolved oxygen, turbidity and discharge were recorded for all site visits. Measurements for pH and dissolved oxygen were within the Arizona state water quality criteria at all sites.

In 2014, *E. coli* samples were collected at BRI02 on Bright Angel Creek and at GAR01 as part of SCPN's quarterly water quality monitoring in that stream. No exceedances of Arizona water quality criteria were observed.

Nutrient and trace metal concentrations were below the Arizona water quality criteria at BRI02 and GAR01, except that selenium exceedances may be an occasional issue at GAR01. Samples for contaminants of emerging concern were collected at GAR01 on Garden Creek. Two contaminants were detected: bisphenol A and tri(2-butoxyethyl phosphate). At BRI02 on Bright Angel Creek we collected three samples. Four contaminants were detected in these samples: imazethapyr, caffeine, tri(dichloroisopropyl) phosphate, and bisphenol A.

The data in this report should be viewed as a snapshot of water quality conditions existing at the time that the data was collected. Data in this report has been validated, but as we continue to explore and use it, we may find issues that cause us to make changes to this data. When sufficient data are available, SCPN plans to produce an interpretive report which will include trend analysis of water quality data for Bright Angel and Garden Creeks in Grand Canyon National Park.

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Appendix A: Southern Colorado Plateau Network Water Quality Monitoring Sites in Grand Canyon National Park

Table A1. Southern Colorado Plateau Network (SCPN) water quality monitoring sites for Grand Canyon NP, 2011–2013.

Site code	Common name	Report name	Easting (m) ^a	Northing (m) ^a	Elevation (m) ^a
GRCABRI01 ^b	Bright Angel Creek below first foot bridge	BRI01	403192	3998996	945
GRCABRI02	Bright Angel Creek near Colorado River	BRI02	401526	3995562	752
GRCAGAR01 ^b	Garden Creek below Tonto Trail	GAR01	399029	3993992	1085
GRCAHER01	Hermit Creek below Tonto Trail	HER01	390832	3993801	867

a Horizontal coordinates are reported in Universal Transverse Mercator (UTM) projection, Zone 12 North, North American Datum of 1983 (NAD 83). Vertical coordinates are referenced to the North American Vertical Datum of 1988 (NAVD 88).

b SCPN long-term water quality monitoring sites.

Appendix B: Water quality monitoring results for Bright Angel and Garden Creeks in Grand Canyon National Park, 2014

Table B1. Water quality core parameter and bacteria data from BRI02 at Bright Angel Creek in Grand Canyon NP, 2014.

Parameter	Sampling date and time			
	1/24/2014 10:05	4/24/2014 17:40	9/5/2014 9:20	10/24/2014 5:20
Water temperature (°C)	6.5	18.0	17.9	13.8
pH	8.3	8.7	8.4	8.4
Specific conductance (µS/cm)	348	343	356	358
Dissolved oxygen (mg/L)	12.3	8.3	8.4	9.5
Dissolved oxygen (% saturation)	107	97.1	96.3	100
Turbidity (NTU)	2.0	2.0	4.6	0.90
Discharge (cfs)	18.8	17.0	15.6	16.6
Total coliforms, MPN/100mL	200	370	2000	460
<i>E. coli</i> , MPN/100mL	<1	<1	5	1

Table B2. Contaminants of Emerging Concern data for samples taken from BRI02 on Bright Angel Creek in Grand Canyon NP in 2014.

Contaminant (ng/L)	Use	Reporting limit (ng/L)	Sampling date and time		
			4/24/2014 17:40	9/5/2014 9:20	10/24/2014 5:20
Pesticides			nondetect	nondetect	
Imazethapyr	Herbicide	20			21
Pharmaceuticals and personal care products			nondetect	nondetect	nondetect
Caffeine	Stimulant drug	50		85.8	
Waste indicators			nondetect		
Tri(dichloroisopropyl) Phosphate	Flame retardant, plasticizer, used in floor polishes	50		96.0	
Bisphenol A	Used in the production of polycarbonate plastics and epoxy resins (such as hard plastic bottles and metal food cans)	50			63.1 ^a

a Analyzed outside holding time; method blank spike yield was low

Table B3. Water quality core parameter and bacteria data from GAR01 on Garden Creek in Grand Canyon NP, 2014. An "nd" indicates no data available.

	Sampling date and time			
	1/24/2014 13:30	4/25/2014 9:30	9/5/2014 12:41	10/24/2014 8:34
Water temperature (°C)	11.2	15.5	21.3	15.3
pH	8.3	8.5	8.4	8.3
Specific conductance (µS/cm)	363	466	488	466
Dissolved oxygen (mg/L)	8.6	8.5	7.7	8.6
Dissolved oxygen (% saturation)	87.8	97.8	99.1	97
Turbidity (NTU)	3.7	0.5	1.2	0.40
Discharge (cfs)	1.2	1.6	nd	0.9
Total coliforms, MPN/100mL	71	1100	1700	1100
<i>E. coli</i> , MPN/100mL	<1	1	4	1

a Exceeded the maximum detection level of the IDEXX system, which is 2400 MPN/100 mL

Table B4. Contaminants of Emerging Concern data for samples taken from GAR01 on Garden Creek in Grand Canyon NP in 2014.

Contaminant (ng/L)	Use	Reporting limit (ng/L)	Sampling date and time					
			5/28 20:40	5/29 8:25	5/29 15:55	5/30 7:57	9/5 12:41	10/24 8:34
Pesticides			non-detect	non-detect	non-detect	non-detect	non-detect	non-detect
Pharmaceuticals and personal care products			non-detect	non-detect	non-detect	non-detect	non-detect	non-detect
Waste indicators			not sampled	not sampled			not sampled	not sampled
Tri(2-butoxyethyl) phosphate	Flame retardant, plasticizer, used in floor polishes	50			96.5 ^a	183 ^a		
Bisphenol A	Used in the production of polycarbonate plastics and epoxy resins (such as hard plastic bottles and metal food cans)	50				71.4		

a Analyzed outside holding time; method blank spike yield was low

Appendix C. List of analytes and reporting limits for contaminants of emerging concern

Table C-1. Target analytes and U.S. Environmental Protection Agency reporting limits for pesticides.

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
2,4,5-T	10.0	Ethoprop	10.0
2,4,5-TP	10.0	Fipronil	20.0
2,4-D	10.0	Fipronil sulfide	10.0
3-Hydroxycarbofuran	10.0	Fipronil sulfone	10.0
Acetochlor	20.0	Foramsulfuron	20.0
Acetochlor OA	20.0	Hexazinone	10.0
Alachlor	20.0	Imazaquin	20.0
Alachlor OA	50.0	Imazethapyr	20.0
Aldicarb	10.0	Imidacloprid	20.0
Aldicarb sulfone	20.0	Linuron	20.0
Aldicarb sulfoxide	10.0	Malathion	10.0
Atraton	10.0	MCPP	20.0
Atrazine	10.0	Metaxyl	10.0
Atrazine de-ethyl	20.0	Methiocarb	20.0
Atrazine de-isopropyl	20.0	Methomyl	20.0
Azoxystrobin	20.0	Metolachlor	10.0
Bentazon	10.0	Metolachlor ESA	20.0
Bromacil	50.0	Metribuzin	20.0
Bromoxynil	10.0	Monuron	10.0
Butachlor ESA	10.0	Neburon	50.0
Carbaryl	10.0	Oryzalin	20.0
Carbofuran	10.0	Oxamyl	10.0
Chlorimuron ethyl	20.0	Prometon	20.0
Chlorsulfuron	20.0	Propachlor	10.0
Clothianidin	20.0	Propachlor ESA	20.0
Cyanazine	10.0	Propachlor OA	10.0
Dacthal monoacid	20.0	Propazine	20.0
Diazinon	20.0	Propiconazole	50.0
Dichloroprop	10.0	Propoxur	10.0
Dimethachlor	10.0	Simazine	20.0
Dimethenamid	10.0	Sulfometuron methyl	20.0
Dimethenamid ESA	20.0	Tebuconazole	50.0
Disulfoton sulfone	20.0	Tebuthiuron	10.0
Diuron	20.0	Terbuthylazine	10.0
Diuron Metabolite	20.0	Thiamethoxam	20.0
EPTC	20.0	Triclopyr	20.0

Table C-2. Target analytes and U.S. Environmental Protection Agency reporting limits for pharmaceuticals and personal care products

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
(+/-)11-nor-9-carboxy-delta-THC	10.0	Duloxetine	25.0
10,11-dihydro-10-hydroxycarbamazepine	10.0	Ecgonine Methyl Ester	10.0
6-Acetylmorphine	10.0	EDDP	10.0
Acebutolol	10.0	Erythromycin	10.0
Acetaminophen	10.0	Erythromycin-anhydro	10.0
Albuterol	10.0	Escitalopram	10.0
Amitriptyline	10.0	Famotidine	10.0
Amitriptyline (+/-)-E-10-hydroxylated	10.0	Fenbufen	25.0
Amphetamine	10.0	Fentanyl	10.0
Aripiprazole	10.0	Fluoxetine	10.0
Atenolol	10.0	Fluticasone propionate	10.0
Atorvastatin	10.0	Furosemide	10.0
Atrazine	10.0	Gabapentin	10.0
Benzoylecgonine	10.0	Gemfibrozil	10.0
Bezafibrate	10.0	Glyburide	10.0
Buprenorphine	10.0	Hydrochlorothiazide	10.0
Bupropion	10.0	Hydrocodone	10.0
Caffeine	25.0	Hydromorphone	10.0
Carbamazepine	10.0	Hydroxybupropion	10.0
Carbamazepine 10,11 epoxide	10.0	Ibuprofen	25.0
Carisoprodol	10.0	Ketoprofen	10.0
Celecoxib	10.0	Lamotrigine	10.0
Chloramphenicol	10.0	Levorphanol	10.0
Chlorpheniramine	10.0	Lidocaine	10.0
Clenbuterol	10.0	Loratadine	10.0
Clopidogrel carboxylic acid	10.0	Lorazepam	25.0
Cocaethylene	10.0	MDA	10.0
Cocaine	10.0	MDEA	10.0
Codeine	10.0	MDMA	10.0
Cotinine	10.0	Mefenamic acid	10.0
DEET	10.0	Meperidine	10.0
Dehydroaripiprazole	10.0	Meprobamate	10.0
Desmethylcitalopram	10.0	Metformin	10.0
Desmethylvenlafaxine	10.0	Methadone	10.0
Dextromethorphan	10.0	Methamphetamine	10.0
Diclofenac	10.0	Methotrexate	10.0
Diclofenac 4-hydroxy	25.0	Methylparaben	25.0
Diltiazem	10.0	Methylphenidate	10.0
Diphenhydramine	10.0	Metoprolol	10.0
Disopyramide	10.0	Mevastatin	10.0
Donepezil	10.0	m-Hydroxybenzoylecgonine	10.0

Table C-2. Target analytes and U.S. Environmental Protection Agency reporting limits for pharmaceuticals and personal care products, *continued*.

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
Modafinil	10.0	Pregabalin	10.0
Modafinil acid	25.0	Primidone	25.0
Monoethylglycinexylidide	10.0	Propranolol	10.0
Montelukast	10.0	Pseudoephedrine	10.0
Morphine	10.0	Quetiapine	10.0
Naproxen	25.0	Ritalinic acid	10.0
n-Butylparaben	25.0	Sertraline	10.0
Nifedipine	10.0	Sildenafil	10.0
Nifedipine oxidized	10.0	Simvastatin	10.0
Norfentanyl	10.0	Sotalol	10.0
Norfluoxetine	10.0	Sulfamethazine	10.0
Normeperidine	10.0	Sulfamethoxazole	10.0
Norquetiapine	10.0	Sumatriptan	10.0
Norsertaline	10.0	Tadalafil	25.0
Norverapamil	10.0	Temazepam	10.0
Omeprazole	10.0	Thiabendazole	10.0
Oxazepam	10.0	Tramadol	10.0
Oxcarbazepine	10.0	Trazodone	10.0
Oxycodone	10.0	Triamterene	10.0
Oxymorphone	10.0	Triclocarban	10.0
Oxymorphone glucuronide	10.0	Triclosan	25.0
Paroxetine	10.0	Trimethoprim	10.0
Phenmetrazine	10.0	Tylosin	25.0
Phenobarbital	25.0	Valsartan	10.0
Phentermine	25.0	Venlafaxine	10.0
Phenylpropanolamine	10.0	Verapamil	10.0
Phenytoin	10.0	Warfarin	10.0
Pioglitazone	10.0	Zolpidem	10.0
Pravastatin	25.0	Zolpidem phenyl-4-carboxylic acid	10.0

Table C-3. Target analytes and U.S. Environmental Protection Agency reporting limits for wastewater indicators.

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
1,4-Dichlorobenzene	50.0	Galaxolide	50.0
17beta-Estradiol	100	Indole	50.0
1-Methylnaphthalene	50.0	Isoborneol	50.0
2,6-Dimethylnaphthalene	50.0	Isophorone	50.0
2-Methylnaphthalene	50.0	Isoquinoline	50.0
3-Methyl Indole	50.0	Menthol	50.0
4-Cumylphenol	50.0	Methyl Salicylate	50.0
4-n-Octylphenol	50.0	Metolachlor	50.0
4-tert-Octylphenol	50.0	Musk ketone	50.0
Acetophenone	50.0	Naphthalene	50.0
Benzophenone	50.0	Nonylphenol	50.0
Bisphenol A	50.0	p-Cresol	50.0
Bromacil	50.0	Pentachlorophenol	100
Butylated Hydroxyanisole	100	Phantolide	50.0
Caffeine	50.0	Phenanthrene	50.0
Camphor	50.0	Phenol	50.0
Carbaryl	50.0	Prometon	50.0
Carbazole	50.0	Pyrene	50.0
Celestolide	50.0	Tonalide	50.0
Chlorpyrifos	50.0	Tri(2-butoxyethyl) Phosphate	50.0
Dacthal	50.0	Tri(2-chloroethyl) Phosphate	50.0
Diazinon	50.0	Tri(dichloroisopropyl) Phosphate	50.0
Dichlorvos	50.0	Tributyl Phosphate	50.0
Equilenin	100	Triclosan	50.0
Estrone	100	Triethyl Citrate	50.0
Ethinylestradiol	100	Triphenyl phosphate	50.0
Fluoranthene	50.0		

Appendix D. Abbreviations, chemical formulas, and symbols used in this report

Term	Definition
ANC	acid neutralizing capacity of solutes plus particulates in an unfiltered water sample
CaCO ₃	chemical formula for calcium carbonate
cfs	cubic feet per second
cfu/100 ml	colony forming units, for bacteria sampling, a measure of the number of viable bacteria per 100 mL
LRL	laboratory reporting level
MDL	method detection level
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25°C, a measure of specific conductance
mg/L	milligrams per liter
Milliequivalents per liter	an expression of the concentration of substances that is chemically equivalent in terms atomic weight and electrical charge
MPN/100 mL	most probable number, for sampling bacteria, a statistical estimation of the number of coliform that would give the results shown by the laboratory examination
N	chemical symbol for the element nitrogen
ng/L	nanograms per liter
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for the element phosphorous

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