



Water Quality Monitoring for Tsaile Creek and Chinle Wash in Canyon de Chelly National Monument

2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/565



ON THE COVER
Tsaile Creek, Canyon de Chelly NM
Photograph by SCPN

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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 defining overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified 7 vital signs pertaining to riparian and spring ecosystems: 1) stream water quality, 2) aquatic macroinvertebrates, 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 of stream water quality monitoring for the SCPN parks are

- Determine status and trends in selected core water quality parameters (water temperature, pH, specific conductivity, 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 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 is available
- data gaps – waters identified as important, but where little or no water quality information exists

Water quality monitoring sites are located where a history of water quality data collection exists, and are colocated with SCPN aquatic macroinvertebrate monitoring sites whenever possible. NPS core water quality data and water quality samples are collected at regular intervals throughout the year. Diurnal variation in NPS core water quality parameters are characterized by deploying a multiparameter sonde to collect data for as many

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).

days as possible during base flows. Water quality samples are analyzed by SCPN staff and by a qualified contract laboratory.

1.2 Water quality monitoring at Canyon de Chelly National Monument

Chinle Wash is an intermittent stream draining a 1655 km² watershed, which includes Canyon de Chelly and a major tributary canyon, Canyon del Muerto. This canyon network was formed by streams originating in the Chuska Mountains along the Arizona/New Mexico border. Located entirely on the Navajo Nation, these canyon bottoms are used extensively for grazing, farming, and tourism, and the broad and sandy streambed of Chinle Wash is used as the main road through the canyon.

Tsaile Creek is a perennial stream draining a 424 km² area on the western flank of the Chuska Mountains. It is the headwater stream to Canyon del Muerto, eventually joining Chinle Wash in Canyon de Chelly. Creek flows are heavily influenced by Tsaile Dam, which was built in 1963 and formed Tsaile Lake. The dam has impacted the stream by reducing base flows and by moderating high flows that normally would result from spring snowmelt (NRCS 2000).

In 2010 SCPN implemented water quality monitoring at the following sites along Chinle Wash and Tsaile Creek in Canyon de Chelly National Monument (CACH). Limited water quality data was also collected at Black Rock Canyon in conjunction with aquatic macroinvertebrate sampling in 2010. This work was continued in 2011:

- *Chinle Wash at Chinle* (CACHCHI01) is identified in this report as CHI01. The site is located just outside the monument boundary (fig. 1), downstream of the mouth of Canyon de Chelly near a streamflow gaging station (Chinle Wash at Chinle, station number 09379025 NN 07), operated by the Navajo Nation Department of Water Resources, Water Management Branch. Samples are collected whenever flow is present in the stream at the time of a site visit.
- *Tsaile Creek below Tsaile Dam* (CACHTSA01) is identified in this report as TSA01. The site is co-located with SCPN's aquatic macroinvertebrate monitoring site. TSA01 is located in Canyon del Muerto, 0.95 km downstream of Tsaile Dam.
- *Black Rock Canyon below confluence of the east and west forks* (CACHBLA01) is identified in this report as BLA01. Black Rock Canyon is a major tributary to Canyon del Muerto.

During 2011, SCPN staff completed seven water quality monitoring visits to TSA01 at approximately six week intervals. On our trips to TSA01 we would drive by CHI01, and if water was flowing in the wash, we would stop and take water quality measurements. If water was not flowing in the wash, we would note that and drive on to TSA01. In 2011 we visited CHI01 four times early in the year. We made one visit to Black Rock Canyon for aquatic macroinvertebrate monitoring in September. This report summarizes all SCPN water quality monitoring activities at CACH in 2011.

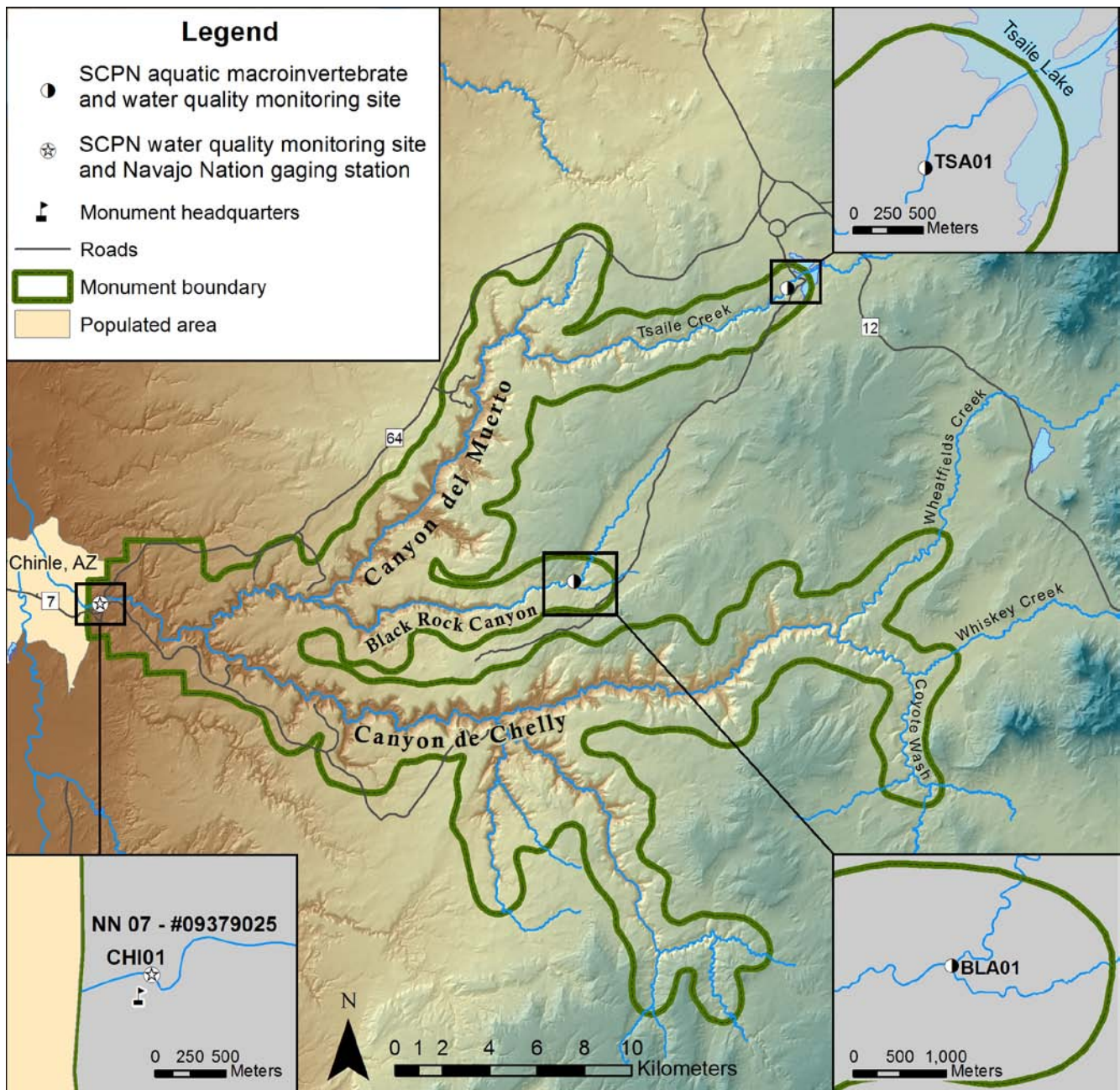


Figure 1. Locations of SCPN water quality monitoring sites, CHI01, TSA01, and BLA01, in Canyon de Chelly NM.

2 Methods

A brief description of water quality data collection and processing methodologies followed by SCPN staff at CACH during 2011 is presented here. Detailed descriptions of these procedures will be available in SCPN's water quality monitoring protocol (Monroe et al. in preparation).

2.1 Water quality core parameters

National Park Service core water quality parameters include water temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge. During each site visit, we noted the hydrologic conditions and collected water quality core parameter data using the following methods:

- 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 conductivity, and dissolved oxygen data at 5-second intervals. The sonde was left stationary in the stream for the entire site visit.
- Turbidity samples were kept on ice for a maximum of 24 hours, and analyzed with a HACH 2100P Portable Turbidimeter (Hach Inc.).
- Discharge was measured using a Marsh-McBirney Flo-mate (Hach, Inc.), a Baski Flume, or a Flowtracker ADV.
- At TSA01, water and air temperatures were recorded at 15-minute intervals by a HOBO Pendant Temperature/Alarm Data Logger, #UA-001-64, hereafter referred to as the logger (Onset Computer Corporation), deployed at the monitoring site. The sensors were downloaded and maintenance was performed during each site visit. Sensor accuracy was confirmed using a NIST-certified thermometer during each download.

2.2 Water quality samples

During each site visit, we collected a sample for bacterial analysis by dipping a sample bottle at the center of flow. The sample was then analyzed by SCPN staff for total coliforms and *E. coli* using the Quanti-Tray® 2000 system (IDEXX Inc.). We collected samples 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. For 2011, SCPN contracted with the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analysis of water samples for selected water quality constituents. These constituents fall into three categories: nutrients, major elements and trace metals (table 1). Information documenting NWQL methods are included in the SCPN water quality monitoring protocol (Monroe et al., in preparation).

Table 1. National Water Quality Laboratory sample analytes.

Analytical group	Analytes
Nutrients	ammonia, nitrite, nitrite + nitrate, orthophosphate
Major elements	calcium, chloride, fluoride, magnesium, potassium, silica, sodium, sulfate, acid neutralizing capacity (ANC; as CaCO ₃), total dissolved solids
Trace metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc

2.3 Data handling and analysis

All SCPN water quality data are entered in NPSTORET, v.1.83, a Microsoft Access database created by the Water Resources Division of the National Park Service. All multiparameter sonde and flow meter electronic data files are stored on the SCPN server.

In this report, we only include the median values of a subset of seven consecutive multiparameter sonde measurements recorded at the time of sample collection. Similarly, we only present the median values for each set of turbidity samples. All results from the NWQL 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 measured by a given analytical method.

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 supports efforts directed towards attainment of NPS's long-term goals to protect pristine water quality and improve impaired water quality 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 monitoring indicate that water quality conditions at many SCPN parks exceed established USEPA, state or tribal standards.

The Navajo Nation EPA has developed water quality standards and criteria to meet requirements of the Federal Clean Water Act. This report includes water quality standards and criteria applicable to waters on the Navajo Nation. A water quality standard refers to a specific 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 aquatic and wildlife habitat (use designation) is 2 µg/L (numeric criterion).

The SCPN water quality monitoring program collects samples several times per year at regular intervals in order to document the range of hydrologic conditions that occur, with a focus on base flow conditions. Thus, rare and short-term events are often not captured. Grab samples represent conditions at the point and time when samples were collected and do not represent the condition of the entire water body, spatially or temporally.

In this report results for each parameter are evaluated against applicable water quality standards as defined for each stream by the Navajo Nation EPA. Navajo Nation surface waters can have up to eight designated uses; most are applicable to the streams discussed in this report. Each use designation may have different criteria for one parameter. Also, aquatic life 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.

SCPN water samples are analyzed for dissolved parameters. This means stream water is passed through a 0.45 µm filter in order to remove the particulate component prior to being shipped for analysis. Water quality criteria may be expressed in terms of either the dissolved or total fraction of a sample. The total fraction concentration will be greater than the dissolved fraction. Because of this, only criteria for dissolved parameters are applicable to our samples, and only these criteria are listed in the Results sections.

For *E. coli*, we compared our results against the criteria for primary and secondary human contact. SCPN bacteria data are expressed as a most probable number (MPN) per 100 mL. 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 (IDEXX Inc.). Although the NNEPA water quality criteria are expressed as the number of colony forming units per 100 mL (cfu/100 mL) and do not assume an estimation, the two units are comparable.

2.4.1 Chronic and acute standards

Numeric criteria for water quality standards often 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). Criteria are much lower for chronic exposure than for acute exposure and are not directly comparable to the results obtained from a one-time grab sample because chronic standards are based on the arithmetic mean of samples collected during four consecutive days (NNEPA 2008). 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 criterion 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. Definitions of water quality standards according to the states of Arizona, Colorado, New Mexico, Utah, and the Navajo Nation are provided in the SCPN Streams and Springs Water Quality Monitoring Protocol (Monroe et al. in preparation).

3 Results

This section presents data collected by SCPN staff from Black Rock Canyon (BLA01), Chinle Wash (CHI01) and Tsaile Creek (TSA01) in 2011. All data for CHI01 and TSA01, including dates and sample times, are also included in Appendix B. At BLA01, only NPS core parameter data were collected during one aquatic macroinvertebrate monitoring site visit in 2010 and one in 2011. At CHI01, NPS core parameter and bacteria data were collected during four site visits. At TSA01, core parameter, bacteria, and NWQL samples for nutrients, major elements and trace metals were collected during each of seven site visits.

3.1 Black Rock Canyon below confluence of the east and west forks

Results for core parameter data collected at BLA01 are presented in Table 2. These data were collected on 11/3/2010 and 9/7/2011 during aquatic macroinvertebrate sampling. With the exception of temperature and dissolved oxygen, measurements were similar between the two years and did not fall outside the NNEPA water quality criteria (NNEPA 2008).

Table 2. Summary of water quality core parameter data from one sample collected at BLA01 in Canyon de Chelly NM, on November 3, 2010 and one collected on September 7, 2011. Associated NNEPA criteria are provided. A “n/c” indicates that no NNEPA criteria exists for a specific parameter.

Core parameter	2010	2011	NNEPA Criteria
Water temperature (°C)	4.0	18.7	n/c
pH	8.2	8.2	>6 and <9
Specific conductivity (µS/cm)	689	647	n/c
Dissolved oxygen (mg/L)	9.5	7.7	>6 mg/L
Turbidity (NTU)	2.4	2.5	n/c
Discharge (cfs)	<0.1	<0.1	n/c

3.2 Chinle Wash at Chinle

3.2.1 Water quality core parameter data

We collected samples at CHI01 during site visits in January, February, March, and May. The March and May visits coincided with dam releases from Tsaile Lake. NPS core parameter data collected during these visits are summarized in Table 3. Water temperature ranged from 0.0°C, when the water in the wash was mostly frozen, to 15.9°C. Dissolved oxygen was at or near saturation and above the water quality criteria during all site visits, ranging from 7.4 to 12.0 mg/L. For all site visits, pH was similar, and ranged from 8.1 to 8.5—within the water quality criteria. Specific conductivity ranged from 378 to 517 µS/cm. Turbidity was highly variable among the site visits and ranged from 62 to 920 NTU. The highest turbidity was observed in February, and the lowest was observed in January. Discharge measurements ranged from 4.4 to 24.2 cfs. No flow was observed in the channel during our site visits in July, September and October.

Table 3. Summary of water quality core parameter data from samples collected at CHI01 in Canyon de Chelly NM during 2010 (n=6) and 2011 (n=4). The median value, range of values across all site visits, and the associated NNEPA criteria are reported. A “n/c” indicates that no criterion exists for a specific parameter.

Core parameter	2010		2011		NNEPA Criteria
	Median	Range	Median	Range	
Water temperature (°C)	16.5	0.5–28.8	10.1	0.0–15.7	n/c
pH	8.5	8.2–8.6	8.5	8.1–8.5	>6 and <9
Specific conductivity (µS/cm)	346	164–446	414	378–517	n/c
Dissolved oxygen (mg/L)	7.9	6.2–11.3	9.1	7.4–12.0	≥6 mg/L
Turbidity (NTU)	2900 ^a	520–7800 ^a	307	62–920	n/c
Discharge (cfs)	20.8	1.6–177	18.1	4.4–24.2	n/c

^aTurbidity exceeded the instrument maximum detection limit of 1000 NTU. Values are estimates based on diluted samples.

3.2.2 Total coliforms and *E. coli*

SCPN bacteria results for total coliforms and *E. coli* are presented in Figure 2; 2010 data are included for comparison. The NNEPA has not established water quality criteria for total coliforms, which are a diverse group of bacteria used in water quality sampling as indicators of the likely presence of pathogenic bacteria such as *E. coli*. Only four samples were collected at CHI01, and all were during winter and spring when bacteria levels are normally lower. Of those, two samples exceeded the maximum detection of the IDEXX system of 2400 MPN/100 mL.

E. coli are a type of coliform bacteria that originate from animal feces, and are of concern because some strains can cause illness upon entering the human digestive system. Two NNEPA *E. coli* standards apply to CHI01: primary (swimming) and secondary (incidental) contact. These standards can be evaluated as either a geometric mean of four samples collected in 30 days, or as a single-sample maximum. The primary contact criteria are a geometric mean of 126 cfu/100 mL, or a single sample maximum of 235 cfu/100 mL. The secondary contact criteria are a geometric mean of 126 cfu/100 mL, or a single sample maximum of 575 cfu/100 mL (NNEPA 2008). In 2011, *E. coli* results for CHI01 ranged between 21 and 86 MPN/100 mL and are displayed in Figure 2, along with the NNEPA criteria levels. None of the 2011 samples were outside the standards for *E. coli*.

3.3 Tsaile Creek below Tsaile Dam

3.3.1 Water quality core parameter data

Air and water temperature logger data obtained at 15-minute intervals at TSA01 in 2011 are displayed in Figure 3. Water temperatures ranged from -4.6°C on January 8 to 29.7°C on July 9. The creek froze several times for brief periods in January and December. The average water temperature was 9.7°C (fig. 3). The water temperature logger was apparently exposed to the air from June 7 through June 16 due to low water levels—this accounts for the gap in water temperature data in Figure 3. Air temperature varied greatly, ranging from a low of -29.8°C on February 3 to a high of 35.9°C on July 24 (fig. 4). The average air temperature at TSA01 2011 was 6.9°C. There are no water temperature criteria applicable to TSA01.

Core parameter data for TSA01 are summarized in Table 4; 2010 data are also included for comparison.

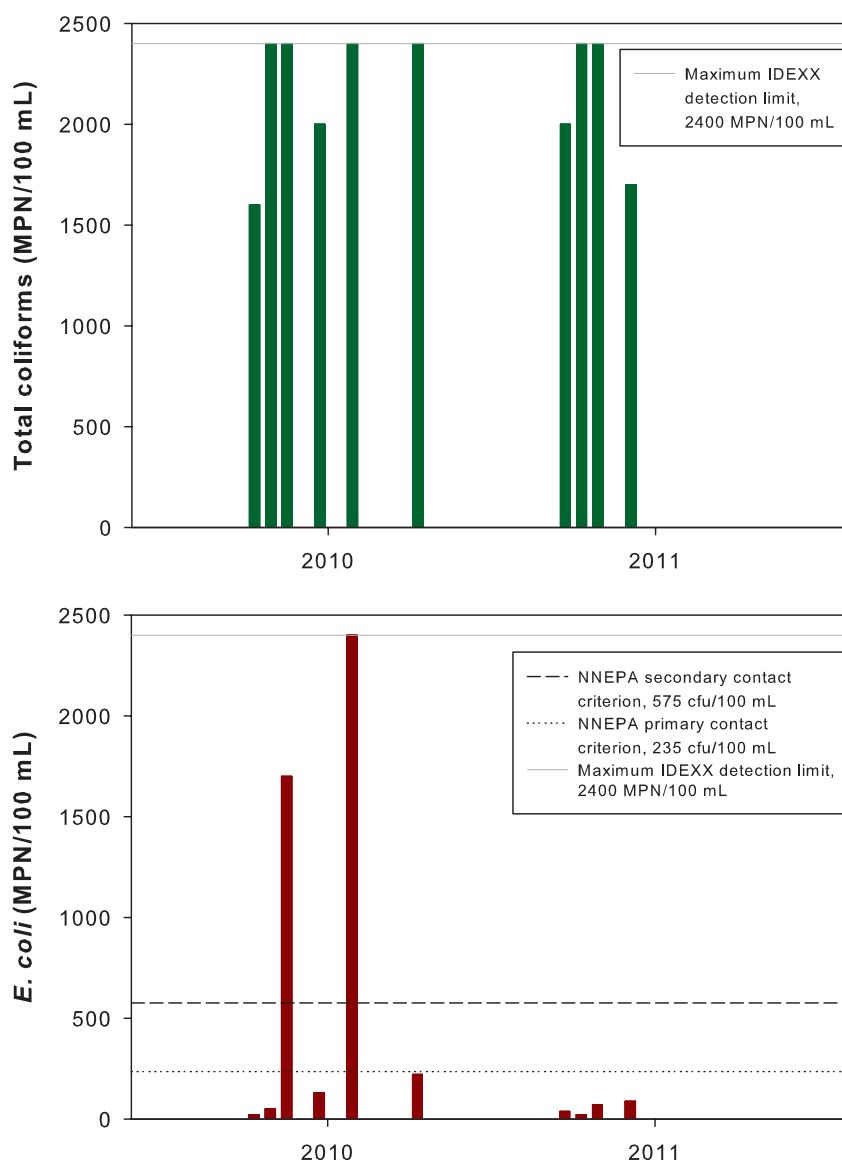


Figure 2. Total coliforms (top) and *E. coli* (bottom) lab results for samples collected at each visit made to CHI01 in Canyon de Chelly NM during 2010 and 2011.

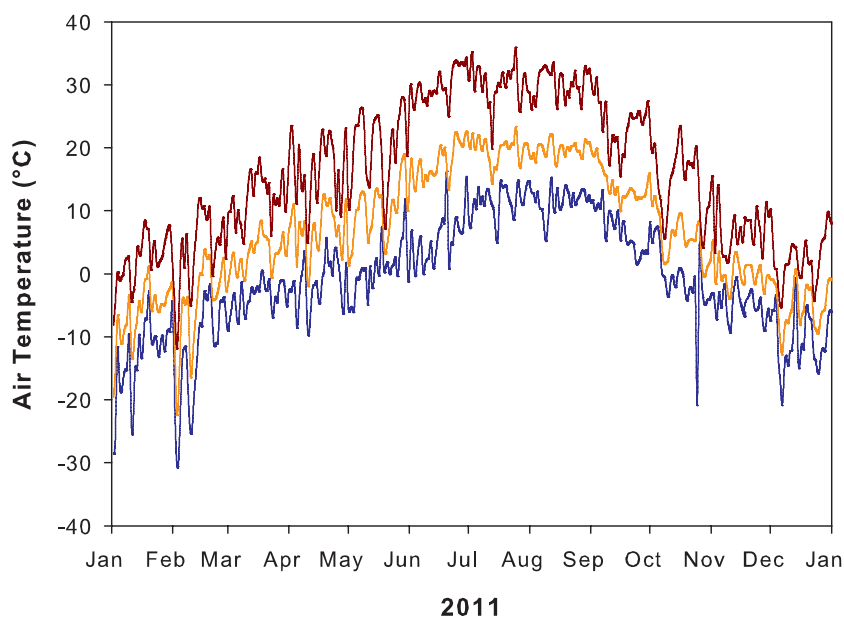
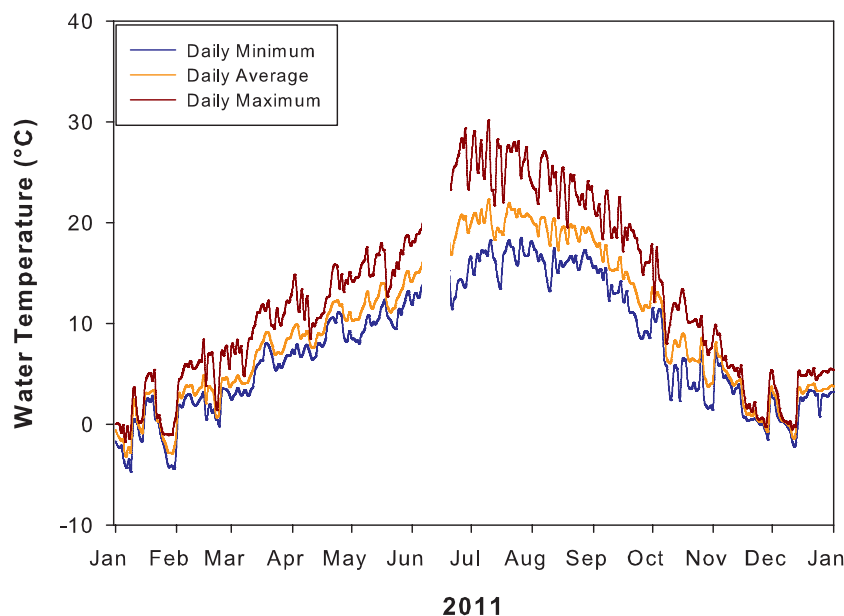


Figure 3. Daily maximum, average, and minimum air (top) and water (bottom) temperatures recorded at TSA01 on Tsaille Creek in Canyon de Chelly NM, 2011. The blank area in the water temperature graph indicates a period in June when the water temperature logger was exposed to air.



All measurements were taken in flowing water. Values for pH ranged from 7.9 to 8.7. The lowest measurement was in July and the highest was in May. Dissolved oxygen varied greatly between site visits and was often super-saturated due to photosynthesis. Concentrations ranged from 5.3 to 11.2 mg/L. The lowest dissolved oxygen concentration occurred in July and was only 72% saturation (5.3 mg/L), which is below the NNEPA water quality criteria. All other readings were near or above 100% saturation despite the low flow conditions that were often present. Specific conductivity ranged from 270 to 537 $\mu\text{S}/\text{cm}$. The lowest measurement occurred in May and the highest occurred in January. Turbidity ranged from 2.3 to 110 NTU. The highest reading occurred in July, three days after an intense thunderstorm. The lowest turbidity was measured in January when most of the water in the stream was frozen.

Discharge at TSA01 was very low throughout the year unless dam releases were occurring. The lowest measured discharge was 0.02 cfs; while the highest was 6.0 cfs. Releases from Tsaille Dam were observed during site visits in February, April, and May; otherwise stream flow was limited to just a trickle at the water quality site.

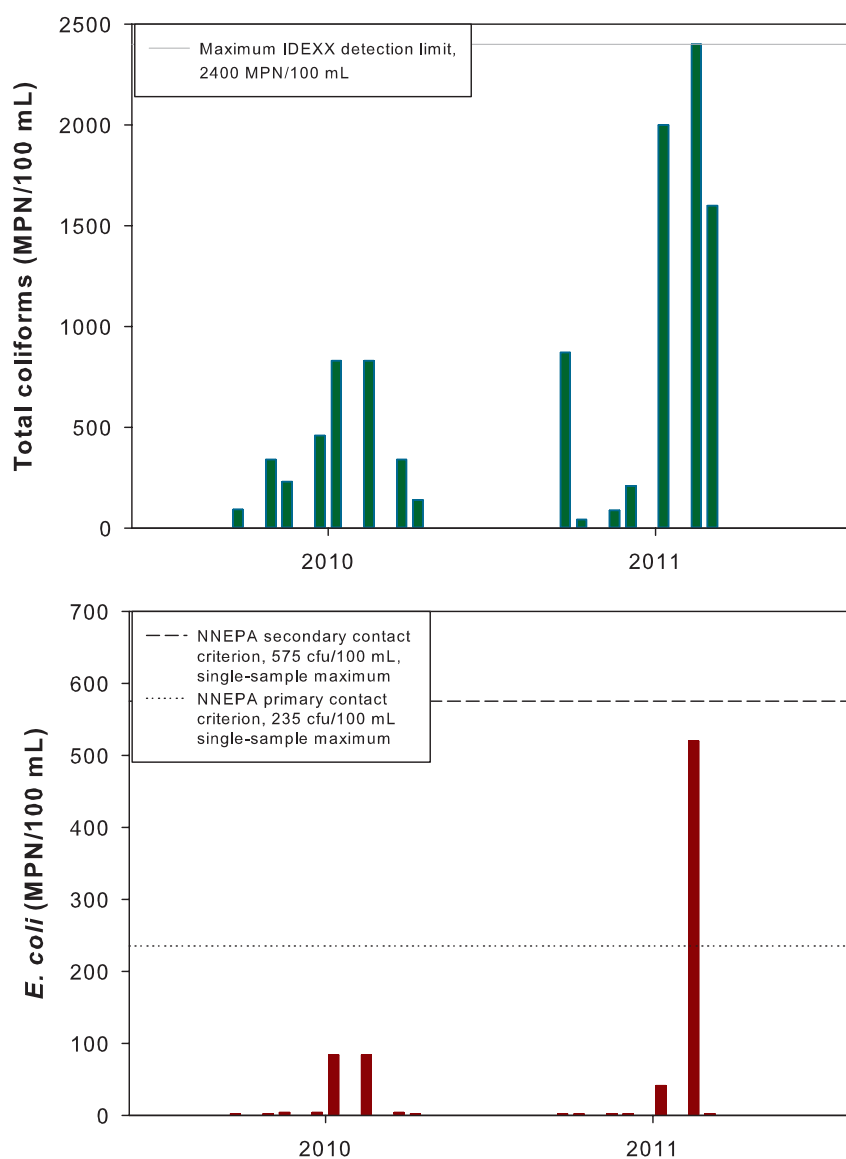


Figure 4. Total coliforms (top) and *E. coli* (bottom) results for samples collected during each visit made to TSA01 in Canyon de Chelly NM in 2010 and 2011.

Table 4. Summary of water quality core parameter data from samples collected at TSA01 in Canyon de Chelly NM, 2010 (n=8) and 2011 (n=7). Number of measurements, and the median value and range of values across all site visits, as well as the associated NNEPA criteria are reported. A “n/c” in this table indicates that no criteria exists for the metric at TSA01.

Core parameter	2010		2011		NNEPA criteria
	Median	Range	Median	Range	
Water temperature (°C)	8.0	3.8–23.4	11.0	0.1–19.4	n/c
pH	8.4	7.9–8.6	8.4	7.9–8.8	>6 and <9
Specific conductivity (µS/cm)	346	193–457	377	270–537	n/c
Dissolved oxygen (mg/L)	9.2	7.7–10.4	9.7	5.3–11.7	≥6 mg/L
Turbidity (NTU)	15	9–81	22	2.3–110	n/c
Discharge (cfs)	10.6	<0.1–21.3	<0.1	0.02–6.0	n/c

3.3.2 Total coliforms and *E. coli*

Seven bacteria samples were collected at TSA01 and analyzed by SCPN during 2011. Total coliforms at TSA01 ranged from 47 to greater than 2400 MPN/100 mL (fig. 4). Results were generally lower in winter than during the summer months.

E. coli levels at TSA01 were low throughout most of the year, but the September sample result was 520 MPN/100 mL (fig. 4). This result exceeds NNEPA primary contact criteria (single sample maximum of 235 cfu/100 mL or a geometric mean of 126 cfu/100 mL), but not the secondary contact criteria (single sample maximum of 575 cfu/100 mL or a geometric mean of 126 cfu/100 mL) (NNEPA 2008) because our monitoring is not designed to assess compliance with chronic standards. The remaining six sample results were either very low or were non-detects.

3.3.3 Water quality laboratory data

Nutrients, major element, and trace metal results from seven water samples collected from TSA01 in 2011 are summarized below in tables 5–7. Complete results are in Appendix B. Where applicable, results are compared against all applicable NNEPA water quality standards (NNEPA 2008).

Nutrient levels for ammonia, nitrite+nitrate, and nitrite were very low (table 5). Of seven samples, ammonia and nitrite were both detected in four samples at levels near their corresponding laboratory reporting levels of 0.0100 mg/L and 0.00100 mg/L. There were no exceedances of water quality criteria for ammonia. Nitrite+nitrate was detected in only three samples, and the detections were near the laboratory reporting level. Orthophosphate was measured in all samples, and concentrations ranged from 0.00948 to 0.0436 mg/L.

Table 5. Summary of nutrient data from samples collected from TSA01 at Canyon de Chelly NM, 2011 (n=7). There are no dissolved criteria for these analytes. Results that were lower than the National Water Quality Laboratory reporting levels are noted as “<[reporting level]”.

Nutrient	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Ammonia as N	<0.0100	0.0841	0.0137	0.0271
Nitrite + nitrate as N	<0.020	0.097	--- ^a	--- ^a
Nitrite as N	<0.00100	0.0127	0.002	0.0043
Orthophosphate as P	0.00948	0.0436	0.0214	0.0129

^a The missing value symbol indicates that the median was not calculated when more than 70% of the results fell below the laboratory reporting level. The median and standard deviation were not calculated for nitrite + nitrate as N because more than 70% of results for this nutrient were below the laboratory reporting level.

Major element data for samples collected at TSA01 in 2011 are summarized in Table 6. Calcium was the dominant dissolved element, followed by silica, magnesium, sodium, sulfate, chloride, potassium, and fluoride. Major ion composition is plotted in Figure 5, showing that the cation chemistry is dominated by calcium and magnesium, with sodium and potassium having a much smaller role. Anion chemistry is dominated by bicarbonate and carbonate ions.

Trace metal results for TSA01 are summarized in Table 7. Of the 21 metals analyzed at the NWQL, only mercury was not detected in any sample. Beryllium, cadmium, chromium, silver, and zinc were not detected in the majority of samples.

Results for three of the twelve metals which have aquatic and wildlife water quality criteria were outside the chronic criteria, though more frequent sampling would be required to confirm this. In the sample collected on October 23, cadmium was detected at 2.71 µg/L, which was above the chronic criterion level of 0.51 µg/L. Aluminum concentrations exceeded the chronic criterion of 87 µg/L during two consecutive sampling events: July 14 (118 µg/L) and September 6 (301 µg/L). Copper was also measured above its chronic water quality criterion of 18.8 µg/L on October 23, with a result of 20.6 µg/L. Compliance with the NNEPA mercury standard was not possible because the criteria are set below the NWQL detection level.

Table 6. Summary of major element data from samples collected from TSA01 in Canyon de Chelly NM, 2011 (n=7). All major elements are dissolved, except for acid neutralizing capacity, which was measured in unfiltered samples. There are no NNEPA water quality criteria for these analytes.

Major element, dissolved	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	48.3	85.6	55.8	13.5
Chloride	2.78	6.59	5.10	1.62
Fluoride	0.084	0.349	0.257	0.109
Magnesium	6.94	17.5	13.5	4.9
Potassium	1.83	2.99	2.30	0.44
Silica	19.5	31.5	25.3	5.1
Sodium	5.98	16.7	13.0	4.9
Sulfate	5.19	10.9	5.99	2.1
Acid neutralizing capacity, as CaCO ₃	147	310	202	56
Total dissolved solids	188	366	228	65

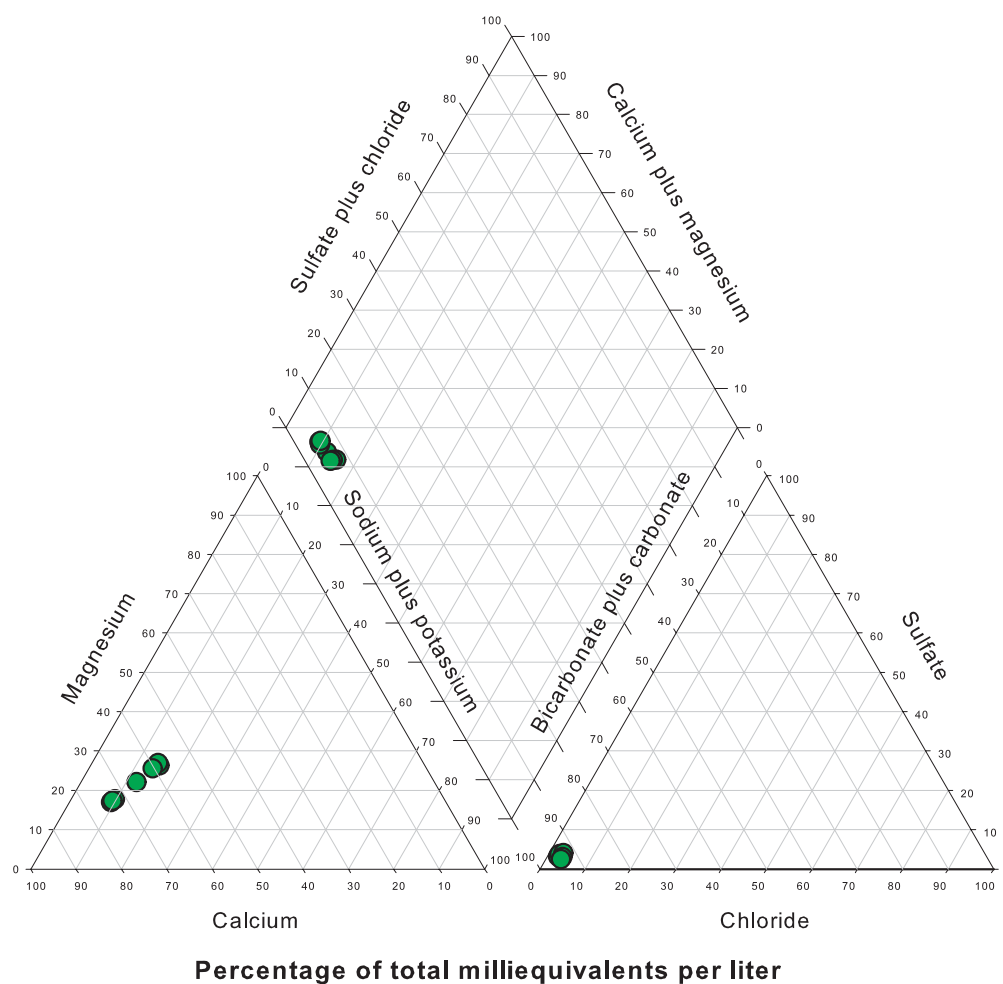


Figure 5. Major ion composition for all water quality samples collected at TSA01 in Canyon de Chelly NM, 2011.

Table 7. Summary of trace metal data for samples collected from TSA01 in Canyon de Chelly NM, 2011 (n=7), NNEPA water quality criteria (most stringent criteria that applies to TSA01), and number of times that the samples were outside those criteria. NNEPA criteria include both dissolved and particulate components. Because our samples were filtered, trace metals were dissolved and we used the criteria for dissolved samples, except when our samples exceeded the NNEPA total concentration, in this case, for aluminum. Results that were lower than the NWQL reporting levels are noted as "<[reporting level]".

Trace metal, dissolved	Minimum (µg/L)	Maximum (µg/L)	Median (µg/L) ^a	Standard deviation ^a	Criterion (µg/L)	Number of exceedances	Use code ^b
Aluminum	2.91	301	24.1	107	87 (total-chronic)	2	A&WHbt
Antimony	0.0658	0.225	0.120	0.051	30 (chronic)	0	A&WHbt
Arsenic	1.13	3.16	2.03	0.68	150 (chronic)	0	A&WHbt
Barium	29.1	430	153	149	n/c	n/c	no dissolved criterion
Beryllium	<0.0060	0.0818	---	0.0298	n/c	n/c	no dissolved criterion
Boron	21.4	59.5	50.5	17.6	5000	0	LW
Cadmium	<0.016	2.71	---	1.02	0.32–0.51 (chronic)	1	A&WHbt
Chromium	<0.060	1.00	---	0.35	11(chronic, for Cr(IV))	0	A&WHbt
Cobalt ^c	0.209	4.38	0.576	1.46	50	0	AgWS
Copper	0.54	20.6	1.01	7.44	12.6–22.0 (chronic)	1	A&WHbt
Iron ^c	3.5	288	13.7	103	n/c	n/c	no dissolved criterion
Lead	0.0285	1.29	0.0610	0.47	3.88–7.73 (chronic)	0	A&WHbt
Manganese ^c	12.4	1240	45.3	447	n/c	n/c	no dissolved criterion
Mercury	<0.005	<0.005	---	---	0.001 (chronic)	unknown	A&WHbt
Molybdenum ^c	0.425	1.19	0.653	0.35	1000	0	AgWS
Nickel	0.683	14.4	0.856	5.1	72.6–126 (chronic)	0	A&WHbt
Selenium	0.092	0.505	0.127	0.147	n/c	n/c	no dissolved criterion
Silver	<0.0050	0.908	---	0.341	6.41–19.6 (acute)	0	A&WHbt
Uranium	0.30	1.54	0.90	0.44	n/c	n/c	no dissolved criterion
Vanadium	0.979	7.64	3.50	2.17	100	0	AgWS/LW
Zinc	<1.40	2.69	---	0.49	166–288	0	A&WHbt

^a Values not reported were not calculated because more than 70% of results were below the laboratory reporting level.

^b Use codes: A&WHbt - aquatic and wildlife habitat; AgWS - agricultural water supply; FC - fish consumption; LW - livestock watering; PrHC - primary human; ScHC - secondary human contact

^cResults of a field blank indicated contamination with small concentrations of cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L), and molybdenum (0.0338 µg/L). Therefore, we have flagged all results for these trace metals except for those that fell below the NWQL reporting levels.

4 Precipitation

Daily precipitation data for 2011 in Tsale are shown below in Figure 6. The data were acquired from a National Oceanic and Atmospheric Administration's National Climatic Data Center (NOAA/NCDC) weather station located at Diné College near TSA01 (TSAILE 1 SSW). Precipitation totaled 31.3 cm for the year; data are missing for May 26 and August 13. Five precipitation events exceeded 1 cm, and the majority of the precipitation (73%) occurred during the latter half of 2011, but creek flow levels remained low during this time of year. There was a pronounced dry period from mid-May through June. None of SCPN's samples were collected within 24 hours of a precipitation event.

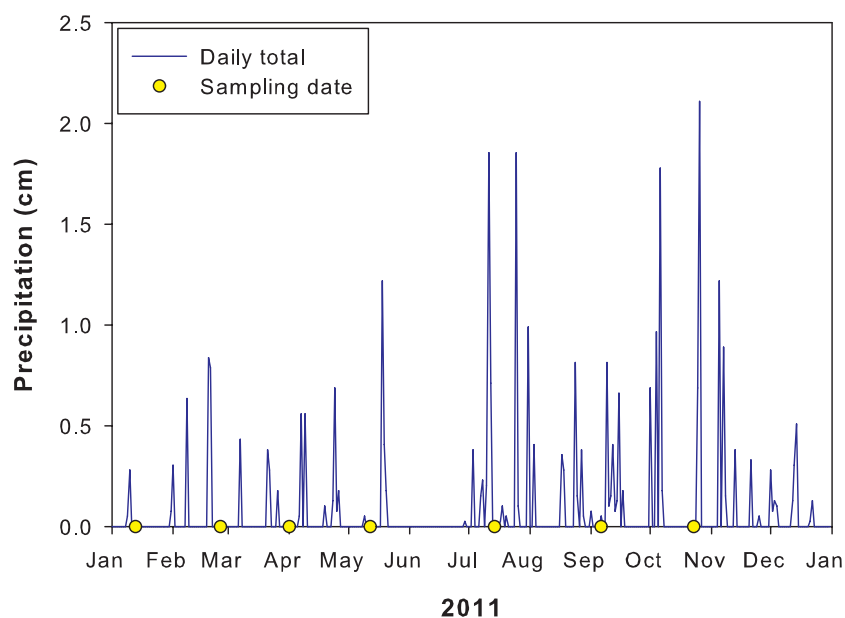


Figure 6. Daily precipitation totals from NOAA/NCDC station TSAILE 1 SSW, near TSA01 in Tsale, AZ. Dates of SCPN water quality sampling dates are shown in yellow.

5 Quality assurance/Quality control

We followed the Quality Assurance/Quality Control procedures described in Monroe et al. (in preparation) and in National Park Service 2012 .

Prior to each sampling event, the multiparameter sondes were calibrated, maintained, and compared to one another indoors. The streamflow current meters were checked to ensure they were in proper working order according to manufacturer recommendations, and the turbidimeter was checked for calibration drift in the lab prior to each sampling event and in the field prior to each measurement. Fifteen duplicate bacteria samples were collected at several SCPN monitoring sites by filling two sample bottles in succession and comparing tray results after the incubation period. Thirteen 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 one sample set of certified inorganic blank water at the end of 2011. Most analytes were not detected, but four trace metals were detected in low concentrations: cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L) and molybdenum (0.0338 µg/L). All cobalt, manganese, and molybdenum sample results were above these detections and it is reasonable to conclude that these sample results are within stated ranges of accuracy. Two iron results are questionable. The January result was 3.5 mg/L, which is below the level detected in the blank sample. The February result was 5.3 mg/L, which is near the concentration in the blank sample. Because the blank detections and water sample detections were low, we included all data, but flagged results for analytes detected in blanks in Table 7 and Appendix B.

6 Summary

In 2010, SCPN implemented water quality monitoring at CHI01 and TSA01 on Chinle Wash and Tsaille Creek in CACH, and continued this work in 2011. This report summarizes data collected during site visits to CHI01 and TSA01 during 2011, and compares these results against applicable NNEPA water quality standards (Navajo Nation Environmental Protection Agency 2008).

CHI01 was visited four times in 2011 between January and May; the wash was dry during site visits later in the year. Only NPS core parameter measurements were made and bacteria samples collected. All core parameters were in compliance with NNEPA water quality standards.

TSA01 was visited seven times in 2011; visits were spaced equally from January to October. During each site visit, NPS core parameter measurements were made, and bacteria samples were collected. Additionally, water samples were collected for nutrients, major element, and trace metal analysis. All core parameters were in compliance with applicable NNEPA water quality standards. For *E. coli*, one sample result of 520 MPN/100 mL exceeded the NNEPA water quality criterion for this stream. Laboratory-measured results for nutrients were low at TSA01 and were well below the applicable water quality criteria. Trace metal concentrations tended to be low, but four exceeded the chronic aquatic and wildlife criteria values. Two aluminum results were higher than the chronic aquatic and wildlife criterion of 87 µg/L but below the acute criterion. Cadmium and copper also exceeded the chronic criteria once each.

The data in this report should be viewed as a snapshot of water quality conditions existing at the time data was collected. Data and analyses in this report are provisional and are subject to change. When sampling has occurred over a sufficient number of years (5 years), SCPN will prepare an in-depth trend analysis report of water quality data for Chinle Wash and Tsaille Creek.

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Appendices

Appendix A: Southern Colorado Plateau Network water quality monitoring sites

Table A1. Southern Colorado Plateau Network water quality monitoring sites for Canyon de Chelly National Monument, 2011.

Site code	Common name	Report name	Northing ¹	Easting ¹	Elevation (m) ¹
CACHBLA01	Black Rock Canyon below confluence of east and west forks	BLA01	4002998	651566	2071
CACHCHI01	Chinle Wash at Chinle	CHI01	4002062	631525	1689
CACHTSA01	Tsaile Creek below Tsaile Dam	TSA01	4015393	660576	2125

¹ Horizontal coordinates are reported in Universal Transverse Mercator (UTM) Projection, Zone 12, North American Datum of 1983 (NAD 83). Vertical coordinates are referenced to the North American Vertical Datum of 1988 (NAVD 88)

Appendix B: Water quality monitoring results for Canyon de Chelly National Monument, 2011

Table B1. Water quality core parameter data for CHI01 on Chinle Wash near Canyon de Chelly NM, 2011

Core parameter	Units	Sample collection date and time			
		1/12/11 18:42	2/25/11 14:43	3/31/11 18:15	5/13/11 08:30
Temperature	°C	0.0	11.6	15.7	8.6
pH	none	8.1	8.5	8.5	8.5
Specific conductivity	µS/cm	517	378	415	413
Dissolved oxygen	mg/L	12.0	8.8	7.4	9.4
Dissolved oxygen	% saturation	99.1	99.7	91.0	97.9
Turbidity	NTU	62	920	440	170
Discharge	cfs	4.4	24.2	13.4	22.8

Table B2. Bacteria data for CHI01 on Chinle Wash near Canyon de Chelly NM, 2011

Total coliforms and <i>E. coli</i> (MPN/100 mL)	Sample collection date and time			
	1/12/11 18:42	2/25/11 14:43	3/31/11 18:15	5/13/11 08:30
Total coliforms	2000	>2400 ^a	>2400 ^a	1700
<i>E. coli</i>	38	21	70	86

^aThe maximum detection level for bacteria is 2400 MPN/100 mL.

Table B3. Water quality core parameter data for TSA01 on Tsaile Creek near Canyon de Chelly NM, 2011

Parameter	Units	Sample collection date and time						
		1/13/11 10:40	2/25/11 11:05	4/1/11 09:18	5/12/11 17:08	7/14/11 11:24	9/6/11 18:30	10/23/11 15:30
Temperature	°C	0.1	4.6	7.9	14.2	17.4	19.4	11.0
pH	none	8.0	8.6	8.4	8.8	7.9	8.6	8.3
Specific conductivity	µS/cm	537	303	306	270	377	410	446
Dissolved oxygen	mg/L	11.2	11.1	8.7	8.9	5.3	9.7	10.8
Dissolved oxygen	% saturation	98	118	94	109	72	136	126
Turbidity	NTU	2.3	6.5	22	67	110	84	9.6
Discharge	cfs	<0.1 ^a	5.8	6.0	5.6	<0.1 ^a	0.10 ^a	0.02 ^a

^aSince the method used in sampling events prior to 9/6/11 could not measure discharge levels below 0.1 cfs, we used a flume when measuring discharge on 9/6/11 and 10/23/11.

Table B4. Bacteria data for TSA01 on Tsaile Creek near Canyon de Chelly NM, 2011

	Sample collection date and time						
	1/13/11 10:40	2/25/11 11:05	4/1/11 09:18	5/12/11 17:08	7/14/11 11:24	9/6/11 18:30	10/23/11 15:30
Total coliforms and <i>E. coli</i> (MPN/100 mL)							
Total coliforms	870	47	87	210	2000	>2400 ^a	1600
<i>E. coli</i>	<1	<1	1	2	41	520	<1

^aThe maximum detection level for bacteria is 2400 MPN/100 mL.

Table B5. Results of laboratory analyses for TSA01, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL). Parameters are dissolved unless otherwise specified. Results that were lower than the NWQL reporting levels are noted as "<[reporting level]"

Analyte	Sample collection date and time						
	1/13/11 10:40	2/25/11 11:05	4/1/11 09:18	5/12/11 17:08	7/14/11 11:24	9/6/11 18:30	10/23/11 15:30
Nutrients (mg/L)							
Ammonia as N	0.0248	0.0143 ^a	<0.0100	<0.0100	0.0841	<0.0100	0.0137
Nitrite + nitrate as N	0.097	<0.020 ^a	<0.020	<0.020	0.076	0.024	<0.040
Nitrite as N	0.00528	0.00203 ^a	<0.00100	<0.00100	0.0127	0.00232	<0.00100
Orthophosphate as P	0.0214	0.0228 ^a	0.0212	0.0436	0.0385	0.0107	0.00948
Trace metals (µg/L)							
Aluminum	2.91	3.50	24.1	20.4	118	301	84.5
Antimony	0.0658	0.120	0.128	0.131	0.0958	0.0934	0.225
Arsenic	2.36	2.03	1.78	1.98	2.87	3.16	1.13
Barium	404	153	145	142	277	430	29.1
Beryllium	<0.0060	<0.0060	<0.0060	<0.0060	0.0136	0.0483	0.0818
Boron	50.6	23.4	21.4	22.3	50.5	59.5	58.1
Cadmium	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	2.71
Cobalt ^b	0.209	0.576	0.572	0.633	0.452	1.39	4.38

Table B5 Results of laboratory analyses for TSA01, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL) *continued*

Analyte	Sample collection date and time						
	1/13/11 10:40	2/25/11 11:05	4/1/11 09:18	5/12/11 17:08	7/14/11 11:24	9/6/11 18:30	10/23/11 15:30
Copper	0.72	0.97	1.04	1.01	0.54	1.29	20.6
Chromium	<0.060	<0.060	<0.060	<0.060	0.093	0.202	1.00
Iron ^b	3.5	5.7	13.7	10.7	87.7	288	45.9
Lead	0.0610	0.0285	0.0502	0.0334	0.128	0.460	1.29
Manganese ^b	36.5	63.7	43.3	12.4	234	45.3	1240
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum ^b	1.19	0.533	0.457	0.425	1.19	1.09	0.653
Nickel	0.856	0.697	0.683	0.706	1.12	1.00	14.4
Selenium	0.093	0.127	0.116	0.140	0.150	0.092	0.505
Silver	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.908
Uranium	0.822	1.54	1.40	1.17	0.900	0.620	0.300
Vanadium	1.72	3.50	3.52	4.72	3.24	7.64	0.979
Zinc	<1.40	<1.40	<1.40	<1.40	<1.40	2.69	<4.20
Major Elements (mg/L)							
Calcium	85.6	55.8	48.9	48.3	49.4	57.8	67.0
Chloride	6.59	3.39	3.08	2.78	5.10	6.02	6.17
Fluoride	0.321	0.141	0.121	0.084	0.257	0.315	0.349
Magnesium	17.5	7.82	7.23	6.94	13.5	16.2	17.2
Potassium	2.60	1.98	1.83	1.84	2.99	2.30	2.53
Silica	29.2	20.6	19.5	21.1	25.3	31.5	30.8
Sodium	16.7	6.85	6.42	5.98	13.0	15.1	16.5
Sulfate	10.9	5.57	5.19	5.58	8.42	6.87	5.99
Acid neutralizing capacity, as CaCO ₃ (mg/L, unfiltered)	310	171	163	147	202	223	237
Total dissolved solids (mg/L)	366	220	193	188	228	303	269

^aNutrient samples arrived warm (7°C) to the NWQL, nutrients should be kept <4°C.

^b Results of a field blank indicated contamination with small concentrations of cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L), and molybdenum (0.0338 µg/L)

Appendix C: Abbreviations, symbols and terms used in this report

Term	Definition
cfs	cubic feet/second
cfu/100mL	colony forming units, for bacteria sampling, it is a measure of the number of viable bacteria per 100mL
mg/L	milligrams per liter
µg/L	micrograms per liter
MPN/100mL	for sampling bacteria, a statistical estimate of the most probable number of viable bacteria per 100mL sample
µS/cm	microsiemens per centimeter at 25°C, a measure of specific conductivity
milliequivalents per liter	an expression of the concentration of substances that is chemically equivalent in terms of atomic weight and electrical charge
N	chemical symbol for nitrogen
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for phosphorus