



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

2010 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/350



ON THE COVER

Tsaile Creek in Canyon de Chelly National Monument
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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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1 Introduction and background

The National Park Service (NPS) Inventory and Monitoring (I&M) 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 strong scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. As part of the effort to create a comprehensive picture of aquatic ecosystem health, the Southern Colorado Plateau Network (SCPN) identified water quality as a core “vital sign” (Thomas et al. 2006).

Specific objectives of stream water quality monitoring for the SCPN parks are

1. determine status and trends in selected core water quality parameters (water temperature, pH, conductivity, dissolved oxygen, and discharge) under base flow conditions at selected sites in priority streams within SCPN parks as a function of flow, season and climatic conditions
2. determine status and trends of water quality constituents, including bacteria, nutrients, major elements, and trace metals at selected sites in priority streams within SCPN parks
3. 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 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 targeted for water quality monitoring were selected 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 generally located where there is a history of water quality data collection, or co-located with aquatic macroinvertebrate monitoring sites. NPS core water quality data and water quality samples are collected six to eight times per year. 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, consisting of 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, with the broad and sandy streambed

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).

of Chinle Wash 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 (Natural Resources Conservation Service (NRCS) 2000).

In 2010 SCPN implemented water quality monitoring at the following sites in Canyon de Chelly National Monument (CACH):

- Chinle Wash at Chinle (CACHCHI01) is identified in this report as CHI01. The site is located at the monument boundary (fig. 1), 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.
- 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.

During 2010, SCPN staff completed eight water quality monitoring visits to CACH at approximately six-week intervals. Samples were collected at TSA01 during each of these visits, but only collected six times at CHI01 because water was not always flowing through Chinle Wash. This report documents the water quality monitoring activities that occurred at Canyon de Chelly National Monument in 2010, and summarizes the data collected.

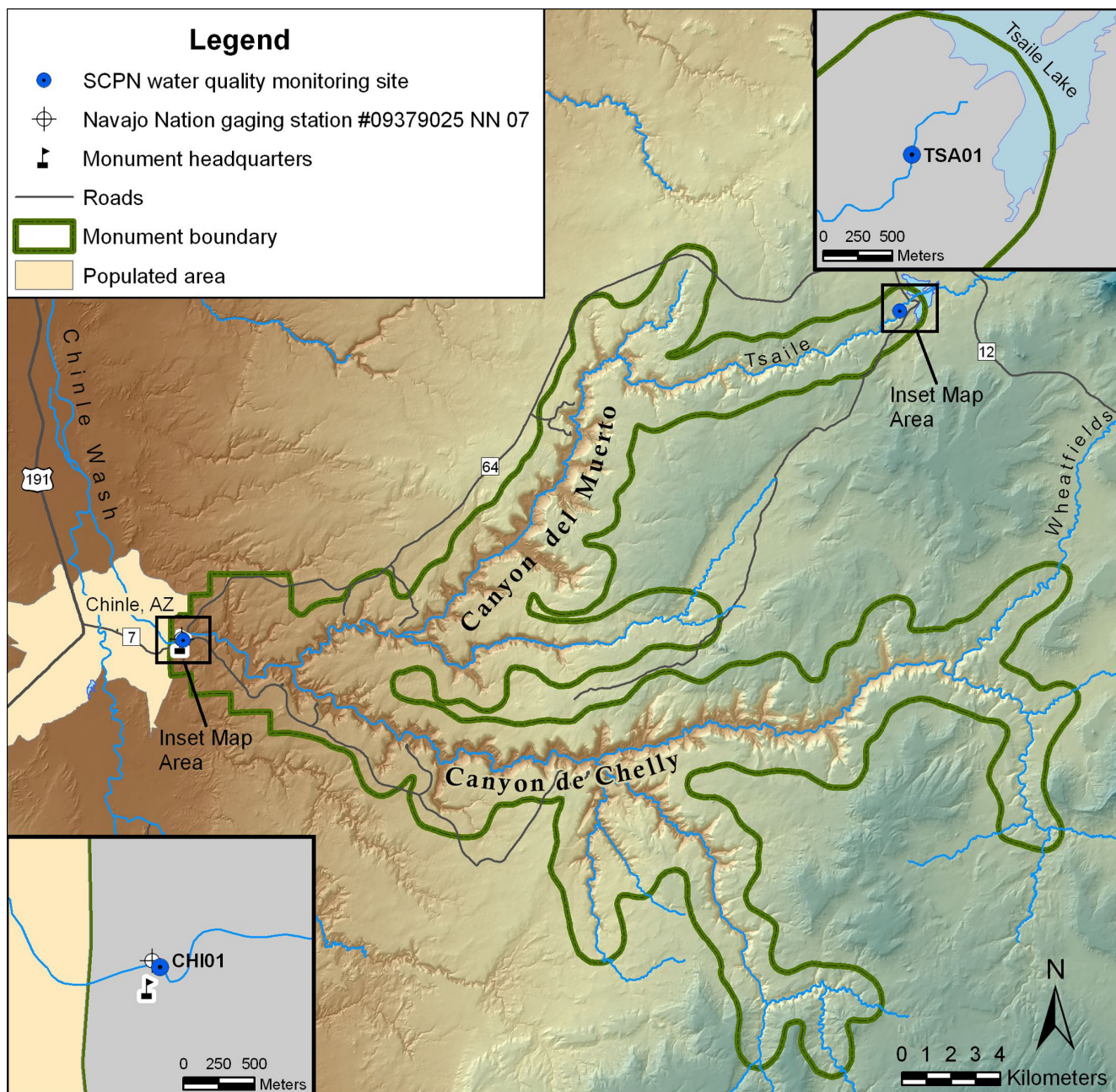


Figure 1. Locations of SCPN water quality monitoring sites, CHI01 and TSA01, in Canyon de Chelly N.M.

2 Methods

Following is a brief outline of water quality data collection and processing methodologies followed by SCPN at CACH during 2010. Please refer to SCPN’s draft water quality monitoring protocol (Monroe and Bliss in preparation) for further details.

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:

- At TSA01, water and air temperatures were recorded at 15-minute intervals by a HOBO Pendant and HOBO TidbiT (Onset Computer Corporation) deployed at the monitoring site. The sensors were downloaded during each site visit. Sensor accuracy was confirmed using a NIST-certified thermometer during each download.
- As soon as possible after arrival at the site, a multi-parameter 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- to 15-second intervals. The sonde was left stationary in the stream for the entire site visit.
- Turbidity samples were collected in triplicate, kept on ice for less than 24 hours, and analyzed with a Hach 2100P Portable Turbidimeter (Hach Inc.). Turbidity samples that exceeded the turbidimeter detection limit of 1000 NTU (Nephelometric Turbidity Units) were diluted; then turbidities were estimated using linear regression equations. Samples were diluted by at least three dilution factors in order to cover the detection range of the turbidimeter—low-range, medium-range, and high-range dilutions.
- Discharge was measured using either a FlowTracker Acoustic Doppler Velocimeter (SonTek Inc.), a Pygmy Meter and AquaCalc Pro (Rickly Inc. and JBS Instruments), or a Marsh McBirney Flo-Mate 2000 (Hach Inc.).

2.2 Water quality samples

During each site visit, we collected a sample for bacterial analysis by dipping a sample bottle into 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 for other analytes in a similar manner and sample water was filtered and/or acid-treated (as required), kept on ice, and shipped to the contract laboratory. For 2010, SCPN contracted with the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analyses of water samples for selected water quality constituents. These analyses 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 and Bliss, in preparation).

In addition to the samples sent to NWQL for analysis we collected samples at CHI01 to determine whether contaminants originating from vehicle usage in Canyon de Chelly were present in Chinle Wash. Test America Labs analyzed these water samples for total petroleum hydrocarbons (TPH) and oil and grease.

Table 1. National Water Quality Laboratory and Test America Lab 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
Hydrocarbons	total petroleum hydrocarbons, oil and grease
Trace metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc

Samples were collected at the center of flow in glass 1-liter bottles, acid-treated, kept on ice, and shipped to Test America within 24 hours of collection.

2.3 Data handling, analysis, and quality assurance/quality control (QA/QC)

All SCPN water quality data is entered to NPSTORET, v.1.83, a Microsoft Access database created by the Water Resources Division of the National Park Service. All multiparameter sonde 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. Similarly, only the median values for each set of turbidity triplicate samples are presented. All results from the NWQL and Test America Lab are presented as reported from the labs. In cases where analytes were not detected, we presented the applicable laboratory reporting level, which is the lowest concentration that can be reliably measured by a given analytical method.

Where applicable, we compared our results against the Navajo Nation Environmental Protection Agency acute and chronic aquatic and wildlife habitat standards (Navajo Nation Environmental Protection Agency (EPA) 2008), which are the water quality standards applicable at CACH. Acute standards apply to a single sample only, and are not to be exceeded at any time. Chronic standards are based on the arithmetic mean of samples collected during four consecutive days. While our sampling regime is not designed to evaluate sampling results against the chronic standards, we compared our results against these standards in order to determine potential exceedances. 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/100 mL)—a statistical estimate of the number of bacteria per 100 mL of stream water, determined by using a lookup table provided by the manufacturer (Idexx Inc.). Although the Navajo Nation EPA 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. The QA/QC procedures described in Monroe and Bliss (in preparation) were followed.

3 Results

This section presents data collected by SCPN staff from Chinle Wash and Tsaile Creek in 2010. All data, including dates and sample times, are included in Appendix B. At CHI01, samples were collected for NWQL analyses on five visits. Because of potential contamination due to off-road vehicular travel in the wash, we collected samples for total petroleum hydrocarbons and oil and grease analyses on four visits. At TSA01, samples for NWQL analyses were collected during all visits, except that a trace metals sample was not collected on April 17.

3.1 Chinle Wash at Chinle

3.1.1 Water quality core parameter data

With the exception of pH, which ranged between 8.2 and 8.6 and was within the Navajo Nation EPA aquatic and wildlife criteria, results for core parameter data for CHI01 were highly variable (table 2). Specific conductivity ranged between 164 and 446 $\mu\text{S}/\text{cm}$. Dissolved oxygen ranged between 6.2 mg/L in June—just within the aquatic and wildlife criterion of 6 mg/L—and 11.3 mg/L in February. Turbidity at CHI01 was generally high, exceeding the turbidimeter's maximum detection limit (1000 NTU) in samples collected during five of the six site visits in 2010. All reported turbidity values above 1000 NTU were estimated through a serial dilution procedure. The highest turbidity was observed in August (7800 NTU) and the lowest in June at 520 NTU.

Table 2. Summary of core parameter data at CHI01 and TSA01 in Canyon de Chelly N.M., 2010

Core parameter	Units	Site	Observations	Minimum	Maximum	Median	Standard deviation	Navajo Nation EPA criteria
Water temperature	$^{\circ}\text{C}$	CHI01	6	0.5	28.8	16.5	11.3	---- ^a
		TSA01	8	3.8	23.4	8.0	7.5	
pH	none	CHI01	6	8.2	8.6	8.5	0.2	>6.5 or <9
		TSA01	8	7.9	8.6	8.4	0.3	
Specific conductivity	$\mu\text{S}/\text{cm}$	CHI01	6	164	446	346	110	----
		TSA01	8	193	457	356	90	
Dissolved oxygen	mg/L	CHI01	6	6.2	11.3	7.9	2.0	>6 mg/L or >90% sat
		TSA01	8	7.7	10.4	9.2	1.1	
Turbidity	NTU	CHI01	6	520	7800 ^b	2900 ^b	2600 ^b	----
		TSA01	8	9	81	15	27	
Discharge	cfs	CHI01	6	1.6	177	20.8	66	----
		TSA01	8	<0.1	21.3	10.6	8.8	

^a "----" means no criterion exists

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

Discharge measurements taken by SCPN staff at CHI01 ranged between 1.6 and 177 cfs, though the channel was dry during our site visits in July, September, and November, reflecting the intermittent nature of this stream. The maximum discharge observed by SCPN was in April during a period of spring snowmelt in a high-precipitation year, while the lowest measured discharge was observed in February.

3.1.2 Total coliforms and *E. coli*

The Navajo Nation EPA has not established water quality criteria for total coliforms. These bacteria are used in water quality sampling as indicators of the likely presence of pathogenic bacteria such as *E. coli*. Total

coliforms at CHI01 reached the upper detection level of 2400 MPN/100 mL in four of six samples (fig. 2).

E. coli are a type of coliform bacteria that originate from animal feces. They are of concern because some strains can cause illness upon entering the human digestive system. Two Navajo Nation EPA *E. coli* standards apply to CHI01 and TSA01: primary contact (e.g. swimming) and secondary contact (incidental contact). These standards can be evaluated as either a geometric mean of four samples taken 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 (Navajo Nation EPA 2008).

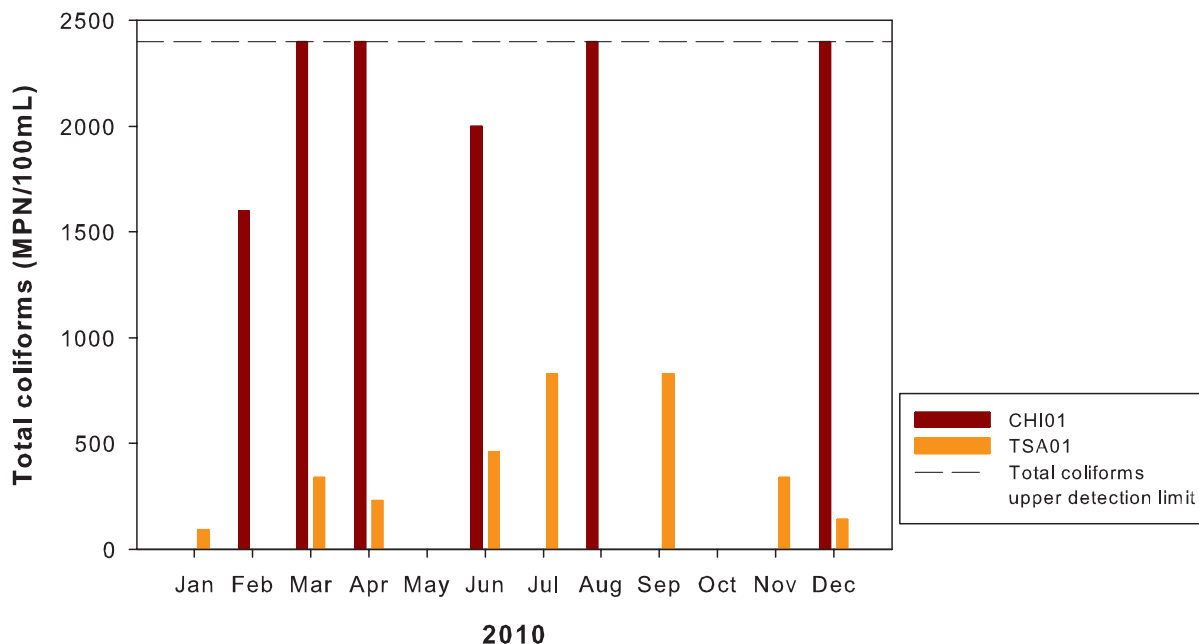


Figure 2. Total coliform results at CHI01 and TSA01 in Canyon de Chelly N.M., 2010

E. coli results for CHI01 ranged between 20 and >2400 MPN/100 mL and are displayed in Figure 3, along with the Navajo Nation EPA criteria levels. Two of the six samples exceeded both the single-sample primary and secondary contact criteria. The August 2 sample also reached the maximum detection level of the IDEXX system of 2400 MPN/100 mL—well above the water quality criteria. Though our sampling regime cannot be used to calculate monthly geometric means, four of the samples exceeded the 126 cfu/100 mL criteria.

3.1.3 Water quality laboratory data

Laboratory results for water samples collected from CHI01 at CACH in 2010, and analyzed for nutrient, major element, and trace metals concentrations are summarized here and in Appendix B, and, where applicable, are compared against the Navajo Nation EPA acute and chronic aquatic life standards. Acute standards apply to a single water sample; the criteria for acute standards are not to be exceeded at any time. Chronic standards apply to the arithmetic mean of samples collected on four consecutive days (Navajo Nation EPA 2008). While our sampling regime did not occur on consecutive days, we evaluated against the chronic standards in order to determine the possibility of a water quality exceedance. Because most water quality criteria varied based on hardness or other factors, the numeric criteria were not included in this report. Samples at CHI01 did not exceed either of the acute or chronic water quality standards. There was no flow in Chinle Wash on November 2, therefore no corresponding data are available for CHI01 on this date.

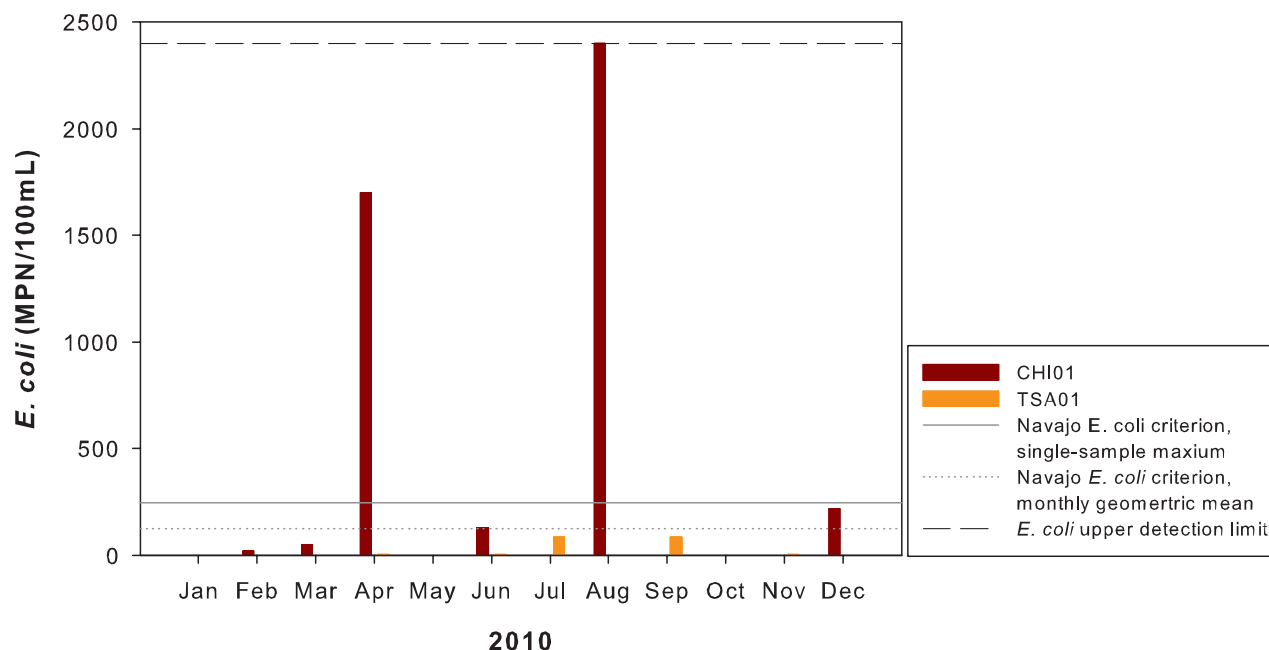


Figure 3. *E. coli* results at CHI01 and TSA01 in Canyon de Chelly N.M., 2010

We also collected samples for total petroleum hydrocarbon and oil and grease analysis in 2010 at CHI01. These substances were not detected above the laboratory reporting levels (4.8–10 mg/L) in any of the four samples we collected.

Nutrients included ammonia, nitrite with nitrate, nitrite, and orthophosphate. Ammonia was not detected above the laboratory reporting level in any of the samples collected at CHI01 (table 3). Median concentrations of nitrite + nitrate were 0.06 mg/L at CHI01 and were detected in all five of the CHI01 samples. Nitrite, by itself, was also detected in all of the CHI01 samples, with a median level that was only slightly above the laboratory reporting level of 0.0010 mg/L. Orthophosphate was detected in all samples collected, with a median level of 0.062 mg/L.

Major element data for CHI01 are summarized in Table 4. These parameters include major ions, silica, acid neutralizing capacity, and total dissolved solids. Combined, the major ions and silica listed below averaged 48% of the total dissolved solids in Chinle Wash. Calcium was the most abundant element, averaging 20% of the dissolved solids, followed by silica (10%), sulfate (7%), sodium (4%), magnesium (4%), and 2% or

Table 3. Summary of nutrient data for CHI01 and TSA01 at Canyon de Chelly N.M., 2010

Nutrient, dissolved	Site	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Ammonia as N	CHI01	5	<0.010 ^a	<0.020	— ^b	—	0
	TSA01	8	<0.010	0.25	0.014	0.10	0
Nitrite + nitrate as N	CHI01	5	0.06	0.18	0.06	0.06	---- ^c
	TSA01	8	<0.02	0.06	<0.02	0.02	----
Nitrite as N	CHI01	5	0.0019	0.0050	0.0030	0.0016	----
	TSA01	8	<0.0010	0.0040	0.0011	0.0013	----
Orthophosphate as P	CHI01	5	0.024	0.070	0.062	0.019	----
	TSA01	8	0.020	0.096	0.046	0.029	----

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Reporting levels changed to match the long-term method detection level starting October 1, 2010, therefore some samples have two different reporting levels displayed.

^b "—" means statistics not calculated because >70% of data were non-detects

^c "----" means no current water quality standard for this analyte

Table 4. Summary of major element data, acid neutralizing capacity, and total dissolved solids at CHI01 and TSA01 at Canyon de Chelly N.M., 2010

Major element, dissolved	Site	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	CHI01	5	21.9	57.7	51.9	16.5
	TSA01	7	31.7	68.1	54.7	10.8
Chloride	CHI01	5	1.88	9.67	4.68	3.10
	TSA01	8	1.91	6.56	3.72	1.60
Fluoride	CHI01	5	0.120	0.190	0.160	0.029
	TSA01	8	0.104	0.314	0.138	0.086
Magnesium	CHI01	5	4.11	11.8	9.17	3.5
	TSA01	7	4.51	15.5	8.11	4.1
Potassium	CHI01	5	1.86	3.71	3.02	0.69
	TSA01	7	1.51	3.20	2.33	0.51
Silica	CHI01	5	11.3	25.0	20.0	6.1
	TSA01	7	17.9	32.3	27.8	5.7
Sodium	CHI01	5	4.25	14.6	9.61	4.3
	TSA01	7	3.42	14.9	6.60	4.5
Sulfate	CHI01	5	6.52	29.1	13.8	9.3
	TSA01	8	5.47	11.2	6.79	1.9
Acid neutralizing capacity, as CaCO ₃ ^a	CHI01	5	215	415	275	78
	TSA01	8	95.7	258	181	52
Total dissolved solids	CHI01	5	114	304	247	84
	TSA01	8	145	313	237	53

^aAcid neutralizing capacity was measured in an unfiltered sample

less each of chloride, potassium, and fluoride. Median value for acid neutralizing capacity was 275 mg/L at CHI01.

Major ion composition for CHI01 is provided in Figure 4. Water chemistry remained consistent throughout the year. Cations primarily consisted of calcium, but also contained lesser amounts of magnesium, sodium, and potassium. Bicarbonate and carbonate ions, which are calculated from the acid neutralizing capacity, comprised the majority of the anions.

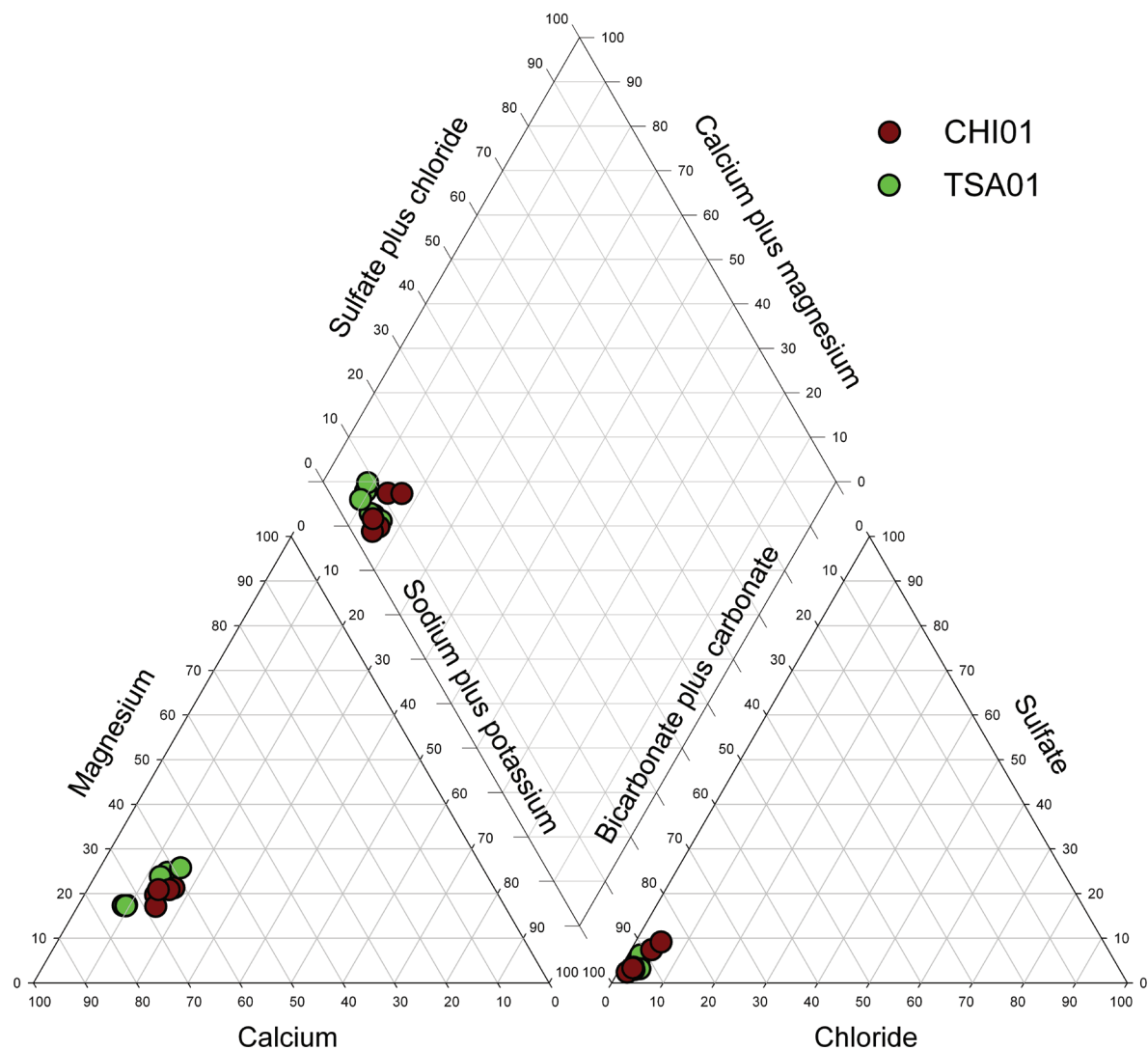
Trace metal results for CHI01 are summarized in Table 5. Beryllium and mercury were not detected. Four metals were only occasionally detected—cadmium, chromium, silver, and zinc.

Of the 11 elements which have water quality criteria, all but mercury were present at levels far below the chronic aquatic life criteria. Because of the very low mercury criteria, it is not possible to evaluate mercury concentrations against Navajo Nation EPA water quality standards. Mercury was not detected at levels above the 0.005 µg/L NWQL method detection level, but the water quality criterion is set below the detection level at 0.001 µg/L.

3.2 Tsaile Creek below Tsaile Dam

3.2.1 Water quality core parameter data

Tsaile Creek was frozen for most of January, and again from late February until early March (fig. 5). Later, beginning in mid-November, the stream went through several freeze/thaw cycles. The water temperature logger was exposed to air when the water level dropped to very low levels between the June 2 and July 19 site visits (shaded area in fig. 5). The logger was repositioned at a lower level on July 19 so that it would remain completely submerged during the lowest flows. Air temperature ranged from a low of -26.2°C on



Percentage of Total Milliequivalents per Liter

Figure 4. Major ion composition for all samples from CHI01 and TSA01 in Canyon de Chelly N.M., 2010

Table 5. Summary of trace metal data at CHI01 and TSA01 in Canyon de Chelly N.M., 2010

Trace metal, dissolved	Site	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Aluminum	CHI01	5	1.76	13.8	<3.40	4.8	0
	TSA01	7	<1.7	195	27.6	67	1
Antimony	CHI01	5	0.112	0.175	0.136	0.023	0
	TSA01	7	0.056	0.181	0.093	0.040	0
Arsenic	CHI01	5	2.20	2.99	2.85	0.34	0
	TSA01	7	1.86	4.05	2.89	0.71	0
Barium	CHI01	5	74.6	194	153	48	---- ^a
	TSA01	7	99.9	415	200	104	----
Beryllium	CHI01	5	<0.006	<0.012 ^b	- ^c	-	----
	TSA01	7	<0.006	<0.012	-	-	----
Boron	CHI01	5	20.5	37.7	30.7	6.7	----
	TSA01	7	17.6	53.5	26.9	16.1	----

Table 5 continued

Trace metal, dissolved	Site	Number of samples	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation	Number of exceedances
Cadmium	CHI01	5	<0.016	<0.020	-	-	0
	TSA01	7	<0.016	0.041	-	-	0
Chromium	CHI01	5	<0.06	<0.12	-	-	----
	TSA01	7	0.080	<0.12	-	-	----
Cobalt	CHI01	5	0.12	1.16	0.17	0.45	----
	TSA01	7	0.22	1.34	0.36	0.42	----
Copper	CHI01	5	1.00	4.30	1.20	1.39	0
	TSA01	7	<0.5	1.10	<1.0	0.3	0
Mercury	CHI01	5	<0.005	<0.010	-	-	unknown
	TSA01	8	<0.005	<0.010	-	-	unknown
Iron	CHI01	5	<3.2	25.2	<6.0	12.5	----
	TSA01	7	<3.2	58.1	25.7	18.7	----
Lead	CHI01	5	<0.030	0.141	<0.030	0.049	0
	TSA01	7	0.020	0.098	0.050	0.024	0
Manganese	CHI01	5	0.34	7.37	2.69	3.14	----
	TSA01	7	3.38	225	12.1	92	----
Molybdenum	CHI01	5	0.742	1.16	0.847	0.17	----
	TSA01	7	0.350	1.25	0.738	0.32	----
Nickel	CHI01	5	0.93	1.36	1.01	0.18	0
	TSA01	7	0.540	1.67	0.850	0.39	0
Selenium	CHI01	5	0.17	0.30	0.21	0.05	0
	TSA01	7	0.070	0.170	0.130	0.037	0
Silver	CHI01	5	<0.005	<0.01	-	-	0
	TSA01	7	<0.005	0.096	-	-	0
Uranium	CHI01	5	0.776	3.06	1.78	0.87	----
	TSA01	7	0.514	2.00	0.745	0.59	----
Vanadium	CHI01	5	3.45	6.35	4.91	1.31	----
	TSA01	7	1.21	5.35	4.14	1.35	----
Zinc	CHI01	5	2.5	<2.8	-	-	0
	TSA01	7	<1.4	<2.8	-	-	0

^a "----" means no current water quality standard for this analyte

^b Results that were lower than the NWQL reporting levels are noted as "<[reporting level]". Reporting levels changed to match the long-term method detection level starting October 1, 2010, therefore some samples have two different reporting levels displayed.

^c "-" means statistics not calculated because >70% of data were non-detects

February 23 to a high of 35.5°C on July 16 (fig. 5). The average air temperature at TSA01 2010 was 7.1°C.

At TSA01, pH values ranged from 7.9 to 8.6, and dissolved oxygen ranged between 7.7 and 10.4 mg/L (table 2), both within the aquatic and wildlife criteria. Dissolved oxygen exceeded 100% saturation during the March, June, July, September, and November site visits because of the presence of algae and aquatic plants in the stream. This occurred whether or not water was being released from Tsaile Dam. The lowest dissolved oxygen concentrations occurred during January and June. The highest occurred in September. Specific conductivity ranged between 193 and 457 $\mu\text{S}/\text{cm}$ —the lowest measurement occurred in June and the highest in November. Turbidity ranged between 9.4 and 81 NTU, and was highest in June and lower during the fall and winter months.

SCPN staff observed discharges from Tsaile Dam during site visits on January 28, March 16, April 17, June 2, and December 9. Discharges were not observed on July 19, September 9, and November 2. Discharge at

TSA01 varied greatly, depending on whether dam releases were occurring, and ranged between 21.3 cfs in January to <0.1cfs in July, September, and November. Flow was observed in the stream during the low flow periods, but we were unable to measure because it was less than our flow meters' lower detection limits. These low flows occurred during periods when water was not being released from the dam.

3.2.2 Total coliforms and *E. coli*

Total coliform levels at TSA01 ranged between 91 and 830 MPN/100 mL (fig. 2). Results were lowest in winter and higher during the warm summer months.

E. coli levels at TSA01 were consistently low throughout the year, with only slightly higher levels in the summer (fig. 3). Our results ranged between <1 and 84 MPN/100 mL. There were no water quality exceedances for bacteria at TSA01.

3.2.3 Water quality laboratory data

Laboratory results for water samples collected from TSA01 at CACH in 2010, and analyzed for nutrient, trace metals, and major element concentrations are summarized here, and where applicable, are compared against the Navajo Nation EPA acute and chronic aquatic life standards.

The nutrient ammonia was detected at TSA01 in four of the eight samples collected, but the maximum concentration was only 0.250 mg/L (table 3), well below the chronic water quality standard for aquatic and wildlife habitat, which at the time of sample collection was 2.80 mg/L (Navajo Nation EPA 2008).

Median concentrations of nitrite + nitrate were below the reporting level at TSA01 (<0.02 mg/L). These nutrients were detected in only two of the TSA01 samples. Nitrite, by itself, was detected in three of the

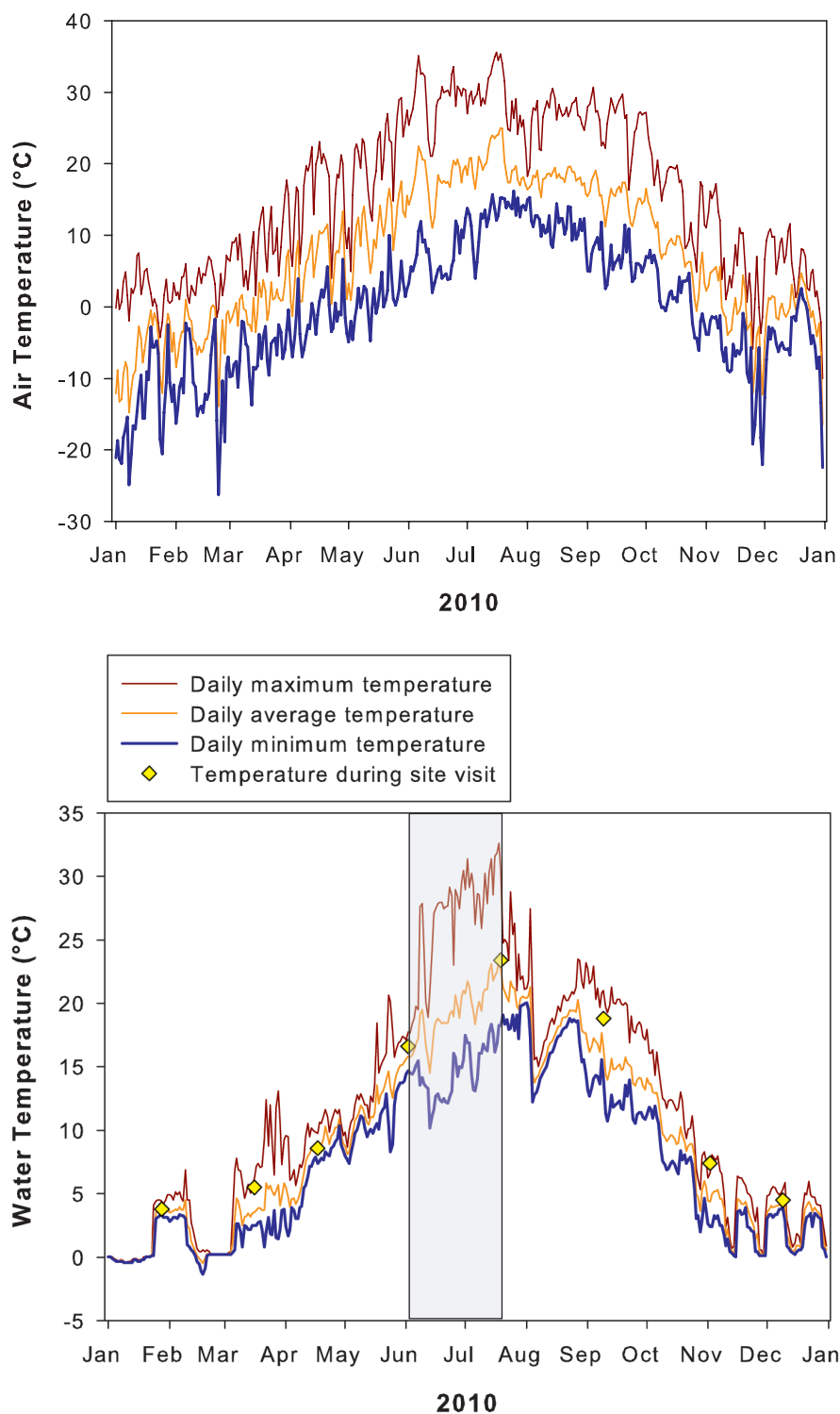


Figure 5. Daily maximum, average, and minimum air temperatures (top) and water temperatures (bottom) recorded at TSA01 at Tsaille Creek in Canyon de Chelly N.M., 2010. Shaded area indicates period where the water temperature logger was exposed to air.

TSA01 samples; median values were low and only slightly above the laboratory reporting level of 0.0010 mg/L. Orthophosphate was detected in all samples collected, with a median level of 0.046 mg/L at TSA01.

Major element data for TSA01 are summarized in Table 4. Calcium and silica were the dominant dissolved solids, making up 22 and 11% of the total dissolved solids, respectively. Magnesium and sodium followed at 4% each; then sulfate (3%), and 2% or less of chloride, potassium, and fluoride. Acid neutralizing capacity was 181 mg/L.

Major ion composition for TSA01 in 2010 is provided in Figure 4. Water chemistry remained consistent throughout the year. Cations primarily consisted of calcium, but also contained lesser amounts of magnesium, sodium, and potassium. Bicarbonate and carbonate ions, which are calculated from the acid neutralizing capacity, comprised the majority of the anions.

Trace metal results for TSA01 are summarized in Table 5. Beryllium and mercury were not detected. Four metals were only occasionally detected—cadmium, chromium, silver, and zinc.

Of the 11 elements which have water quality criteria, all but mercury and aluminum were present at levels far below the chronic aquatic life criteria. Aluminum concentrations at TSA01 exceeded the Navajo Nation EPA chronic aquatic life water quality standard of 87 µg/L during the November 2nd sampling event, when levels measured 195 µg/L. However, this result was well below the acute criterion of 750 µg/L.

4 Summary

In 2010, SCPN implemented water quality monitoring at CHI01 and TSA01 on Chinle Wash and Tsaille Creek in CACH. This report summarizes data collected during site visits to CHI01 and TSA01 during 2010 and compares these results against Navajo Nation EPA aquatic and wildlife habitat standards (Navajo Nation EPA 2008).

Measurements of discharge and turbidity at CACH varied greatly between the two sites and between site visits; and tended to be much higher at CHI01 than TSA01. Specific conductivity and pH were similar between the two sites but varied during the year, and values for pH at both sites were within the water quality criteria. Dissolved oxygen was generally higher at TSA01 than at CHI01. Measurements did not fall below the water quality criteria at either site.

Total coliform results were much higher at CHI01 than at TSA01 (fig. 2, p. 6 and Appendix B1, B3). Four of the six samples exceeded the detection limit of 2400 MPN/100 mL while the highest result at TSA01 was 830 MPN/100 mL. *E. coli* was also much higher at CHI01 (fig. 3, p. 6); two of the results were well above the water quality criteria, and one result exceeded the 2400 MPN/100 mL detection limit. No water quality exceedances were observed at TSA01.

Laboratory-measured results for nutrients (Appendix B1, B3) were low at both sites and were well below the water quality criteria. Trace metal concentrations tended to be low, and six trace metals—beryllium, cadmium, chromium, mercury, silver, and zinc—were either rarely or never detected above the laboratory reporting levels at either site. Median values for trace metals were similar between CHI01 and TSA01, with a few exceptions. Median concentrations of aluminum, iron, and manganese were much higher at TSA01 than at CHI01. One aluminum result at TSA01 was 195 µg/L, which is higher than the chronic aquatic and wildlife criterion of 87 µg/L but below the acute criterion. Additional samples would be needed to confirm whether this is a chronic exceedance. Total petroleum hydrocarbon and oil and grease samples were collected during four site visits to CHI01. These analytes were not present above the laboratory reporting levels.

The results of major ion analyses for CHI01 and TSA01 show that water chemistry of the two sites is very similar, and major ions are dominated by bicarbonate and calcium (fig. 4, p. 8). Median values for total dissolved solids were similar at both sites; and acid neutralizing capacity was higher at CHI01 than at TSA01 (Appendix B1, B3).

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 sufficient data are available, SCPN plans to produce an interpretive report that will include trend analysis of water quality data for Chinle Wash and Tsaille Creek.

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Appendix A: Southern Colorado Plateau Network water quality monitoring sites at Canyon de Chelly National Monument

Site code	Common name	Report name	UTM (NAD 83, Zone 12)		Elevation (m)
			X	Y	
CACHCHI01	Chinle Wash at Chinle	CHI01	631525	4002062	1689
CACHTSA01	Tsaile Creek below Tsaile Dam	TSA01	660576	4015393	2125

Appendix B: 2010 Water quality results for Canyon de Chelly National Monument

Table B1. Results of laboratory analyses for CACHCHI01, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL)^a

Analyte ^b	Sample collection date and time					
	2/3/10	3/16/10	4/17/10	6/2/10	8/2/10	12/9/10
	13:40	17:00	15:10	14:15	15:50	14:13
Nutrients (mg/L)						
Ammonia as N	<0.020	<0.020	<0.020		<0.020	<0.010
Nitrite + nitrate as N	0.15	0.06	0.18		0.06	0.06
Nitrite as N	0.005	0.003	0.005		0.002	0.002
Orthophosphate as P	0.062	0.047	0.067		0.070	0.024
Major elements (mg/L)						
Calcium	51.9	57.7	21.9		27.2	52.9
Chloride	5.86	9.67	2.54		1.88	4.68
Fluoride	0.16	0.19	0.12		0.18	0.14
Magnesium	9.17	11.8	4.32		4.11	10.1
Potassium	2.92	3.02	1.86		3.71	3.29
Silica	25.0	24.9	15.0		11.3	20.0
Sodium	9.61	14.6	4.73		4.25	9.79
Sulfate	18.9	29.1	7.60		6.52	13.8
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	239	291	215		275	415
Total dissolved solids	257	304	114		128	247
Trace metals (µg/L)						
Aluminum	5.11	<3.40	13.8		2.91	1.76
Antimony	0.175	0.136	0.147		0.131	0.112
Arsenic	2.85	2.99	2.20		2.88	2.43

Table B1. *continued*

Analyte ^b	Sample collection date and time					
	2/3/10	3/16/10	4/17/10	6/2/10	8/2/10	12/9/10
	13:40	17:00	15:10	14:15	15:50	14:13
Barium	153	177	74.6		115	194
Beryllium	<0.012	<0.012	<0.012		<0.012	<0.006
Boron	24.3	31.9	20.5		37.7	30.7
Cadmium	<0.020	<0.020	<0.020		<0.020	<0.016
Chromium	<0.12	<0.12	<0.12		<0.12	<0.06
Cobalt	1.16	0.17	0.17		0.12	0.21
Copper	1.0	1.5	1.2		1.8	4.3
Iron	<6.0	<6.0	25.2		<6.0	<3.2
Lead	<0.030	<0.030	0.031		<0.030	0.140
Manganese	6.45	7.37	1.24		0.34	2.69
Mercury	<0.010	<0.010	<0.010		<0.010	<0.005
Molybdenum	0.847	1.16	0.770		0.951	0.742
Nickel	1.36	0.99	1.22		1.01	0.93
Selenium	0.21	0.23	0.30		0.17	0.17
Silver	<0.01	<0.01	<0.01		<0.01	<0.005
Uranium	2.24	3.06	1.32		0.776	1.78
Vanadium	3.45	5.89	4.91		6.35	3.58
Zinc	<2.80	<2.80	<2.80		<2.80	2.50
Total coliforms and <i>E. coli</i> (MPN/100 mL)						
Total coliforms	580	110	1400	1200	>2400 ^c	290
<i>E. coli</i>	45	<1	210	99	59	58
Oil and grease, TPH, (mg/L) ^d		<4.8	<10		<5.1	<5.3

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Note that reporting levels changed starting October, 2010.

^bParameters are dissolved unless otherwise specified.

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

^dOil and grease data are from the Test America Lab. TPH stands for total petroleum hydrocarbons.

Table B-2. NPS water quality core parameter field data for CACHCHI01

Core parameter	Unit	Sample collection date and time					
		2/3/10	3/16/10	4/17/10	6/2/10	8/2/10	12/9/10
		13:40	17:00	15:10	14:15	15:50	14:13
Water temperature	°C	0.5	17.7	15.1	28.8	27.7	6.5
pH	none	8.5	8.6	8.2	8.6	8.3	8.4
Specific conductivity	µS/cm	367	446	164	346	189	345
Dissolved oxygen	mg/L	11.3	7.5	8.2	6.2	6.4	9.6
Turbidity	NTU	1200 ^a	2050	3600	520	7800	3700
Discharge	cfs	1.6	19.7	177	8.7	40.7	21.8

^a Turbidity levels above 1000 NTU are estimated

Table B3. Results of laboratory analyses for CACHTSA01, as reported by the U.S. Geological Survey National Water Quality Laboratory (NWQL)^a

Analyte ^b	Sample collection date and time							
	1/28/10 13:00	3/16/10 15:09	4/17/10 19:00	6/2/10 18:00	7/19/10 20:55	9/9/10 17:46	11/2/10 17:53	12/9/10 11:36
Nutrients (mg/L)								
Ammonia as N	0.246	0.173	<0.020	<0.020	<0.020	0.023	<0.010	0.014
Nitrite + nitrate as N	<0.04	0.06	<0.04	<0.04	<0.04	0.06	<0.02	<0.02
Nitrite as N	<0.002	0.003	<0.002	<0.002	<0.002	0.004	0.001	<0.001
Orthophosphate as P	0.088	0.096	0.046	0.061	0.029	0.030	0.024	0.020
Major elements (mg/L)								
Calcium	56.5	53.0		31.7	52.1	54.7	68.1	54.7
Chloride	3.86	3.57	2.44	1.91	4.72	6.56	5.70	2.98
Fluoride	0.15	0.13	0.11	0.10	0.24	0.31	0.30	0.13
Magnesium	8.11	7.65		4.51	12.7	14.6	15.5	7.79
Potassium	2.33	2.18		1.51	2.40	3.20	2.33	2.68
Silica	32.3	31.3		22.2	27.8	17.9	28.4	19.6
Sodium	6.60	6.47		3.42	11.8	14.9	14.3	6.37
Sulfate	11.2	8.96	6.05	6.26	6.59	6.98	7.68	5.47
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	183	178	115	95.7	198	217	258	168
Total dissolved solids	264	241	158	145	232	255	313	214
Trace metals (µg/L)								
Aluminum	27.6	28.3		61.6	10.1	18.8	195	<1.70
Antimony	0.091	0.092		0.181	0.127	0.093	0.056	0.124
Arsenic	2.65	2.31		1.86	4.05	3.32	3.13	2.89
Barium	200	168		99.9	285	281	415	176
Beryllium	<0.012	<0.012		<0.012	<0.012	<0.012	<0.006	<0.006
Boron	26.3	21.2		17.6	51.9	52.3	53.5	26.9
Cadmium	<0.02	<0.02		<0.02	<0.02	<0.02	0.041	<0.016
Chromium	<0.12	<0.12		<0.12	<0.12	<0.12	0.08	0.08
Cobalt	0.30	0.22		1.34	0.96	0.43	0.34	0.36
Copper	<1.0	<1.0		1.1	<1.0	<1.0	<0.5	1.1
Iron	39.3	29.8		58.1	11.1	25.7	14.0	<3.2
Lead	0.05	0.06		0.10	0.04	0.05	0.04	0.02
Manganese	225	172		12.1	3.38	9.04	3.96	74.3
Mercury	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005
Molybdenum	0.738	0.591		0.350	0.958	1.15	1.25	0.678
Nickel	1.26	0.75		1.67	0.85	0.70	0.54	0.95
Selenium	0.10	0.14		0.17	0.12	0.13	0.07	0.17
Silver	<0.01	<0.01		<0.01	<0.01	<0.01	0.096	<0.005
Uranium	2.00	1.67		0.699	0.745	0.619	0.514	1.37
Vanadium	4.06	3.19		4.61	5.35	4.14	1.21	4.55
Zinc	<2.8	<2.8		<2.8	<2.8	<2.8	<1.4	<1.4
Total coliforms and <i>E. coli</i> (MPN/100 mL)								
Total coliforms	91	340	230	460	830	830	340	140
<i>E. coli</i>	1	1	4	4	84	84	4	<1

^aResults that were lower than the NWQL reporting levels are noted as "<[reporting level]". Note that reporting levels changed starting October, 2010.

^bParameters are dissolved unless otherwise specified.

Table B-4. NPS water quality core parameter field data for CACHTSA01

Core parameter	Unit	Sample collection date and time							
		2/3/10	3/16/10	4/17/10	6/2/10	8/2/10	12/9/10	11/2/10	12/9/10
		13:40	17:00	15:10	14:15	15:50	14:13	17:53	11:36
Water temperature	°C	3.8	5.5	8.6	16.6	23.4	18.8	7.4	4.5
pH	none	7.9	8.3	8.2	8.6	8.4	8.5	8.4	8.6
Specific conductivity	µS/cm	361	350	228	193	380	418	457	310
Dissolved oxygen	mg/L	7.7	10.1	8.6	7.7	8.4	10.4	10.0	9.8
Turbidity	NTU	11	16	50	81	46	14	9.4	10
Discharge	cfs	21.3	10.7	19.3	10.4	<0.1	<0.1	<0.1	15.5

Appendix C: Abbreviations and terms

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
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25°C, a measure of specific conductivity
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 bacterial per 100 mL of sample water
N	chemical symbol for the element nitrogen
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for the element phosphorous