



Hydrologic Monitoring for Cañon Sapato in the Quarai Unit of Salinas Pueblo Missions National Monument

2010–2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/358



ON THE COVER

Pool near the Cañon Sapato pedestrian bridge in the Quarai Unit of Salinas Pueblo Missions National Monument
Photograph courtesy of SCPN

Hydrologic Monitoring for Cañon Sapato in the Quarai Unit of Salinas Pueblo Missions National Monument

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1 Introduction and background

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, the first two of which we focus on in this report: 1) stream flow and depth to groundwater, 2) spring, seep and tinaja ecosystems, 3) channel morphology, 4) spring water quality, 5) stream water quality, 6) riparian vegetation, composition, and structure, and 7) aquatic macroinvertebrates. 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).

Salinas Pueblo Missions National Monument (SAPU) is located in central New Mexico and consists of 3 non-contiguous resource units. These are the Quarai Unit, the Abo Unit, and the Gran Quivira Unit. Of these only the Quarai and Abo Units have water resources such as streams or springs. Cañon Sapato passes through the Quarai Unit and Cañon Espinoso passes through the Abo Unit. Within park boundaries these canyons contain springs and ephemeral streams, and both units have significant cultural resources closely associated with the water features. The combination of surface runoff, shallow alluvial groundwater, and springs supports extensive riparian and aquatic ecosystems.

This report focuses on SCPN hydrologic monitoring activities in Cañon Sapato at SAPU's Quarai Unit. The *Water Resources Management Plan: Salinas Pueblo Missions National Monument* (National Park Service 1997) describes an arroyo extending for a distance of about 150 m through Cañon Sapato. The report suggests extensive arroyo incision took place during the past several hundred years as the result of changing land use in the watershed. Outcrops of the Permian Abo Formation occur in the arroyo bottom just downstream from a pedestrian bridge across the arroyo. Presence of this red sandstone probably limits further downcutting while bringing groundwater to the surface, resulting in perennial spring flow in Cañon Sapato within the Quarai Unit. A spring-fed pool exists approximately 10 meters upstream from the pedestrian bridge. This pool is the furthest upstream extent of surface water in Cañon Sapato. Spring flow supports continuous dense wetland and riparian vegetation extending from the spring pool downstream to the monument boundary.

While data describing the hydrology and geomorphology of the Quarai Unit are limited, some information is available. During the 1980s, the U.S. Army Corps of Engineers developed a HEC-2 model for the Cañon Sapato watershed, estimating discharge for large infrequent runoff events (United States Army Corp of Engineers 1985). In 2006, SAPU staff submitted a technical assistance request to the National Park Service Water Resources Division (WRD) for the purpose of addressing channel erosion affecting archaeological features near Cañon Sapato. The WRD evaluated hydrologic and geomorphic conditions in the arroyo and recommended several mitigation measures intended to reduce erosion (Inglis 2006). Knowledge of associated biologic systems is limited.

In 2010, the SCPN implemented hydrologic monitoring in Cañon Sapato at the Quarai Unit of SAPU with the objectives of documenting the timing, duration, and magnitude of surface water flow events and changes in shallow ground water levels. This information will improve understanding of the stream's surface water-ground water interactions. Water resources staff installed 3 piezometers to monitor water levels, installed recording instrumentation, and surveyed the installations and key channel features. We monitored the following sites (fig. 1), and list their locations, codes and common names in Appendix A:

- *Cañon Sapato Spring* (SAPUQUA01) is identified in this report as QUA01.
- *Cañon Sapato upstream from pedestrian bridge* (SAPUQUA02) is identified in this report as QUA02.
- *Cañon Sapato downstream from bedrock ledges* (SAPUQUA03) is identified in this report as QUA03.

The purpose of this report is to (a) document SCPN hydrologic monitoring activities that have occurred at the Quarai Unit in SAPU, (b) summarize the data collected, and (c) where appropriate, place the data in the context of current environmental conditions.

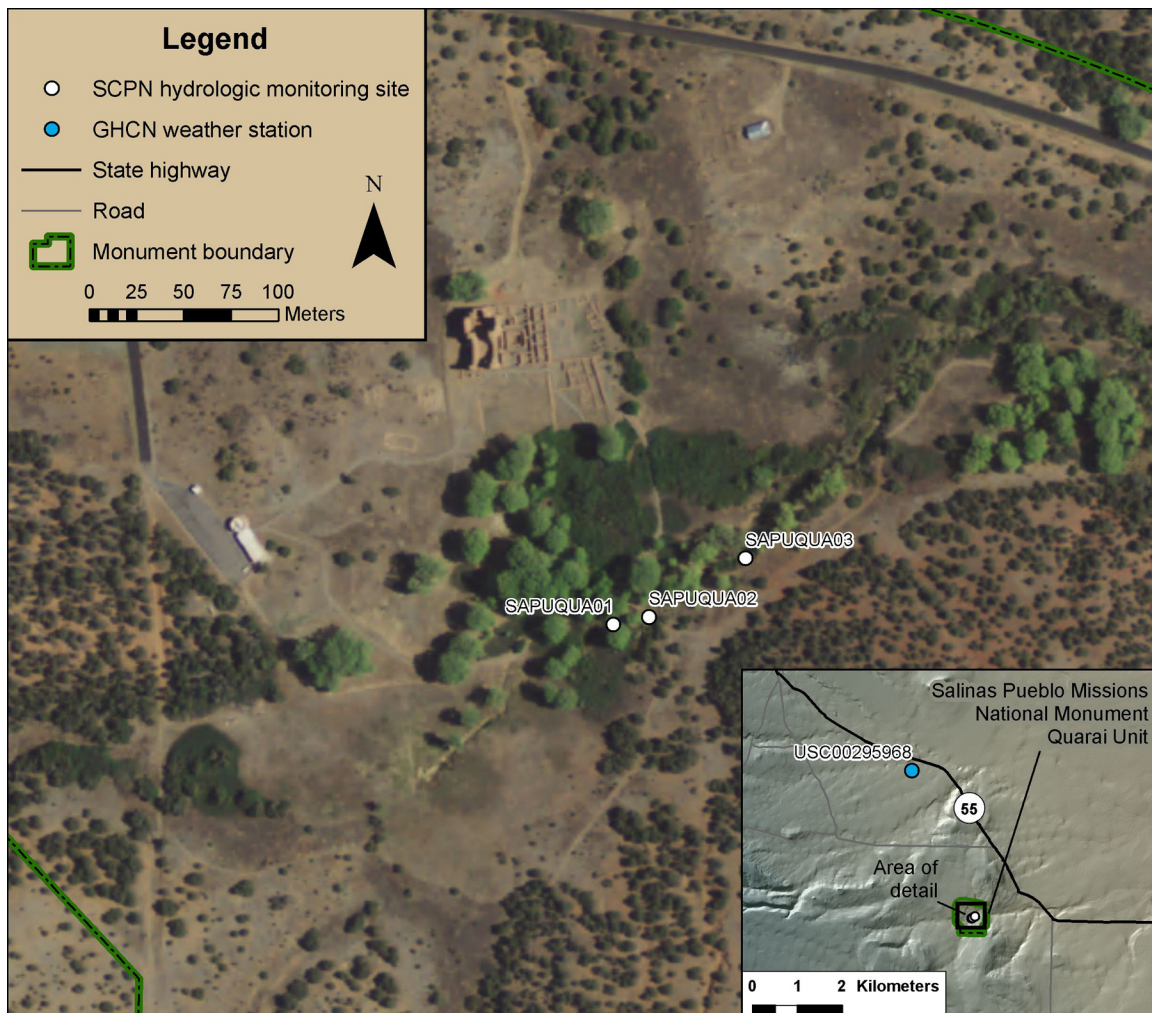


Figure 1. Location of sites associated with SCPN hydrologic monitoring in Salinas Pueblo Missions N.M., New Mexico, 2010–2011

2 Methods

Following is a brief outline of hydrologic monitoring data collection and processing methodologies followed by SCPN staff at SAPU during 2010–2011. This report covers the period from monitoring implementation (October 28, 2010) through the remainder of water year (WY) 2011 (September 30, 2011). SCPN water resources staff visits SAPU on a quarterly basis to download all instrumentation, obtain manual measurements at the piezometers, and photograph the channel and the spring pool just upstream of the interpretive trail pedestrian bridge. Appendix A describes location, metrics, and collection time frames for each monitoring site. For further details please refer to the hydrologic standard operating procedures (SOPs) of the network's draft integrated riparian monitoring protocol (Monroe et al. in preparation).

2.1 Field methods

2.1.1 *Hydrologic monitoring equipment installation*

On October 28, 2010, SCPN water resources crew members installed 3 piezometers in Cañon Sapato to monitor changing surface and groundwater levels at locations near the interpretive trail pedestrian bridge. Each is constructed of 1¼-inch galvanized steel pipe, and was manually installed with a post pounder. One was installed near the downstream edge of the Cañon Sapato spring pool (QUA01), located about 20 m upstream of the pedestrian bridge. A second, (QUA02), was a modified piezometer set up to function as a recording stage gage (RSG) to monitor surface water rather than ground water, and placed in the channel beneath the upstream face of the pedestrian bridge. The RSG is constructed of a 0.9 m (3 feet) length of solid pipe, coupled to a 0.9 m screened well section, and installed so that both the solid pipe and about 0.4 m of the screened section are below the stream channel bottom. Approximately 0.5 m of the screened section extends above the channel bottom; water enters the piezometer through the screen during surface flow events. The third piezometer (QUA03) was installed in a wetland area approximately 50 m downstream from the pedestrian bridge. The piezometers at QUA01 and QUA03 were installed in the standard orientation, with the screened well point driven below ground surface, coupled to the bottom end of the solid riser pipe that extends above the ground surface.

A recording water pressure transducer (Solinst Levelogger Junior) was suspended in each of the 3 piezometers. A recording barometric pressure logger (Solinst Barologger Gold) was suspended in a tree on the left side of the channel (all “left” and “right” are as facing downstream) about 5 m upstream from the pedestrian bridge. In addition to recording pressure, both instruments also include temperature sensors. The recording interval for all instruments was set to 15 minutes. A locking well plug was placed in each piezometer. A 1-inch diameter steel pipe was installed near the water edge on the upstream end of the spring pool at QUA01, for obtaining manual measurements to the pool water surface during site visits. These measurements provide quality control for data reported by the recording transducer in the QUA01 piezometer. Approximately 12 cm of the pipe was exposed above the water surface on the day of installation.

2.1.2 *Survey*

On the same day that hydrologic equipment was installed, (October 28, 2010), the SCPN water resources crew surveyed the hydrologic monitoring equipment installations and important channel features in Cañon Sapato using Topcon GTS-229 total station instrumentation. We established 6 permanent survey control points for future repeatability of comparative surveys.

All survey control points, the top of the 1-inch steel pipe at the spring pool, and the lip (well plug removed) and ground surface at each of the 3 piezometers were surveyed. The transect across the channel at the recording stage gage, the main channel profile along the channel bottom (thalweg), and points where surface water intersected the channel bottom ground surface were also mapped. The mapped channel profile began approximately 10 m upstream of a steep headcut just upstream of the spring pool at QUA01, and extended 170 m downstream. Two secondary channels (identified as separate profiles) diverged from the main channel around the steep bedrock-controlled drop about 12 m and 20 m downstream of the pedestrian bridge, and these were also surveyed. We documented and photographed all of the piezometer installations and survey control points.

2.1.3 *Hydrologic data collection*

SCPN water resources staff visited SAPU at quarterly intervals during 2011. These visits were on February 8, May 6, August 16, and November 21. During each site visit, depth to water in each of the 3 piezometers was

measured, and data were downloaded from all data loggers deployed at the site. Photographs were taken of QUA01 and the spring pool, the stream channel at QUA02, and the downstream channel near QUA03. A manual measurement was obtained from the top of the 1-inch pipe to the spring pool water surface at QUA01 during the August 2011 site visit.

Local daily precipitation data were also downloaded from the National Climatic Data Center (National Climatic Data Center, Climate Data Online n.d.). The nearest station at which these data are collected is the Global Historical Climatology Network (GHCN) station USC00295968, located about 3.2 km north-northwest of the Quarai Unit.

2.2 Data analysis

2.2.1 Hydrologic data processing

Hydrologic data collected by SCPN consist of (a) water and barometric pressure data collected by the Solinst transducers and Barologger, respectively, in metric units; (b) water and air temperature data collected by the same 2 instruments (in °C); and (c) manual measurements of the depth to water made within each piezometer, and from the top of the 1-inch metal pipe installed at the spring pool to the pool water surface. The Barologger pressure data are used to correct (compensate) for barometric pressure effects on the raw transducer water level data.

We used points surveyed on the top of the spring pool 1-inch metal pipe, and on the top of the piezometers at QUA01 and QUA03 and the RSG at QUA02, to transform water levels recorded by the transducers (compensated for barometric pressure) into elevation format. Water levels obtained by manual measurements are converted to elevation format by the same method. Data are archived in the SCPN groundwater database. The transformed data document surface flow events through the Cañon Sapato channel at the pedestrian bridge, and relative water levels in the spring pool and wetland area downstream. These water level data can be evaluated relative to measurements of daily precipitation collected at the GHCN station USC00295968.

2.2.2 Survey data processing

The survey data consist of coordinates (x, y) and elevations (z) for each point mapped during the total station survey, reported in metric units relative to the arbitrary survey origin and datum. Terramodel terrain modeling software (v. 10.4, 2005) was used to construct a plan view diagram of the surveyed points. Diagrams of the surveyed thalweg profile and transect, including the locations and depths of the hydrologic monitoring equipment installations, were constructed in SigmaPlot (v. 8.0, 2007).

3 Results

Results from the data collected during the 2011 WY, from October 28, 2010, through September 2011, are summarized below.

3.1 Hydrologic conditions

Two different types of hydrologic data were collected: water levels, and air and water temperatures.

3.1.1 Water levels

Table 1 presents water level and elevation data, collected on October 28, 2010.

Table 1. Depths and elevations from the hydrologic instrumentation installation and survey on October 28, 2010, in Salinas Pueblo Missions N.M.

Measurement	Depth (m) ^a	Elevation (m) ^b
QUA01		
Pool, maximum depth	0.84	
Piezometer, total depth	1.83	
Pool water surface elevation		998.19
Piezometer, lip elevation		998.65
Piezometer, ground surface elevation		998.36
QUA02		
Gage depth, lip to channel bottom	0.56	
Channel bottom elevation		998.65
Gage elevation at lip		999.21
QUA03		
Pool depth	0.81	
Piezometer, total depth	2.44	
Pool water surface elevation		993.63
Piezometer elevation at lip		994.17
Piezometer elevation at ground surface		993.94

^aPool depths are measured from the bottom of pool to water surface. Piezometer depths are total depths; the QUA02 depth is from the lip of the RSG to the channel bottom (ground surface).

^bElevation is relative to the arbitrary survey datum at 1000.00 m.

Figure 2 shows recorded water levels at QUA01, QUA02, and QUA03 with daily precipitation reported at GHCN station USC00295968 during the 2011 WY (October 1, 2010, through September 30, 2011). All water level elevations are graphed relative to the arbitrary survey datum of 1000.00 m. The ground surface elevation at QUA02 is shown for reference. Manual measurements of the spring pool water level at QUA01, and of water levels inside the piezometer at QUA03, are also shown. We were unable to measure the water level in the spring pool in February because the pool was frozen, and in May because the water in the pool was very high, prohibiting access to the steel pipe.

Zero rainfall was recorded on 304 days (83%) of the 2011 WY. Water levels in the spring pool recorded at QUA01 rose approximately 0.7 m between early January and February 2011; just over 54 mm of precipitation was recorded during the same period. Water in the spring pool remained at about this level through mid-April, although recorded precipitation between February 10 and April 30 was only 9 mm. From May through July, recorded precipitation was about 37 mm, and the spring pool water level fell more than 1 m during this period. The greatest 48 h rainfall, 28 mm, was recorded on August 21–22, 2011. The spring pool level rose nearly 2 m in 15 minutes in the late afternoon on August 21, and surface flows at QUA02 peaked at about 1.3 m deep immediately thereafter. SAPU staff reported that they removed large amounts of flood debris, especially cattails, from QUA02 the following day, but that surface flows through the park did not reach the downstream park boundary (Salinas Pueblo Missions N.M., Quarai Unit, M. Sullivan, ranger, conversation with Ellen Soles, Northern Arizona University, 21 November 2011). Surface flow at QUA02 ended after 3 hours. The spring pool

water level receded somewhat, but remained elevated more than 1 m above the pre-flood level until a second, smaller event on August 23, when the water level increased by 0.7 m in 15 minutes. Surface flow again reached QUA02, which recorded a maximum water depth of 0.4 m. Surface flow at QUA02 was recorded for another 3 hours and SAPU staff noted continuous surface flow through the park. By September 30, water levels in the spring pool had receded to near the lowest levels recorded since late October 2010.

Changes in the recorded water levels at QUA03 for the period were generally subdued by comparison to those in the spring pool, but followed the same general pattern. Water levels recorded at QUA03 during the winter of 2011 rose less than 0.2 m. They also declined less than those at QUA01, about 0.5 m total, between May and July. The water level at QUA03 rose approximately 0.7 m over an hour-long period during the surface flow event on August 21, and 0.5 m during the second event 2 days later. The water level at QUA03 fluctuated more than the water level at QUA01 during a series of rainfall events in September 2011, and remained approximately 0.2 m higher than the lowest levels recorded during the WY as of September 30.

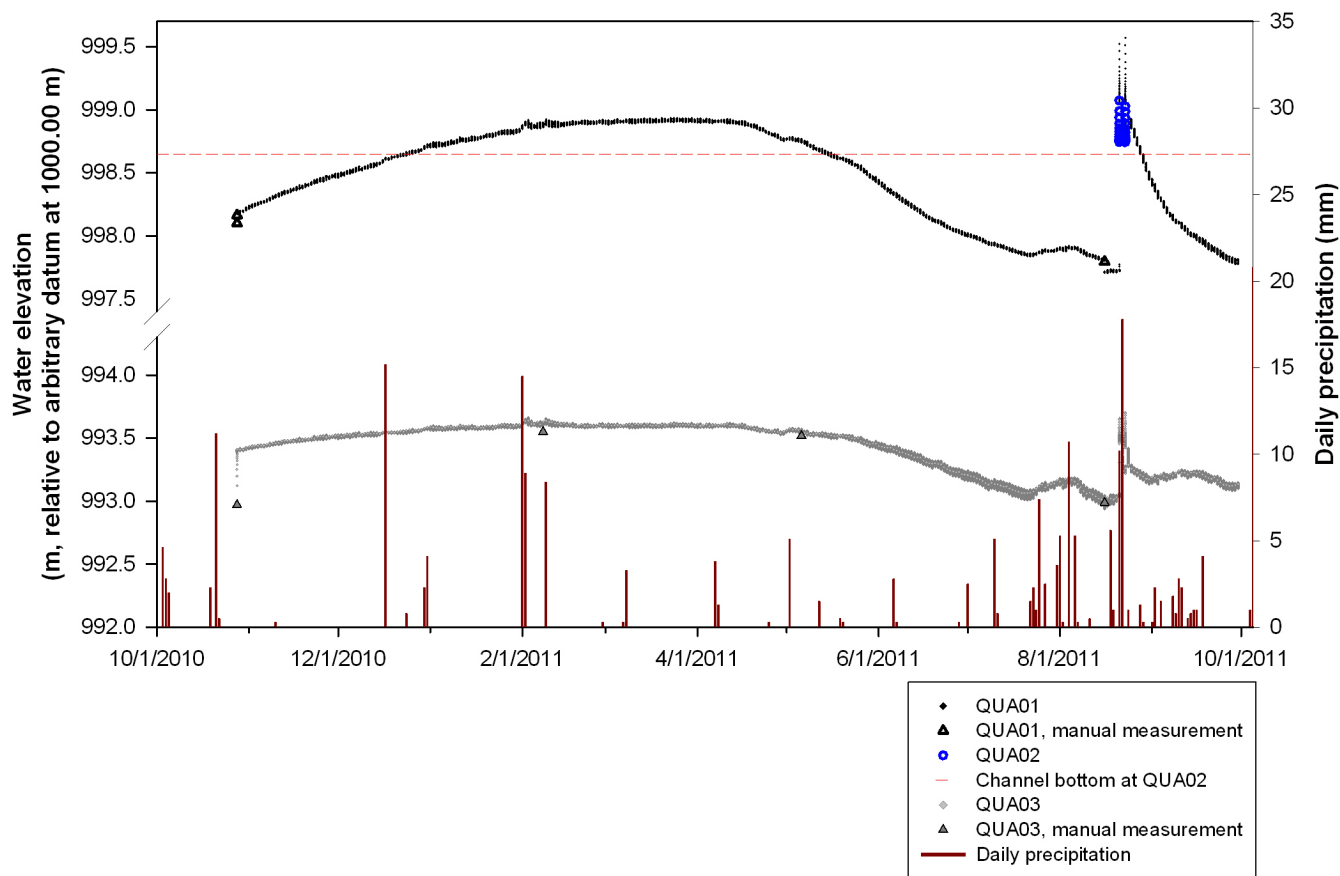


Figure 2. Manual and recorded water levels in the piezometers at QUA01 and QUA03 and the RSG at QUA02 through September 30, 2011, in Salinas Pueblo Missions N.M. Daily precipitation recorded at the GHCN weather station near Quarai from October 1, 2010, through September 30, 2011, is plotted relative to the right axis. The only 2 surface flows recorded at QUA02 both occurred in August 2011.

3.1.2 Air and water temperature

Table 2 and Figure 3 show comparative water and air temperature data recorded by the water level transducers and Barologger, respectively, during the monitoring period (October 28, 2010, through September 30, 2011).

Seasonal air temperatures varied widely, from about -36°C to 33°C. Daily fluctuations in air temperature were between 20°C and 30°C.

Water temperatures varied much less. Except during the August 2011 flood events, daily changes in water temperatures at both the QUA01 and QUA03 piezometers were never >0.1°C, even during the coldest and warmest periods. Water temperature in the spring pool at QUA01 rose by about 0.3°C during each flood, but no change in downstream wetland water temperature at QUA03 was recorded during either event. Seasonally, water temperatures changed slowly. The variation between highest and lowest water temperatures at the QUA01 piezometer recorded during the period was 8.1°C.

Table 2. Recorded air temperatures at QUA02, and water temperatures at QUA01 and QUA03, October 28, 2010–September 30, 2011, in Salinas Pueblo Missions N.M.

Location	Temperature (°C) during the period October 28, 2010–March 31, 2011	Temperature (°C) during the period April 1, 2011–September 30, 2011	Temperature (°C) during the period October 28, 2010–September 30, 2011
QUA01			
Median	8.1	13.7	10.3
Minimum	7.4	8.6	7.4
Maximum	12.1	16.1	16.1
QUA02 Barologger (air)			
Median	3.6	17.1	11.9
Minimum	-36.5	-7.2	-36.5
Maximum	29.8	33.4	33.4
QUA03			
Median	6.7	9.7	8.3
Minimum	4.9	6.5	4.9
Maximum	13.0	13.0	13.0

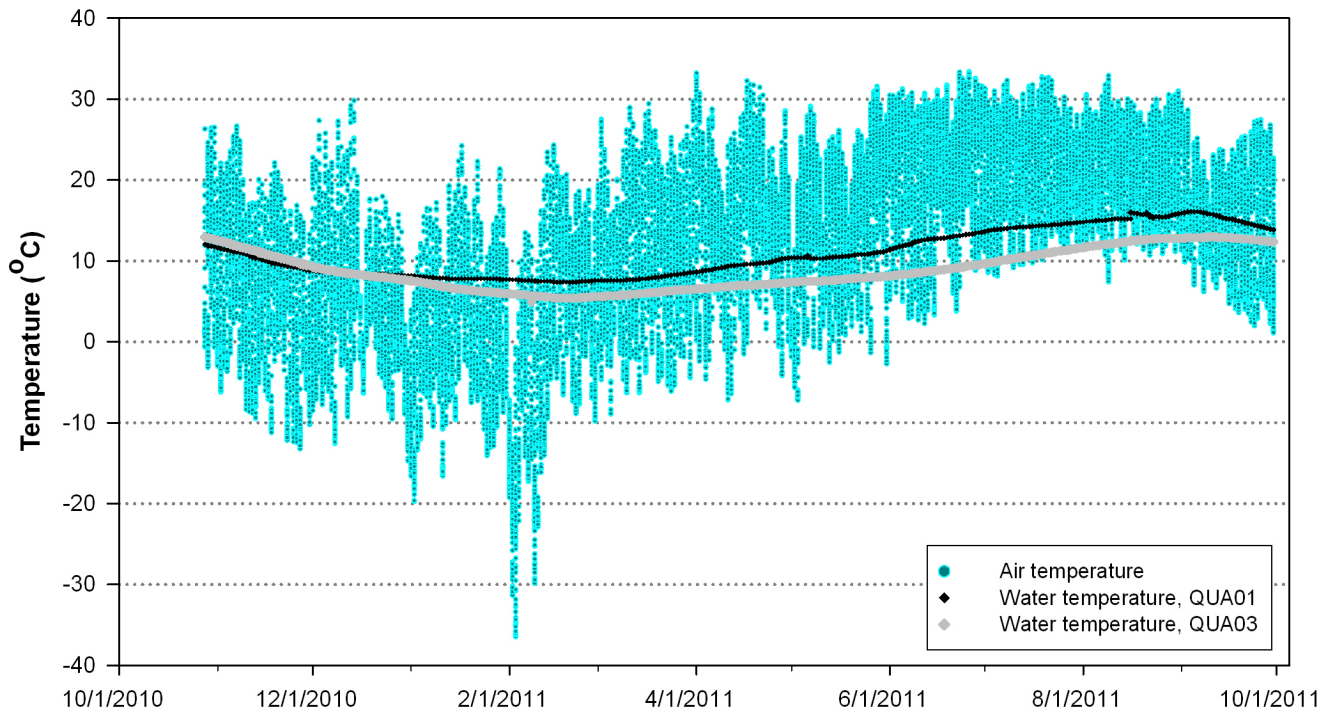


Figure 3. Air temperature recorded by the Barologger near QUA02, and water temperature recorded at QUA01 and QUA03, for the period of October 28, 2010 through September 30, 2011, in Salinas Pueblo Missions N.M.

Minimum water temperature at QUA01 during the months of October through March was 7.4°C and only slightly higher during the months of April through September, at 8.6°C. Variations in maximum water temperature at QUA01 were greater; the maximum temperature was 12.1°C during the months of October through March, and 16.1°C during April through September.

Water temperatures at QUA03 in the downstream wetland were generally—though not always—lower than those at QUA01. The variation between highest and lowest water temperatures at QUA03 for the monitoring period was 8.7°C. Minimum water temperature during the months of October through March was 4.9°C, and 6.5°C during the months of April through September. Maximum water temperature was the same for the October–March and April–September periods, at 13°C. While the lowest water levels at both QUA01 and QUA03 occurred in late July and mid-August, 2011, the highest water temperatures at both locations were recorded in early September 2011.

3.2 Topographic and hydrologic instrumentation mapping

We created a plan view from the survey data of the Cañon Sapato thalweg and transect, hydrologic monitoring installations, and survey controls in Terramodel (v. 10.4, 2005) (fig. 4). The internal horizontal and vertical survey precision was ± 0.01 m.

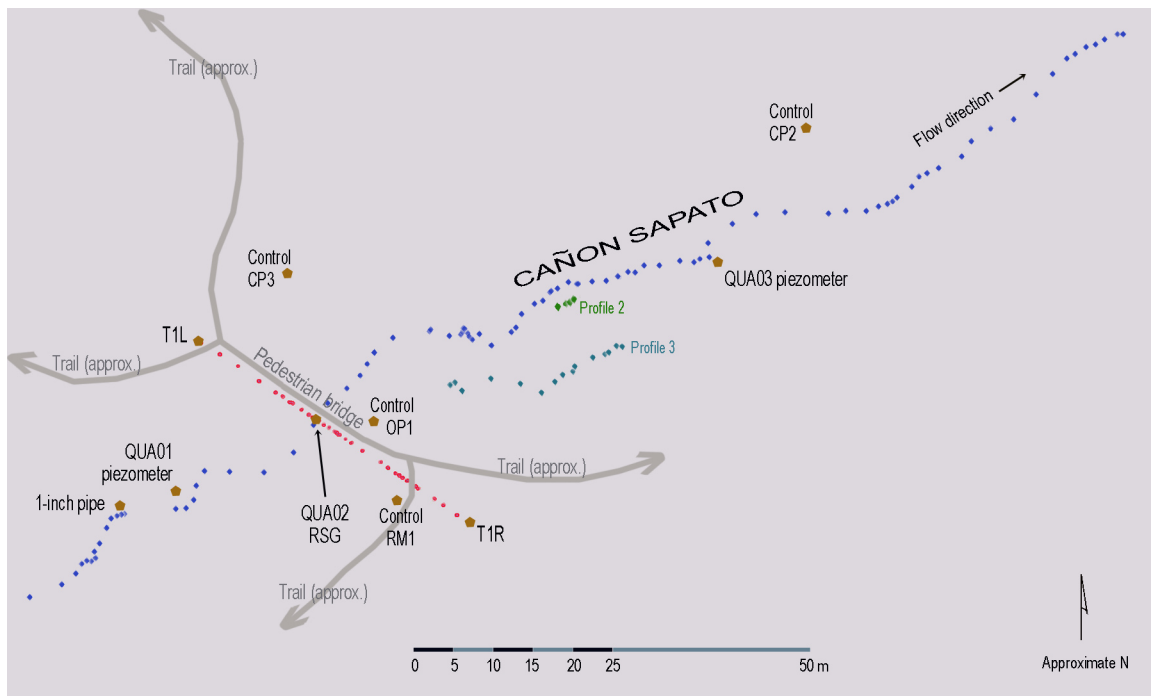


Figure 4. Plan view of Cañon Sapato in Salinas Pueblo Missions N.M., created from the SCPN survey in October 2010. The small red dots are points surveyed along the cross-channel transect on the upstream side of the pedestrian bridge; large blue diamonds are points surveyed in the main channel thalweg. Points mapped through 2 secondary channels that have developed around the bedrock ledges downstream of the pedestrian bridge are also diamonds, labeled as Profiles 2 and 3. Brown polygons indicate the survey control points (CP2–CP3, RM1, OP1) and the installed equipment; T1L and T1R are controls at the left and right ends, respectively, of the surveyed transect. The surveyed profile reach is approximately 170 m long.

Control OP1 was the initial survey instrument setup location; controls CP2 and CP3 were established as additional instrument setup locations. Two of the 5 rebar controls (T1L, T1R) mark the left and right ends of a cross-channel transect established perpendicular to the channel and in line with the recording stage gage at the pedestrian bridge. These control points were marked by 5/8-inch rebar driven to near the ground surface, and topped with labeled aluminum caps. A sixth control (RM1) was identified as the high point on a prominent boulder just upstream of the pedestrian bridge on channel right. All survey point coordinates were relative to the arbitrary survey origin and vertical datum established at OP1. The survey datum was set to 1000.00 m.

The surveyed thalweg profile and transect (T1) were plotted from the survey data in standard elevation and stationing format (figs. 5 and 6). The overall slope through the 170 m surveyed reach shown on Figure 5 is 5.7%. At QUA01, the channel drops nearly 3 m from the top of the headcut above the spring pool to the bottom of the spring pool. Dense vegetation grows in the bottom of the channel between the spring pool and the pedestrian bridge, and the channel thalweg rises more than 0.5 m between the downstream end of the pool and the RSG installed beneath the upstream side of the pedestrian bridge at QUA02. The steepest drop in the surveyed reach occurs through a series of bedrock ledges beginning about 12 m downstream of the pedestrian bridge, near the upstream end of Profile 3. The Profile 3 channel begins as a grassy swale before reaching the right end of the series of bedrock ledges that drop to the wetland area below. The drop from the head of Profile 3 to the wetland area at QUA03 where the downstream piezometer was installed is approximately 5 m, accounting for about half of the total 10 m drop through the surveyed reach. Water depth in the spring pool at QUA01 on the survey date was about 0.8 m, and surface water in the 3 pools mapped downstream of the bedrock ledge ranged in depth from approximately 0.6 to 0.9 m.

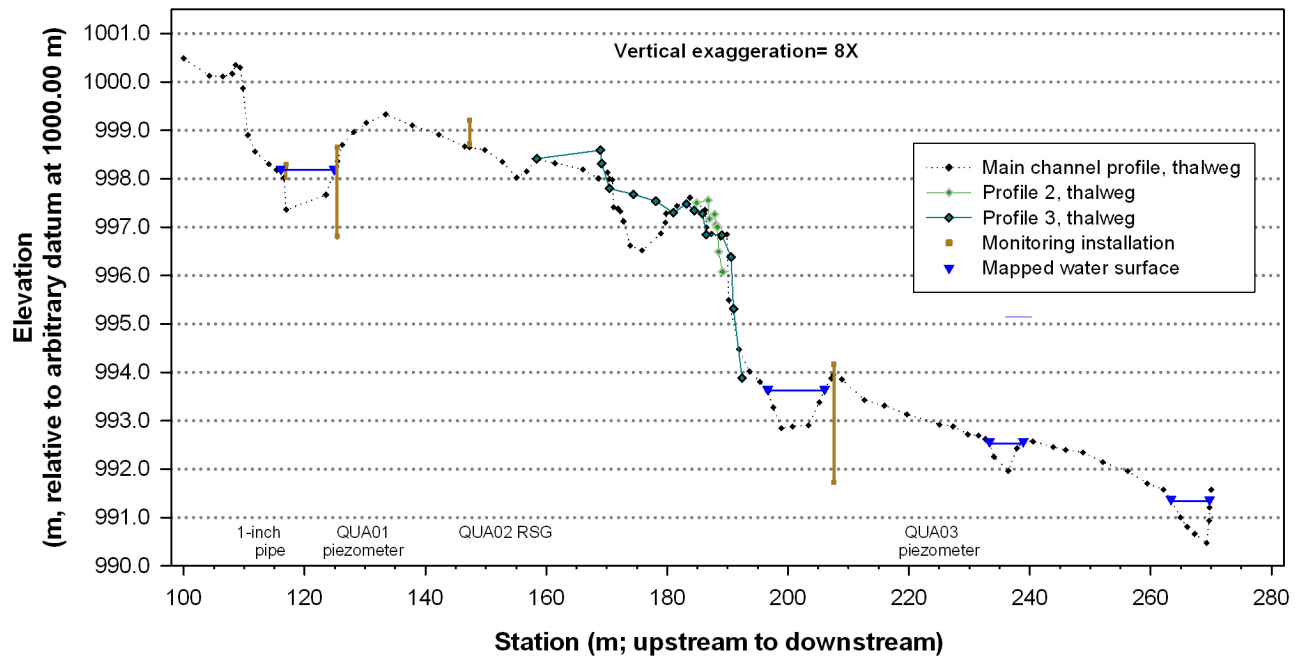


Figure 5. Profile view of the Cañon Sapato thalweg through the surveyed reach, including surface water present on the survey date, and the locations and relative elevations of the hydrologic monitoring equipment installed in Salinas Pueblo Missions N.M. in October 2010. X axis stationing is distance from the profile origin (arbitrarily set to 100.00 m); Y axis scaling is exaggerated 8 times to show detail. Each monitoring installation location is labeled just above the bottom axis. The elevations of both the top and bottom of each piezometer and the RSG are graphed for reference. Profile 2 is in a secondary channel that diverges from the main channel at the lowest bedrock ledge. The Profile 3 channel begins farther upstream and to the right of the Profile 2 channel and then drops over the final bedrock ledge upstream of QUA03.

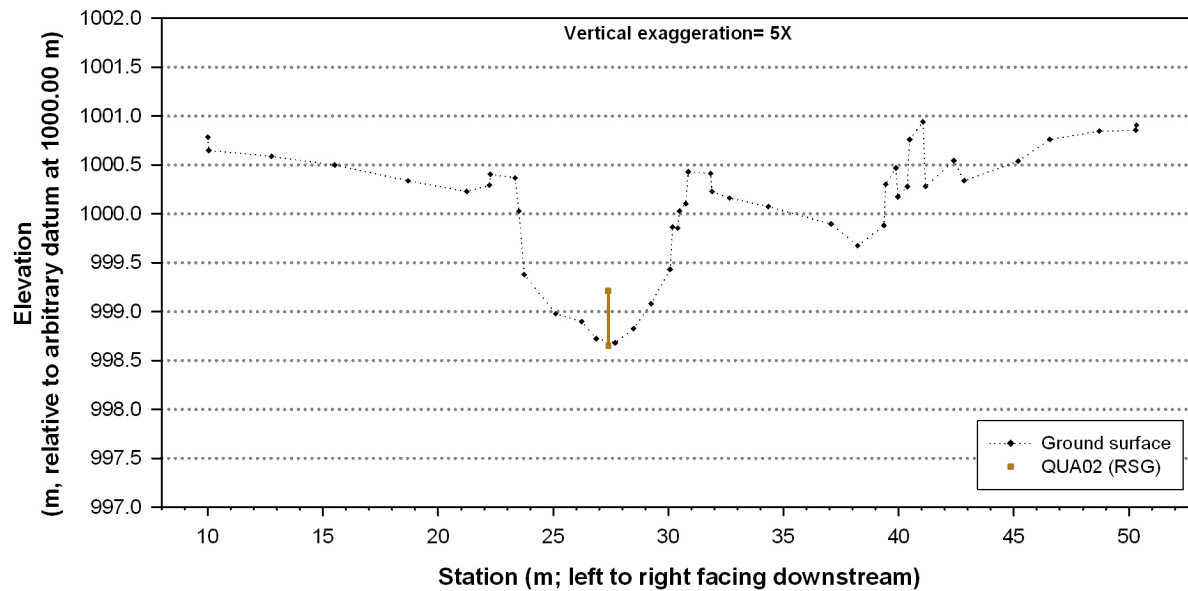


Figure 6. Cross-section view of transect T1 in Salinas Pueblo Missions N.M., established and surveyed in October 2010. X axis stationing is distance from the left endpoint (arbitrarily set to 10.00 m); Y axis scaling is exaggerated 5 times to show detail. The transect is perpendicular to Cañon Sapato just upstream of the pedestrian bridge. The RSG at QUA02 was placed in the lowest point in the channel in order to capture data during small surface flows. The pedestrian bridge (not surveyed) is located approximately between stations 22 and 31. The channel at the transect was dry on the day of the survey.

The surveyed transect, T1, is approximately 40 m long, extending from the left rebar control set about 1.5 m to the left of the interpretive trail sidewalk, to the right end control, placed about 20 m shoreward of the right end of the bridge. No surface flow was present in the channel at T1 on the day of the installation and survey. The main channel at T1 is about 7 m wide and 1.5 m deep, much shallower than downstream of the bedrock ledges, where the channel is incised 3.5 to 5 m between nearly vertical banks (figs. 7a and 7b).

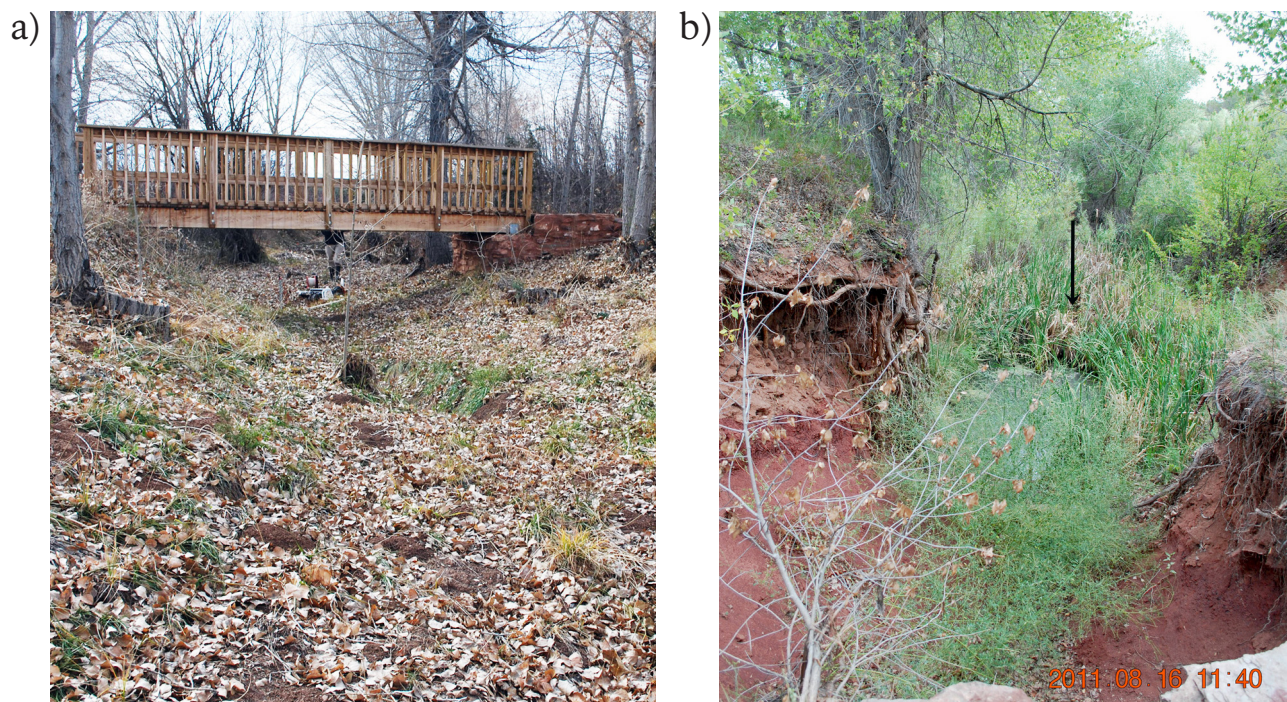


Figure 7. Figure 7a (left) shows the view facing upstream through the surveyed reach of Cañon Sapato in Salinas Pueblo Missions N.M., from the upper end of the bedrock ledge in the main channel approximately 20 m downstream of the pedestrian bridge, November 2011. The streambanks upstream of the bedrock ledge are about 1.5 m high. Figure 7b (right) is the view facing downstream from the lowest end of the bedrock ledge (bottom edge of image), August 2011. The vertical bank on the left is approximately 4 m high. The piezometer at QUA03 (beneath black arrow in photo center) was installed in the wetland area in the center of the image.

4 Summary

This report presents the results of data collected during the first year of SCPN hydrologic monitoring at the Quarai Unit of Salinas Pueblo Missions National Monument. The instrumentation installed by SCPN monitors water levels in the spring pool (QUA01) in Cañon Sapato, and in a wetland area a short distance downstream (QUA03), as well as any surface flows that occur in the stream channel near the interpretive trail pedestrian bridge (QUA02). Water and air temperatures were also recorded. The data are summarized here and are available on request. Evaluations of hydrologic trends at any site in this region depend on long-term monitoring because of the region's high climatic variability. SCPN water resources staff will continue quarterly site visits to download the instrumentation placed at the site and to collect manual measurements. Repeat surveys of the stream channel may be added in the future as an additional monitoring component in order to document geomorphic changes after major flood events.

4.1 Cañon Sapato water levels and temperatures

Throughout the period for which data were collected, water levels at QUA01 varied by just under 1 m, except during 2 flood events in August 2011. During the first of the 2 events, the spring pool water level at QUA01 rose by more than 2 m, and was high enough during both events to overtop a rise in the channel bottom between the pool and the RSG at QUA02, allowing surface flow to continue past the RSG into the wetland area at QUA03 at the base of the bedrock ledges just downstream of the pedestrian bridge. Water level changes at QUA03 generally mimicked those at QUA01, but rose and fell less than at QUA01. Sustained water levels at both QUA01 and QUA03 were highest from January through April 2011.

Water temperatures recorded by both transducers varied much less than air temperatures recorded by the Barologger. Except during the 2 floods in August 2011, variation in recorded water temperatures during any 24 h period was never greater than 0.1°C, compared to daily air temperature fluctuations that ranged from 20°C to 30°C during the monitoring period. Median, minimum and maximum temperatures at QUA01 were typically higher than in the downstream wetland at QUA03. However, water temperatures recorded at QUA03 from late October 2010 through November 2010 were about 1°C higher than at QUA01, gradually decreasing below QUA01 temperatures by mid-December. Water temperature at QUA01 rose by about 0.3°C during each flood in August 2011, but no change in downstream wetland water temperature at QUA03 was recorded during either event. High water temperatures at both QUA01 and QUA03 did not correspond with the lowest water levels; the lowest water levels at both sites occurred in late July and mid-August, 2011, while the highest water temperatures at both locations were recorded in early September 2011.

4.2 Cañon Sapato channel survey

The initial total station survey of the Cañon Sapato thalweg from upstream of the spring pool at QUA01 through the downstream wetland area at QUA03 established a baseline condition against which channel elevation, slope, and form can be compared with data collected during future surveys. Additional incision or aggradation of the channel could affect water levels at QUA01 and QUA03, and could also affect the extent of any surface flows through the park.

5 Literature cited

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Appendix A: Monitoring site locations, metrics, collection methods, and time frames for hydrologic data collected at Cañon Sapato in the Quarai Unit of Salinas Pueblo Missions National Monument, October 2010–September 2011

Site code	Site common name	Coordinates UTM NAD 83 (m)	Elevation (m)	Data type(s)	Data period	Collection method, interval
SAPUQUA01	Cañon Sapato Spring	381222 E, 3828852 N	2015 (est.)	water levels	10/28/2010– 9/30/2011	recording, 15-minute
				water levels	10/28/2010– 9/30/2011	manual, quarterly
				topographic	10/28/2010	total station, once
SAPUQUA02	RSG at pedestrian bridge	381237 E, 3828868 N	2016 (est.)	water levels, baro- metric pressure	10/28/2010– 9/30/2011	recording, 15-minute
				water levels		manual, quarterly
SAPUQUA03	Downstream wet- land piezometer	381288 E, 38288899 N	2010 (est.)	water levels	10/28/2010– 9/30/2011	recording, 15-minute
				water levels		manual, quarterly
USC00295968	GHCN climate station near Quarai	379917.4 E, 3833938.6 N	2033.6	precipitation	10/1/2010– 9/30/2011	unknown, daily