

Spring, Seep and Hanging Garden Monitoring Protocol Implementation Plan for Park Units in the Southern Colorado Plateau Network

Standard Operating Procedure (SOP) # 5

Hydrologic Monitoring

Version SCPN_Springs_SOP5_20180930

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP is adopted from the Northern Colorado Plateau Network's SOP #5 Hydrologic Monitoring, Version 1.00 (June 2016) in Weissinger, R., M. Moran, S. Monroe, and H. Thomas. 2017. Springs and seeps monitoring protocol for park units in the Northern Colorado Plateau Network, Version 1.00. Natural Resource Report NPS/NCPN/NRR—2017/1439. National Park Service, Fort Collins, Colorado.

Water quantity and core parameters of water quality (pH, water temperature, and specific conductance) are recorded at every spring with sufficient surface water during four site visits from March – November during the sampling year. The recommended water quantity measurement equipment is located in each site's access document.

Weather

Recent precipitation

Indicate whether there has been precipitation during the previous week. Use direct observation if possible. Use weather station data if available to determine the date and amount.

Rain

Using the list below, indicate the level of intensity most representative of the site visit.

No rain
Mist or fog
Light drizzle
Light rain
Heavy rain
Snow

Air temperature

Record the air temperature (°C) in the shade at 1m above ground level.

Cloud cover

Record cloud cover to the nearest 10%.

Flow

Indicate whether flow is measurable or not. Unmeasurable flow does not mean “no flow” but rather that conditions may not permit either direct or indirect estimates (i.e. site in flood, channel conditions changed, etc.).

Flow Severity:

- Dry – No surface water present.
- No flow – Pooled surface water present, but no flow.
- Normal – Flowing spring water present.
- Flood – Flowing surface water present due to precipitation run-off. Flow measurement is not representative of spring flow.

Consult the site’s access document for the specific equipment needed for each site. Attempt to collect a flow measurement downstream of all significant spring orifices. The same flow measurement site should be used at each visit unless geomorphic change at the site necessitates that a different site be selected. If multiple channels exist at a site, select the dominant channel (channel with the most flow) for the discharge measurement. If possible to measure flow in more than one channel, do this and sum the measurements. Clearly document the discharge measurement location(s) on the data sheet and on the site sketch. Estimate the percent of total flow not captured by the discharge measurement(s) and record this percent loss on the datasheet.

Most springs sampled in this monitoring program are sampled using the volumetric method. For this method, if necessary, capture the flow by constructing a small dam using local materials or plumber’s putty, inserting a weir plate, or channelizing the flow through a flume. For the most minimal flows, it may be helpful to insert a length of plastic tubing in the dam, making sure to leave enough height below the downstream end of the tube for a plastic container. Wait several minutes to allow the pool behind the dam to stabilize. Record the pool height before and after sampling to determine that the pool is stable.

Place a plastic container (cup or Tupperware container of pre-determined volume or plastic bag) below the flow stream to capture all of the water. If there is not sufficient drop to fit a reasonably-sized container into the flow stream, the flow may be captured with a large, intact plastic bag. Volume can be determined by pouring captured water from the bag into volumetric containers.

Use a stopwatch to measure the total time required to fill the container. Record the volume of water (1 mL) and fill time (0.01 sec). The desired fill time is between 10 and 60 seconds; adjust the container size accordingly, if possible. Repeat this measurement a minimum of five times. The desired precision is that all measurements are within 1% of each other (e.g., if the fill time is 60 seconds, each sample should be within 0.6 seconds of each other). Up to 5% precision is acceptable at sites that cannot be reliably measured in the desired 10-60 second interval. Calculate the average fill time while on-site or when back in the office.

Stage

At limnocene springs that under normal conditions have pooled water but no flow, measure the distance from a fixed reference marker such as an embedded object in a cliff wall or a permanent staff gage to the surface of the water. See each site’s access document for site-specific instructions. Record stage to the nearest tenth of a centimeter.

Water Quality

Water temperature (°C), pH, and specific conductance ($\mu\text{S}/\text{cm}$) are determined in the field using a multi-parameter water quality sonde or more accurate field water quality meter (Table 1). Equipment manufacturer, model, and serial number should be documented on each datasheet. Complete instructions for this equipment can be obtained from the manufacturers’ website and are available in electronic format on the SCPN server. The crew leader or person responsible for water quality measurements should be thoroughly familiar with all equipment and software prior to going into the field. Prior to each sampling trip, the crew leader must ensure that all equipment needed for water quality measurements are in working order.

Table 1. Acceptable post-calibration ranges for core parameter measurements with Hydrolab MS-5 (Gibs et al. 2007).

Core Parameter	Post-Calibration Range
Temperature	± 0.2 °C
pH	± 0.2 S.U. ¹
Specific Conductance	± 5 μ S/cm if <100 μ S/cm or $\pm 3\%$ if ≥ 100 μ S/cm
Dissolved oxygen	± 0.3 mg/L, $\pm 3\%$ saturation

¹If drifting persists or if measuring low conductance waters (≤ 75 μ S/cm), allow ± 0.2 to ± 0.3 pH units

Measuring water temperature, pH, specific conductance and dissolved oxygen

SCPN uses multiparameter sondes or small, combination water quality meters to collect NPS core water quality parameter data. Using multiparameter sondes is an efficient and effective way to collect NPS core water quality parameter data at most sites. A sonde can collect data for multiple parameters at the same time, can be used to collect discrete water quality field measurements, or can be deployed for long-term collection of continuous data. SCPN will use a Hydrolab Mini Sonde 5 and a PDA for determining NPS core water quality parameters in the field, including temperature, pH, specific conductance (SpC), and dissolved oxygen (LDO). At remote or very small sites SCPN will use a Hanna Combo HI98129 to measure pH and SpC. Instructions for using these instruments are provided below and are based on documentation provided by equipment manufacturers.

Guidelines for using water quality sondes for routine field measurements are provided in Gibs et al (2007). Guidelines for continuous water quality monitoring are provided in Wagner et al. (2006).

Calibrating water quality meters in the field

Fill out the following information at the top of the Water Quality Datasheet:

Site code
Site name
Date (yyyymmdd)
Observer
Calibration date and time
Water quality instrument make & model
Instrument set to local time (yes or no)

Sensor calibrations should be done in an area with stable air temperatures, out of direct wind and sun. Perform a 2-point pH calibration for all meters. For the Hydrolab MS5 perform a 2-point SpC calibration as well as a 1-point LDO calibration in stream water saturated with air. For the Hanna Combo meter perform a 1-point SpC calibration. During all calibrations, temperature sensors should be fully submerged in the standard, as the sensors require temperature compensation. When calibrating, first record the temperature of the standard in the “Temperature” column and the pre-calibration value in the “Readings” column of the Field Calibration section of the Water Quality Datasheet. The standard temperatures should be similar (within 5°C) to the stream temperature. Field calibrations are performed identically to lab calibrations, with the exception of LDO.

Water temperature

Upon reaching the water quality monitoring site, equilibrate both the water quality meter (make sure the flow-through cap is attached to the Hydrolab) and the calibration standards to ambient water temperature by immersing in the

stream/spring. Compare the standard temperatures to the water temperature to confirm that they are equilibrated. If a Hydrolab is not being used, then measure temperature with a NIST-certified thermometer. Record the stream water temperature at the time of calibration in °C on the Water Quality Datasheet.

Specific conductance

Specific conductance should be calibrated first. This is because pH buffers have much higher conductivities and can potentially contaminate the SpC buffers through solution carry over if pH is calibrated first. When using the Hydrolab select two conductivity standards that bracket the anticipated water conductivity. For most SCPN streams and springs, the 100 and 1413 $\mu\text{S}/\text{cm}$ standards will be used, however some sites (such as Mancos River at low flow) may require a higher standard. Indicate this higher standard on the Water Quality Datasheet. When using the Hanna, use the 1413 $\mu\text{S}/\text{cm}$ standard. Prior to each calibration, write the temperature of the calibration standard and the pre-calibration value on the Water Quality Datasheet. Be aware that the value of the SpC calibration standard can change by more than 3% if the temperature is less than 6°C. If the anticipated water temperature is less than this, calibrate the SpC indoors.

pH

Values for pH buffers should bracket the anticipated site conditions. For most SCPN surface waters, pH 7 and pH 10 buffers will be used. Be aware that pH buffer values increase as the temperature decreases—the buffer values are 7.00 and 10.00 only at 25°C. Refer to the table provided by the manufacturer (Table 2) for the correct pH value for the temperature, and use this value when calibrating. Write the buffer temperature and the pre-calibration value on the Water Quality Datasheet.

Table 2. Aqua Solutions pH buffer standard values from 0 – 25°C.

Temperature, °C	pH 7	pH 10
0	7.13	10.34
5	7.10	10.26
10	7.07	10.19
15	7.05	10.12
20	7.02	10.06
25	7.00	10.00

Dissolved oxygen

The Hach Hydrolab uses a luminescent dissolved oxygen (LDO) sensor to determine DO concentrations in water. In the field, the Hach LDO sensor should be calibrated using air-saturated stream or spring water, but avoid using water that is likely to be supersaturated with oxygen (such as a stream with lots of algae). In this case, another water source should be selected. Because barometric pressure (BP) changes with elevation, if there is a more than 500 foot change in elevation between site visits, the LDO sensor must be re-calibrated. Changes in water temperature during LDO sensor calibration must be minimized, or the calibration will be unsuccessful. If necessary, use a damp towel (if air temperature is greater than the water temperature) or a dry towel (if air temperature is colder than water temperature) to insulate the calibration cup.

Use a handheld barometer to obtain the local atmospheric pressure, and record this on the Water Quality Datasheet. Record the temperature of the air-saturated water at time of calibration. The differences between these temperatures and the temperature of the stream or spring water (measured after equilibration and immediately prior to calibration) should

be similar. In case of a barometer malfunction in the field, it may be necessary to estimate the local BP. Use this equation and note that BP was estimated in the calibration notes:

BP'= barometric pressure at altitude and
Aft= altitude in feet

After each calibration is complete, check the standards again to ensure that the calibration is accurate. For SpC and pH, choose the standard that is closest to the anticipated sample value, re-rinse the sensors with the standard, and measure. Write the post-calibration value and temperature on the Water Quality Datasheet. The post-calibration measurements must fall within the values in Table 1. If not, the calibration must be done again. If the sonde still doesn't meet the calibration requirements in Table 1, it may need to be sent to the manufacturer for repair.

Measuring water quality core parameters using the Hydrolab MS5

After the water quality sonde has been calibrated, take in-situ measurements of the water quality core parameters. The sonde should be placed in a section of the stream where depth is sufficient to cover the sensors completely, the water is visibly flowing, and flow is mixed sufficiently to allow for representative measurements. Be careful to avoid direct contact of probes with bottom substrates; in swift, sandy streams the sensors could become buried.

Prior to recording measurements, sonde measurements must meet the calibration requirements (Table 1). Allow the sonde to equilibrate to stream conditions (this should take several minutes). Determine the ranges of core parameters and compare them against the stabilization criteria. If the range in measurements over several minutes is not within these criteria, this may indicate that the area of the stream being measured is not well-mixed. Try moving to an alternative point in the stream (near the thalweg) that appears well-mixed.

Short-Term (discrete measurements) vs. Long-Term (data logging) Sonde deployments

There are two alternate methods that can be used to save core parameter data with the Hydrolab MS5. If the Hydrolab will be deployed for a short period of time (less than a day), use only Method A. If it will be deployed for a day or more, or if the PDA will be needed for other purposes, use both Method A and Method B. When both methods are used, Method A should be used prior to Method B, to ensure that a set of discrete measurements is recorded in the event of data loss during Method B. Method A also ensures that the sensors have stabilized prior to the recording of measurements.

For Method A, use the Monitoring function to observe and record data. With this method the PDA must remain attached to the sonde. Core parameter data is stored in the PDA (only after the file is manually saved).

For Method B (long-term deployment), create and activate a log file. With this method the PDA must be detached from the sonde; otherwise, sonde will not start recording. Core parameter data is stored in the sonde and can later be downloaded to the PDA.

When saving data files on the PDA, use the following naming convention: YYYYMMDD_SITECODE. For example, "20100913_BANDRIT01". If there is more than one data file with the same date and site code, order the files chronologically by adding an extension, i.e. "20100913_BANDRIT01_1", "20100913_BANDRIT01_2", etc. The location where the files will be saved can be user-specified and later viewed on the PDA by navigating to the specified location.

Data files stored on the PDA should be downloaded to the SCPN server as soon as possible after each field trip.

Method A: Data monitoring

Follow these steps to ensure that valid data is collected and record the values in the “Water Quality Field Measurements” section of the datasheet:

1. Place the sonde in the water with the flow-through cap installed and allow it to equilibrate to the stream water temperature (this usually takes several minutes). Meanwhile, make sure the clock in the display and the sonde are synchronized to local date/time.
2. Start a monitoring file to collect data at 5 second intervals. View the graph to make sure the measurement curves are stable (see the user manual for instructions)
3. If the measurement curves are not already stable, it may be necessary to wait until they stabilize and re-start the monitoring file so that all saved data are valid.
4. As soon as 7 samples have been taken, click the “Statistics” button, and verify that the ranges (maxima minus minima) of each parameter meet the stabilization criteria in Table 1.
5. If the stabilization criteria are met, keep the Hydrolab in monitoring mode for the duration of the visit, occasionally writing down core parameter values on the datasheet in case the monitoring file is lost before being downloaded to the SCPN server.
6. Before exiting Monitoring mode, save the data file.

Method B: Data Logging

Follow these steps to ensure that valid data is collected during long-term deployment of a day or longer. With a log file, the data are stored in the Hydrolab and the PDA must be detached in order for data logging to occur. Care should be taken to ensure that the sonde is deployed in a stream section that is hidden from passersby, and locked in place where theft is a possibility, so it will not be disturbed or stolen. It should be installed very securely to a permanent structure, so that there is no danger of it being carried downstream by flash floods.

1. Create a log file and name it according to this convention: 20100913_BANDRIT01_log.
2. Select a start and end time. Set the start time to approximately 10 minutes later than the current time displayed in the upper-right corner of the PDA (to allow ample time to setup and activate the log file). Be very careful, the software defaults to a 1-hour log file. Always set an end time if a >1-hour log file is desired. Record the start and end time and date in the Water Quality Datasheet.
3. Set the interval to one that is appropriate for the length of time that the data is to be recorded. The logging interval, sensor warm-up time, and water temperature all affect the battery life. A typical log interval is 15 minutes, synchronized to the nearest quarter hour, such as 12:00, 12:15, 12:30, etc. For the longest possible battery life, set the Hydrolab to a 1-hour recording interval and a 30-second sensor warm-up time. Otherwise, the sensor warm-up time default (02:00) is okay. SCPN does not use Hydrolab MS5s with circulators installed, so this can be left as the default as well.
4. Uncheck the Audio box.
5. Select the following parameters to be logged: date-time (seconds), internal-battery (% left), temperature (°C), SpC (µS/cm), pH (Units), LDO% (Sat), LDO (mg/l), and LDO_BP (mmHg).
6. Be sure to enable the log file by clicking the button that says “enable”. If the log file is not enabled, data will not be collected.
7. Disconnect the Hydrolab from the PDA. If the PDA is not disconnected, data will not be collected.
8. When retrieving the sonde after long-term deployment, disable the log file and download it to the PDA, using the naming convention listed above.
9. Check the sonde against two SpC standards, pH 7 and 10 standards, and air-saturated water for DO to determine if there was calibration drift. Write these values in a field notebook and enter these in the database.
10. Consult SOP #4 for instructions for maintenance of the sonde after deployment.

All water quality instruments should be field calibrated at least once per day or if environmental conditions change extremely.

- Field water-quality measurements from flowing water spring sites should be taken as close to the orifice as possible. Ideally the water quality measurement location will have uniform flow, stable bottom conditions, and water will be well mixed along the flow path. If the water is too shallow for a probe, a clean beaker may be rinsed three times with the spring water, then placed in the flow stream. Allow the beaker to fill and overflow, then place the water quality probe into the flowing water captured in the beaker. Water quality measurements should be taken upstream from the flow measurement site or prior to the flow measurement.

- Field water-quality measurements from still water or pooled sites are taken using a vertical profile and spatially distributed to accommodate each site. The depth of the still water or pool should be measured and water-quality parameters should be measured at a minimum of 3 depths at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ of the depth.

After the optimum sample location at a spring has been determined, the crewmember responsible for water quality sampling should place the instrument in the water, being careful to avoid direct contact of probes with bottom substrates. The water quality sample location should be described in detail on the datasheet and should be identified on the site sketch map.

- a. Place the water quality instrument in water and allow it to equilibrate for several minutes (5 at a minimum).
- b. After the instrument has equilibrated record at least three measurements.
- c. Record measurement time and values, including temperature, on the hydrology datasheet.

The median reading for each parameter is entered into the water quality database. If no water quality measurements can be taken, describe why in the comments field (e.g., no surface water present, instrument malfunction, etc.).

Major disturbance

Indicate whether a major disturbance has occurred (fire, severe flooding, catastrophic rock fall, etc.), necessitating a new sketch map and vegetation characterization.

Literature Cited

Gibs, J., F. D. Wilde, and H. A. Heckathorn. 2007. Use of multiparameter instruments for routine field measurements. In U.S. Geological Survey Techniques of Water Resources Investigations, book 9, chap. A6, Section 6.8, August, available online only from <https://water.usgs.gov/owq/FieldManual/Chapter6/6.8.pdf>.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed at <https://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf>.

Park Code: _____ Site Name: _____ Date: _____

Observer(s): _____ Air Temp: _____ °C

Current conditions: No rain Mist or fog Light drizzle Light rain Heavy rain Snow Cloud cover: _____ %

Precipitation dates & est. amounts in previous week: _____

Water Quantity Field Measurementsmeasurable
dischar. (y/n)Visual est.
of mixing

disch.method

serial #

flow value

units
(C,G,M,blank)meas type
(M,E,blank)avg veloc
(ft/s, blank)vtype
(M,E,blank)estimated
discharge (cfs)estimate
typeseverity
(dry, no
flow, normal
or flood)**Volumetric**Documenting stable pool

Time

Depth

At tape placement:

Before measurement:

After measurement:

estimated
% loss
adjusted
flow
(cfs)

measurement

vol.(mL)

time (s)

(mL/s)

(gpm)

(cfs)

1

2

3

4

5

6

stable flow?

average
sum**Pool Surface Elevation**

measurement

stage (m)

Relative pool elevation (1.5m – stage value)

1

Flume

Look up

estimated

adjusted
flow

measurement

stage (ft)

(gpm)

(cfs)

% loss

(cfs)

1

2

3

4

5

stable flow?

max

Discharge comments and description of where measurement was taken:

Water Quality Instrument Calibration			Instrument Make and Model: _____		
Calibration Date: _____			Calibration Time: _____		Calibration Location: _____
Parameter	Standard Value	Initial Reading	Temperature	Calibrated Reading	Temperature
pH	7.01			---	---
pH	10.01	---	---		
Conductivity	1413				
Comments on calibration:					

Water Quality Field Measurements							
Measurements Taken? (Y/N): _____ Water: ☐ flowing ☐ still/pooled							
Time	Depth (cm)	Location	pH	Sp. Conductivity (μS/cm)	Water Temperature (°C)	Baro. Pressure (mmHg)	Dissolved Oxygen (mg/L)
Median:							
Comments and description of where water quality measurements were taken:							

Major Disturbance	New sketch map and vegetation characterization needed?	Yes	No
If so, briefly describe disturbance:			

Photos taken?
Photo notes:

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Water Quality Datasheet

Park code: _____ Site name: _____ Date: (yyyymmdd): _____

Site code: _____ Observer(s): _____

Start time: _____ End time: _____ MST or MDT (circle one)

Site access notes, general observations, and other work done:

Precipitation during sampling (circle one): None Rain Freezing rain Hail Sleet Snow

Precipitation 24 hours prior to sampling (circle one): Yes No

Stream channel and flow conditions at the water quality sampling site												
Stream Channel	Channel (check one)	☐ Pool ☐ Riffle ☐ Open channel ☐ Braided ☐ Backwater										
	Substrate	☐ Clay grains not visible, smooth texture	☐ Silt grains not visible, gritty texture	☐ Sand coarse visible grits, to lady- bug size	☐ Gravel ladybug to tennis ball size	☐ Cobble tennis ball to basketball size	☐ Boulder soccerball to car size	☐ Bedrock larger than a car	☐ Vegetation	☐ Wood	☐ Other	
Flow (check one in each category)	Stream color	Clear	Milky	Foamy	Tea	Muddy	Green	Scum/odor	Other: _____			
	Flow embank	Excellent	Good	Fair	Poor	% ice cover: _____		Average ice thickness (cm): _____				
	Flow severity	Dry	No flow	Low	Normal	Above normal	Flood	Comments:				
	Hydro-graph limb	Base	Rising	Peak	Falling							
Flood evidence (Check all that apply)	None											
	Fresh debris line in channel / above active channel (circle one)											
	Overwash/debris laid over											
	Recent flood event greater than baseflow, but less than bankfull											
	Recent deposition of sediments on floodplain											
	Riparian vegetation scoured away											
Other (note in comments)												

Aquatic and air temperature loggers			
Existing logger stop/DL time:	Serial number:	Existing logger stop/DL time:	Serial number:
New logger placement time:	Serial number:	New logger placement time:	Serial number:
Notes on sensor condition, battery %, and actions taken:		Notes on sensor condition, battery %, and actions taken:	
Data file name:		Data file name:	
NIST-traceable thermometer model and serial number:			
NIST thermometer temp at time of download (°C):		Temperature at time of download (°C):	

Figure 5-3a. Water Quality Datasheet, page 1