



Mojave Desert Network Inventory and Monitoring Selected Large Springs Protocol

Standard Operating Procedures

Natural Resource Report NPS/MOJN/NRR—2016/1108.1



ON THE COVER

Photograph of Saratoga Spring in DEVA, February 2015.
Photo courtesy of MOJN.

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Geoff Moret
National Park Service
Mojave Desert Network Inventory and Monitoring
601 Nevada Highway, Boulder City, NV 89005

Christopher C. Caudill
University of Idaho
Moscow, ID 83844-1136

Nita Tallent
National Park Service
Mojave Desert Network Inventory and Monitoring
601 Nevada Highway, Boulder City, NV 89005

Mark Lehman
National Park Service
Mojave Desert Network Inventory and Monitoring
601 Nevada Highway, Boulder City, NV 89005

Leigh Ann Harrod Starceovich
PO Box 1032
Corvallis, OR 97339

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Standard Operating Procedure 1: Safety

Version 1.0

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[Portions of this SOP were adapted from Thoma et al. (2009)]

1. The MOJN I&M Safety Plan

The MOJN I&M Field Safety Plan (Tallent et al. 2014, included in the Supplementary Materials) outlines the safety procedures that MOJN I&M crews will follow in the field. The topics covered by the safety plan include the following:

- Safety philosophy
- Training
- Hazards in Network Parks
- Driver Safety
- Situational Awareness and Risk Management
- Back Country Travel Plans
- Communications Equipment
- Status Checks to Dispatch
- Equipment Requirements and Expectations
- Accident/Injury Reporting
- Chemical Handling

The Field Safety Plan is a living document, and crews are required to follow the procedures described in the most recent version, available on the internal MOJN I&M servers at:

M:\ORG\Safety\MOJN_Safety_Plan\most_current_version

If there is a conflict between the information in this SOP and the information in the most current version of the Safety Plan, crews should follow the Safety Plan.

2. Job Hazard Analysis

Each National Park Service employee performing field inventory and monitoring activities in MOJN will, in conjunction with his/her supervisor (and, if appropriate, other knowledgeable persons), develop a Job Hazard Analysis (JHA) of the task to be performed. The procedure to be used is presented in NPS Reference Manual #50B, Occupational Safety and Health Program. Section 13 of that document, a step-by-step procedure for performing a JHA, is presented below. In addition, a list of suggested hazards (to be used in STEP 3) and a sample JHA are given in subsequent sections.

2.1. JHA Procedures from NPS Reference Manual

The following is an excerpt Section 13 of NPS Reference Manual 50B. Section numbers are maintained as per the original document.

13. JOB HAZARD ANALYSIS (JHA)

13.1 REFERENCE

A. Departmental Manual (DM), Part 485, Chapter 14.

13.2 REQUIREMENTS

A. Each operating unit will develop and implement a system by which major activities and individual jobs are analyzed. The Job Hazard Analysis (JHA) system will be used in the planning and completion of work assignments and projects as to:

- The sequence of work,
- The potential hazards associated with the sequence (action), and
- The methods, procedures, and safeguards to prevent, reduce and or control at-risk behaviors and reinforce safe behaviors.

B. When work is performed by others (e.g., contractors) the contracting officer (CO) will require that the contractor develops appropriate Job Hazard Analyses (JHAs) for the tasks to be performed. This information will be provided to the Contracting Officer (CO) or Contracting Officer's Representative (COR) as part of the accident prevention plan, and will be approved/accepted by the CO/COR prior to permitting the contractor to proceed with the work. The written JHA will be retained at the job site by the contractor, and made available, upon request, to persons evaluating/monitoring the activity.

13.3 PROCEDURES:

A Job Hazard Analysis (JHA) is a procedure used to review job methods and uncover hazards. Employees and supervisors should work together in the development of the JHA to assure that all characteristics of the job are examined, and the most efficient means of addressing the safety factors can be accomplished. A JHA should be used for job clarification, hazard awareness, training, and as an accident investigation tool. The following steps are involved in the development of a JHA:

STEP 1

Identify jobs posing the greatest accident risk, and prioritize selected jobs into three main areas:

- Jobs with highest rates of accidents and disabling injuries.
- Jobs where "close calls" (serious accident potential) have occurred.
- New jobs or jobs where changes have been made.

STEP 2

Targeting the top-priority jobs, break the selected job down into successive steps, actions, or activities and observe how these actions are performed. This is best done by jointly analyzing each step in order of occurrence. Each step should accomplish some major task. The task will consist of a set of behaviors/actions; list all the steps in a job in logical succession.

STEP 3

Identify the hazards, unsafe behaviors, and potential accidents for the job. Identify all hazards produced by the environment, equipment, materials, and those connected with the job procedure, as well as hazards that “might result.”

Close observation and knowledge of the particular job, as well as discussion of the job, will help you to develop a reliable list of hazards, unsafe behaviors, and potential accidents. The job observation should be repeated as often as necessary until all hazards have been identified.

STEP 4

Develop safe job procedures to eliminate the hazards and prevent the potential accidents. Produce a written description of how to do each step safely and avoid the identified hazards.

The principal solutions may include:

- Find a new way to do the job. Determine the work goal and analyze the various ways of reaching this goal to see which way is safest.
- Change the physical conditions that create the hazard. Ask the question: “What change in physical condition will eliminate the hazard or prevent the accident?” When a change is found, analyze it for other benefits that might also accrue, i.e., cost/time savings.
- Change the work procedure. Ask, “What should the employee do or not do to eliminate this hazard or prevent this potential accident?” Answers should precisely state what to do and how to do it; general precautions such as “be alert” or “use caution” are useless.
- Try to reduce the necessity of doing a job, or at least the frequency with which it must be performed. However, reducing the frequency of the job ONLY limits the exposure; it does not eliminate the hazard.

STEP 5

Established JHAs should be reevaluated periodically to ensure that they reflect the latest, safest, and most efficient way to perform the task. New equipment, tools, methods, and safety standards can require changes in JHAs. All employees concerned with the job should be informed of the changes and instructed in any new procedures. All new employees should be trained on applicable JHAs.

STEP 6

If an accident or injury occurs on a specific job, the JHA should be reviewed immediately to determine whether changes are needed in the job procedure. If the accident results from failure to follow JHA procedures, the facts should be discussed with all those who do the job.

STEP 7

Supervisors are responsible for maintaining JHA records within their work group.

2.2. Risks Inherent in Field Activities

Risks inherent in water quality monitoring in general, and specifically to monitoring the sites selected in MOJN parks, include the following:

Working alone

Field staff may work alone when making measurements and collecting samples in the field. As a result, particular attention must be given to safety. Field staff should not work alone in the backcountry, during major floods, or when they will enter deep water.

Long road trips

Travel between parks will require long road trips at all times of the year and under varied weather and road conditions. Fatigue, road conditions, and wildlife encounters are all concerns. MOJN I&M employees will follow the official NPS Travel Driving Policy, which states “Employees embarking on travel after working a partial shift or attending training, are limited to a maximum total work/driving period of 12 hours.”

Backcountry roads and trails

Many backcountry roads in MOJN parks are not maintained. Risks include damage to tires, becoming stuck in mud or soft sand, and damage to the vehicle in very rough sections. Almost all monitoring requires hiking on maintained trails, unmaintained trails, and across trail-less areas, with possible areas of mud, snow, and ice. Slips, trips, and falls are concerns when hiking. The major risk with all backcountry travel is that, in the event of a problem (broken ankle, inoperable vehicle, snow storm) the field crew will be stranded in the backcountry for some time before help arrives.

Wildlife

Mountain lions are present in many of the MOJN parks. Field crew should be familiar with park directives regarding encounters with lions, and should not hike alone in the dark or twilight.

There are numerous stinging insects and venomous snakes in the desert. While some bites are an annoyance (e.g., black fly), field crews should seek medical attention immediately for scorpion stings. A bite by a rattlesnake, particularly the Mojave green rattlesnake (*Crotalus scutulatus*), constitutes a serious medical emergency.

Africanized bees are present at many of the springs monitored in the protocol. Crew members allergic to bee stings should stay away from sites where bees are observed. Crew members who are “bumped” or stung by a bee should leave the site as quickly as possible, leaving equipment behind if necessary.

Activities in and on the water

While most of the springs monitored in this protocol do not have large enough pools or springbrooks to pose a significant safety hazard, Saratoga Spring in DEVA and Pakoon Spring in PARA have large spring pools. Care should be taken when working in the vicinity of these pools to avoid slipping or falling into the water. In addition, field staff should avoid flowing water in washes during rain events. For all but the most minor flows, field staff should wait until floods recede rather than attempting to drive or hike across flowing washes.

An additional hazard is that many warm-water springs in the region contain an amoeba (*Naegleria fowleri*) that can cause an extremely rare but serious disease (Centers for Disease Control and

Prevention, 2010). The risk of infection is extremely small, and can be eliminated by not allowing water to enter the nose.

Excerpts from USGS Field Manual section 9.4 (included in the Supplementary Materials) give excellent guidance for safety precautions working on, in, and near water.

Vegetation

The vegetation in riparian areas surrounding springs in the Mojave Desert is thick and thorny. Field crew should wear long pants, long-sleeved shirts, and eye protection (e.g., sunglasses) to prevent injuries. Crews should select alternate routes rather than attempting to travel through particularly thick patches of vegetation.

Varied weather conditions

The region spanned by MOJN is characterized by weather conditions that vary considerably through the seasons, day-to-day, and hour-by-hour. Snow, wind, and temperatures below freezing occur in the winter, and summer temperatures are often well above 100°F. Lightning is common during the summer monsoon storms. Hypothermia and heat-related injury are possible, and occasional discomfort is certain. Successful field work requires preparation for this wide range of conditions.

Use of hazardous materials

Some of the chemicals used to preserve samples are hazardous and require proper storage, handling, and personal protection, including eye and skin protection. These risks are discussed in section 4 of this SOP.

2.3. Sample JHA

The following JHA is general in nature- specific hazards should be reviewed prior to each day in the field. Parts of the JHA are adapted from JHAs provided by parks (included in the Supplementary Materials).

Table 1.1. Sample JHA for MOJN I&M fieldwork.

Sequence of Steps	Hazards	Solutions
Travel from MOJN I&M office to parks	poor road conditions fatigue collisions with wildlife	postpone travel if road conditions are poor or driver is over-tired do not drive in the dark along roads known to be frequented by deer, sheep, or other large animals.
Backcountry driving	poor road conditions stranded due to vehicle failure	postpone travel if road conditions are poor ensure vehicle is properly maintained and has at least two spare tires. follow park protocols for notifying dispatch of location
Hiking	slips, trips, and falls stranded due to injury or trail conditions	Understand and practice situational awareness & risk management at all times. Plan ahead & identify necessary PPE for your trip (i.e. Wear proper footwear; ensure protection from environmental conditions such as precipitation, wind, cold, heat; anticipate a full day and even a night out; consider you may have to care for someone else; anticipate whether you might need a helmet for the trip, etc.). Guard against overloading yourself with unnecessary equipment. Be alert to changes in terrain & weather. Know & monitor your personal fitness level & that of others in your group. Adjust plans accordingly. Carry water or a filter. Have an approved First Aid Kit on hand. If possible, take a coworker when traveling in areas of high risk or when conducting high risk activities.
Working near large spring pools	Drowning, hypothermia, of Naegleria infection due to slipping into the pool	Exercise caution when working near the pools. Wear appropriate footwear If you do fall into the water, try not to allow your head to become submerged
Working with chemicals in the field	Potential risk of toxicity, corrosive burns (although not with chemicals used in this protocol)	Do not ingest chemicals Wear proper PPE as specified in MSDS If chemicals are spilled on skin, rinse with water immediately
Miscellaneous Backcountry hazards	Mountain lions Extreme heat Cold/hypothermia Lightning Poisonous snakes and insects Hantavirus Water-borne illness	Do not hike alone at night or in twilight. If you encounter a mountain lion, wave your arms and shout in an attempt to intimidate it. Avoid working in extreme heat. Drink adequate water to avoid heat stroke. Take adequate clothing for all possible weather conditions. Avoid working in very cold weather. Do not get wet. Avoid working when thunderstorms are expected. If caught in a storm, avoid open areas and metal. A vehicle or sturdy building is the best shelter, if available. Know how to identify poisonous insects and snakes. Seek medical attention as soon as possible, and notify dispatch over radio if a crew member is bitten. Do not enter older structures that may pose a risk of hantavirus Do not drink untreated water

3. Handling Chemicals

3.1. Chemical Storage

Chemicals must be stored according to their Material Safety Data Sheet (MSDS) information. All chemicals are in the main cabinet for storage with the exception of alcohol, which is kept in the LAKE RM fireproof cabinet. The MSDS sheets for all chemicals are kept in a clearly marked folder in the MOJN I&M office.

A list of all chemicals must be posted on the outside of the cabinet door. This is done so that: (1) emergency personnel are able to identify the contents in case of an emergency and (2) people who are sensitive to certain materials are able to avoid exposure. The list of chemicals should include the name of the chemical, the quantity of that chemical in storage, and the quantity of that chemical that has been used (this includes anything that has been opened). A sample list is included in Table 1.2.

Table 1.2. Example of chemical list to be posted on chemical cabinet.

Water Quality Lab Chemical List		
Solution	Quantity stored	Quantity used
pH Buffer Solution 4	500ml-3	500ml-1 Lg-1
pH Buffer Solution 7	500ml-2	Lg-2
pH Buffer Solution 10	500ml-1	500ml-2 Lg-1
Conductivity Standard 1413	500ml-1	0
pH Electrode	1	1
Clorox Bleach	0	0
Arm and Hammer Baking Soda	0	0
Unless otherwise noted all chemicals are in main cabinet for storage.		

3.2. Chemical Handling in the Field

None of the chemicals used by MOJN I&M personnel in Selected Large Springs monitoring are extremely dangerous, but the pH buffers and bleach are corrosive. Gloves should be worn when handling these chemicals to avoid contact with skin, and eye protection (e.g., sunglasses) should be worn when pouring bleach to avoid contact with eyes. In the event that these chemicals come into contact with skin or eyes, flush with water immediately.

Detailed information about the necessary safety procedures for all of the chemicals used can be found in the MSDSs included in the supplementary materials. It is the responsibility of the field personnel to be familiar with this information.

4. Literature Cited

- Centers for Disease Control and Prevention. 2010. Parasites - Naegleria. Available online at: <http://www.cdc.gov/parasites/naegleria/> (accessed 13 December 2010).
- Tallent, N., G. Moret, and J. Brackin. 2014. Mojave Desert Network Inventory and Monitoring Field Safety Plan. Unpublished Document.
- Thoma, D., D. Sharrow, K. Wynn, J. Brown, M. Beer, and H. Thomas. 2009. Water Quality Vital Signs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network. National Park Service, Fort Collins, Colorado. Available online at <http://irmafiles.nps.gov/reference/holding/434309> (accessed 28 October 2014).

Standard Operating Procedure 2: Staff Training

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1. Introduction

This Standard Operating Procedure (SOP) describes how the personnel conducting field work for the Selected Large Springs protocol (SLS) will be trained.

The current staffing structure, and that for the foreseeable future, includes a protocol lead, a shared field technician, and several park-based scientists. It is the responsibility of the protocol lead to ensure that all personnel conducting protocol-related monitoring are properly trained.

2. Water Sampling, BMI Sampling, and Springsnail Monitoring

It is anticipated that the protocol lead will directly supervise the biennial sampling and monitoring activities, so no additional staff require formal training. Water sampling and BMI sampling do not require specialized training beyond the information given in the SOPs. In the event that the protocol lead does not feel able to undertake the springsnail monitoring, they should arrange to be trained by a malacologist specializing in the study of springsnails such as Dr. Donald Sada of the Desert Research Institute in Reno, NV or Dr. Robert Hershler of the Smithsonian Institute in Washington DC.

3. Handheld Water Quality Instrument

Training personnel on the use of handheld water quality instruments is relatively straightforward. After one field demonstration, most field staff should be able to use the instrument with the aid of the SOP. However, the protocol requires more frequent calibrations than is common in many settings, so the protocol lead should be sure to explain the importance of these calibrations to all personnel making measurements.

4. Discharge and Well Levels

Discharge measurements at flumes and data-logger download procedures are relatively straightforward, and can be taught by 2-3 field demonstrations. At each of these demonstrations, the personnel being trained should make a separate set of measurements to ensure that they are comfortable with the procedure and accurate in their results. If the protocol lead is unfamiliar with these measurements, they should consult a park scientist or a hydrologist from another agency.

Training for USGS stream gaging discharge measurements (i.e. the measurements made at Boiler Spring in GRBA) are described in the Streams and Lakes protocol Staff Training SOP.

The measurement water levels in wells using either of the methods described in the SOP is straightforward, and can be taught over 2-3 field demonstrations.

5. QA/QC

The protocol lead should arrange to “ride along” at least once a year with any park personnel who carry out protocol-related monitoring. This will allow for refresher training, and will allow the protocol lead to assess the success of the SOPs in the field.

Standard Operating Procedure 3: Spring Locations and Spring-Specific Procedures

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1. Introduction

This SOP provides the directions needed to reach each of the springs monitored in the SLS Protocol, and documents spring-specific information needed to implement the other SOPs.

The sites in this protocol are not difficult to find, but each crew sent to a spring should have at least one member who has monitored the spring previously. GPS points and site photographs should be taken into the field to ensure that the correct locations are being visited.

2. Travertine Springs in DEVA

2.1. Access

Travertine Springs is located near Furnace Creek Road in DEVA (Figure 3.1). From the MOJN I&M office in Boulder City, the drive (via Pahrump and Death Valley Junction) is approximately three hours. Park at the gate on the access road (Table 3.1, Figure 3.1) on your right as you drive into the park.

Table 3.1. UTM (11N NAD83) coordinates for selected Travertine Springs waypoints.

	Easting (m)	Northing (m)
Gate	0514855	4032952
Travertine No. 1 Source	0515431	4033086
Travertine No. 2 Source	0515229	4033249
Patch of snail habitat in Travertine #2	0515224	4033241

From the parking spot, walk approximately 500 meters up the road. The springbrook to the right of the road is Travertine No. 2. Travertine No. 1 is located about 200 meters southeast of Travertine No. 2, and can be accessed by hiking cross-country from Travertine No. 2 (there is a dry drainage between the springs) or by walking uphill from the parking spot along the shoulder of the road.

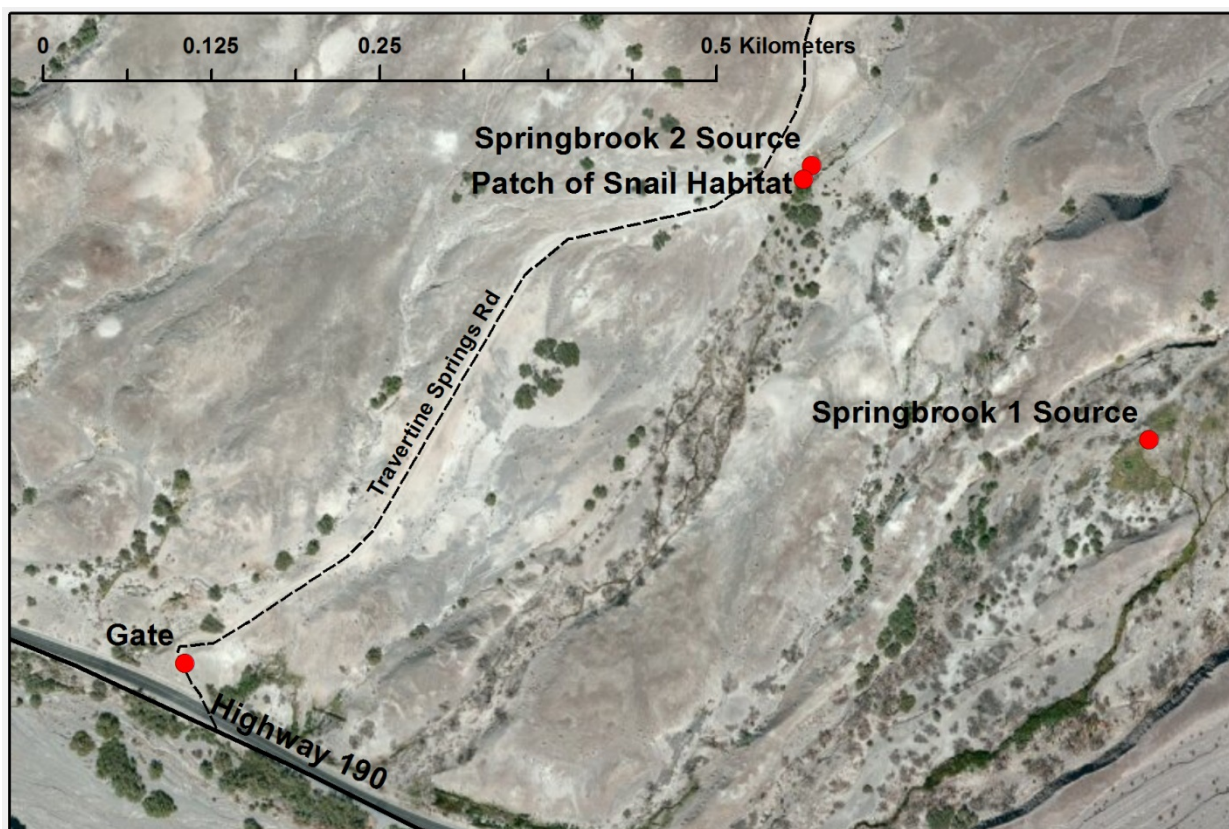


Figure 3.1. Map of selected Travertine Springs waypoints.

2.2. Spring Description

Travertine No. 1 flows from a pipe (part of a former collection system) on top of a spring mound. The spring flows through a narrow channel down the flank of the spring mound into a wash below. Once in the wash, the spring flows for several hundred meters until it is diverted into a drain on the shoulder of Furnace Creek Road.

Travertine No. 2 flows from a pipe near the head of a wash approximately 200 meters to the west of Travertine No. 1. Currently, flow from the spring flows for several hundred meters until it reaches a patch of cattails. Travertine No. 2 is currently undergoing rehabilitation, and the pattern of springflow may change.

2.3. Discharge Monitoring

As of 2014, the DEVA hydrology staff collects discharge data at Travertine Springs, and provides the data to the NPS WRB. MOJN I&M is not involved in the collection or analysis of the data.

2.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality and collect a sample for laboratory analysis of water chemistry at two locations: the source of Travertine No.1 and the source of Travertine No. 2 (Table 3.1). At each location, collect a sample and make three measurements at least 60 seconds apart within 1 meter of the pipe.

2.5. BMI and Springsnails (SOP 8)

At **Travertine No. 1**, two BMI samples will be collected on each biennial visit: a source sample from the spring mound and a downstream sample from the wash. Springsnail population density will be measured along the entire springbrook.

The source BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the springbrook between the source on top of the mound and the bottom of the mound, a channel length of approximately 60 m. A total of seven 10 cm by 10 cm quadrats 10 m apart will be collected using the 15 cm net.

The downstream BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the springbrook between the bottom of the mound and the shoulder of Furnace Creek Road. A total of 11 10 cm by 10 cm quadrats will be collected every 30 m using the 15 cm net.

The springsnail population density should be monitored at the same locations that BMI samples are collected.

At **Travertine No. 2**, a single BMI sample will be collected on each biennial visit from the entire length of the springbrook. Springsnail presence/absence will be recorded for each quadrat, and Springsnail population density will be measured where present.

The BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the springbrook between the source and the end of the surface water, a channel length of approximately 120 m. A total of 13 10 cm by 10 cm quadrats 10 m apart will be collected using the 15 cm net.

At each quadrat, inspect the BMI sample and determine whether springsnails are present. Record the presence/absence of springsnails, and, if present, monitor their population density using the methods outlined in SOP 8. In 2014, springsnails were only observed in one location in Travertine No. 2, an area of slack water separated from the main channel by a boulder approximately 10 m downstream of the source.

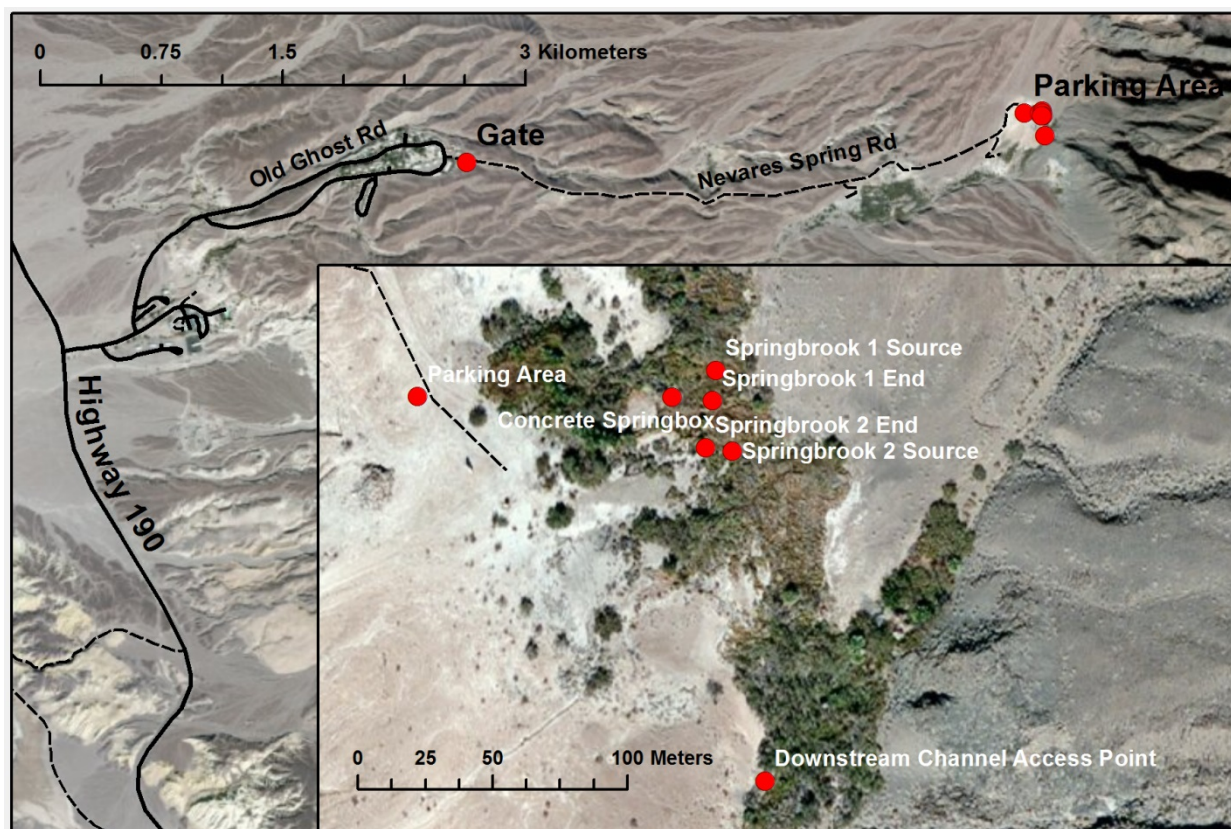
3. Nevares Springs in DEVA

3.1. Access

Nevares Springs is located near Cow Creek Road in DEVA (Figure 3.2). From the MOJN I&M office in Boulder City, the drive (via Pahrump and Death Valley Junction) is approximately three hours. Head north from the visitor center, and turn right into the Cow Creek maintenance area. Turn left before you reach the office buildings, and drive through the park housing area. **There is a locked gate where the pavement ends- arrange to borrow a key from DEVA staff.** Follow the dirt road beyond the gate to the parking areas on top of the spring mound or adjacent to the wash (Table 3.2, Figure 3.2).

Table 3.2. UTM (11N NAD83) coordinates for selected Nevares Springs waypoints.

	Easting (m)	Northing (m)
Gate	0513158	4040564
Parking Area	0515931	4040813
Spring 1 source	0516020	4040821
Spring 1 end	0516019	4040812
Spring 2 source	0516025	4040797
Spring 2 end	0516017	4040798
Concrete Springbox	0516007	4040813
Downstream channel access point	0516035	4040699

**Figure 3.2.** Map of selected Nevares Springs waypoints.

3.2. Spring Description

The source area on top of the spring mound supports a dense area of riparian vegetation. Several small channels emerge from the mound, and join near a large concrete springbox (Table 3.2, Figure 3.2). Surface water is present for only a few meters beyond the springbox.

Water also flows from the flank of the spring mound into the wash below. The flank of the spring mound has dense vegetation, unstable ground, and steep slopes, so it should not be traversed by MOJN I&M crews.

3.3. Discharge Monitoring

As of 2014, the DEVA hydrology staff collects discharge data at Nevares Springs, and provides the data to the NPS WRB. MOJN I&M is not involved in the collection or analysis of the data.

3.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality (three measurements at least 60 seconds apart) at two locations: the source area on the top of the spring mound and the furthest upstream point of the springbrook in the wash (Table 3.2). A single sample for laboratory analysis of water chemistry will be collected from the source area on top of the spring mound.

3.5. BMI and Springsnails (SOP 8)

Two BMI samples will be collected on each biennial visit: a source sample from the top of the spring mound and a downstream sample from the springbrook in the wash. Springsnail population density will be measured in both areas.

The source BMI sample will be collected from the marshy area on top of the spring mound using the Channel method in SOP 8. The sampling reaches are the two small channels (Springs 1 and 2) and the springbrook downstream of the concrete springbox. In each reach, three 10 cm by 10 cm quadrats were collected along the channel using the 15 cm net, with more two quadrats collected in each of the pools at their sources. If the three channels cannot be relocated, then the altered sampling plan should involve collecting BMI from 15 10 cm by 10 cm quadrats.

The downstream BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the first 300 m of the springbrook between the bottom of the mound and the shoulder of Furnace Creek Road. A total of 11 10 cm by 10 cm quadrats will be collected every 30 m using the 15 cm net.

The springsnail population density should be monitored at the same locations that BMI samples are collected.

4. Texas Springs in DEVA

4.1. Access

Texas Springs is located near the Texas Springs Campground in DEVA (Figure 3.3). From the MOJN I&M office in Boulder City, the drive (via Pahrump and Death Valley Junction) is approximately three hours. From Route 190, follow the signs for Texas Springs Campground onto Texas Springs Road, and turn right onto a gated road area. **Arrange to borrow a key from DEVA staff.** The dirt road beyond the gate follows the edge of a steep ravine to a parking area on top of the spring mound (Table 3.3, Figure 3.3).

Table 3.3. UTM (11N NAD83) coordinates for selected Texas Springs waypoints.

	Easting (m)	Northing (m)
Gate	0512652	4034712
Source	0514434	4034676
Tunnel Mouth	0514505	4034719

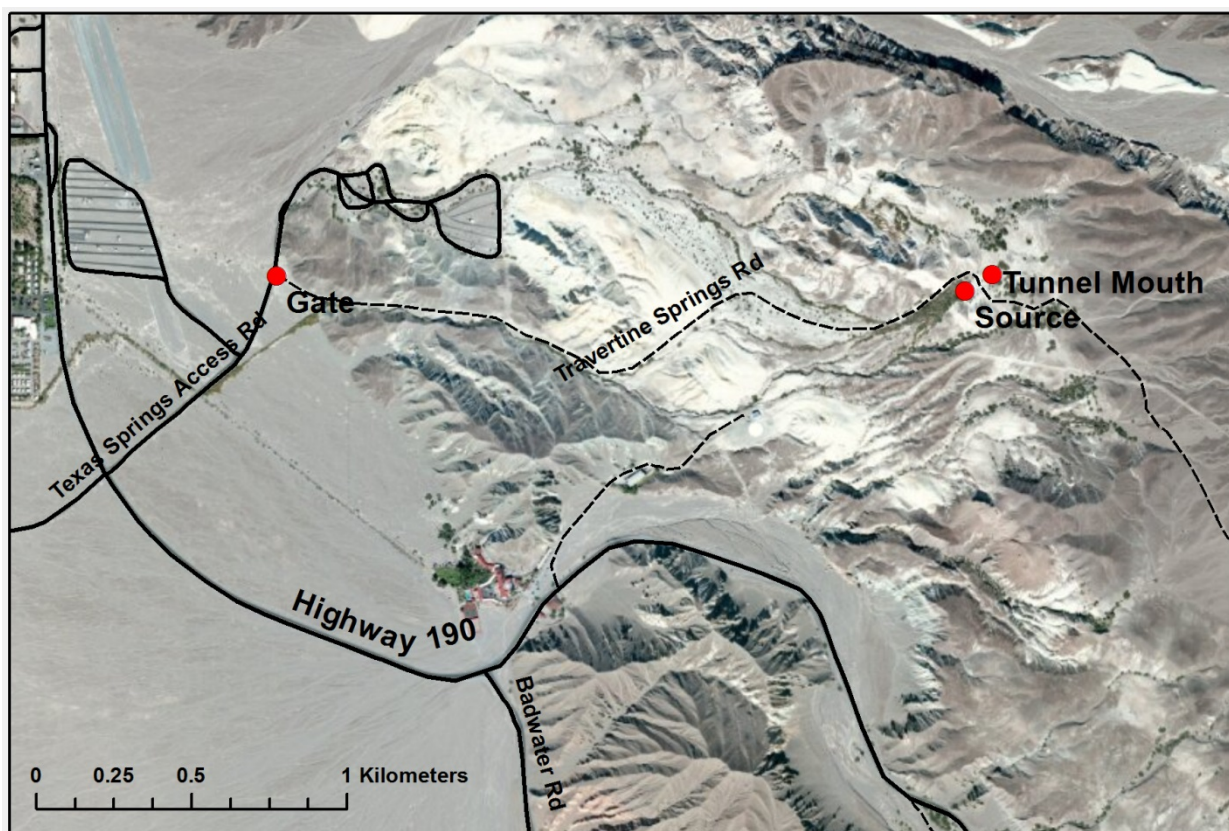


Figure 3.3. Map of selected Texas Springs waypoints.

4.2. Spring Description

The source of Texas Springs is a pipe that was part of a historic diversion system. A springbrook flows from the pipe for approximately 40 m, then plunges into a narrow, unstable ravine (Table 3.3, Figure 3.3). **Under no circumstances should crew members enter the ravine.** A historic adit, or tunnel, is located near the source. **Under no circumstances should crew members enter the tunnel.**

4.3. Discharge Monitoring

As of 2014, the DEVA hydrology staff collects discharge data at Texas Springs, and provides the data to the NPS WRB. MOJN I&M is not involved in the collection or analysis of the data.

4.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality at the source (three measurements at least 60 seconds apart) within 1 m of the pipe (Table 3.3). A single sample for laboratory analysis of water chemistry will also be collected from the source.

4.5. BMI and Springsnails (SOP 8)

One source BMI sample will be collected from Texas Springs on each biennial visit. Springsnail population density will also be measured.

The source BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the springbrook between the source and the furthest downstream point of the springbrook that can be accessed safely, a channel length of approximately 100 m. A total of 11 10 cm by 10 cm quadrats 10 m apart will be collected using the 15 cm net.

The springsnail population density should be monitored at locations spaced 5 m apart between the source and the furthest downstream extent of the springsnail population (approximately 40 m).

5. Saratoga Spring in DEVA

5.1. Access

Saratoga Spring is located near the southern border of DEVA off Harry Wade Road (Figure 3.4). From the MOJN I&M office in Boulder City, the drive (via Pahrump and Tecopa) is approximately three-and-a-half hours. Drive south from Tecopa on Route 127, and turn right on Harry Wade Road, just past the BLM recreational facilities at Ibex Dunes. Drive west for approximately 6 miles, then turn right on an unmarked dirt road. Follow this road until it ends at a parking area. Saratoga Spring is a short walk from the parking area, but hidden from view by a rocky outcrop (Table 3.4, Figure 3.4).

Table 3.4. UTM (11N NAD83) coordinates for selected Saratoga Spring waypoints.

	Easting (m)	Northing (m)
Parking Area	0552294	3948697
Springbox	0552334	3948925
Source Pool	0552272	3948893

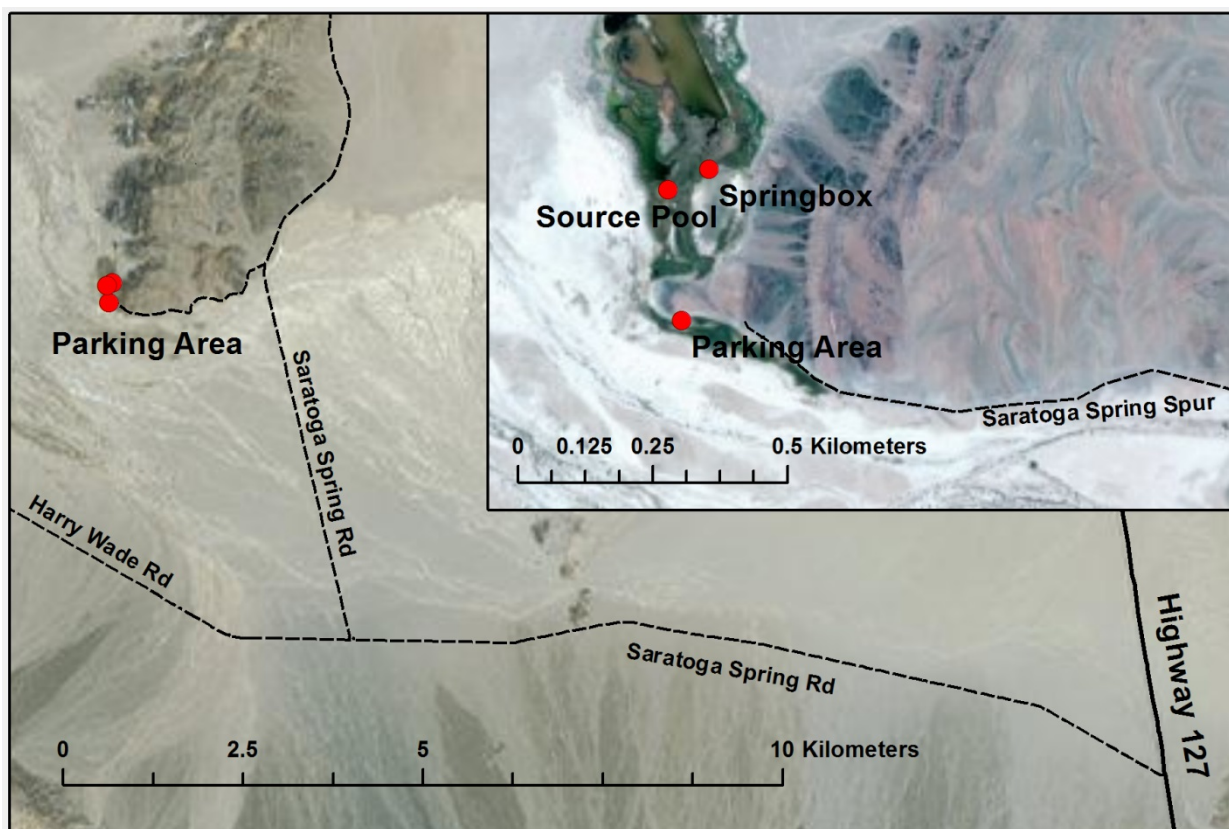


Figure 3.4. Map of selected Saratoga Spring waypoints.

5.2. Spring Description

Saratoga Spring consists of 7 hectares of wetlands vegetation (primarily reeds and bulrushes) and open water (Figure 3.4). At the southern end of the spring, water flows from a historic spring box to a source pool that is approximately 10 m in diameter. From the source pool, water flows north along a low-banked channel through the reeds to a series of artificial downstream ponds, the largest of which is approximately 60 m by 200 m.

5.3. Discharge Monitoring

As of 2014, the DEVA hydrology staff collects stage data in the historic springbox. MOJN I&M is not involved in the collection or analysis of the data.

5.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality at the source pool and the historic springbox (Table 3.4). In the source pool, a depth profile will be collected, with measurements made near the surface, at 1/3 the depth of the pool, 2/3 the depth of the pool, and near the bottom. At the springbox, three measurements will be made at least 60 seconds apart. A single sample for laboratory analysis of water chemistry will also be collected from the source pool.

5.5. BMI and Springsnails (SOP 8)

Three BMI samples will be collected from Saratoga Spring on each biennial visit: a source pool sample, a channel sample, and a downstream ponds sample. Springsnail population density will also be measured in the source pool and the channel.

The source pool BMI sample will be collected using the Large Pool method (SOP 8). The 15 cm net will be used with a special long handle. Springsnails in the source pool will be monitored using the method described the section of SOP 8 entitled “Special Cases for Springsnail Monitoring”. Springsnails will be monitored in five 10 cm x 10 cm quadrats, and underwater photography will be used to assist in interpreting monitoring data.

The source BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the springbrook between the source pool and the downstream ponds, a channel length of approximately 200 m. A total of 21 10 cm by 10 cm quadrats 10 m apart will be collected using the 15 cm net. The springsnail population density in the channel should be monitored at the same locations that BMI samples are collected.

The downstream ponds BMI sample will be collected in the three largest ponds using the Large Pool method (SOP 8). The 30 cm kicknet will be used with the long handle. BMI from the three ponds will be combined into a single sample.

6. Mound Spring in DEVA

6.1. Access

Mound Spring is located near Lower Grapevine Ranch (Figure 3.5). From the MOJN I&M office in Boulder City, the drive (via Pahrump and Furnace Creek) is approximately four hours. Drive north from Furnace Creek on Route 190, and turn right onto Scotty’s Castle Road. Head north, and turn left onto Ubehebe Crater Road. Follow this road for about 2.5 km, and turn onto a gated dirt road that forks off to the right. **Arrange to borrow a key from DEVA staff.** The dirt road ends at a parking area next to Lower Vine Ranch. Mound Spring is about an 800 m hike uphill from the parking area (Table 3.5, Figure 3.5).

Table 3.5. UTM (11N NAD83) coordinates for selected Mound Spring waypoints.

	Easting (m)	Northing (m)
Gate	464742.79	4096700.39
Parking Area	465530.36	4096935.94
Flume	465795.32	4097535.02
Palm Cluster Site 1	465823.66	4097485.60
Palm Cluster Site 2	465818.55	4097498.76

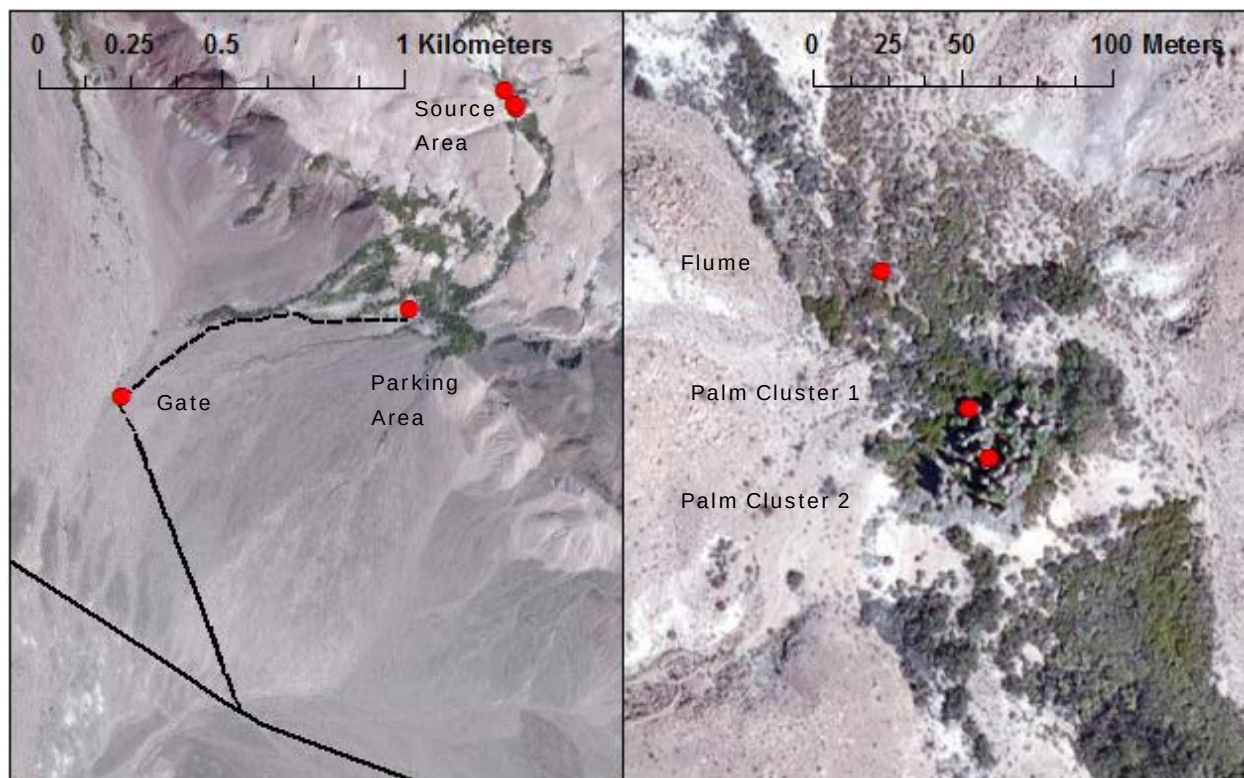


Figure 3.5. Map of selected Mound Spring waypoints.

6.2. Spring Description

Mound Spring is located on the top of a spring mound in the Grapevine Mountains. Water emerges from a source and flows through a flume. Below the flume, the water diffuses to flow through a marshy area and two clusters of palm trees before flowing off the side of the mound.

6.3. Discharge Monitoring

In 2008, MOJN I&M and DEVA personnel installed a flume at Mound Spring, one of the highest elevation springs in the Grapevine Springs Complex. This outlet was chosen as an index site for the Grapevine Springs Complex because of its relatively high discharge, and the suitability of its source for flume installation. As of 2014, the DEVA hydrology staff collect and manage the discharge data.

6.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality at the source (three measurements at least 60 seconds apart) above the flume. A single sample for laboratory analysis of water chemistry will also be collected from the source.

6.5. BMI and Springsnails (SOP 8)

At each biennial visit, two BMI samples will be collected: one from each of the palm cluster sites. These samples will be collected using the Shallow Pool method (SOP 8). Both samples will combine five 10 cm by 10 cm quadrats collected from evenly spaced sampling points using a 15-cm wide kicknet.

7. Strawberry Source Spring in GRBA

7.1. Access

Note: Visits to Strawberry Source Spring are considered backcountry trips- follow backcountry safety procedures.

Strawberry Source Spring is located at the headwaters of Strawberry Creek in the northwest corner of GRBA (Figure 3.6). From the MOJN I&M office in Boulder City, the drive (via Route 93) is approximately five hours. From Route 50, turn south onto Strawberry Creek Road. Follow the road until it ends at a parking area bounded by a stone fence. Walk to the stream, but do not cross the bridge. Follow the trail on the south side of the stream (the left bank, facing upstream) until you reach the source.

Table 3.6. UTM (11N NAD83) coordinates for selected Strawberry Source Spring waypoints.

	Easting (m)	Northing (m)
Parking Area	0732596	4326078
Source	0731871	4325548

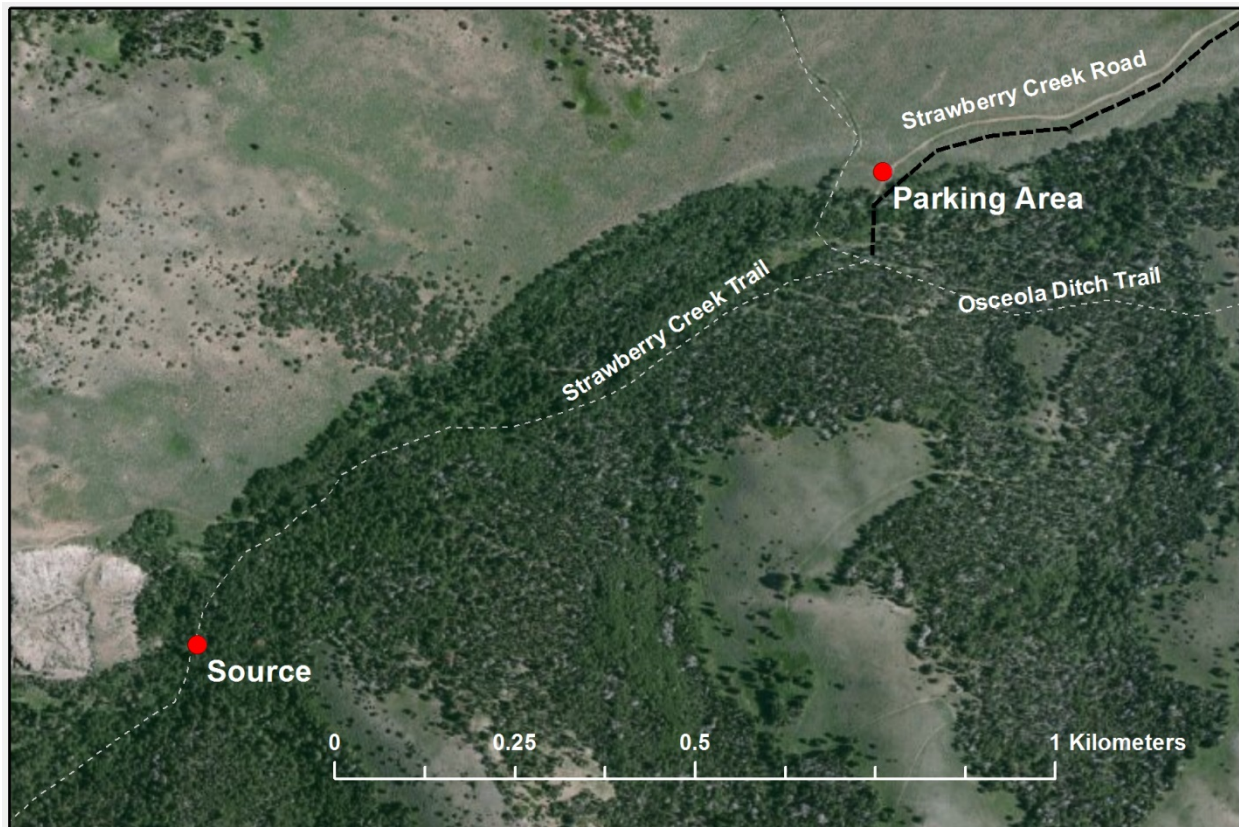


Figure 3.6. Map of selected Strawberry Source Spring waypoints.

7.2. Spring Description

Strawberry Source Spring is the source of Strawberry Creek. Water trickles from the base of a rocky slope through mossy rocks to the stream channel.

7.3. Discharge Monitoring (SOP 7)

The discharge of Strawberry Source Spring will be monitored twice a year (in June and October) using the Stream Gaging method (SOP 7).

7.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each semi-annual and biennial visit, the MOJN I&M or GRBA crew will measure water quality (three measurements made at least 60 seconds apart) within 1 m of the spring source (Table 3.7). A single sample for laboratory analysis of water chemistry will be collected from the same location on each biennial visit.

7.5. BMI (SOP 8)

One BMI sample will be collected from a 100 m reach immediately downstream of the source using the EMAP method (SOP 8).

8. Marmot Spring in GRBA

8.1. Access

Marmot Spring is located near Baker Creek Road in GRBA (Figure 3.7). From the MOJN I&M office in Boulder City, the drive (via Route 93) is approximately five hours. From Baker, drive west on Route 488. Turn left on Baker Creek Road shortly after the crossing the park boundary. Marmot Spring will be on your right.

Table 3.7. UTM (11N NAD83) coordinates for selected Marmot Spring waypoints.

	Easting (m)	Northing (m)
Source	0739705	4319524
Culvert outlet	0739693	4319488

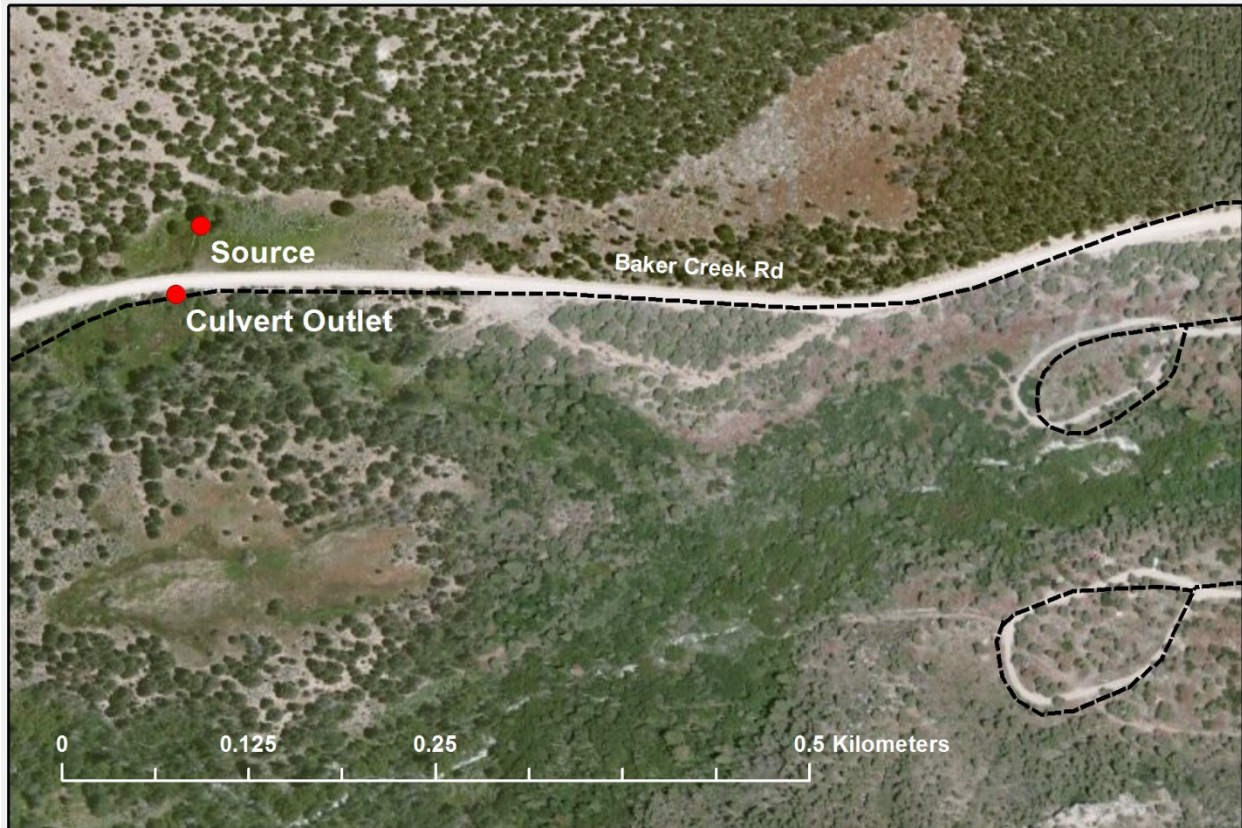


Figure 3.7. Map of selected Marmot Spring waypoints.

8.2. Spring Description

Marmot Spring consists of several channels in a grassy area that flow into a culvert below Baker Creek Road. Any discharge from the culvert flows down a steep embankment.

8.3. Discharge Monitoring (SOP 7)

The discharge of Marmot Spring will be monitored three times a year (in May, July, and October) using the Volumetric method (SOP 7). Measurements will be made at the culvert outlet.

8.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each three-times-annually and biennial visit, the MOJN I&M or GRBA crew will measure water quality (three measurements made at least 60 seconds apart) at the source of the highest-discharge springbrook (Table 3.7). A single sample for laboratory analysis of water chemistry will be collected from the same location on each biennial visit.

8.5. BMI (SOP 8)

One BMI sample will be collected from the highest-discharge springbrook on each biennial visit using the Channel method (SOP 8). A total of 11 30 cm by 30 cm quadrats 1 m apart will be collected using the 30 cm kicknet.

9. Boiler Spring in GRBA

9.1. Access

Note: Visits to Boiler Spring are considered backcountry trips- follow backcountry safety procedures.

Boiler Spring is located at the headwaters of the upper perennial reach of South Fork Big Wash in the southeast portion of GRBA (Figure 3.8). From the MOJN I&M office in Boulder City, the drive (via Route 93) is approximately five and a half hours. From Baker, drive southeast on Route 487. Continue east across the state line through Garrison, UT, where the road becomes Utah Route 21. Turn right (west) on NF-450 (Lexington Creek Road) just after Pruess Lake. After 0.4 miles, keep right at the fork to stay on NF-450. Keep left at the second fork to stay on NF-450. Continue up the road into the mountains, and keep right (north) at the fork to stay on NF-450. Park where the road ends near the park boundary, and continue on foot. Follow the established primitive trail over the ridge and into the South Fork Big Wash drainage, then hike cross-country uphill from the trail to the spring.

Table 3.8. UTM (11N NAD83) coordinates for selected Boiler Spring waypoints.

	Easting (m)	Northing (m)
Turnoff from Utah Route 21 to NF-450	0759932	4307131
First Fork	0759579	4306595
Second Fork	0754005	4304329
Third Fork	0746340	4304825
Parking Area	0741220	4304490
Trailhead	0741179	4304528
Spring Source	0740857	4306180

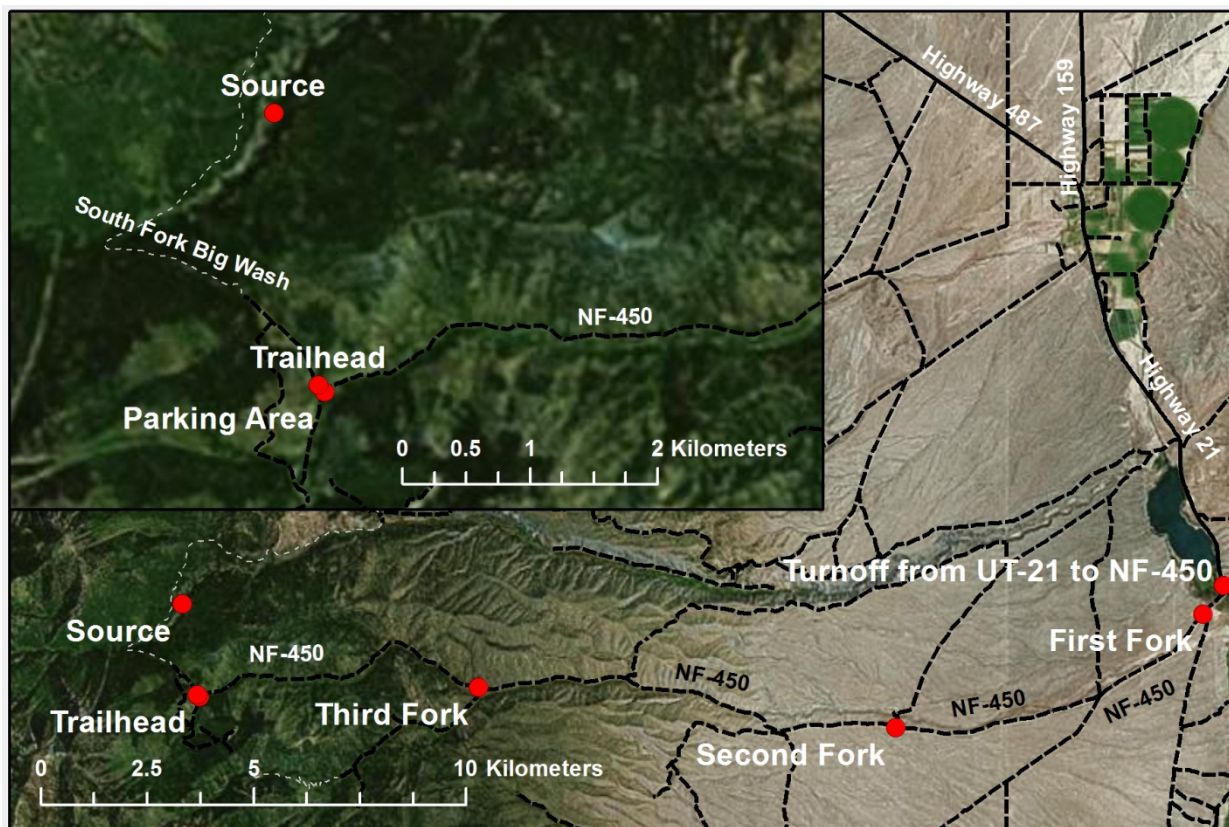


Figure 3.8. Map of selected Boiler Spring waypoints.

9.2. Spring Description

Boiler Spring is the headwater of a perennial reach of South Fork Big Wash. A flowing mountain stream emerges from the source.

9.3. Discharge Monitoring (SOP 7)

The discharge of Strawberry Source Spring will be monitored twice a year (in June and October) using the Stream Gaging method (SOP 7).

9.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each semi-annual and biennial visit, the MOJN I&M or GRBA crew will measure water quality (three measurements made at least 60 seconds apart) within 1 m of the spring source (Table 3.8). A single sample for laboratory analysis of water chemistry will be collected from the same location on each biennial visit.

9.5. BMI (SOP 8)

One BMI sample will be collected from a 100 m reach immediately downstream of the source using the EMAP method (SOP 8).

10. Fortynine Palms Oasis in JOTR

10.1. Access

Fortynine Palms Oasis is located in the northwest portion of JOTR west of 29 Palms (Figure 3.9). From the MOJN I&M office in Boulder City, the drive (via Searchlight, Goffs, and Amboy) is approximately three-and-a-half hours. From 29 Palms, take Route 62 west. Turn left at the sign for Fortynine Palms Oasis, and follow the road to the trailhead. Take the developed trail south to the oasis (Table 3.9, Figure 3.9).

Table 3.9. UTM (11N NAD83) coordinates for selected Fortynine Palms Oasis waypoints.

	Easting (m)	Northing (m)
Parking Area	0581893	3775745
Source Pool	0582544	3774260

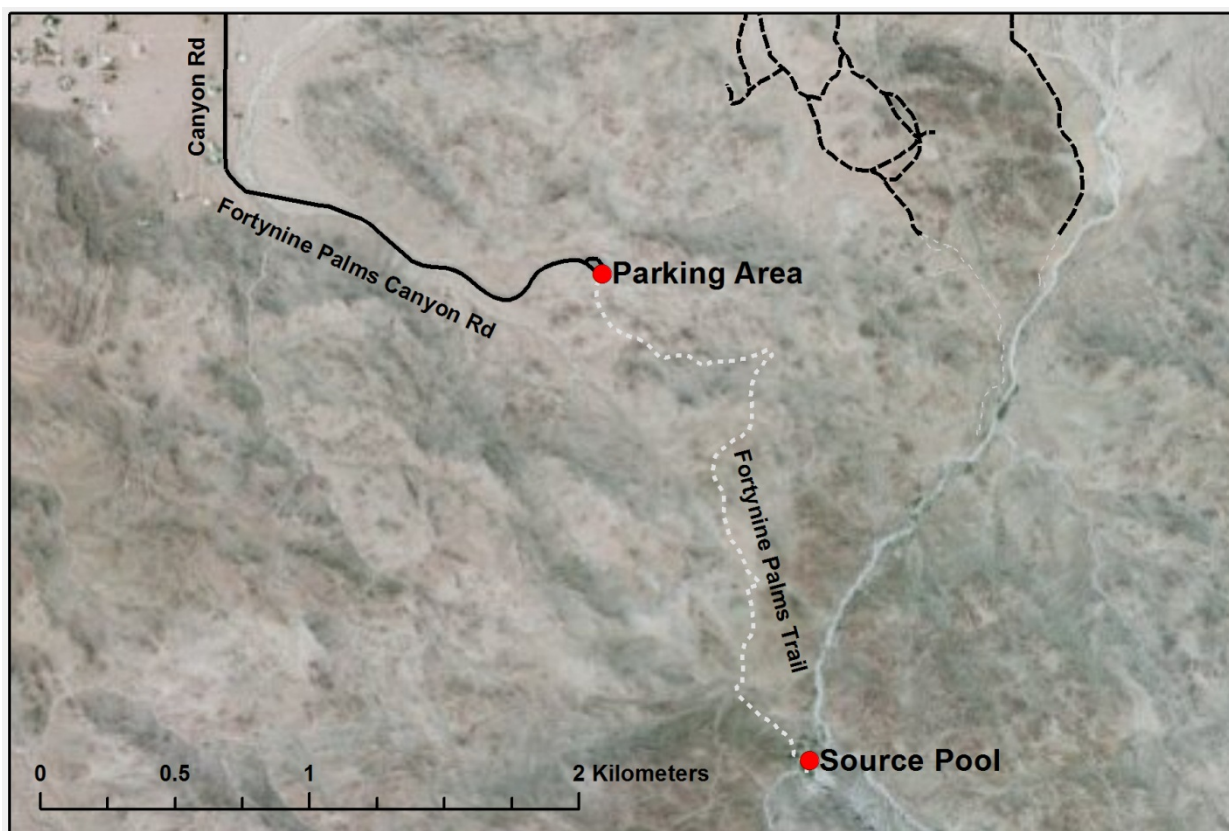


Figure 3.9. Map of selected Fortynine Palms Oasis waypoints.

10.2. Spring Description

Fortynine Palms Oasis consists of a chain of pools of water located in and near a stand of fan palms in a canyon.

10.3. Discharge Monitoring (SOP 7)

The availability of surface water at Fortynine Palms Oasis is monitored using the Total Open Water Area method (SOP 7). The open water area will be measured quarterly.

10.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each quarterly and biennial visit, MOJN I&M will measure water quality in the source pool (Table 3.9). A depth profile will be collected, with measurements made near the surface, at 1/3 the depth of the pool, 2/3 the depth of the pool, and near the bottom. A single sample for laboratory analysis of water chemistry will be collected from the same pool on each biennial visit.

10.5. BMI (SOP 8)

One BMI sample will be collected from all of the pools in the oasis. The sample will be collected on the biennial visit using the Multi-Pool Grab Sample method (SOP 8).

11. Smith Water Canyon Springs in JOTR

11.1. Access

Note: Visits to Smith Water Canyon Springs are considered backcountry trips- follow backcountry safety procedures (SOP 1).

Smith Water Canyon is located in the northwest portion of JOTR to the southeast of the town of Yucca Valley (Figure 3.10). From the MOJN I&M office in Boulder City, the drive (via Searchlight, Goffs, and Amboy) is approximately three-and-a-half hours. From Twentynine Palms, take Route 62 west. Turn left onto La Contenta Road, and follow the road to the south. La Contenta Road turns to dirt, then reaches a fork. Take the left fork onto Covington Flat Road, and continue until the road ends at a trailhead (Table 3.10, Figure 3.10). Hike south along the developed trail (lower Covington Trail) for 0.5 miles, then turn to the left into Smith Water Canyon. Hike cross-country into the canyon until reaching the springs.

Table 3.10. UTM (11N NAD83) coordinates for selected Smith Water Canyon Springs waypoints.

	Easting (m)	Northing (m)
Fork in Road	0558088	3772770
Parking Area/Trailhead	0564439	3765436
Turnoff from Trail	0565569	3764638
Pool 1	0566556	3765674
Pool 2	0566620	3765694
Pool 3	0566675	3765671
Pool 4	0566722	3765645

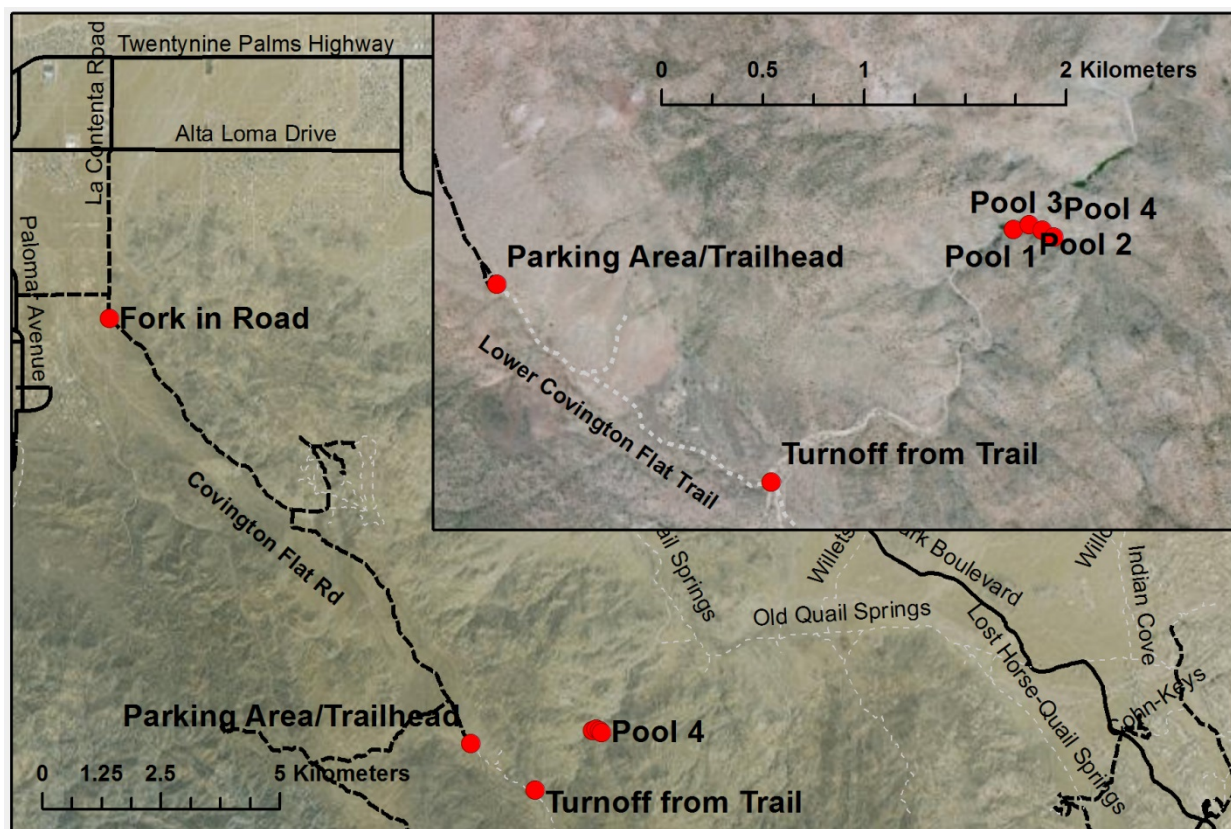


Figure 3.10. Map of selected Smith Water Canyon Springs waypoints.

11.2. Spring Description

Smith Water Canyon Springs consists of four spring outlets in narrow, steep canyon. Each of these outlets has a shallow pool at their source that flows into a springbrook and over a granite cliff, forming a waterfall. Most of the cliffs are ~2 m high, but the cliff at Pool 4 is higher (~5 m high).

MOJN I&M crews should not traverse the cliff below Pool 4.

11.3. Discharge Monitoring (SOP 7)

The availability of surface water at Smith Water Canyon Springs is monitored using the Springbrook Length method (SOP 7). The spring will be monitored quarterly.

11.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each quarterly and biennial visit, MOJN I&M will measure water quality (three measurements made at least 60 seconds apart) in the furthest upstream pool (Table 3.10). A single sample for laboratory analysis of water chemistry will be collected from the same pool on each biennial visit.

11.5. BMI (SOP 8)

One BMI sample will be collected from all of the sources. The sample will be collected on the biennial visit using the Multi-Pool Grab Sample method (SOP 8).

12. Blue Point Spring in LAKE

12.1. Access

Blue Point Spring is located off North Shore Road in LAKE (Figure 3.11). From the MOJN I&M office in Boulder City, the drive is approximately one-and-a-half hours. From the entrance station off Route 93, take Lakeshore Drive, then turn right onto North Shore Drive. Turn left into the Blue Point Spring parking lot, which is less than a mile from beyond the Rogers Spring parking lot. Follow the trail to the west to the source (Table 3.11, Figure 3.11).

Table 3.11. UTM (11N NAD83) coordinates for selected Blue Point Spring waypoints.

	Easting (m)	Northing (m)
Parking Area	0730558	4030204
Spring Source	0730244	4030199

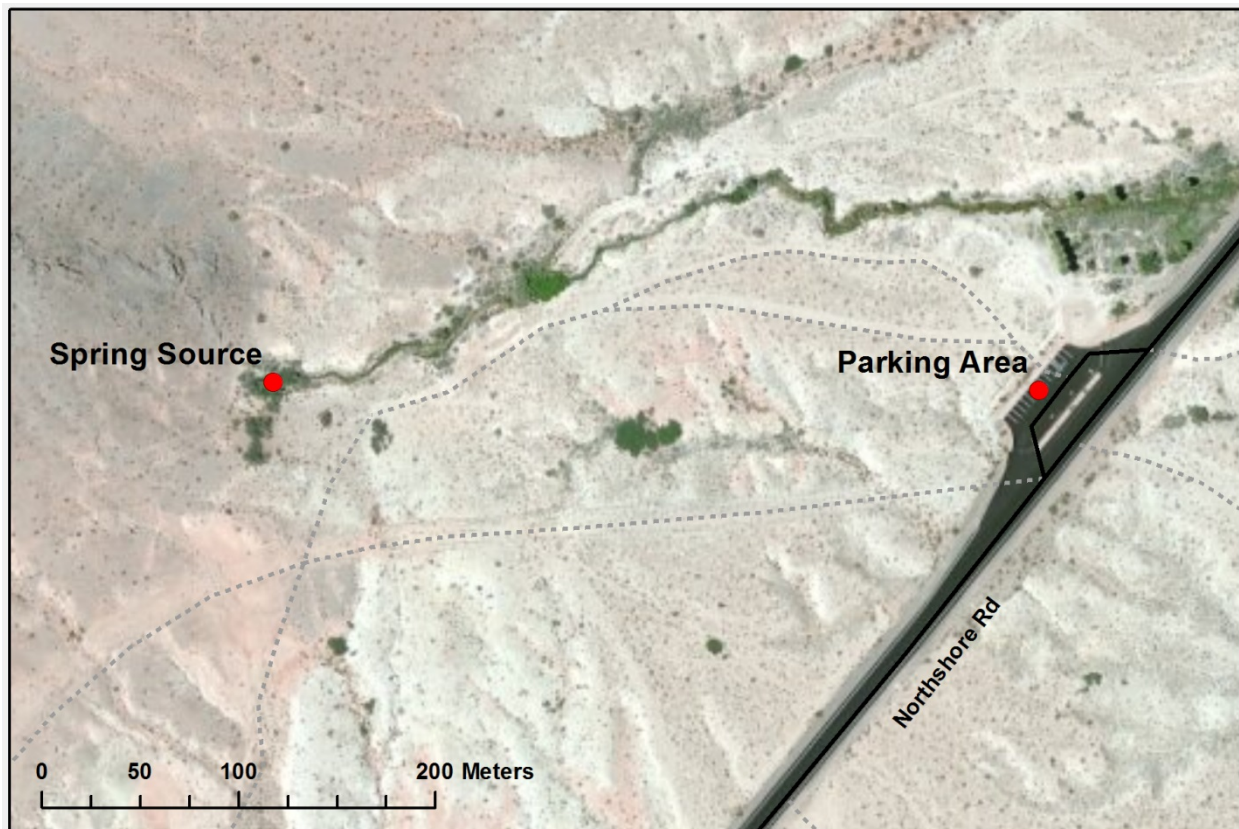


Figure 3.11. Map of selected Blue Point Spring waypoints.

12.2. Spring Description

Blue Point Spring consists of a pool behind a V-notch weir. The spring's discharge spills from the weir into a springbrook hundreds of meters long.

12.3. Discharge Monitoring

MOJN I&M monitors the discharge of Blue Point Spring using the Control Structure method (SOP 7). An hourly record of pool stage is recorded using a pressure transducer, and a rating curve (the theoretical curve for a V-notch weir) is used to convert the flow to discharge. MOJN I&M crews visit the spring quarterly to collect volumetric discharge measurements, download data from the pressure transducer, read the staff gage, and maintain equipment.

12.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each quarterly and biennial visit, MOJN I&M will measure water quality (three measurements made at least 60 seconds apart) in the source pool, a few meters upstream of the weir (Table 3.11). At each biennial visit, a single sample for laboratory analysis of water chemistry will also be collected from the source.

12.5. BMI and Springsnails (SOP 8)

Two BMI samples will be collected from Blue Point Spring on each biennial visit- a source sample from the pool above the weir and a downstream sample from the springbrook below the weir. Springsnail population density will also be measured.

The source pool BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the entire length of the source pool above the weir. Eleven 10 cm by 10 cm quadrats will be collected every 30 m using the 15 cm net.

The downstream BMI sample will be collected using the Channel method in SOP 8. The sampling reach extends for 380 m below the weir to a point near North Shore Road. A total of 20 10 cm by 10 cm quadrats will be collected every 30 m using the 15 cm net.

The springsnail population density should be monitored at the same locations that the source pool BMI samples are collected. The muddy pools below the weir (in the vicinity of 0730306 m E, 4030210 m N) should be searched to see if *Tryonia* sp. are present.

13. Rogers Spring in LAKE

13.1. Access

Rogers Spring is located off North Shore Road in LAKE (Figure 3.12). From the MOJN I&M office in Boulder City, the drive is approximately one-and-a-half hours. From the entrance station off Route 93, take Lakeshore Drive, then turn right onto North Shore Drive. Turn left into the Rogers Spring parking lot. The source is a large pool visible from the parking lot, the flume is reached by crossing the bridge near the pool then following the trail downstream (Table 3.12, Figure 3.12).

Table 3.12. UTM (11N NAD83) coordinates for selected Rogers Spring waypoints.

	Easting (m)	Northing (m)
Parking Area	0729350	4028884
Flume	0729321	4028754



Figure 3.12. Map of selected Rogers Spring waypoints.

13.2. Spring Description

Rogers Spring flows from a dissolution feature in the limestone cliff behind the spring into a large artificial pool (Figure 3.12). The discharge from the pool flows into a springbrook hundreds of meters long. A 9-inch Parshall flume has been installed in the springbrook approximately 100 meters below the pool.

13.3. Discharge Monitoring

The USGS monitors the discharge of Rogers Spring at the Parshall flume. USGS data for the site is available at:

http://waterdata.usgs.gov/nwis/dv/?site_no=09419550&agency_cd=USGS&referred_module=s_w.

13.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each biennial visit, MOJN I&M will measure water quality (three measurements made at least 60 seconds apart) in the source pool (on the bank at the nearest accessible point to the source) and at the pool outlet. At each biennial visit, a single sample for laboratory analysis of water chemistry will also be collected from the pool outlet.

13.5. BMI (SOP 8)

No BMI sample will be collected due the highly disturbed nature of the spring ecosystem.

14. MC Spring in MOJA

14.1. Access

MC Spring is located near the Desert Studies Center in MOJA (Figure 3.13). From the MOJN I&M office in Boulder City, the drive (via Searchlight, Nipton, and Baker, CA) is approximately two hours. Take the Zzyzx Road exit from I-15, and follow the gravel road to the unlocked gate. Turn left into the Desert Science Center, and follow the driveway until it is blocked by 55-gallon drums near the swimming pool. Follow the trail beyond the drums to the spring. (Table 3.13, Figure 3.13).

Table 3.13. UTM (11N NAD83) coordinates for selected MC Spring waypoints.

	Easting (m)	Northing (m)
Parking Area	0581705	3889242
Spring Pool	0581628	3889017

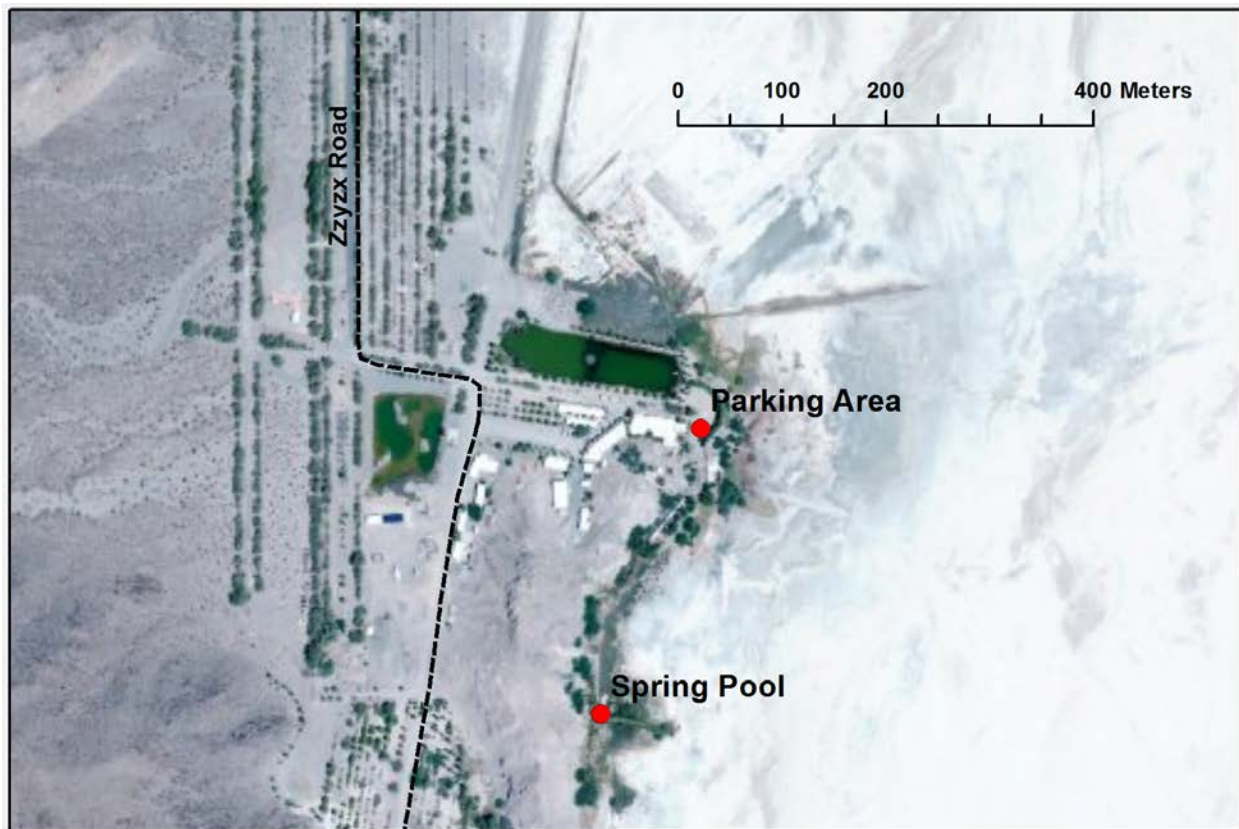


Figure 3.13. Map of selected MC Spring waypoints.

14.2. Spring Description

MC Spring is a pool with an area of approximate 23 m² surrounded by sedges and cattails.

14.3. Pool Stage Monitoring

MOJN I&M monitors the pool stage of MC Spring using the Pool Stage method (SOP 7). MOJN I&M crews visit the spring quarterly to download data from the pressure transducer, read the staff gage, and maintain equipment.

14.4. Water Quality (SOP 6) and Chemistry (SOP 8)

At each quarterly and biennial visit, MOJN I&M will measure water quality in the source pool from the northernmost point on the bank. A depth profile will be collected, with measurements made near the surface, at 1/3 the depth of the pool, 2/3 the depth of the pool, and near the bottom. At each biennial visit, a single sample for laboratory analysis of water chemistry will also be collected from the same location.

14.5. BMI (SOP 8)

No BMI sample will be collected due to the presence of a federally-listed species in the spring.

15. Pakoon Spring in PARA

15.1. Access

Note: Visits to Pakoon Spring are considered backcountry trips due to the remoteness of the area- follow backcountry safety procedures.

Note: as of 2015, Pakoon Spring and Tassi Spring should be accessed via St. George, UT. Please consult PARA staff for the appropriate access routes.

Pakoon Spring is located in the western portion of Parashant (Figure 3.14). From the MOJN I&M office in Boulder City, the drive (via I-15, New Gold Butte Road, and Whitney Pass) is approximately two hours. Take the Riverside Road exit from I-15, and head south on Riverside Road. Turn left on New Gold Butte Road just past the bridge, and follow it to Whitney Pass. Just beyond the pass, turn right onto County Road 111 at the fork. Follow County Road 111 for 10 miles, then turn left onto the Pakoon Springs access road. Park at the fenceline, and follow the trail beyond the fence to the spring. (Table 3.14, Figure 3.14).

Table 3.14. UTM (12N NAD83) coordinates for selected Pakoon Spring waypoints.

	Easting (m)	Northing (m)
Whitney Pass	0759480	4046933
Fork just past Whitney Pass	0763360	4046238
Turnoff to Pakoon Springs Access Road	0772136	4034790
Parking Area	0772762	4034451
Spring Pool	0772891	4034242

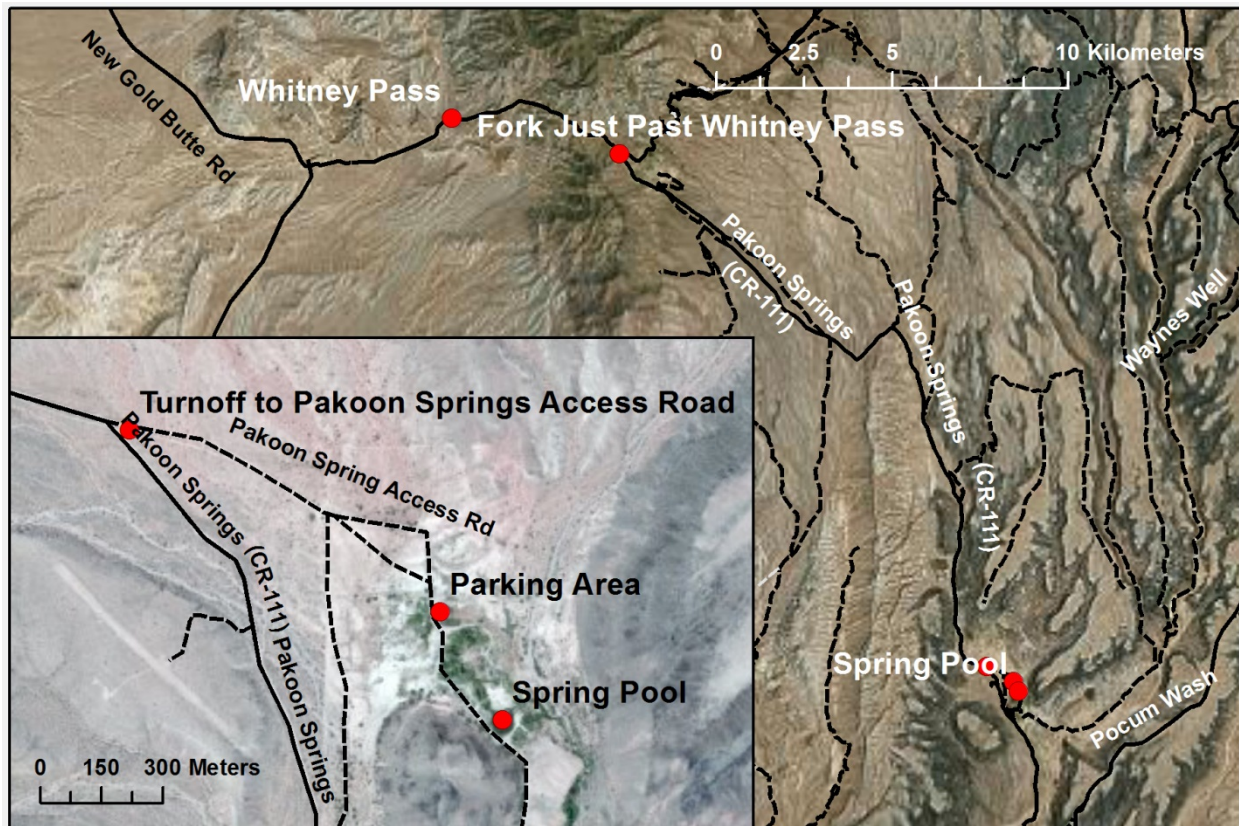


Figure 3.14. Map of selected Pakoon Spring waypoints.

15.2. Spring Description

A farm was located on the Pakoon Springs site for most of the 20th century. The spring was rehabilitated by the BLM beginning in the mid-2000s, but a 2013 monsoon damaged the gabions installed in the wash and formed deep rills in the re-contoured areas. PARA re-contoured the site in April 2015, removing an artificial pond and most of the gabions. Further work at the site is planned for the near future.

As of spring 2015, Pakoon Spring emerges in a marshy area, and then flows into a broad channel where wetlands vegetation has not yet been established. The water then flows over the bank into Pakoon Wash, and runs for approximately 1000 m.

Spring monitoring methods will be determined when the rehabilitation has been completed.

16. Tassi Spring in PARA

16.1. Access

Note: Visits to Tassi Spring are considered backcountry trips due to the remoteness of the area—follow backcountry safety procedures.

Note: as of 2015, Pakoon Spring and Tassi Spring should be accessed via St. George, UT. Please consult PARA staff for the appropriate access routes.

Tassi Spring is located in the western portion of Parashant (Figure 3.15). From the MOJN I&M office in Boulder City, the drive (via I-15, New Gold Butte Road, and Whitney Pass) is approximately three hours. Take the Riverside Road exit from I-15, and head south on Riverside Road. Turn left on New Gold Butte Road just past the bridge, and follow it to Whitney Pass. Just beyond the pass, turn right onto County Road 111 at the fork. Follow County Road 111 until it ends, then turn right onto County Road 113. Follow County Road 113 into NPS property, where it becomes NP 150. Head south on NP 150, then turn left onto NP152. Head east on NP152, then turn right onto NP 148. Follow NP148 to Tassi Ranch, and park by the split rail fence. Follow the trail up the hill behind the historic ranch house to the historic canal. Follow the canal upstream to the spring source. (Table 3.15, Figure 3.15).

Table 3.15. UTM (12N NAD83) coordinates for selected Tassi Spring waypoints.

	Easting (m)	Northing (m)
Whitney Pass	0759480	4046933
Fork just past Whitney Pass	0763360	4046238
Junction of CR 111 and CR 113	0768850	4026079
Junction of NP150 and NP152	0769512	4017641
Junction of NP152 and NP148	0774620	4018821
Parking Area	0773351	4016630
Spring Source	0773311	4016710

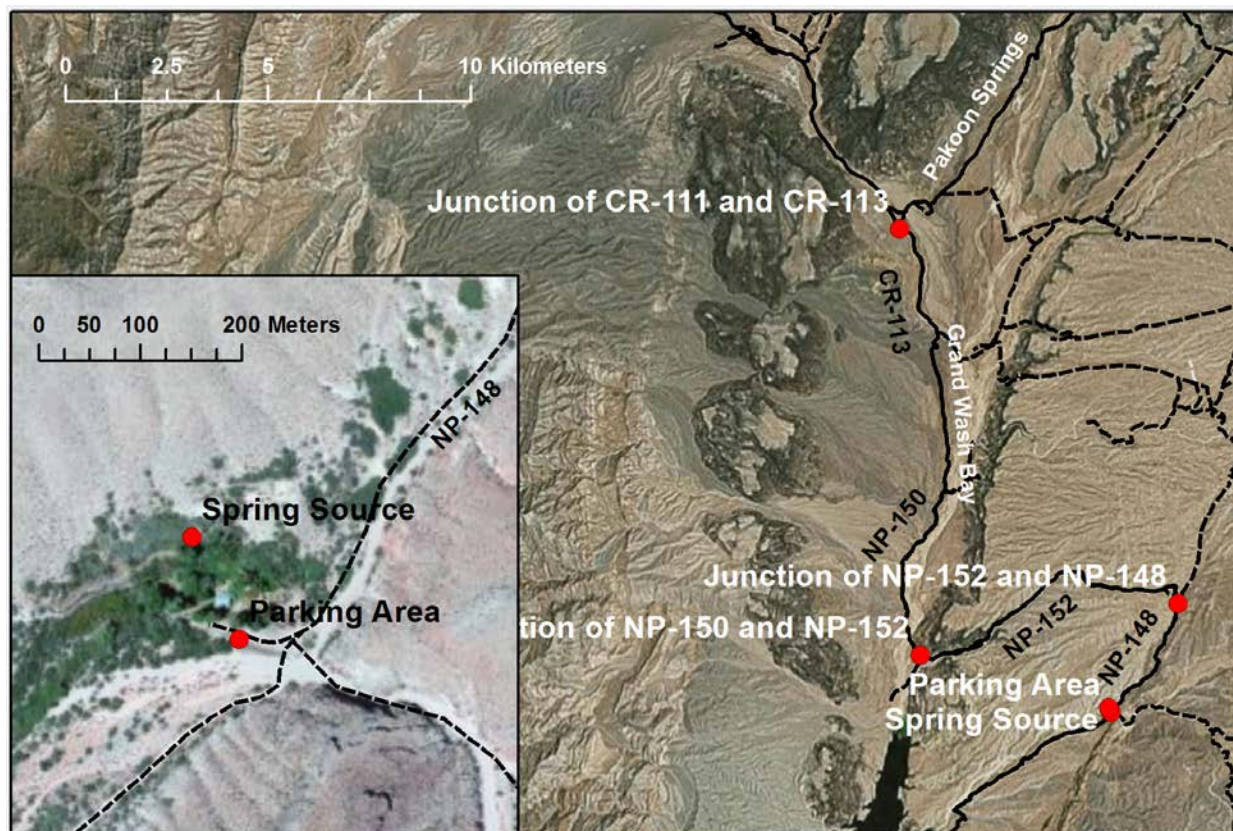


Figure 3.15. Map of selected Tassi Spring waypoints.

16.2. Spring Description

Tassi Spring emerges on a hillside behind the historic ranch. Currently, the spring's discharge flows in a historic canal for approximately 80 m. At that point, it flows down the hillside through a breach in the canal wall. The NPS is currently planning cultural restoration of the ranch, and may repair the canal as part of that process.

16.3. Discharge Monitoring

A portable flume will be used to monitor spring discharge at each quarterly visit.

16.4. Water Quality (SOP 6) and Chemistry (SOP 8)

MOJN I&M will collect water quality measurements (three measurements made at least 60 seconds apart) at each quarterly and biennial visit from the spring source at the head of the canal. MOJN I&M will collect a single sample for laboratory analysis of water chemistry at each biennial visit from the same location.

16.5. BMI and Springsnails (SOP 8)

One source BMI sample will be collected from Tassi Spring on each biennial visit. Springsnail population density will also be measured.

The source BMI sample will be collected using the Channel method in SOP 8. The sampling reach is the canal between the source and the breach. The sampling reach will be extended if the breach is

repaired. A total of approximately eight 10 cm by 10 cm quadrats 10 m apart will be collected using the 15 cm net.

The springsnail population density should be monitored at the same locations that BMI samples are collected.

Standard Operating Procedure 4: Field Mobilization and De-Mobilization

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

Unlike many protocols, the Selected Large Springs protocol (SLS) runs year-round. It is therefore appropriate to include a Field Mobilization and Demobilization SOP rather than the more usual Pre-Field Season Activities and Post-Field Season Activities SOPs. This SOP describes the logistical procedures that must be undertaken before and after each quarterly site visit and each biennial sampling and monitoring event.

2. Quarterly Site Visit

2.1. Mobilization

Each spring will be visited every three months to collect measurements of discharge and water quality. These visits should generally be scheduled at least a week in advance. At that time, the appropriate park personnel should be notified and a travel plan should be filed (see *SOP 1: Safety*). The expendable supplies (calibration standards, bleach, drinking water, sunscreen, etc.) should also be checked to ensure that there are sufficient quantities to carry out the work.

A day before the trip, the crew leader should review the appropriate safety procedures (*SOP 1: Safety* and the MOJN I&M Safety Plan). Also at that time, the following equipment and supplies should be assembled:

Digital camera	Sunscreen
GPS	Bug repellent
Handheld YSI multimeter	Field form(s) and backups
pH buffers	Field computer (if needed)
Conductivity standard	Clipboard, pens, pencils, permanent markers
Park Radio and spare batteries	Ruler (for measuring water levels in flumes)
Satellite Phone	<i>SOP 1: Safety</i> and park-specific documents
SPOT locator, GeoPro, or similar device	<i>SOP 6: Handheld Water Quality Instrument</i>
Topographic map of park and aerial imagery	<i>SOP 7: Spring Discharge Monitoring</i>
First aid kit	<i>SOP 9: Monitoring Water Levels in Wells</i> (if needed)
Water jug	

2.2. Demobilization

Upon return to the office, clean the multimeter using the guidelines given in the user manual. This wash is separate from the decontamination procedures described in *SOP 5: Equipment Disinfection*. Generally this means cleaning the external surface of the probe with a clean brush, soap and water. It is important that only water be used to clean the optical DO probe. After washing with soap, rinse with clean tap water and allow the outside of the probe casing (NOT the sensors) to dry.

All sealing surfaces such as O-rings should be lightly lubricated using silicone grease. Any O-rings that appear to be damaged should be replaced.

Remove the batteries from the multimeter prior to storage.

Use the probe's storage cup (filled with one inch of tap water) to protect the sensors from damage, and especially from drying out. If the sensors dry out they will no longer be useable, so make sure the storage cup has water and has been screwed on tightly enough to form an airtight seal before storing the unit.

The probe should be stored in a hard plastic case in the MOJN I&M office to prevent damage and to prevent the water in the storage cup from freezing.

The cable should be stored in the same case as the probe, and should be in coils of at least 15cm (6 inches) in diameter. If cable is coiled tighter than 15cm in diameter it will be damaged.

Replace all chemicals in the cabinet, and note the amount used on the list on the cabinet door. Order replacement chemicals if needed.

Decontaminate boots and all equipment that has been in contact with the spring (*SOP 5: Equipment Disinfection*), and charge any rechargeable batteries.

3. Water Sampling, BMI Sampling, and Springsnail Monitoring

3.1. Mobilization

The biennial visits to collect water and BMI samples and monitor springsnails require more field equipment than the quarterly visits. The protocol lead should check that all the equipment is available at least six weeks in advance in case additional equipment or alcohol need to be ordered. At this time, the protocol lead should also check to make sure all necessary permits have been obtained.

A week before the trip, the appropriate park personnel should be notified and a travel plan should be filed (see *SOP 1: Safety*). The protocol lead should contact the testing laboratory and arrange to pick up the water sample bottles and to have them dropped off.

A day before the trip, the crew leader should review the appropriate safety procedures (*SOP 1: Safety* and the MOJN I&M Safety Plan). Also at that time, the following equipment and supplies should be assembled:

Digital camera

GPS

Handheld YSI multimeter

pH buffers

Conductivity standard

Decontamination supplies (see *SOP 5: Equipment Disinfection*)

Park Radio and spare batteries

Topographic map of park and aerial imagery

First Aid Kit

Water Jug	Water sample bottles and cooler
Sun screen	Latex gloves
Field safety notebook	100 m measuring tape
Bug repellent	D-frame kicknet 500 µm mesh and 1 spare
Field form(s) and backups	Stopwatch
Clipboard, pens, pencils, permanent markers	Compositing Buckets (2)
Steel ruler (for measuring water levels in flumes)	Sieves with 500 µm mesh (2)
<i>SOP 1: Safety and Safety Plan</i>	Wash bottle
<i>SOP 6: Handheld Water Quality Instrument</i>	Sample jars, HDPE plastic with screw caps, 1-L capacity, suitable for use with ethanol (2 to 3 per planned sample)
<i>SOP 7: Spring Discharge Monitoring</i>	95% ethanol, in a proper container (2 gal)
<i>SOP 9: Monitoring Water Levels in Wells (if needed)</i>	Cooler for transporting ethanol and samples
<i>SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring</i>	Kitchen sieve with 1 mm mesh
	10 cm x 10 cm quadrat frame

3.2. Demobilization

As described in *SOP 12: Laboratory Analysis of Water Chemistry*, drop the water samples at the laboratory or arrange to have them picked up as soon as possible after leaving the field.

Upon return to the office, clean and store the multimeter as described above. Wash all sampling equipment with a hose, using soap if necessary (this wash is separate from the decontamination procedures described in *SOP 5: Equipment Disinfection*).

Replace all chemicals in the cabinet, and note the amount used on the list on the cabinet door. Order replacement chemicals if needed.

Decontaminate boots and all equipment that has been in contact with the spring (*SOP 5: Equipment Disinfection*), and charge any rechargeable batteries.

Standard Operating Procedure 5: Equipment Disinfection

Version 1.0

Change History for this Document

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1.0	11/20/2014	G. Moret	Original draft	

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1. Introduction

Field personnel have the potential to introduce and spread parasites and non-native organisms. Therefore, MOJN I&M personnel will sterilize equipment prior to sample collection.

MOJN I&M personnel will use the decontamination techniques developed by Michael Bower (Bower 2009) for the Devils Hole Ecosystem Monitoring Plan (Wilson et al. 2009). Bower (2009) states:

“As the golden rule, if there is any doubt about the potential contamination of a piece of equipment or its history of use in other aquatic ecosystems, avoid its use in Devils Hole until it can be properly decontaminated.”

This principle should be followed by personnel working at any of the springs in the MOJN parks.

2. Priority of Park Procedures

Some of the MOJN parks have disinfection procedures in place that vary from water body to water body, and may vary from year to year. These procedures take priority over the MOJN I&M disinfection procedures described below. In all cases, park staff should be consulted regarding the appropriate disinfection procedures. The procedures described below should be used when they are approved by the park or when the equipment is being moved between parks.

3. Difficult-to-Disinfect Equipment

Equipment that is difficult to disinfect properly, such as felt-soled waders, should not be used. If no substitute for difficult-to-disinfect equipment can be found, the protocol lead should research the best possible disinfection procedures and discuss them with park managers well ahead of the scheduled field work. At all times, MOJN personnel should remember that it is preferable to miss a monitoring cycle rather than risk introducing an invasive species to a spring.

Water quality sensors are a special case for disinfection because the pH and DO electrodes would be destroyed by the processes described in this SOP. The steps for disinfecting water quality instruments are as follows:

- Use quaternary ammonium and extended desiccation to disinfect the cable as described below.
- Before use, rinse the sensor probe three times with clean water (not spring water), taking care that ALL sediment, algae, etc. is washed away. Use a small soft brush if necessary. Capture the rinsate in a bottle and pack it out.
- To the extent possible, avoid fouling the sensor probe in sediment, algae, etc. during use.
- Immediately after use, rinse the sensor probe three times with clean water again.

4. Disinfection

[The following text is taken directly from Bower (2009), with minor changes in wording]

There are two steps to the decontamination procedure, an initial cleaning and chemical disinfection followed by a physical disinfection treatment. It should be noted that this protocol is only effective when BOTH steps are followed. Step One below will not suffice to decontaminate equipment. Several known threats, such as the red-rim melania (*Melanoides tuberculatus*), an exotic operculated snail, are extremely tolerant of chemical disinfectants (e.g. Mitchell et al. 2007) and will require one of the physical disinfection treatments described in Step Two for eradication. Conversely, the physical disinfection treatment options described in Step Two below are not effective against many potential pathogens. Both steps, in combination, are necessary to ensure adequate decontamination of equipment.

Following completion of Steps One and Two, equipment should be stored in a cool and dry central location where there is no potential for cross-contamination by equipment used in other aquatic ecosystems.

STEP ONE: Cleaning and Chemical Disinfection

Option 1. Quaternary ammonium detergent disinfectant

This technique includes the dual benefits of cleaning equipment of chemical residues and killing many pathogens that are intolerant of quaternary ammonium. This chemical has also been shown to kill NZ mudsnails in 5 min (Hosea and Finlayson 2005).

1. Dilute quaternary ammonium detergent disinfectant per label directions.
2. Using detergent, thoroughly wash all equipment surfaces, internal and external, making sure to remove all organic matter and soil that could retain contaminants, invasive organisms, or residual moisture.
3. Thoroughly rinse all equipment surfaces in fresh water.

STEP TWO: Physical Disinfection

Option 1. Extended desiccation

This option requires minimal effort and works equally well for sturdy field gear and sensitive electronic instruments. Thoroughly drying equipment should kill most aquatic organisms, though desiccation-resistant invasive species are well established in the area. For this reason, it is imperative that a THOROUGH drying of equipment be extended for a minimum of 14 d after complete drying prior to use in a spring.

1. Complete Step One.
2. Thoroughly rinse equipment and place in a well-ventilated and secure area.

3. Drying racks or hangers can help to speed the drying process.
4. Occasionally check equipment to see if internal surfaces, fabrics, or pores are drying or if they continue to retain moisture.
5. Where necessary, utilize drying aids such as fans and boot dryers to initially dry equipment.
6. Continue the desiccation treatment for 14 d following the complete drying of ALL surfaces.
7. If personnel are unable to document the complete drying of ALL equipment surfaces, internal and external, prior to and during the treatment, this technique should not be used.

Option 2. Freezing

This is a convenient technique for gear that is easily cleaned and can be subjected to freezing conditions without sustaining damage. Most aquatic organisms, particularly those living in thermal springs, are not tolerant of freezing conditions.

1. Complete Step One.
2. Thoroughly rinse all equipment and let drip dry.
3. Adjust temperature within the freezer to -10°C (14°F) prior to placement of equipment.
4. Maintain equipment in the freezer at -10°C (14°F) overnight.
5. If personnel are unable to document that air temperature reaches and maintains -10°C (14°F) overnight, this technique should not be used.

Option 3. Superheated water bath

This technique can be used to easily disinfect equipment that can be subjected to intense heat without sustaining damage.

1. Complete Step One.
2. Establish and maintain a 50°C (120°F) hot water bath. This can be accomplished in several ways, including use of a home water heater and bathtub, use of a metal trough and propane blaster, or use of a laboratory autoclave.
3. After a sufficient heating period, check water temperature with a mercury thermometer.
4. Place equipment into hot water bath for a minimum of one hour.
5. If personnel are unable to document that water temperature reaches and maintains 50°C (120°F), the technique should not be used.

Personal products and clothing

People that conduct field work and have mud or organic matter on their clothes and shoes have the potential to introduce exotic organisms to the monitored springs. Individuals entering the springs should be prepared to have clean clothes and footwear that have not been exposed to other aquatic environments. If the footwear has been exposed to other wetlands, it must be decontaminated using one of the above-mentioned techniques.

5. Literature Cited

- Bower, M. R. 2009. SOP VIII – Equipment use and decontamination. Version 1.0. in Wilson et al. 2009. Devils Hole Ecosystem Monitoring Plan. Death Valley National Park. Natural Resource Report NPS/DEVA/NRR—2009/001. National Park Service, Fort Collins, Colorado.
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- Mitchell, A. J., M. S. Hobbs, and T. M. Brandt. 2007. The effect of chemical treatments on red-rim melania *Melanoides tuberculata*, an exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA. *North American Journal of Fisheries Management* 27:1287-1293.
- Wilson, K. P., M. R. Bower, C. Gable, J. Back, G. Nelson, S. D. Hillyard, Z. L. Marshall, D. B. Gaines, and D. W. Blinn. 2009. Devils Hole Ecosystem Monitoring Plan. Death Valley National Park. Natural Resource Report NPS/DEVA/NRR—2009/001. National Park Service, Fort Collins, Colorado.

Standard Operating Procedure 6: Handheld Water Quality Instrument

Version 1.0

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1.0	11/20/2014	G. Moret	Original draft	

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1. Introduction

This document details the methods used to monitor water quality in all SLS springs in MOJN parks. The NPS Water Resources Division (WRD) requires four core water quality parameters at all freshwater monitoring sites. These parameters are dissolved oxygen, specific conductance, temperature, and pH. This SOP contains specific instruction on the use of MOJN I&M's handheld instrument, the YSI 556.

WRD requires that conductivity sensors be calibrated a minimum of once a day, while pH and DO sensors must be calibrated at each site, immediately prior to data collection. Temperature sensors do not need to be calibrated. However, their performance should be regularly compared to a separate NIST-traceable thermometer. It is common practice to calibrate instruments less frequently than described above for other programs. However, these protocols must be followed in order to collect credible data that could be defended in court or be used to detect long-term changes in water quality.

Water quality measurements at GRBA and DEVA will be collected by park staff using park instruments. While the specific instructions in this SOP are specific to MOJN I&M's instrument, the procedures outlined, particularly regarding frequency of calibration, should be followed in these parks as well.

2. Measurement Locations

The four core parameters (pH, temperature, DO, and specific conductance) must be collected at each site. The instruments actually measure electrical conductivity, and use a temperature correction algorithm to convert these values to specific conductance. Because these algorithms vary between instruments, the raw conductivity must be reported as well.

The measurement location for each spring is given in *SOP 3: Spring Locations and Spring-Specific Procedures*.

In general, three measurements should be taken to prevent the inclusion of outlier data. The measurements should be taken at least 60 seconds apart. The median value will be used for reporting and analysis, but all three values should be recorded on the field sheet.

3. YSI 556

MOJN I&M owns a YSI 556 MPS, an instrument that measures temperature, conductivity, pH, and DO. A diagram of the instrument is shown below (Figure 5.1). The YSI 556 MPS should be used for all measurements made at the springs. The manual for the YSI 556 MPS is included in the Supplementary Materials. The instructions below are taken from the manual.

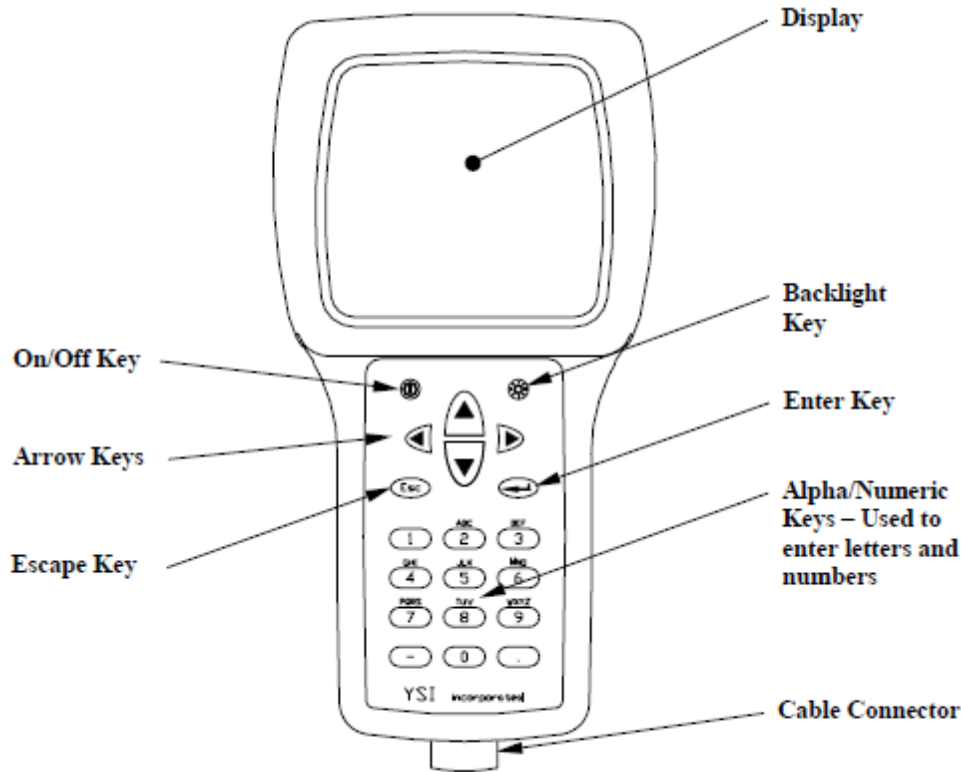


Figure 5.1. Diagram of a YSI 556. Image taken from the YSI 556 manual.

3.1. DO Calibration

Errors in DO calibration are common, so care should be taken to follow these instructions carefully. The objective of the procedure is to use water-saturated air as a calibration standard. However, the saturation point changes as a function of temperature and pressure. The multiprobe automatically corrects for temperature, and pressure is measured by a barometer built into the control unit. If the control unit is not available, pressure can be read from a handheld barometer.

1. Place the sensor in a calibration cup containing 3 mm (1/8 inch) of water. The intent of the procedure is to perform the measurement in water-saturated air, so the sensor should not be underwater. Loosely thread the calibration cup onto the probe housing, ensuring that the air pressure inside the cup is the same as the atmospheric pressure. Wait 10 minutes to allow the water and air in the cup to reach the ambient temperature and equilibrate.
2. From the main menu, select “Calibrate”. From the Calibrate Menu, select “ODOsat %,” then “1-point.” Accept the barometric pressure in mm of Hg displayed as the default option on the control unit (or enter a value read from a handheld barometer).
3. All of the enabled sensor readings will be displayed on the screen. Once the DO readings have been stable (defined by WRD as less than or equal to 0.3 mg/L of variation) for 30 seconds, accept the calibration by pressing “Enter.” It may take as long as 15 minutes for the readings to stabilize.

3.2. Specific Conductance (Conductivity) Calibration

The NPS WRD suggests that all freshwater conductivity measurements be made with instruments calibrated using 1413 $\mu\text{S}/\text{cm}$ conductivity standard.

1. Before a final calibration is performed, the sensors and calibration cup should be rinsed with water, dried, and then double-rinsed with small amounts of standard. Discard the rinsate.
2. Fill the calibration cup with approximately 200 mL of the calibration solution. Enough solution should be used to cover the vent hole on the side of the sensor. Allow one minute for the temperature to equilibrate.
3. From the main menu, select “Calibrate”. From the Calibrate Menu, select “Conductivity,” then “SpCond.” Enter the specific conductivity of the calibration solution.
4. All of the enabled sensor readings will be displayed on the screen. Once the specific conductivity readings have been stable for 30 seconds, accept the calibration by pressing “Enter.”

3.3. pH Calibration

Preliminary measurements of the pH of the springs in the protocol have generally been between 7 and 9. Therefore, a two-point pH calibration with pH 7 and pH 10 buffers is appropriate.

Note: If the response of the pH sensor appears to be slower than normal, then the sensor should be cleaned according to the instructions given in the manual.

1. Pour enough pH 7 buffers into the calibration to immerse the pH sensor (approximately 125 mL). Do not thread the cup onto the probe. Allow one minute for temperature to equilibrate.
2. Measure the temperature of the buffer in the cup using a digital thermometer. Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.
3. Thread the cup onto the probe. From the main menu, select “Calibrate”. From the Calibrate Menu, select “ISE1 pH,” then “2-point.” Enter the temperature-corrected pH.
4. All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the first point of the calibration by pressing “Enter.”
5. Rinse the sensor and calibration cup with pH 10 buffer. Discard the rinsate.
6. Pour enough pH 10 buffer into the calibration to immerse the pH sensor (approximately 125 mL). Do not thread the cup onto the probe. Allow one minute for temperature to equilibrate.
7. Measure the temperature of the buffer in the cup using a digital thermometer. Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.

8. Follow the instructions on the screen to continue the calibration. Enter the temperature-corrected pH of the buffer.
9. All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the calibration by pressing “Enter.”

3.4. Collecting Readings

After calibration, place the instrument in the water body, allowing it to equilibrate with the water for approximately 2 minutes. Select “Run” from the main menu, and record the readings once they have stabilized.

4. AMS+

As described in *SOP 13: Quality Assurance Project Plan (QAPP)*, Alternative Measurement Sensitivity Plus (AMS+) is a concept used to evaluate measurement precision in an ambient condition such as a well-mixed springbrook. It includes instrument noise and natural heterogeneity. AMS+ is calculated using:

$$AMS+ = t \times s,$$

where

s = sample standard deviation of 7 in-situ measurement values, and

t = 3.708, the 99% confidence middle (two-sided) t-value for a sample size of 7.

AMS+ does include some natural variability in water-quality parameters between the seven measurements, but it is intended primarily as a measurement of instrument precision rather than the variability of a particular water body. Therefore, it is not necessary to calculate separate AMS+ values for each site. Instead, the AMS+ for each instrument should be calculated once near the beginning of the field season and once near the end of the field season. The seven core parameter measurements should be made no more than approximately one minute apart, and recorded on the AMS+ field sheet (included in the Supplementary Materials).

AMS+ measurements will be made for MOJN I&M’s YSI 556 as part of the QA/QC procedures for the Streams and Lakes protocol. It is the responsibility of the protocol lead to ensure that AMS+ data is collected for any additional instruments used to collect Selected Large Springs protocol data.

Standard Operating Procedure 7: Spring Discharge Monitoring

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

This document details the methods used to monitor discharge in Selected Large Springs in the MOJN parks. Discharge will be monitored in three different ways: using stream gaging techniques, the volumetric method, and flumes. In addition, pool stage will be monitored at limnocrone springs with no springbrook. At some springs discharge will be measured continuously using data-logging pressure transducers, while at others quarterly measurements will be made.

2. Overview

Discharge will be monitored on a quarterly basis unless park staff choose to make measurements more frequently, as at DEVA. Measurements will be made in late February/Early March, late May/Early June, late August/early September, and late November/Early October. Due the phased implementation of this protocol, it is possible that not all of these springs will be sampled in 2011 and 2012.

The monitoring methods for each spring are summarized in Table 7.1.

Table 7.1. Discharge monitoring overview for selected large springs.

Park	Spring	Method	Crew	Pressure transducer installed?
DEVA	Travertine	flume	DEVA	yes
	Texas	flume	DEVA	Yes
	Nevaras	flume	DEVA	Yes
	Saratoga	Pool stage	DEVA	yes
	Grapevine	flume	DEVA	yes
GRBA	Strawberry Source	Portable flume	GRBA	no
	Boiler	flowmeter	GRBA	no
	Marmot	Volumetric	GRBA	no
JOTR	49 Palms	Open water area	MOJN I&M	no
	Smith Water Canyon	Springbrook length	MOJN I&M	no
LAKE	Blue Point	weir	MOJN I&M	yes
	Rogers Spring	flume	USGS	yes
MOJA	MC Spring	Pool Stage	MOJN I&M	yes
PARA	Pakoon	TBD ¹	MOJN I&M	TBD
	Tassi	Portable flume	MOJN I&M	No

TBD = to be determined once spring rehabilitation is complete.

2.1. Discharge Measurements at DEVA Springs

As of 2015, the DEVA hydrology staff is working with the NPS Water Rights Branch to monitor discharge at Texas Springs, Travertine Springs, and Nevares Springs. MOJN I&M will not be involved in monitoring or analyzing data from those springs unless the park requests it.

2.2. USGS Stream Gages

When the USGS is monitoring one of the Selected Large Springs (e.g., Rogers Spring at LAKE), MOJN I&M will not monitor discharge at the site.

3. Pressure Transducers

Data logging pressure transducers are installed at many of the monitored springs to record stage (Table 7.1). As of 2015, MOJN I&M uses WL-16 vented pressure transducers manufactured by Global Water Inc. The following instructions describe how they should be maintained.

1. Take a staff gage reading. Record the time of the reading.
2. Turn on the field computer. Connect the computer to the pressure transducer using a type A-to-type B USB cable. Click on the “Global Logger II” icon to start the program.
3. Choose direct connection to a Global Water USB device. Click “Connect”.
4. Click “Get Sample”. Record the pressure transducer reading and the time.
5. Record a second staff gage reading as close as possible to the time of the pressure transducer reading. Record the time.
6. Repeat steps 4 and 5 two additional times, with the readings separated by at least three minutes.
7. Click “Get history”. Quickly inspect the resulting list of numbers for obvious problems (missing data, etc.), then click “save to comma-separated values file”. Save the file on the desktop of the field computer with a file name including the spring name and the date (e.g. “BluePoint09-26-14.csv”).
8. Save a copy of the .csv file on a thumb drive. This back-up step should be performed in the field to minimize the chance that data is lost.
9. Replace the two 9 V batteries if the battery voltage is less than 15 V or after six months. Make a note on the field form if the batteries are replaced.
10. Click ‘Clear History’ and exit the program.

4. Volumetric Method

The volumetric method consists of measuring the time required for a spring’s discharge to fill a container of known volume. The discharge is then calculated by dividing the container’s volume by

the time needed to fill it. The method below is taken from Turnipseed and Sauer (2010), who describe the volumetric method as “the most accurate method of measuring small discharges.”

1. Choose a location near the spring source to make the measurement. If there is a location where all of the spring’s flow can be captured in a container without channel modification, proceed to the next step. Otherwise, build a temporary earthen dam to channel the entire springflow through a section of pipe. The location and building materials should be chosen to minimize the transport of sediment downstream.
2. Use a stopwatch to record the length of time taken to fill a container of known volume, such as a 1 L flask or a 5 gallon bucket. In general, timing will be accurate to within 1 second, so times of less than 10 seconds should be avoided by using a larger container. Record the times and the volumes for three measurements if the times are 20 seconds or longer and five measurements if the times are less than 20 seconds.
3. Carefully remove the dam (if used) from the springbrook, taking care to minimize the sediment released downstream.

5. Permanent Flumes and Weirs

The use of flumes and weirs to measure discharge is discussed extensively in Kilpatrick and Schneider (1983). The flumes installed at the springs monitored in this protocol are Parshall flumes with 1-, 2-, or 3-inch throats. The details of the staff gages, chart recorders, and pressure transducers installed at each site are discussed in *SOP 3: Spring Locations and Spring Specific Procedures*. The general steps for monitoring discharge at a flumes and weirs are as follows:

1. Ensure that the flume or weir is free of debris, and that water from the downstream portion of the channel is not backing up into the flume. If water is backing up, then clear the downstream channel of debris, or arrange to have the outlet pipe cleared, if applicable.
2. Collect three readings of all staff gages and the pressure transducer separated by 3 minutes.

6. Portable Flumes

Portable flumes should be positioned in such a way that:

- they capture the entire discharge of the spring,
- they are level, and
- water spills from their downstream ends instead of backing up.

Figure 7.1 shows a portable flume being used in the field. Once the flume is in position, wait for 30 minutes to ensure that water levels have stabilized. After the waiting period, the staff gage should be read three times.



Figure 7.1. Portable flume deployed at Burro Spring in LAKE. Photo by G. Karst.

7. Pool Stage

Pool stage is measured using a staff gage. Record at least three readings each site visit, read to the nearest thousandth of a foot.

8. Flowmeter

Boiler Spring at GRBA is gaged using standard USGS methods for streams to ensure comparability with data collected as part of the MOJN I&M Streams and Lakes protocol. The SOP for this work is *SOP 9: Stream Discharge* (Moret et al. 2012). The MOJN I&M Streams and Lakes protocol lead should be consulted to obtain a copy of the most up-to-date version of the SOP.

9. Open Water Area

The total open water area at Fortynine Palms Oasis in JOTR will be estimated using the method described by the Nova Scotia Environment Vernal Pool Mapping and Monitoring Project (<http://www.novascotia.ca/nse/wetland/vernal.pool.mapping.project.asp>, accessed 12 September 2014).

1. Find the furthest upstream pool. Record the UTM (11N NAD83) coordinates of this pool as determined using a GPS unit.

2. Measure and record the maximum length and width of the pool using a measuring tape. Draw the pool to scale on graph paper, with additional measurements made as needed to ensure that the total area is accurate to within 10% or 1 m², whichever is greater.
3. Repeat steps 1 and 2 at the other pools in the oasis.
4. Record the UTM (11N NAD83) coordinates of the furthest downstream pool as determined using a GPS unit.

10. Springbrook Length

Springbrook length is used to monitor water availability at a series of spring outlets in Smith Water Canyon.

1. For each spring, record whether surface water is present.
2. If surface water is present, measure the length of the wetted channel to the nearest 0.5 m using a measuring tape.
3. Repeat steps 1 and 2 for all spring outlets.

11. Literature Cited

- Kilpatrick, F. A., and V. R. Schneider. 1983. Use of flumes in measuring discharge: Techniques of water-resources investigations of the United States Geological Survey. Book 3: Applications of Hydraulics, Chapter A14. U.S. Geological Survey, Reston, Virginia.
- Moret, G. J. M., C. C. Caudill, and J. Burke. 2012. Mojave Desert Network Inventory and Monitoring streams and lakes protocol: standard operating procedures and supplementary materials version 1.0. Natural Resource Report NPS/MOJN/NRR—2012/593.1. National Park Service, Fort Collins, Colorado.
- Turnipseed, D. P., and V. B. Sauer. 2010. Discharge measurements at gaging stations. U.S. Geological Survey Techniques and Methods 3-A8. U.S. Geological Survey, Washington, D.C.

Standard Operating Procedure 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

This document details the methods used to collect water samples, collect benthic macroinvertebrate (BMI) samples, and monitor springsnail populations in selected springs in the MOJN parks. Water samples will be collected from all springs monitored in this protocol. BMI samples will be collected from all springs but Rogers Spring (a highly disturbed ecosystem) and MC Spring (a very small pool that is a critical habitat for the Mohave Chub). Springsnails will be monitored in those springs with extant springsnail populations: Nevares Springs, Texas Springs, Travertine Springs, Saratoga Spring, and Grapevine Springs in DEVA, Blue Point Spring in LAKE, and Tassi Spring in PARA.

2. Schedule

Water and BMI sample collection and springsnail monitoring for each spring will be carried out every two years in late March or early April in all of the parks but GRBA, where the springs will be visited in late August or early September to be consistent with BMI samples collected as part of the Streams and Lakes protocol (Caudill et al 2012), and DEVA, where the springs will be visited in February to avoid inclement weather conditions. Beginning in 2015, springs will be sampled on the following rotation:

Odd years: DEVA, PARA, and LAKE

Even years: GRBA, JOTR, and MOJA.

3. Spring Visit Procedures

On the biennial visits described in this protocol, activities should be carried out in the following order:

1. Staff gage reading or water depth measurement and data logger download (at continuously monitored sites), described in *SOP 7: Spring Discharge Monitoring*.
2. Site photos and GPS readings at source and end of springbrook.
3. Water sample collection, described in this SOP.
4. Water quality measurements, described in *SOP 6: Handheld Water Quality Instrument*.
5. Downstream BMI sample collection and springsnail monitoring, described in this SOP.
6. Spring source BMI sample collection and springsnail monitoring (when necessary), described in this SOP.
7. Volumetric or temporary flume discharge measurements (at quarterly discharge monitoring sites) or stream gaging at Rowland Spring, described in *SOP 7: Spring Discharge Monitoring*.

4. Water Sample Collection

Water samples will be collected at all springs on the biennial schedule described in Section 2. The testing laboratory should be consulted for the amount and type (filtered or unfiltered) of sample required and the preservation methods required. At this time, it is anticipated that one 1 L bottle of unfiltered sample should be collected. Don new latex or other clean, waterproof disposable gloves at each sampling site to minimize cross-contamination. Uncap the sample bottle (washed appropriately, provided by the laboratory), and fill it by dipping it in the spring as near to the source as is feasible. Do not stir up bottom sediment during sample collection. In springbrooks that are shallower than the diameter of the sample bottle, it may be necessary to use a second clean sample bottle to fill the sample bottle. This second sample bottle should only be used at one site to avoid cross-contamination.

5. BMI Sampling

Sampling benthic macroinvertebrates is challenging in springs and requires varying methods that are suitable for the various spring types and microhabitats present within springs. The specific methods and spring reaches chosen for each spring were based on pilot testing and site visits.

Special Note: There is a “toe biter” (belostomon) bug in Saratoga Spring that can take bites of flesh from bare feet. Closed-toe shoes should always be worn in Saratoga Spring.

5.1. Spring-Specific Instructions

BMI samples will be collected biennially in all of the monitored springs except MC Spring. Rogers Spring is highly disturbed and heavily used for recreation, while MC Spring is very small, and one of the only Mohave Chub habitats in existence. The methods that will be used in the other 13 springs are given in Table 8.1, below.

Table 8.1. BMI sampling overview for selected large springs.

Park	Spring	Sample	Method	Sampling Reach	Quadrat Size	Total Sample Area
DEVA	Travertine	Travertine No. 1 Source	Channel	Source to 60 m (base of mound), 10 m spacing (7 quadrats)	10 cm x 10 cm	0.07m ²
		Travertine No. 1 Downstream	Channel	90 m to road, 30 m spacing (11 quadrats)	10 cm x 10 cm	0.11 m ²
		Travertine No. 2	Channel	Source to end of surface water, 10 m spacing (13 quadrats)	10 cm x 10 cm	0.13 m ²
	Texas	Texas	Channel	Source to 100 m, 10 m spacing (11 quadrats)	10 cm x 10 cm	0.11 m ²
	Nevares	Nevares Source	Channel (x3)	Source to end of marshy area along each of three channels, 5 m spacing (13 quadrats)	10 cm x 10 cm	0.13 m ²
		Nevares Downstream	Channel	Base of mound to 300 m further downstream, 30 m spacing (11 quadrats)	10 cm x 10 cm	0.11 m ²
	Saratoga	Saratoga Source	Large Pool	N/A	15 cm net	N/A
		Saratoga Channel	Channel	Source pool to near downstream pools, 10 m spacing (21 quadrats)	10 cm x 10 cm	0.21 m ²
	Grapevine	Saratoga Pools	Large Pool (x3)	N/A	30 cm kicknet	N/A
		TBD ¹	TBD	TBD	TBD	TBD
GRBA	Strawberry Source	Strawberry Source	EMAP	Source to 100 m, 10 m spacing (11 quadrats)	30 cm x 30 cm	0.99 m ²
	Boiler	Boiler	EMAP	Source to 100 m, 10 m spacing (11 quadrats)	30 cm x 30 cm	0.99 m ²
	Marmot	Marmot	Channel	Source to 10 m 1 m spacing (11 quadrats)	30 cm x 30 cm	0.99 m ²
JOTR	49 Palms	49 Palms	Multi-Pool Grab	N/A	N/A	N/A
	Smith Water Canyon	Smith Water Canyon	Multi-Pool Grab	N/A	N/A	N/A
LAKE	Blue Point	Blue Point Source	Channel	Source to weir, 1 m spacing (11 quadrats)	10 cm x 10 cm	0.11 m ²
		Blue Point Downstream	Channel	Weir to road, 20 m spacing (20 quadrats)	10 cm x 10 cm	0.20 m ²
PARA	Pakoon	TBD	TBD	TBD	TBD	TBD
	Tassi	Tassi	Channel	Source to breach in canal wall, 10 m spacing (8 quadrats)	10 cm x 10 cm	0.08 m ²

¹ TBD = to be determined once spring is visited (Grapevine) or spring rehabilitation is complete (Pakoon).

5.2. Combining BMI Sampling with Springsnail Monitoring

The protocol does not require that the BMI sampling occurs concurrently with the springsnail monitoring. However, at most springs with springsnails, it will be most efficient to combine the two procedures.

When the procedures are combined, the BMI sample should be collected using the methods described below. The quadrat for springsnail monitoring should then be placed a few centimeters upstream from location of the BMI quadrat. The random “left center right” positions of the quadrats (discussed below) should be separately assigned for each monitoring procedure.

5.3. Equipment

NOTE: Ensure all equipment meets the decontamination standards in SOP 5: *Equipment Disinfection*. We would rather miss a sample than bring a new invasive species to a spring!

- 500 µm mesh D-frame net and 1 spare (30 cm or 15 cm, depending on quadrat size)
- 10 cm x 10 cm quadrat (if needed)
- Digital watch with readout for seconds
- Bucket
- Sieve with 500 µm mesh
- Wash bottle
- Watchmakers’ forceps
- Sample jars, HDPE plastic with screw caps, 1-L capacity, suitable for use with ethanol. Two jars per sample plus a spare.
- 95% ethanol, in a proper container (2 gal)
- Rubber gloves (optional)
- Cooler for transporting ethanol and samples
- BMI sampling data sheet
- Ruler, marked in millimeters
- Pencil

5.4. Channel Sampling

[Adapted from Section 10 of the EMAP Wadeable Streams Protocols (Peck et al., 2006)]

1. Lay out a tape along the sampling reach. For reaches greater than 100 m in length, lay out the first 100 m of tape, and move the tape as required.
2. Begin at the downstream end of the reach. The assigned sampling points (left, center, or right as you face downstream) are at 25%, 50%, or 75% of the wetted width, respectively. Check the digital watch, and use the last digit of the recorded time (in seconds) to determine

whether the sample will be collected at the left, center, or right of the spring (1-3=L, 4-6=C, 7-9=R, 0 = check again).

3. Use a 30-cm wide D net for springs with 30 cm x 30 cm quadrats or a 15-cm wide net for small springs with 10 cm x 10 cm quadrats (Table 8.1).
 - a. For vegetation-choked sampling points, sweep the net back and forth through the vegetation within the quadrat for 30 seconds.
 - b. For sampling points with flowing water (sufficient current to fully extend the net), visually define the quadrat using a quadrat frame. Place the net at the downstream end of the quadrat. Pick up any loose rocks or other larger substrate particles in the quadrat. Use your hands or a small scrub brush to dislodge organisms so that they are washed into the net. Holding the net firmly against the streambed, use your feet (for 30 cm x 30 cm quadrats) or your fingers (for 10 cm x 10 cm quadrats) to vigorously agitate the upper 4 to 5 cm (1.5 to 2 inches) of the remaining finer substrate within the quadrat for 30 seconds (use a stopwatch). Avoid going too deep into the substrate; the aim is to dislodge organisms on or just under the substrate surface.
 - c. For sampling points with slack water (insufficient current fully to extend the net), follow the procedures for flowing water described above, but keep the net moving to prevent organisms from escaping.
4. Invert the net into a plastic bucket and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the bucket. Use a squirt bottle and watchmakers' forceps if necessary to remove organisms from the net. Replace the lid on the bucket.
5. Determine the predominant substrate type you observed in the sampling quadrat. Place an "X" in the appropriate substrate type box for the transect on the Sample Collection Form. Use a ruler to determine characteristic sediment size if necessary.

NOTE: If there are co-dominant substrate types, you may check more than one box; note the co-dominants on the Comments section of the form.

Fine: not gritty (silt/clay/muck < 0.06 mm diam.) to gritty,

Sand: up to ladybug sized (2 mm diam.)

Gravel: fine to coarse gravel (ladybug to tennis ball sized; 2 mm to 64 mm diam.)

Coarse: Cobble to boulder (tennis ball to car sized; 64 mm to 4000 mm)

Plant matter: aquatic vegetation, decaying plant matter, wood

Algae: algae, note color in notes

Travertine: travertine-armored channel

Other: bedrock (larger than car sized; > 4000 mm), hardpan (firm, consolidated fine substrate), etc. Note type of "other" substrate in comments on field form.

6. Identify the habitat type where the sampling quadrant was located. Place an “X” in the appropriate channel habitat type box for the quadrat on the Sample Collection Form.

Pool: Still water; low velocity; with smooth, glassy surface; usually deep compared to other parts of the channel.

GLide: Water moving slowly with smooth unbroken surface; low turbulence.

RIffle: Water moving with small ripples waves, and eddies; waves not breaking, and surface tension is not broken; “babbling” or “gurgling” sound.

RApid: Water movement is rapid and turbulent; surface with intermittent “white water” with breaking waves; continuous rushing sound.

7. Identify the degree of shade at the sample quadrat. Place an “X” in the appropriate channel habitat type box for the quadrat on the Sample Collection Form.

Full: completely shaded

Partial: partially shaded

None: no shade

8. Working upstream, repeat Steps 3 through 7 at the other quadrat locations, with spacing and locations as specified in Table 8.1. Combine all samples in the bucket.
9. Pour off the water from the bucket through a sieve (or sieve bucket) with 500 μm mesh size. Carefully inspect any large objects (such as rocks, sticks, and leaves) in the bucket and wash any organisms found off of the objects and into the bucket before returning the objects to the water. Remove as much detritus as possible without losing any organisms.
10. Wash the contents of the bucket to one side. Transfer the sample from the bucket into a jar, using a large-bore funnel if necessary. Use as little water from the wash bottle as possible to help transfer the material. If the jar becomes too full of liquid, carefully pour off some water through the sieve. Continue to transfer sample material to the jar until it is not more than $\frac{1}{4}$ full of solid material. Use additional jars for the remaining sample. Carefully examine the bucket for any remaining organisms place them into the sample jar.
11. Label the bottle using a pencil and a label sticker. Include the following information:
 - Date of collection
 - Sample name (e.g. “Travertine No. 1 SOURCE”)
 - Name of spring
 - Sample number, if necessary to distinguish multiple samples from the same spring
12. Remove as much water as you can from each sample jar without including any sample material by pouring it through a sieve. Completely fill the jar with 95% ethanol (no headspace) so that the final concentration of ethanol is between 75 and 90%. It is very important that sufficient ethanol be used, or the organisms will not be properly preserved.

NOTE: Prepared composite samples can be transported back to the vehicle before adding ethanol if necessary. Fill each jar with stream water to cushion the organisms from the grinding action of non-biological material in the sample. Replace the water with ethanol at the vehicle.

13. Replace the lid on the jar. Slowly tip the jar to a horizontal position, then gently rotate the jar to mix the preservative. Do not invert or shake the jar. After mixing, seal the jar with electrical tape.
14. Store labeled sample jars in a container with absorbent material that is suitable for use with 95% ethanol until transport or shipment to the laboratory. Shipping is discussed in *SOP 10: Sample Handling*.

5.5. EMAP Sampling

The BMI samples from two springs in GRBA will be collected in accordance with the EPA EMAP protocol (Peck et al., 2006) to ensure comparability with samples collected from GRBA streams as part of the MOJN Streams and Lakes protocol. The SOPs from the Streams and Lakes protocol (Moret et al. 2012) should be followed when collecting these samples.

5.6. Shallow Pool Sampling

The method below is a hybrid of the Large Pool Sampling method and the Multi-Pool Grab Sampling method.

1. Locate the furthest downstream pool. Visually define a 10 cm x 10 cm quadrat (see Table 8.1; a quadrat frame may be used). Place the 15-cm wide kicknet at one end of the quadrat. Pick up any loose rocks or other larger substrate particles in the quadrat. Use your hands or a small scrub brush to dislodge organisms so that they are washed into the net. Holding the net firmly against the streambed, use your hands or the brush to vigorously agitate the upper 4 to 5 cm (1.5 to 2 inches) of the remaining finer substrate within the quadrat for 30 seconds (use a watch). Avoid going too deep into the substrate; the aim is to dislodge organisms on or just under the substrate surface. Keep the net moving at all times to prevent organisms from escaping.
2. Invert the net into a jar and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the jar. Use a squirt bottle and watchmakers' forceps if necessary to remove organisms from the net.
3. Replace the lid on the jar. Clean the net thoroughly.
4. Repeat steps 1 to 3 at four more sampling points spaced evenly throughout the pool. The locations of the sampling points can be estimated visually. Any large or rare macroinvertebrates observed in the pool should be collected as well. Combine all five samples into one composite jar.
5. Repeat steps 1 to 4 at each of the pools in the spring, working upstream. Each pool will have five samples combined into its own composite jar.

6. Label the bottle using a pencil and a label sticker. Include the following information:
 - Name of spring (e.g. “Mound Spring)
 - Sample location (e.g. “Palm Cluster 2”)
 - Sample number (if necessary to distinguish multiple samples from the same location)
 - Date of collection
7. Decant as much water as you can from each jar without removing any sample material. Completely fill the jar with 95% ethanol (no headspace) so that the final concentration of ethanol is between 75 and 90%. It is very important that sufficient ethanol be used, or the organisms will not be properly preserved.

NOTE: Prepared composite jars can be transported back to the vehicle before adding ethanol if necessary. Fill each jar with stream water to cushion the organisms from the grinding action of non-biological material in the sample. Replace the water with ethanol at the vehicle.

8. Replace the lid on the jar. Slowly tip the jar to a horizontal position, then gently rotate the jar to mix the preservative. Do not invert or shake the jar. After mixing, seal the jar with plastic tape.
9. Store labeled sample jars in a container with absorbent material that is suitable for use with 95% ethanol until transport or shipment to the laboratory. Shipping is discussed in *SOP 10: Sample Handling*.

5.7. Large Pool Sampling

The method below is loosely based on the methods developed by the National Aquatic Monitoring Center (NAMC) for the Western Lake Survey Project (NAMC 2006).

1. Locate the northernmost point of the pool. This will be the first sampling point. Locate the nearest patch of emergent vegetation in the pool (if the nearest patch of emergent vegetation is more than halfway to the next sampling point, then do not collect a sample and record it on the field sheet). Collect a 1 m sweep sample with a 30-cm wide D net (note the 30 cm kicknet is used for emergent vegetation regardless of quadrat size). Make three passes with the net along a 1 m line parallel to the pool’s edge, shaking the vegetation vigorously. The net should touch the bottom without digging deeply into the substrate. Between the second and third passes, scrape the vegetation by hand to dislodge more organisms. Keep the net moving at all times to prevent organisms from escaping.
2. Invert the net into a plastic bucket and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the bucket. Use a squirt bottle and watchmakers’ forceps if necessary to remove organisms from the net. Carefully inspect any large objects (such as rocks, sticks, and leaves) in the bucket and wash any organisms found off of the objects and into the bucket before discarding the object. Remove as much detritus as possible without losing any organisms. Replace the lid on the bucket. Clean the net thoroughly.

3. Locate the nearest patch of open water in the pool (if the nearest patch of emergent vegetation is more than halfway to the next sampling point, then do not collect a sample and record it on the field sheet). Visually define a 30 cm x 30 cm or 10 cm x 10 cm quadrat (see Table 8.1; a quadrat frame may be used). Place the net at one end of the quadrat. Pick up any loose rocks or other larger substrate particles in the quadrat. Use your hands or a small scrub brush to dislodge organisms so that they are washed into the net. Holding the net firmly against the streambed, use your feet (for 30 cm x 30 cm quadrats) or your fingers (for 10 cm x 10 cm quadrats) to vigorously agitate the upper 4 to 5 cm (1.5 to 2 inches) of the remaining finer substrate within the quadrat for 30 seconds (use a stopwatch). Avoid going too deep into the substrate; the aim is to dislodge organisms on or just under the substrate surface. Keep the net moving at all times to prevent organisms from escaping.
4. Invert the net into the bucket and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the bucket. Use a squirt bottle to remove organisms from the net. Carefully inspect any large objects (such as rocks, sticks, and leaves) in the bucket and wash any organisms found off of the objects and into the bucket before discarding the object. Remove as much detritus as possible without losing any organisms. Replace the lid on the bucket. Clean the net thoroughly.
5. Repeat steps 1 to 4 at nine more sampling points spaced equally around the circumference of the pool. The locations of the sampling points can be estimated visually, but they should not be moved to allow for ease of access.
6. Pour off the water from the bucket through a sieve with 500 µm mesh size. Remove any large objects such as sticks, rocks, or plant material from the bucket. Inspect these objects carefully and dislodge any clinging organisms back into the bucket before discarding.
7. Wash the contents of the bucket to one side. Transfer the sample from the bucket into a jar, using a large-bore funnel if necessary. Use as little water from the wash bottle as possible to help transfer the material. If the jar becomes too full of liquid, carefully pour off some water through the sieve. Continue to transfer sample material to the jar until it is not more than ¼ full of solid material. Use additional jars for the remaining sample. Carefully examine the bucket for any remaining organisms and use watchmakers' forceps to place them into the sample jar.
8. Label the bottle using a pencil and a label sticker. Include the following information:
 - Date of collection
 - Sample name (e.g. "Saratoga Spring Downstream Pool")
 - Name of spring
 - Sample number, if necessary to distinguish multiple samples from the same spring
9. Remove as much water as you can from each sample jar without including any sample material by pouring it through a sieve. Completely fill the jar with 95% ethanol (no

headspace) so that the final concentration of ethanol is between 75 and 90%. It is very important that sufficient ethanol be used, or the organisms will not be properly preserved.

NOTE: Prepared composite samples can be transported back to the vehicle before adding ethanol if necessary. Fill each jar with stream water to cushion the organisms from the grinding action of non-biological material in the sample. Replace the water with ethanol at the vehicle.

10. Replace the lid on the jar. Slowly tip the jar to a horizontal position, then gently rotate the jar to mix the preservative. Do not invert or shake the jar. After mixing, seal the jar with plastic tape.
11. Store labeled sample jars in a container with absorbent material that is suitable for use with 95% ethanol until transport or shipment to the laboratory. Shipping is discussed in *SOP 10: Sample Handling*.

5.8. Multi-Pool Grab Sampling

The multi-pool grab sampling method is not intended to produce quantitative data, but rather a snapshot of the macroinvertebrates present in a series of pools at a spring.

1. Locate the furthest downstream pool. Visually define a 10 cm x 10 cm quadrat (see Table 8.1; a quadrat frame may be used). Place the net at one end of the quadrat. Pick up any loose rocks or other larger substrate particles in the quadrat. Use your hands or a small scrub brush to dislodge organisms so that they are washed into the net. Holding the net firmly against the streambed, use a small brush to vigorously agitate the upper 4 to 5 cm (1.5 to 2 inches) of the remaining finer substrate within the quadrat for 30 seconds (use a watch). Avoid going too deep into the substrate; the aim is to dislodge organisms on or just under the substrate surface. Keep the net moving at all times to prevent organisms from escaping.
2. Invert the net into a plastic bucket and transfer the sample. Inspect the net for any residual organisms clinging to the net and deposit them into the bucket. Use a squirt bottle and watchmakers' forceps if necessary to remove organisms from the net. Carefully inspect any large objects (such as rocks, sticks, and leaves) in the bucket and wash any organisms found off of the objects and into the bucket before discarding the object. Remove as much detritus as possible without losing any organisms. Replace the lid on the bucket. Clean the net thoroughly.
3. Repeat steps 1 and 2 at two more quadrats in the pool. Generally, one quadrat should be placed in each third of the pool's area, but an attempt should be made to sample different substrates, if they are present. Any large or rare macroinvertebrates observed in the pool should be collected as well.
4. Repeat steps 1 to 3 at each of the pools in the spring, working upstream.

5. Pour off the water from the bucket through a sieve with 500 µm mesh size. Remove any large objects such as sticks, rocks, or plant material from the bucket. Inspect these objects carefully and dislodge any clinging organisms back into the bucket before discarding.
6. Wash the contents of the bucket to one side. Transfer the sample from the bucket into a jar, using a large-bore funnel if necessary. Use as little water from the wash bottle as possible to help transfer the material. If the jar becomes too full of liquid, carefully pour off some water through the sieve. Continue to transfer sample material to the jar until it is not more than ¼ full of solid material. Use additional jars for the remaining sample. Carefully examine the bucket for any remaining organisms and use watchmakers' forceps to place them into the sample jar.
7. Label the bottle using a pencil and a label sticker. Include the following information:
 - Date of collection
 - Sample name (e.g. "Smithwater Falls Multi-Pool Grab Sample")
 - Name of spring
 - Sample number, if necessary to distinguish multiple samples from the same spring
8. Remove as much water as you can from each sample jar without including any sample material by pouring it through a sieve. Completely fill the jar with 95% ethanol (no headspace) so that the final concentration of ethanol is between 75 and 90%. It is very important that sufficient ethanol be used, or the organisms will not be properly preserved.

NOTE: Prepared composite samples can be transported back to the vehicle before adding ethanol if necessary. Fill each jar with stream water to cushion the organisms from the grinding action of non-biological material in the sample. Replace the water with ethanol at the vehicle.
9. Replace the lid on the jar. Slowly tip the jar to a horizontal position, then gently rotate the jar to mix the preservative. Do not invert or shake the jar. After mixing, seal the jar with plastic tape.
10. Store labeled sample jars in a container with absorbent material that is suitable for use with 95% ethanol until transport or shipment to the laboratory. Shipping is discussed in *SOP 10: Sample Handling*.

6. Springsnail Monitoring

[Monitoring methods adapted from Sada (2009)]

Springsnails will be monitored in those springs with extant springsnail populations: Grapevine, Texas, Travertine, Nevares, and Saratoga in DEVA, Blue Point in LAKE, and Tassi in PARA. The monitoring method is based on Method I as described by Sada (2009).

Table 8.2. Springsnail monitoring method.

Park	Spring	Reach*	Spacing	Special Cases
DEVA	Grapevine	TBD	TBD	TBD
	Texas	Source to 40 m downstream	5 m	
	Travertine	Travertine No. 1: source to road Travertine No. 2: Patch near source	Travertine No. 1: 10 m from source to base of spring mound, 30 m further downstream	Travertine No. 2: One quadrat in patch near source
	Nevares	Three channels on spring mound	5 m	
	Saratoga	Source pool to downstream pond	10 m	5 quadrats in source pool
LAKE	Blue Point	Source to weir	1 m	Check for presence of Tryonia
PARA	Tassi	Source to breach in canal wall.	10 m	

*As described in the SOP, the reach where springsnails are present is determined in the field during each visit- the extent of the population is one of the parameters being monitored. The protocol descriptions in this table are meant as a rough guide.

6.1. Monitoring Method

1. Determine the extent of the springsnail population. Collect small grab samples of substrate, and work them through a kitchen sieve with a ~1 mm mesh, which will retain snails but allow most sediment to pass through. Transfer the snails from the sieve to a shallow tray containing ~1 cm of spring water (the collecting tray). A hand lens or magnifying glass may be useful in distinguishing the snails from small rocks. Locate the furthest downstream extent of the springsnail population, and record GPS coordinates for that location. This will be the end point for the snail survey.
2. Stretch a measuring tape along the springbrook from the source to the end point, and record the distance. Monitoring points will be established at the source, the endpoint, and at points between, with the spacing between points specified in Table 8.2.
3. Beginning at the end point and working upstream, assess the snail population at each monitoring. At each monitoring point, three quadrats, left, center, and right as you face downstream at 25%, 50%, or 75% of the wetted width, respectively, will be assessed. Place a metal 10 cm x 10 cm quadrat frame on the bed of the springbrook to visually define each quadrat. Suspend the substrate within the quadrat into the sieve, and work the sediment through the sieve. Transfer the snails to a second shallow tray of spring water (the counting tray) and count them, recording the number in each quadrat on the field sheet. After the snails have been counted, return them to the stream.

6.2. Special Cases for Springsnail Monitoring

As of Spring 2014, only one small patch (less than 1 m²) of springsnails have been observed in Travertine No. 2. This population should be monitored by counting the snails present in a single

quadrat near the center of the patch. If the extent of the population expands, the standard monitoring method should be used.

The source pool of Saratoga Spring is approximately 1 m deep, and has a very high springsnail density. Five 10 cm x 10 cm quadrats should be monitored on the pool bottom, and underwater photography should be used to assess qualitative changes (e.g., Figure 8.1). A long-handled scoop should be used to bring the sediment within the quadrat to the surface. **AT NO TIME SHOULD THE MONITORING CREW SUBMERGE THEIR HEADS IN THIS OR ANY SPRING.**

The *Tryonia* springsnail at Blue Point Spring inhabits a series of muddy pools on either side of the main channel below the weir. The springsnails are present at a low density, and the pools are also habitat for *Rana onca*, so systematic monitoring is not feasible. Instead, the monitoring crew should attempt to document the presence of the species in the spring during each monitoring event.

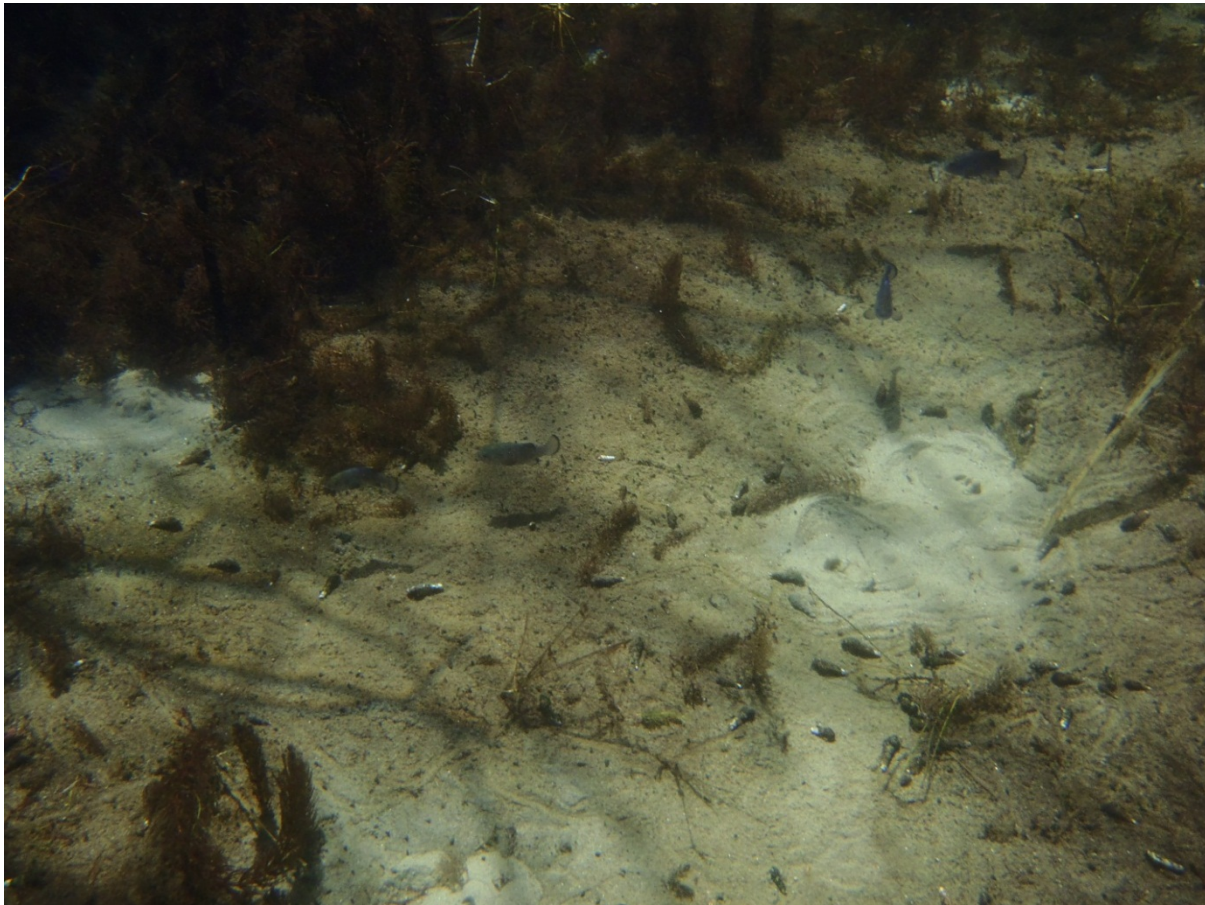


Figure 8.1. Underwater photograph of the source pool in Saratoga Spring.

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Standard Operating Procedure 9: Monitoring Water Levels in Wells

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

This document details the method used to monitor water levels in wells. Water levels will be measured using two standard methods: the steel tape method and the electrical tape method.

2. Wells to Be Monitored

The two wells included in this protocol are the Rogers Bay Well in LAKE and the Baker Creek Road Well in GRBA (Table 9.1). The Baker Creek Road Well contains a cluster of three monitoring wells. The method for a given well may be changed if large changes in groundwater level make the current method infeasible.

Table 9.1. Wells included in the MOJN I&M SLS protocol.

Park	Well	Method
LAKE	Rogers Bay Well	Steel Tape
	Baker Creek Road Well	Well 1 Electronic Tape
		Well 2 Electronic Tape
		Well 3 Electronic Tape

3. Steel Tape Method

[The following section is derived from USGS GWPD 1 (Cunningham and Schalk 2011)]

1. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk. A wetted chalk mark will identify that part of the tape that was submerged.
2. Review recent measurements from the well, if available, to estimate the hold point on the tape.
3. Lower the weight and tape into the well until the lower end of the tape is submerged below the water. The weight and tape should be lowered into the water slowly to prevent splashing. Place the thumb and index finger on the tape graduation that is 0.01 less than the next whole foot mark. Continue to lower the end of the tape into the well until the thumb and index finger meet the MP. Record the graduation value (the HOLD) in the Hold column of the water-level measurement field form.
4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the length of the wetted chalk (the CUT) in the Cut row of the water-level measurement field form. Record the time of the measurement in the "Time" row of the form.
5. Subtract the CUT from the HOLD and record this number in the "WL below MP" column of the water-level measurement field form. The difference between the HOLD and the CUT is the depth to water below the MP.

6. Make a check measurement by repeating steps 1 through 5. The check measurement should be made using a different HOLD value than that used for the original measurement. If the check measurement does not agree with the original measurement within 0.02 foot, continue to make measurements until the reason for lack of agreement is determined or the results are shown to be reliable. If more than two measurements are made, use best judgment to select the measurement most representative of field conditions.
7. After completing the water-level measurement, disinfect and rinse that part of the tape that was submerged below the water surface as described in *SOP 5: Equipment Disinfection*.

4. Electrical Tape Method

[The following section is derived from USGS GWPD 4 (Cunningham and Schalk 2011)]

Water levels in monitoring wells will be measured using an electric water-level tape. All measurements will be made from either the marked measuring point or from the north side of the casing. Before measurements are made, the tape should be decontaminated (see *SOP 5: Equipment Disinfection*) and the battery checked. The tape will be unspooled into the well until the buzzer sounds, and the depth-to-water will be recorded at the exact point where the buzzer begins to sound. Readings will be recorded to the nearest 0.01 feet. Once the reading has been recorded, the tape will be reeled in, and two additional duplicate measurements will be made.

1. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Place the nail of the index finger on the insulated wire at the MP and read the depth to water.
2. Record the date and time of the measurement. Record the depth to water measurement in the row “Hold”. If the tape has been repaired and spliced or has a calibration correction (see the section above on using a repaired/spliced tape), subtract the “Tape Correction” value from the “Hold” value, and record this difference in the row “WL below MP”.
3. Pull the tape up and make a check measurement by repeating steps 3–5. Record the check measurement in column 2 of the field form. If the check measurement does not agree with the original measurement within 0.02 foot, continue to make measurements until the reason for lack of agreement is determined or the results are shown to be reliable. If more than two measurements are made, use best judgment to select the measurement most representative of field conditions. Complete the “Final Measurement for GWSI” portion of the field form.
4. After completing the water-level measurement, disinfect and rinse that part of the tape that was submerged below the water surface as described in *SOP 5: Equipment Disinfection*.

6. Literature Cited

Cunningham, W. L., and C. W. Schalk, comps. 2011. Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1. U.S. Geological Survey, Reston, Virginia. Available online: <http://pubs.usgs.gov/tm/1a1/> (accessed 7 November 2014).

Standard Operating Procedure 10: Sample Handling

Version 1.0

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1. Introduction

There are two types of samples collected for the MOJN I&M SLS protocol: water samples and BMI samples. This SOP describes how these samples should be handled, stored, and shipped. Some of the information contained in these SOPs was taken from the websites of the water chemistry laboratory (EFFEX) and the BMI laboratory (USU BugLab) used by the network.

2. Water Samples

The water samples will be handled in accordance with the guidance of the testing laboratory (*SOP 12: Laboratory Analysis of Water Chemistry*). At a minimum, sample bottles should be kept cool ($<4^{\circ}\text{C}$) in the field in a cooler, and the samples should be dropped at the analytical laboratory as soon as possible. If several consecutive days of field work without visiting the Las Vegas area are planned, then the samples can be kept in a fridge or cooler with sufficient ice to keep the temperature below 4°C . Chain of custody forms will be included with the sample bottles. A form must be completed each time samples are dropped off.

3. BMI Samples

As described in *SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring*, the BMI samples are preserved in ethanol, with a label on the jar and a duplicate label on waterproof paper inside the jar. The label inside the jar should be made with laser printer, photocopying or with pencil as the ink in inkjet printers and many ballpoint pens and permanent markers are soluble in ethanol. The jars should be stored in a climate-controlled environment away from direct sunlight until they are shipped.

Ethanol is considered a hazardous material. Therefore, unless special arrangements are made, samples cannot be shipped in alcohol. Instead, the samples should be shipped overnight while in water, which the BugLab can replace with alcohol the following day. Samples should be stored at the MOJN I&M office until all of the year's samples have been collected. The following protocol should be followed:

1. Arrange for the disposal of the ethanol with LAKE's Environmental Manager. As of 2010, this position is filled by Michael Moran (702-293-8705).
2. The samples should be preserved in alcohol for at least two weeks prior to shipment.
3. Arrange with FedEx, UPS, or another courier service for the samples to be shipped overnight.
4. On the morning of the day that the samples will be picked up, pour the alcohol from each sample jar into a 2-gallon or 5-gallon pail with a watertight lid. The alcohol should be poured through a 500-micron sieve, and any invertebrates or organic material caught in the sieve should be washed back into the sample jar using a spray bottle. The sieve should be cleaned between samples. It is acceptable if a few milliliters of alcohol remain in the sample jar, as low concentrations of ethanol do not constitute a flammable or ignitable waste.

5. Fill the jars $\frac{3}{4}$ full with tap water so that the specimens are not damaged by jostling. The jars should be shipped in a box with sufficient packing material to prevent breakage. The BMI sample submittal sheet and the field sheets for the samples should be included in a plastic bag. Ship samples to:

The BugLab
Department of Watershed Sciences
Utah State University
Logan, UT 84322-5210

6. Upon shipping, the lab should be contacted by telephone at (435) 797-2612 to ensure that they are expecting the shipment. The BugLab provides notification of the receipt of shipments by postcard.
7. Place the watertight lid on the pail, and store or dispose of the waste as instructed by the Environmental Manager.

Standard Operating Procedure 11: Laboratory Analysis of Benthic Macroinvertebrates

Version 1.0

Change History for this Document

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1. Introduction

The composition of benthic macroinvertebrate (BMI) communities can be a key indicator of stream health. As discussed in the *Data Analysis and Reporting SOP*, many metrics are used to assess these communities. In order to calculate these metrics, however, BMI samples have to be processed in a way that is quantitative and repeatable. The procedures described in this SOP are similar to those described by the USGS NAWQA program (Cuffney et al. 1993, Moulton et al. 2000), and were described by Vinson and Hawkins (1996). The descriptions below were taken directly from the web page of the BLM/USU National Aquatic Monitoring Center (also known as the USU BugLab), the lab that will analyze MOJN I&M's BMI samples. Their web page was accessed on April 15, 2015, at the following address:

<http://www.usu.edu/buglab/SampleProcessing/LaboratoryProcedures/#item=24>

2. Procedures

1. A sample will be subsampled if it appears to contain more than 600 organisms. Pour the preservative from the sample through a 500 micron sieve into the laboratory waste container.
2. If the sample contains a lot of sand and gravel you will need to separate the organic matter from these inorganic particles. To do this, pour the entire sample from the sieve into a bucket. Partially fill the bucket with water. Swirl the bucket so that the organisms and organic matter become suspended in the water column and the heavier sand and gravel fall to the bottom. Carefully decant the water and floating organisms back through a 500 micron sieve. Continue to add water to the bucket and swirl and decant until no organic matter remains in the bucket. When finished, closely examine the remaining material in the bucket and pick out any caddis flies, snails, clams, or other organisms that remain. Add these organisms to those on your sieve.
3. Keep the sample in the sieve and rinse the sample under the faucet to wash additional fine particles and silt into the sink.
4. Place the sieve in an enamel pan or bucket that is partially filled with water and "float" the sample so that it becomes level within the sieve. Once leveled, carefully remove the sieve from the enamel pan. Place an appropriately sized separator bar into the sieve to split sample material in half. Make sure it appears that there is an equal amount of sample material in each half.
5. Flip a coin to determine which half of the sample is to be processed; heads = right or top, tails = left or bottom. Keep the portion of the sample to be processed in the sieve. Place the other half into a cup using a spoon, or rinse the material into the cup using an alcohol filled squeeze bottle. Cover the cup with ParaFilm, and write the portion or split of the sample on the lid, e.g., 50%.

6. Continue floating and dividing the sample until approximately 600 organisms remain in one half of the sieve. Place the material you are not going to process immediately in a different cup. Cover the cup with ParaFilm, and label the split percentage, e.g., 25%.
7. Once you start processing a split, you must finish it in its entirety, so it is best to start with small splits to assess how many organisms you will find, e.g., 3.125%, 6.25%. If you start to process a split and realize that this split will contain considerably more than 600 organisms, e.g., upwards of 1000, stop and pour all the material, including the organisms you have already removed from the sample, back into the sieve and split it down to a more appropriate percentage.
8. Place the subsampled material into a Petri dish. Examine the material under a dissecting microscope at 7x magnification, where it will be illuminated by a fiber optic light source. Draw gridded lines on the bottom of the dish with a permanent marker. These lines subdivide the dish so that you can systematically move across the dish. Remove all organisms that you encounter in the Petri dish.
9. As you remove the organisms count them using a clicker and drop them into vials separated by the major taxonomic orders, i.e., Diptera, Coleoptera, Ephemeroptera, Plecoptera, Trichoptera, other insects, and non-insects. You need to remove all of the organisms from the debris, but not all organisms will be counted. Remove, but do not count, the following in your 600 minimum count:
 - damaged and immature organisms
 - adult insects [excluding water-dwelling adults such as beetles (Coleoptera) and true bugs (Hemiptera)]
 - zooplankton
 - Collembola
 - pupae
 - worms
 - terrestrial insects
 - fish

The following items do not need to be counted or removed:

- molt skins (exuviae)
- eggs
- empty snail shells

Identify Chironomidae (Diptera) to subfamily. Place any organisms that you cannot clearly identify into the Diptera vial for further examination by taxonomists. Further information can be found on the USU BugLab website.

10. Continue processing splits until at least 600 organisms are counted. Once you start processing a split, remove all the organisms within it. It is fine if you exceed 700 organisms, but try not to exceed 1000.
11. When you have removed a minimum of 600 organisms, perform a "big/rare" search. This search is called a big/rare search because we tend to find larger individuals, but the goal is to collect rarer taxa that may not have been present in the subsample. Spread the entire unsorted portion of the sample into an appropriately sized white enamel pan. Place this pan under the lighted magnifier lamp. Systematically search the pan and remove any organisms that you did not find in your subsample. Perform this search for 10 minutes. If you are in doubt that an organism is new, it is much better to pick up duplicates than to miss an organism. Put these organisms into a separate vial labeled B/R for big/rare.
12. Print a sheet of labels onto waterproof paper. The label will contain the following information:

Sample #	<i>Sample #3</i>
Sample Set/Customer name	<i>Wasatch-Cache National Forest</i>
Site name/Station ID	<i>Wood Camp-Logan River</i>
County, State	<i>Cache County, UT</i>
Date collected	<i>Collected 12/12/03</i>
Sorter, Date sorted, Total split percent, Total # organisms sorted	<i>BB, 12/23/03, 25%, 616 bugs</i>
Identifier, Date identified	<i>MT, 01/05/04</i>
# of Chironominae, Orthocladinae, Tanypodinae counted	<i>5 C, 12 O, 20 T</i>

Use waterproof paper and either a waterproof pen or pencil. Put the label into the Chironomidae vial. If you do not know the county, search for it at www.topozone.com.

13. Place a smaller label with the sample number (e.g. #3, from the example above) in each vial, and label the lids of the vials with this same number using a dry erase marker. Label the big /rare vial "B/R." Put a rubber band around the vials, and place them on the appropriate shelf for that project.
14. Record your sample sort time, the sample sort date, and your initials on the sample tracking data sheet in the folder.
15. All samples are eligible to have QA/QC performed to check for sorter efficiency in removing organisms. Keep sorted material separate, and make sure it is labeled with the word "Sorted". Also keep the unsorted material separate, and make sure it is labeled with the word "Unsorted". Sample material will be discarded only after the organisms have been identified, the sample data is approved, and the data has been sent to the customer. Place the sorted and unsorted material on the appropriate shelf for that project.
16. All of the organisms removed during the sorting process will be identified by qualified taxonomists, who will try to identify organisms to a consistent taxonomic level. Small (early instar) and poorly preserved organisms may be identified to a higher level than specified.

Insects are normally identified to genus, some to species, and others to family. Non-insects are identified to the lowest taxonomic level feasible without slide-mounting.

3. Taxonomic Level

The USU BugLab's standard taxonomic identification levels are listed in Table 11.1. The only variation from the standard is for Chironomidae, which will be identified to the genus level at the request of MOJN I&M. The standard was taken from the USU BugLab's website, accessed on April 15, 2015 at the following address:

<http://www.usu.edu/buglab/SampleProcessing/LaboratoryProcedures/#item=73>

Table.11.1. USU BugLab's standard taxonomic identification levels.

Phylogenetic Level	Taxonomic Resolution
Annelida	
Hirudinea	Order/Family/Genus/Species
Oligochaeta	Subclass
Arthropoda	
Trombidiformes	Order
Crustacea	
Cladocera	Order/Family/Genus/Species
Copepoda	Order/Family/Genus/Species
Decapoda	Order/Family/Genus/Species
Ostracoda	Order/Family/Genus/Species
Amphipoda	Genus/species
Isopoda	Order/Family/Genus
Entognatha	
Collembola	Order
Insecta	
Coleoptera	Genus
Except Curculionidae and Heteroceridae	Family
Diptera	
Atherceridae	Genus/Species
Blephariceridae	Genus
Ceratopogonidae	Family/Genus
Chaoboridae	Genus
Chironomidae	Genus
Culicidae	Genus
Deuterophlebiidae	Genus
Dixidae	Genus
Empididae	Genus
Ephydriidae	Family
Muscidae	Family
Pelecorhynchidae	Genus
Psychodidae	Genus
Ptychopteridae	Genus
Sciomyzidae	Family
Simuliidae	Genus

Table.11.1. USU BugLab's standard taxonomic identification levels (continued).

Phylogenetic Level	Taxonomic Resolution
Stratiomyidae	Genus
Tabanidae	Genus
Tanyderidae	Family
Thaumaleidae	Genus
Tipulidae	Genus
Ephemeroptera	Genus/Species
Hemiptera	Genus
Lepidoptera	Genus
Megaloptera	Genus
Odonata	Genus/Species
Plecoptera	Genus/Species
Trichoptera	Genus/Species
Coelenterata	Class/Order
Mollusca	Order/Family/Genus
Nematoda	Phylum
Nematophora	Phylum
Turbellaria	Class

4. QA/QC Procedures

The following description of the USU BugLab's QA/QC procedures was taken from their website, accessed on April 15, 2015, at the following address:

www.usu.edu/buglab/SampleProcessing/QualityStandards/

4.1. Sample sorting

Sorting aquatic invertebrate samples involves removing aquatic macroinvertebrates from the organic and inorganic material within each sample. Error can occur if the sample is not split correctly and if all the organisms are not removed from a sample split. To reduce error associated with subsampling procedures we use a relatively easy subsampling method, record all information associated with each sample, and review this information on a weekly basis. The information recorded for each sample includes who sorted each sample, the date the sample was sorted, the time required to sort the sample, the number of invertebrates removed from the sample, and the percent of the sample that was sorted. Any abnormalities are assessed and corrected.

To ensure that all organisms are removed from sample splits, all sorting is done using a binocular microscope at 7x magnification. We intensively train all new employees and check all of their samples for the first month. Spot checks are then done on individual employees if there appears to be any consistent abnormalities in their samples. Abnormalities typically include distinct differences in sample characteristics between one technician and other technicians working on the same set of samples. These differences include differences in the percent of the sample sorted, the time required to sort a sample, or the number of invertebrates removed during the sample splitting or the big/rare search.

Individuals invertebrates left on a sieve from a previous sample can also be a source of error. We try to prevent this from happening by carefully washing the sieves after a sample is split, by inspecting each sieve prior to putting a new sample into it, drying the sieves following their use, and by noticing if any invertebrates in a sample appear to look "dried out" with respect to other invertebrates in that sample. These desiccated invertebrates may have been leftover from a previous sample, i.e., they were not removed from the sieve during a previous subsampling event and were inadvertently added to a different sample. These invertebrates are removed from the current sample and discarded as there is no way of determining which sample they were supposed to belong to.

10% of all sorted samples are examined to ensure that at least 95% of the organisms are removed from the examined material. Specifically, a second sorter examines the organic and inorganic matter from which organisms have been removed (i.e., remnant material) for at least 10% of the time that the sample was originally sorted. Remaining organisms are added to sample vials for identification and enumeration. Sorting effectiveness (E_s) is subsequently computed as:

$$E_s = 100 \times \frac{S}{R + S}$$

Where R is the total number of organisms obtained during the re-sort of the remnant material and S is the total number of organisms originally obtained from the sample sorting. The goal of this is for $\geq 95\%$ of the organisms be removed during the original sort. Additionally, sorters are evaluated semi-annually in regards to sorting effectiveness and productivity.

If sorting efficiency is between 90 and 94.4%, one additional sample is checked for that particular sorter. If the second sample does not pass, additional randomly selected samples are checked until three consecutive samples achieve 95% sorting efficiency. If sorting efficiency is below 90% for the initial sample, additional randomly selected samples are checked until three consecutive samples achieve 95% sorting efficiency for a particular sorter.

4.2. Consistency of taxonomic identifications

The BugLab attempts to reduce the number of misidentifications and improve the consistency in taxonomic resolution among taxonomists through a number of conscientious efforts. These efforts include conducting in-house workshops and participating in outside taxonomic seminars. All Buglab taxonomists are certified in the identification of Western EPT taxa by the Society for Freshwater Science (formally North American Benthological Society). BugLab taxonomists also attend regional taxonomic seminars offered by the Northwest Bioassessment Work Group, Southwest Association of Freshwater Invertebrate Taxonomists, local universities and other entities. Lastly, BugLab taxonomists bring questionable taxa to the taxonomy fairs and workshops to consult taxonomic experts on an approximately annual basis.

The Buglab also insists on constant and consistent communication among all taxonomists and dealing with any questionable taxa on the spot. Questionable specimens are immediately shared with all other taxonomists and compared to voucher specimens from our laboratory and the Utah State University insect collection. If consensus cannot be reached among our taxonomists, the specimens

are shown to entomologists at Utah State University. If consensus is still not reached, the taxonomic resolution is revised to a coarser level (e.g., from genus to family) and the specimen is set aside to be shown to an outside expert.

Composite taxa lists are reviewed for taxonomic consistency (e.g., all monotypic taxa identified to species) among taxonomists and rare, invasive, or unusual taxa for the habitats or geographical location sampled. Particular attention is given to taxa found at low frequencies within a set or documented by only one taxonomist. These taxa are then re-examined to ensure the accuracy of identifications.

A second taxonomist, who was not responsible for the original identifications, re-identifies and re-enumerates a minimum of 10% of the samples identified per year (and 10% from a given sample set as requested). This allows for the detection of both isolated (single occurrences) and systematic (multiple regular occurrences) taxonomic errors, which dictates the corrective action that should be taken. Similarity between taxonomists is assessed using Sorensen's similarity index (B):

$$B = \frac{\sum_{i=1}^n |X_{ij} - X_{ik}|}{\sum_{i=1}^n (X_{ij} + X_{ik})}$$

Where X_{ij} and X_{ik} are the number of individuals of species i in the respective samples (j,k). The comparison between both samples is summed for n number of species in the samples. The goal is to have 95% similarity between paired samples. If 95% similarity is not achieved between taxonomists and discrepancies do not result from taxonomic ambiguities, all misidentified operational taxonomic units identified by the taxonomist in question are independently checked for all samples within a particular sample set.

10% of all operational taxonomic units (OTUs) plus 20% of rare OTUs identified within a given calendar year are verified by external experts. The specimens are randomly selected from our database regardless of original taxonomist and excluding taxa identified to a coarser resolution relative to the Standard Effort Levels given in Table 11.1. Prior to sending specimens for verification, at least two taxonomists review the specimen and come to a consensus on the identification. Once specimens are returned, the expert's identification is compared to both the original identification and the consensus identification. If there is a misidentification bias by a particular taxonomist, the issue is addressed. The verified specimens are retained in the reference collection.

4.3. Data processing and sample verification

Data processing involves entering the data from the bench sheets and the sample information data sheets into an SQL database. Bench sheet information includes the unique code for each invertebrate taxon, the life stage, the split count, the count from the big/rare search, and any notes. Once entered, the computer program displays the taxonomic name for each code, the life stage, enumerations, and taxonomic notes. These data are then verified or corrected before the data are uploaded to the main database. Once all the data from a set of samples have been entered into the computer, a composite taxa list and the counts for each taxon is printed and reviewed for accuracy and consistency.

Sample verification is the process of making sure that the taxonomic lists produced for each sample get assigned to the correct sampling location. As of 2012, customers can submit sample and site data directly to our lab via an online submission process, last accessed on April 15, 2015, at the following address:

<http://www.usu.edu/buglab/SampleProcessing/SampleSubmission/>

Before acceptance into the processing queue, this data is thoroughly checked for common issues, including matching to jar labels, feasible sampling areas, comparison to historical methods, and proximity to existing sites. Customers are contacted when discrepancies arise to clarify current and past methods, station locations, and sample information.

5. Literature Cited

- Cuffney, T. F., M. E. Gurtz, and M. R. Meador. 1993. Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program. United States Geological Survey Open-File Report 93-406.
- Moulton, S. R. II, J. L. Carter, S. A. Grotheer, T. F. Cuffney, and T. M. Short. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory - processing, taxonomy, and quality control of benthic macroinvertebrate samples. United States Geological Survey Open-File Report 00-212.
- Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedures on comparisons of taxa richness among streams. *Journal of the North American Benthological Society* 15:393-400.

Standard Operating Procedure 12: Laboratory Analysis of Water Chemistry

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Testing Laboratory

The biennial water samples collected from the springs will be analyzed by a commercial testing laboratory near the MOJN office (i.e., in the Las Vegas metropolitan area). The lab must be near the MOJN office to ensure that samples are analyzed within their hold times. The lab that will be used has not been selected at this time.

The testing laboratory will establish procedures regarding bottles, sample preservation, field filtration, sample hold times, and other procedures. It is important that MOJN follows the laboratory's guidance in these areas to ensure that the laboratory can meet the project's Measurement Quality Objectives (MQOs).

2. Analytical Methods

Table 12.1 lists the standard analytical methods that will be used for each analyte. The Standard Methods are taken from the American Public Health Association (2005). The EPA method is taken from the US EPA.

3. QA/QC Procedures

The laboratory will be certified by the state of Nevada for work performed under the Safe Drinking Water Act, the Clean Water Act, and the Resource Conservation and Recovery Act. To obtain this certification, laboratories are required to make a Demonstration of Capability (DOC) for each analysis they offer. DOCs requires that each analysis be performed on four spiked samples every twelve months, and that the results of the analysis agree with the known concentration of the analyte within a certain specified tolerance.

Independent QA/QC information will be provided by submitting either a field blank (a sample of de-ionized water) or a field duplicate (a second sample from one of the sampled springs) each year. As Table 12.1 indicates, the MQOs for these analyses are that no analytes should be detected in the field blank and the duplicate sample results should be within 30% of each other. Additional information on the MQOs can be found in *SOP 13: Quality Assurance Project Plan*.

Table 12.1. Analytical methods and measurement quality objectives (MQOs) for parameters measured in the laboratory.

Parameter	Method	Precision MQO	Bias MQOs		Sensitivity MQOs	
		Relative percent difference (RPD of duplicates) ¹	Blanks (field)	Measurement systematic error (% recovery) ²	Method detection limit (MDL) ³	Laboratory-Defined Reporting Limit (RL) ⁴
Alkalinity (mg/L as HCO ₃ ⁻)	Standard Method (SM) 2320 B	+/-30%	<MDL	90–110%	0.01	20
Chloride (mg/L)	SM 4500 Cl B	+/-30%	<MDL	90–110%	5	10
Sulfate (mg/L)	EPA Method 375.4	+/-30%	<MDL	90–110%	0.1	10
Calcium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.7	10
Sodium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	2	10
Potassium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.04	0.25
Magnesium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.01	1
Total nitrogen (mg/L)	SM 4500- NH3-D,NO3-E,NO2-B	+/-30%		90–110%		1
Total phosphorus (mg/L)	Prep: SM 4500-PB(5) Analysis: SM 4500-PE	+/-30%	<MDL	90–110%	0.03	0.1

¹RPD is the relative percent difference between two or more measurements calculated as percent recovery:

$$RPD = \left[\frac{S_1 - S_2}{(S_1 + S_2)/2} \right] \times 100$$

where,

S₁ = the larger test result value,

S₂ = the smaller test result value.

²Measurement systematic error is set to 90–110% in the absence of any specific guidance for laboratory rejection criteria

³Defined by National Environmental Methods Index (NEMI) as the lowest "measurable" concentration for an analyte by the specified method (http://web1.er.usgs.gov/nemi/field_def.jsp?method_field_name=DL_VALUE).

⁴The RL is defined by the laboratory, and should never be less than the MDL multiplied by 3.18.

4. Literature Cited

American Public Health Association. 2005. Standard methods for the examination of water and wastewater. American Public Health Association, Washington, D.C.

Standard Operating Procedure 13: Quality Assurance Project Plan

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

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1. Introduction

The Quality Assurance Project Plan (QAPP) is the written record of the QA/QC program.

Quality assurance (QA) refers to the overall *management system* which includes the organization, planning, data collection, quality control, documentation, evaluation, and reporting activities of the group. QA provides the information needed to ascertain the quality of data and whether it meets the requirements of the program. QA ensures that data will meet defined standards of quality with a stated level of confidence.

Quality control (QC) refers to the routine *technical activities* whose purpose is, essentially, error control. Since errors can occur in either the field, the laboratory or in the office, QC must be part of each of these functions. QC should include both internal and external measures.

This QAPP was modified and expanded from an SOP prepared by Thoma et al. (2009):

Water Quality Vital Signs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network - Standard Operating Procedure (SOP) #7: Quality Assurance Project Plan (QAPP) for Water Quality Monitoring.

2. Distribution list and contact information

Table 13.1. People who will be aware of the project goals, tasks, and products.

Name/Title/Agency	Contact
Nita Tallent /Program Manager/MOJN I&M	702-293-8911, nita_tallent@nps.gov
Geoffrey Moret/Hydrologist/MOJN I&M	702-293-8843, geoffrey_moret@ nps.gov

3. Project Management

This project is intended to be a long-term (30+ years) monitoring effort. As such, consideration in this QAPP is given to potential change in equipment, laboratory method, and staff. The plan will be managed by network (MOJN I&M) personnel, with some of the field work implemented by park personnel. Some sites will be monitored in cooperation with USGS and technical assistance will be provided by USGS and NPS Water Resources Division (WRD). Decisions regarding protocol development and long term monitoring plan have been and will continue to be made by consensus of the MOJN I&M Water Resources Working Group consisting of key network and park staff. Broader-based, long-term decisions are approved by the NPS-WRD and the MOJN I&M technical committee. These include approval of the overall monitoring plan.

Table 13.2. Project tasks and responsibilities.

Name (Affiliation)	Title/Responsibility
Geoffrey Moret (MOJN I&M)	Hydrologist/Technical Lead - coordinate collection of monitoring data and data management, coordinate report writing and protocol revision.
Ben Roberts (GRBA)	Chief of Natural Resources/ Work with MOJN to arrange crews for the collection of discharge, BMI, and water quality data at springs in GRBA.
Richard Friese (DEVA)	Hydrologist/Oversee the collection of discharge and water quality data at springs in DEVA.
Nita Tallent (MOJN I&M)	MOJN I&M Program manager/ Coordinate with water quality technical lead on reporting requirements, assist with peer review process, program oversight
Mark Lehman (MOJN I&M)	MOJN I&M Data Manager/Assist with database management, archive, and uploading to NPS and national data bases

4. Problem Definition/Background

4.1. Monitoring Questions

The Selected Large Springs Protocol outlines a monitoring program that will address two primary monitoring questions:

1. Is the hydrology of any of the selected large springs in the MOJN parks changing?
2. Is the overall ecological condition of any of the selected large springs in the MOJN parks changing?

4.2. Measurable Objectives

In light of these questions outlined above, this protocol will address the following specific measurable objectives:

1. Determine the status, trend, and natural range of variability of the discharge of each of the selected large springs.
2. Determine the status, trend, and natural range of variability of water levels in existing monitoring wells completed in the vicinity of the selected large springs.
3. Determine the status, trend, and natural range of variability of water quality parameters (pH, temperature, dissolved oxygen, and specific conductance) and chemical constituents in each of the selected large springs.
4. Determine the status, trend, and natural range of variability of metrics calculated from the macroinvertebrate assemblages in each of the selected large springs.
5. Determine the status, trend, and natural range of variability of the population and spatial extent of springsnails within each of the selected large springs that they inhabit.

5. Project/Task Description Synopsis

5.1. Spring Discharge

Spring discharge (or pool stage, at limnocene springs) will be monitored continuously at some springs and quarterly at other springs (see *SOP 7: Spring Discharge Monitoring*). At the continuously monitored springs, pressure transducers will record water depth every hour, and the data will be processed using the Aquarius software package (see *SOP 15: Data Analysis and Reporting*).

In the springs where it is not feasible to measure discharge or pool stage, the presence and absence of water, open water area, and/or spring brook length will be measured each quarter (see *SOP 7: Spring Discharge Monitoring*).

The discharges of the five SLS protocol springs in DEVA are jointly monitored by the park staff and WRD. The discharge of Rogers Spring at LAKE is monitored by the USGS. MOJN I&M will not be involved in discharge monitoring at these springs as long as these arrangements persists.

5.2. Water Levels in Monitoring Wells

Water levels will be monitored quarterly in the Baker Creek Road well in GRBA and the Rogers Bay well in LAKE. See *SOP 9: Monitoring Water Levels in Wells*.

5.3. Water Quality and Water Chemistry

Core water quality parameters (temperature, specific conductivity, dissolved oxygen, and pH) will be measured in each spring every quarter. These measurements are discussed in *SOP 6: Handheld Water Quality Instrument*.

A water sample will be collected every two years from each monitored spring. The samples will be analyzed by a contract laboratory for acid neutralizing capacity, major ions, sulfate, total nitrogen (TN), and total phosphorus (TP). Sampling methods are discussed in *SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring*.

5.4. Benthic Macroinvertebrates

Benthic macroinvertebrate (BMI) samples will be collected biennially from each of the monitored springs. The sampling plan for each spring is described in *SOP 3: Spring Locations and Spring-Specific Procedures*. The sampling methods are described in *SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring*.

5.5. Springsnails

Springsnails will be monitored biennially in all springs that have springsnail populations. The measured parameters will be the downstream extent of the springsnails and their population density as a function of distance from the source. The monitoring procedures are described in *SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring*.

6. Data Quality Objectives (DQOs)

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information. Data credibility necessary for the intended uses will be achieved when it is:

1. consistent over time and consistent between staff members
2. collected and analyzed using standardized and acceptable techniques
3. comparable to data collected in other assessments using the same methods
4. used appropriately to make decisions based on sound statistics

Specific, quantitative objectives for the quality of measured data are referred to as Measurement Quality Objectives (MQOs). The MQOs for this protocol are discussed in Section 7.

6.1. Target population

Data from different springs will not be combined to make inferences regarding a larger population.

6.2. Spatial Representativeness

The sampling and monitoring methods for water quality, BMI, and springsnail population density have been designed to ensure that they are spatially representative at the scale of individual springs.

When the core water quality parameters are measured in a spring pool, a depth profile will be recorded. All parameters will be measured at four depths: near the surface, at 1/3 of the total depth, at 2/3 of the total depth, and near the bottom.

The wide variety of spring morphologies requires a different BMI sampling plan for each spring (see *SOP 3: Spring Locations and Spring-Specific Procedures*). In each case, the spatial representativeness of these samples is assured by collecting samples from across the entire area of the spring rather than just a specific aquatic environment.

Springsnails population density will be monitored by counting the number of snails in quadrats placed on the bed of the springbrook on between the source and the maximum downstream extent of the snail habitat. The spatial representativeness of the resulting density estimate is assured by monitoring population density over the entire area of the snail habitat.

6.3. Temporal Representativeness

Spring discharge will be recorded hourly at the springs with permanent flumes, a sample frequency sufficient to characterize all of the hydrologic processes relevant to the monitoring questions addressed by the SLS protocol.

Discharge at the springs without permanent flumes will be measured on a quarterly basis. A power analysis of this sampling plan based on historical data from Piute Spring indicated that quarterly sampling of these springs would provide acceptable power to detect trends, and that monthly

sampling would improve that power only minimally. While it would be ideal to continuously monitor discharge at all of the monitored springs, it is not logistically possible.

Water levels in monitoring wells will be measured quarterly. This frequency is logistically desirable, but may not be sufficient in wells with water levels that vary over short timescales. The decision to monitor water levels quarterly will be reviewed once two years of data are available.

The impact of diel and annual variations on water chemistry, BMI communities, and springsnail populations will be minimized by collecting the samples and performing the monitoring between 10:00 AM and 2:00 PM during the same index period each year. As the historical water chemistry data for Saratoga Spring compiled in the narrative indicate, water chemistry changes very slowly in springs fed by large aquifers. Therefore, biennial sampling will be sufficient.

6.4. Completeness

Every effort will be made to achieve 100% completion of data collection for all springs.

6.5. Internal Data Comparability

Data comparability through time across network parks even when sensors, instruments, and staff change occur is ensured by following guidelines laid out in the SOPs for staff training, sample handling, field methods and laboratory methods. When methods or equipment change, a record will be made in the appropriate SOP and in *SOP 14: Cumulative Measurement Bias*. The avoidance of cumulative measurement biases is described in detail in *SOP 14: Cumulative Measurement Bias*.

6.6. External Data Comparability

External data comparability is a concern for the water quality, water chemistry, BMI, and springsnail components of the monitoring program.

Data comparability in core parameters is maximized by employing NPS WRD guidelines for calibration frequency and methodology (*SOP 6: Handheld Water Quality Instrument*). Additionally, careful attention is paid to equipment manufacturer guidelines to maintain equipment in optimum working condition. Further assurance of data comparability in core parameter data is achieved by using National Institutes of Standards and Technology (NIST) traceable standards for calibration.

No standardized national BMI sampling methods have been developed for springs because no one method is suitable for all springs. However, external data comparability is important in the taxonomic identification the sampled organisms. The samples will be identified and enumerated by the Utah State University BugLab, a qualified macroinvertebrate taxonomy laboratory with expertise in western BMI communities. The BugLab is also used by the MOJN I&M Streams and Lakes protocol and by the Sonoran Desert Network I&M and the Chihuahuan Desert Network I&M. The BugLab maintains an archive of all the samples they process, so future workers can inspect the actual samples if concerns about changes in identification over time (taxonomic drift) arise.

The springsnail monitoring component of the protocol is a modified version of the method described by Sada (2009), so it is broadly comparable to other springsnail monitoring programs in the Western United States.

7. Measurement Quality Objectives

The measurement quality objectives (MQOs) discussed in this section apply to the analytical water chemistry data and the core water quality parameter data only. Quantitative QA/QC goals for the analysis of the BMI samples are discussed in *SOP 11: Laboratory Analysis of Benthic Macroinvertebrates*.

7.1. Measurement Sensitivity

7.1.1. Water Chemistry

The method detection limit (MDL) and minimum level of quantitation (ML) are the terms used to describe the minimum concentration of an analyte that can be observed and measured accurately, respectively. They are important concepts in water quality data reporting and analysis for many reasons, especially when considering chronic low level pollution that is near the detection limits of analysis methods (Irwin 2008). These values will be updated / reported at least once per year or when methods change and become part of the permanent data record. Some laboratories also define a Reporting Limit (RL) or Minimum Reporting Level (MRL) for each analyte. These limits are discussed by Oblinger Childress et al. (1999):

“Since the definition of the MRL is not specific, an MRL can be set at any concentration acceptable to the data user and the laboratory as long as reliable measurement is achieved. Examples of specific types of MRL’s include practical MRL’s that are based on regulatory-action limits, water-solubility limits, or analytical capability. Statistically derived MRL’s may include those that are equivalent to a practical-quantitation limit, the limit of quantitation, the method detection limit, the limit of detection, or the limit of identification... The NWQL (*USGS National Water Quality Lab*) historically has used MRL’s for reporting non-detections. Establishment of the MRL has been inconsistent across methods and typically inadequately defined and often undocumented. In many cases, statistical procedures may have been used to set MRL’s during development of a method, but the MRL likely was based on subjective criteria (perhaps an easily prepared concentration or the same MRL for all compounds in a method for ease of reporting) or on an analyst’s professional judgment of detection capability. As a result, the NWQL has determined that MRL’s for some methods are no longer appropriate.”

Thus the MLs will be used to determine whether analytes have been detected.

The MDL for an analytical method or sample is the lowest value that can be distinguished from zero. The MDLs that will be used as MQOs for all water chemistry analytes are listed in Table 13.5. Given the assumptions of constant standard deviation at low concentration, normal distribution, and minimal matrix interferences, the MDL is the concentration at which no more than 1 percent of the blank measurements result in a false positive detection. Therefore, detections at concentrations greater than or equal to the MDL concentration should be true detections 99 percent of the time.

The MDL is calculated as:

$$\text{MDL} = s * t_{(n-1, 1-\alpha = 0.99)},$$

where

- n = number of replicate spike determinations at 1 to 5 times the estimated MDL,
- s = standard deviation of measured concentrations of n spike determinations,
- α = level of significance, and
- t = Student's t value at $n-1$ degrees of freedom and $1-\alpha$ (99percent) confidence level.

The ML is the lowest value that can be reliably measured. Its minimum value is generally the MDL multiplied by 3.18.

Results cannot be reported for values less than the Method Detection Limit (MDL). Most MDLs are much lower than water quality standards and provide the rationale for confidence in the data. However some parameters, particularly nutrients, often have extremely low values in pristine waters. It is these water bodies that NPS hopes to prevent from degrading, and monitoring them requires an effective method for dealing with parameter values near detection limits of analytical procedures (Irwin 2004). Data values below an MDL will not be presented numerically. Data falling between the MDL and minimum level of quantitation (ML) are considered "semi-quantitative" and can be presented as greater than zero. These semi-quantitative values will be handled according to Helsel (2005) consistent with the modernized STORET recommendation. Modernized STORET suggests not reporting into a database any value higher than the MDL but lower than the ML. Instead, the detection condition field is set to "Present, below Quantification Limit (PQL)". With that detection condition, STORET automatically enters "*Present <QL" in the result field. A major advantage of this approach is that no "estimates" are treated as quantitative when in fact they are not quantitative. In later statistical analyses these data between the two limits are best interpreted using either an interval-censored method (parametric), or a rank-based method (nonparametric) where all in-between values are represented as the same tied rank. Values above the PQL are classified in EPA's modernized STORET database with the detection condition of "Detected and Quantified" This is ideal, and according to EPA STORET Staff, this is optimally the only choice which permits reporting a single number (Irwin 2004).

7.1.2. Core Water Quality Parameters

The manufacturer specified measurement sensitivities (resolutions) for the YSI multi parameter sonde are given in Table 13.3, below:

Table 13.3. Manufacturer-specified sensitivities for the YSI multiprobe.

Parameter	Accuracy	Resolution
Temperature	+/- 0.15 °C	0.01 °C
pH	+/- 0.2	0.01
Conductivity	+/- 0.5% of reading + 1 µS/cm	Range-dependent- 1 to 100 µS/cm
DO	+/- 1% of reading or 0.1 mg/L, whichever is greater	0.01 mg/L

However, manufacturer's claims for resolution specifications are not consistent and not necessarily good representations of instrument measurement sensitivity in harsh outdoor environments. Instead a

measure known as Alternative Measurement Sensitivity Plus (AMS+) will be documented for each parameter as measured by each field instrument once a year.

AMS+ is a concept used to evaluate measurement precision in an ambient condition such as a well mixed flowing stream or springbrook. Seven repeated measurements are made in rapid succession in situ. AMS+ is affected by instrument noise and natural heterogeneity, and is useful in the range of quantitative values where low level detection limits are not an issue. AMS+ is calculated as:

$$AMS+ = t \times s$$

where:

s = sample standard deviation of the 7 in-situ measurement values, and

$t = 3.708$, the 99% confidence middle (two-sided) t-value for a sample size of 7.

The result is functionally analogous to a ML but uses the two-sided (middle) t-value because we are not only interested in one side (distinguishing a value from zero) but in the two-sided issue of how large of a difference between two individual values we can justify as actually being a true difference (from one another) rather than being due to measurement noise.

Like MDLs, AMS+ should be re-calculated when something significant in the measurement process changes or every sampling season at a minimum. For example, if the measuring instrument or the methods or SOPs change, recalculate AMS+ to see if measurement sensitivity has changed (Irwin 2008).

7.2. Measurement Precision

7.2.1. Water Chemistry

The precision of laboratory analyses of water chemistry is monitored by the laboratory performing the analysis. The most important measure of precision at low concentrations is the MDL, which is a measure of sensitivity and precision (see previous section).

MOJN I&M staff will monitor laboratory precision by submitting a field duplicate sample to the testing laboratory every other year. The analytical results for the duplicate samples are compared using Relative Percent Difference (RPD). RPD is a less rigorous measure of repeatability than AMS or AMS+ (sample size 2 rather than 7), but it is used more frequently in assessing analytical laboratories, where the analysis of 7 duplicates is not economical. The RPD for each analyte is calculated as:

$$RPD = \left[\frac{S_1 - S_2}{(S_1 + S_2)/2} \right] \times 100$$

where:

S_1 = the larger test result value, and

S_2 = the smaller test result value.

7.2.2. Core Water Quality Parameters

As described above, AMS+ will be used to measure the sensitivity of core parameters. AMS+ is a measure of the precision of the measurements as well as their sensitivity, so the AMS+ MQO will be used to evaluate both the sensitivity and the precision of the core parameter measurements.

The precision of core water quality parameter measurements can also be evaluated by conducting a field stabilization check. When the probe is placed in the stream or lake, the fluctuations in measured parameter values are observed, and the ranges of the fluctuations are compared to the field stabilization criteria (Table 13.4).

7.3. Bias

Systematic error/bias is the systematic or persistent distortion of a measurement process that causes errors in only one direction (either high or low). The bias of a measurement technique is evaluated by measuring a sample where the true value of the measured parameter is known. The avoidance of cumulative measurement bias is described in the *Cumulative Measurement Bias SOP*, and is not addressed here.

7.3.1. Water Chemistry

Testing laboratories have extensive QA/QC procedures to minimize measurement bias. These procedures include analyzing blanks and standards.

MOJN I&M will test these procedures by submitting a “blank” sample (de-ionized water) to the laboratory for analysis every other year. The blank water should be placed in a bottle, stored, and shipped using the same procedures and equipment used for sample water.

7.3.2. Core Water Quality Parameters

Bias in core water quality parameters is avoided by frequent calibration. Bias can be evaluated in pH, DO, and specific conductivity by measuring these parameters in the appropriate calibration standards immediately after calibration. The difference between the standard value and the measured value should be less than the field calibration check tolerance, or the instrument should be recalibrated. This process is described in *SOP 6: Handheld Water Quality Instrument*.

Bias in temperature readings can be assessed by comparing two or more NIST-certified thermometers across a range of temperature conditions. This test should be carried out at least once a field season.

Table 13.4. MQOs for field measurements.

Parameter	Instrument	PRECISION MQO	BIAS MQO	SENSITIVITY MQO
		Field Stabilization Criteria	Field Calibration Check Tolerance	Alternative measurement sensitivity (AMS+) ¹
Field pH	Sonde or handheld multiprobe	±0.1	±0.1	±0.3
Field Dissolved Oxygen (mg/L)	Sonde or handheld multiprobe	±0.3	±0.3	±0.4
Field Temperature (°C)	Sonde or handheld multiprobe	±0.2	±0.2 ²	±0.3
Field Specific Conductance (µs/cm)	Sonde or handheld multiprobe	±5 µs/cm or ±3%, whichever is greater	±5 µs/cm or ±3%, whichever is greater	±5 µs/cm or ±3%, whichever is greater

¹ AMS+ a measure of uncertainty (99% confidence interval) based on 7 in-situ measurements.

² The “field calibration check” for temperature is actually performed in the laboratory once a field season.

Table 13.5. MQOs for laboratory analyses. All terms are defined in the text.

Parameter	Method	Precision MQO	Bias MQOs		Sensitivity MQOs	
		Relative percent difference (RPD of duplicates)	Blanks (field)	Measurement systematic error (% recovery)	Method detection limit (MDL)	Minimum Level of Quantitation (ML)
Alkalinity (mg/L as HCO ₃ ⁻)	Standard Method (SM) 2320 B	+/-30%	<MDL	90–110%	0.01	0.032
Chloride (mg/L)	SM 4500 Cl B	+/-30%	<MDL	90–110%	5	16
Sulfate (mg/L)	EPA Method 375.4	+/-30%	<MDL	90–110%	0.1	0.32
Calcium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.7	2.2
Sodium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	2	6.4
Potassium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.04	0.13
Magnesium (mg/L)	SM 3111B	+/-30%	<MDL	90–110%	0.01	0.32
Total nitrogen (mg/L)	SM 4500- NH3-D, NO3-E, NO2-B	+/-30%		90–110%	0.05	0.16
Total phosphorus (mg/L)	Prep: SM 4500-PB(5) Analysis: SM 4500-PE	+/-30%	<MDL	90–110%	0.03	0.095

7.4. Violation of Measurement Quality Objectives

The MQOs are designed to allow data comparability through space and time keeping in mind limitations of the sampling design when drawing conclusions. It is likely at times that some of the MQOs cannot be met. In these cases data must either be discarded or considered in isolation to avoid drawing misleading or erroneous conclusions. This is especially true near the detection limits for laboratory analyses and when evaluating data from different laboratory techniques that attempt to quantify the same parameter.

If measurements do not meet or exceed these criteria they will be discarded and re-runs for laboratory samples will be requested if possible. Appropriate measures will be taken to determine the source of error so that future measurements will comply with these minimum requirements. If problems persist, a different analytical laboratory should be used.

8. Training Requirements / Certification

Staff training is covered in the *SOP 2: Staff Training*.

9. Documentation and Records

9.1. Field Data

MOJN I&M core parameter data will be collected and generated for all sampling events and locations. Additional field data will be completed for specific monitoring activities. At this time, paper copies of the forms are taken to the field for recording data, and pencil is used to record observations.

The data from the form or forms will be entered into electronic copies in the office. Quality control for completeness is determined by a visually scanning the entered data. Hard copy output is scanned and maintained in both digital and paper format for archival purposes according to NPS Director's Order #19. The original paper forms used in the field, the digital scanned field form, and the digital data are stored indefinitely with MOJN I&M.

A series of three rotating backups are made for all field data. Short term backups are made on the PC hard drive as data entry progresses. Daily backups are conducted to the MOJN I&M server or SharePoint site following data entry on any day, and an archival backup is made on CD after a quality assurance review and the data are certified by the protocol lead. All digital data are stored on the MOJN I&M server which is maintained by LAKE IT department's backup and recovery procedures.

9.2. Laboratory Data

Both the water chemistry testing laboratory and the BMI laboratory (USU BugLab) will submit electronic reports of their results. These files will be uploaded to the M-drive in the MOJN I&M office as soon as they are received and checked in as received in the database log for laboratory results. In addition, a hard copy of each report will be printed out and kept on file in the MOJN I&M office.

9.3. Data management

Field crews are responsible for reviewing the field data and ensuring the field forms are complete and legible. Field crews will deliver the hard copy field data sheets and digital logger data to MOJN I&M as soon as they return to the office. Hardcopy archive and interim digital backup are the responsibility of the individual scientists in charge of data collection for different cooperating groups within MOJN. The MOJN I&M hydrologist and the MOJN I&M data manager are jointly responsible for organizing and uploading data to MOJN and national databases.

9.4. Evaluation

Data evaluation for internal consistency, outliers and quality control checks are the responsibility of the MOJN I&M hydrologist and network data manager. After these quality assurance reviews the MOJN I&M hydrologist will certify the data. The MOJN I&M hydrologist will then compile the data for water quality reporting. Having one person responsible for this step will ensure consistency in a final quality control check before data are uploaded to the Servicewide EQuIS database and then transferred to EPA STORET. Additionally, this will provide consistency in reporting values near detection and quantitation limits. Procedures are detailed in *SOP 16: Data Management*.

9.5. Reporting

The MOJN I&M hydrologist with the help of park personnel and the MOJN I&M data manager is responsible for reporting. These reports are described in *SOP 15: Data Analysis and Reporting*.

10. Sampling Process Design

10.1. Program design

The MOJN I&M program is designed to monitor the quantity and quality of springflow in selected springs in MOJN parks. Section 2 of the monitoring protocol narrative has more information about the process of monitoring program development.

10.2. Type, frequency and timing of sample collection

As described in section 2 of the monitoring protocol narrative, the type of data collected was determined based on the objectives of the program. The frequency of data collection was determined by balancing the data needed to answer the monitoring questions with the resources available, a determination aided by statistical power analyses. The timing of data collection was restricted by the logistical difficulties of summer field work in the southern desert parks and winter field work in GRBA.

10.3. Sample site selection

The springs selected for monitoring are not representative of a larger population, and were selected in consultation with park managers. Only existing wells were considered for water level monitoring.

11. Sampling Methods Requirements

Sampling and measurement techniques are discussed in the *SOP 7: Spring Discharge Monitoring*, *SOP 6: Handheld Water Quality Instrument*, *SOP 8: Water Sampling, BMI Sampling, and Springsnail Monitoring*, and *SOP 9: Monitoring Water Levels in Wells*.

12. Sample Handling and Custody Requirements

Details of sample handling, storage, shipping, and custody requirements are described in *SOP 10: Sample Handling*.

13. Analytical Methods Requirements

The laboratory methods used to analyze the benthic macroinvertebrate samples are described in *SOP 11: Laboratory Analysis of Benthic Macroinvertebrates*. The laboratory methods used to analyze water samples are described in *SOP 12: Laboratory Analysis of Water Chemistry*.

14. Quality Control Requirements

Quality control for precision and accuracy of both field and laboratory measurement has been addressed in section 7 of this document.

15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Preparation of equipment for field work and its care and handling are discussed in the *SOP 4: Field Mobilization and De-Mobilization*, as well as in the user manuals.

16. Instrument Calibration and Frequency

As described in *SOP 6: Handheld Water Quality Instrument*, field instruments are checked for integrity and calibrated at each site prior to collecting data.

17. Inspection/Acceptance Requirements for Supplies

All reagents and standards are National Institutes of Standards and Technology (NIST) traceable and measurement instrumentation meets NPS WRD and USGS specifications. It is the responsibility of the protocol lead to order new supplies of consumables and replacement parts as necessary at the end of each sampling run so that adequate supplies within their expiration date are on hand for the next monthly sampling run.

18. Data Acquisition Requirements

Data acquisition is discussed in the *SOP 7: Spring Discharge Monitoring*, *SOP 6: Handheld Water Quality Instrument*, *SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling*, and *Springsnail Monitoring*, and *SOP 9: Monitoring Water Levels in Wells*.

19. Data Management

Data management is addressed in *SOP 16: Data Management*.

20. Assessment and Response Actions

Evaluation of field, lab, and data management activities will be a routine and on-going responsibility of the MOJN I&M hydrologist. The MOJN I&M hydrologist will be responsible for checking completeness and internal consistency of the collected data. It will be up to the MOJN I&M hydrologist to follow-up and determine if errors can be corrected, or if data should be discarded.

21. Reports

Reporting is discussed in *SOP 15: Data Analysis and Reporting*.

22. Data Review, Validation, and Verification Requirements

There are three levels of data quality review for all water data collected by MOJN I&M.

1. Field review of core parameters is built into the data collection protocols. Review of data as it is collected in the field is paramount to successfully collecting representative field data. The test for “representativeness” is based on the reported range of previously-measured values for the site and professional judgment. All field data must meet the MQOs listed in Table 13.4. Corrective measures to ensure un-biased and precise measurement of core parameters can only be made while the operator is in the field.
2. The next level of data review occurs at the laboratory where results are screened for spurious values before sending data to the MOJN I&M hydrologist for review. Prompt review (< 7 days after receipt of data) of laboratory data by the hydrologist is critical to ensure re-runs are possible before samples are discarded or mature beyond their holding times.

MOJN I&M staff will conduct an internal review of laboratory results as they are received from the laboratory that includes the following:

- a. Comparison of duplicate samples using a 10% threshold for further investigation.
 - b. Screen all the blanks and audit standards, and require lab to respond to every inconsistent result.
 - c. Compare dissolved P and N to total P and N (dissolved should be less than or equal to total).
3. The final level of review occurs when the MOJN I&M hydrologist or member of the MOJN I&M data management team performs checks on bounds and internal consistency. Other checks that occur at this stage include ensuring that data,
 - a. contain all required fields,
 - b. have encoded valid values from constrained look-up lists where specified, and

- c. are in the correct format (text in text fields and values in numeric fields, etc.).

At any point in the data collection and review process the MOJN I&M hydrologist can make decisions to discard or flag data that they know is not representative.

22.1. Verification and Validation Methods

Two levels of data entry review will be performed by MOJN I&M personnel to determine consistency between field sheets and the digital database with an eye toward agreement and data gaps. The first review is performed by a MOJN I&M technician conducting a 100% review of data correctness in the database compared to the field datasheets. Following this review, the network data manager will review 5% of the sample events for correctness in the database compared to the field datasheets.

Additional checks on data quality will be conducted as data are analyzed in the analysis and reporting phase. Often subtle trends or occasional data outliers are not detected until examined in context with other data collected from a site in the form of graphs, and tables. At this stage it is the collective responsibility of all cooperating personnel to track down potential sources of error and make corrections where appropriate or flag data as necessary. However, no data will be removed from the database unless a compelling and rational reason exists to explain why it should be removed.

The final review is conducted by the MOJN I&M hydrologist prior to the data being certified and migrated to the master database for eventual water quality reporting to NPS WRD and EPA.

22.2. Reconciliation with Data Quality Objectives

To ensure data collection, compilation, and review meet the project objectives, the annual report preparation will include an evaluation of the data with respect to the DQOs and MQOs discussed in Sections 6 and 7. In addition, the effectiveness and completeness of the monitoring activities will be evaluated.

Effectiveness, E will be calculated as

$$E = (U / C) \times 100 \text{ ,}$$

where:

U = number of usable parameter values, and
C = number of parameter values collected.

Completeness C, will be calculated as

$$C = (U / P) \times 100 \text{ ,}$$

where:

U = number of usable parameter values, and
P = number of potential parameter values collected.

These results will be used to make corrective actions that will improve the quality and efficiency of data collection where necessary.

23. Literature Cited

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Standard Operating Procedure 14: Cumulative Measurement Bias

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

This is a long term monitoring program and as such it is expected that field personnel, instruments, field methods, and laboratory analytical methods. It is extremely important to quantify the effect that change in these factors may have on data so to ensure that data comparability proceeds through the life of the monitoring program and beyond. This SOP outlines the major types of change, and how changes can be mitigated to ensure change detection is due to environmental conditions rather than observer, sensor or methodology.

[This SOP was adapted and expanded from Thoma et al., (2009)]

2. Changes in Personnel

Observer variability needs to be controlled because although most of the water quality measurements are made with electronic instruments, the exact location of a monitoring and sampling site is somewhat subjective. Therefore, there is the potential for bias in selecting where measurements are made.

Cumulative bias could be created by turnover in the MOJN I&M hydrologist position. Ideally, this bias would be evaluated by having the outgoing and incoming hydrologists make a full season of duplicate measurements and collect duplicate samples. The number of duplicates for each data type should be determined by the magnitude of the effect of differences between observers, the ease with which measurements can be collected, and the cost of sample analysis. However, there may not be a period of overlapping employment for the outgoing and incoming hydrologists. For this reason, it is important that the SOPs describe the field procedures in detail, and that the MOJN I&M hydrologist either follows the methods described in the SOPs or updates the SOPs to reflect any changes in procedure.

When the only change is in personnel, a minimum of seven paired measurements should be made on the same object or sample by each observer. To ensure the highest possible degree of repeatability, readings should be taken close together in both space and time.

3. Replacement of Instruments

Changing instruments and sensors over time introduces the potential for bias, even when they are calibrated using the same standards. For instance, pH probes may have different algorithms for temperature compensation.

When the only change is in instrument or sensor a minimum of 30 measurements will be made on the same object or sample with each instrument. Sonde measurements should be made in containerized samples to avoid natural variation. DO measurements should be made in an agitated sample to avoid oxygen consumption at the sensor tip if using a polarographic-type sensor.

Unfortunately, it is common for a new instrument to be purchased when the old instrument breaks or is lost, making paired measurements impossible. It is best to avoid this situation by replacing

instruments before they are unusable. Regular AMS+ estimates and head-to-head performance comparisons may provide some information about instrument performance.

4. Level Changes at Gaging Stations

At continuous discharge or pool stage monitoring sites, long-term records can be imperiled by small changes in elevation due to settling, subsidence, scouring, disturbance, etc. The USGS has developed protocols for running levels at gaging station stations (Kenney 2010) to detect any changes and correct for them. MOJN I&M will run levels (or have the USGS run levels) using USGS protocols every year at Blue Point Spring, MC Spring, and any other springs where it is responsible for collecting continuous discharge or pool stage data.

5. Changes in Field Methods

Changes in field methods may be necessary as new techniques are developed that prove to be superior to older techniques. Rather than use inferior techniques for the sake of continuity, this monitoring program should adopt new methods while taking the appropriate precautions to avoid cumulative bias.

It should always be possible to collect paired measurements using the old and new methods. The number of duplicates should be determined by the magnitude of the effect of the change in methods (as determined from the first few paired measurements), the ease with which measurements can be collected, and the cost of sample analysis. If possible, at least 50 paired measurements will be made. More measurements are necessary when indicators (as opposed to measured parameters) change because very few indicators respond in exactly the same way to environmental stimuli. The more complex the relationship between the measured value and what it is intended to represent the more measurements need to be made to ensure data from the two indicators or methods can be compared through time.

6. Changes in Laboratory Methods

The MOJN I&M SLS protocol uses outside labs for chemical analyses and benthic macroinvertebrate enumeration.

6.1. Chemical Analysis

Analytical laboratories have procedures in place to avoid the introduction of long term bias, including interlaboratory comparisons, comparisons between technicians, and frequent calibration of instruments. In the event that the testing laboratory replaces its instruments or changes its SOPs, it is the responsibility of the laboratory to avoid cumulative bias. The protocol lead should discuss whether any changes have occurred at the laboratory at the beginning of the field season.

Over the course of the sampling program, it may be necessary to switch laboratories. In this case, it is highly desirable, although expensive, to have both laboratories analyze split samples, preferably for an entire field season. If the same procedures are used by both laboratories, and both laboratories

participate in rigorous external QA/QC programs, then the differences may be minimal. If different analytical methods are used, the literature should be reviewed for any comparisons of the two methods. In any case, it is important that laboratory procedures for all analyses that have historically been conducted or are currently being conducted on MOJN I&M samples are included in the supplementary materials for this SOP.

6.2. Taxonomic Identification

BMI data are generated by laboratory staff identifying and counting insect specimens. Experience has shown that the way these specimens are identified can drift over time, as personnel change and the science moves forward. The laboratory used by MOJN I&M (the USU BugLab) follows internal QA/QC procedures to attempt to minimize this drift. However, over the long term, the key to avoiding bias in BMI samples is archiving. MOJN I&M's BMI specimens are on long-term loan to the USU BugLab, who will properly archive the samples so that they are preserved indefinitely. As a result, any questions of cumulative bias in taxonomic identification can be resolved by having future laboratory staff "re-identify" the sample. The protocol lead may wish to have the BugLab re-run samples if significant trends in BMI indices are observed over a period of decades.

A change in BMI laboratories should be avoided because of the convenience of having all past samples archived in the same location. However, if a change becomes necessary, then it is highly desirable, although expensive, to have both laboratories analyze split samples, preferably for an entire field season.

MOJN I&M will collect voucher specimens of springsnails from each monitored spring, and have them identified by a taxonomist every 10 years or as needed. The voucher collection will be maintained permanently.

7. Major Changes in Spring Environments

Springs can undergo major changes due to fire, scouring, restoration, natural geomorphic processes, etc. If there are major changes (e.g., the course of the springbrook changes, a pool is filled in), then it may not be possible to collect consistent data using the same SOPs. In the event of major changes at the spring, the MOJN hydrologist should document the changes and attempt to develop new methods that will be useful in demonstrating how the spring has changed. If a spring changes frequently, then new methods should be developed that can produce consistent data in the face of these changes. An example of this is the use of the open water area method used at 49 Palms Oasis in JOTR, which can produce comparable data over time even as individual pools are filled and scoured.

8. Statistical Analysis of Paired Measurements

As noted above, paired measurements will be made whenever possible to avoid cumulative bias.

These measurements may involve changes in instruments, observers, methods, or indicators. In this section, "methods" will be used as shorthand for all of these possible changes.

8.1. Detecting Changes in Precision

Precision refers to how closely individual measurements agree with one another. Ideally, repeated measures made using the same method on the same sample will be very similar.

Precision will be assessed using the standard deviation of repeated measures of a normal environmental sample. Standard deviation is a measure of the amount by which estimates in a distribution differ from the mean of measured values. It can be calculated using any statistical software package or Microsoft Excel.

When a set of paired measurements is made in such a way that seven or more measurements are taken on a single sample, the standard deviations for each method should be reported in this SOP. For laboratory analyses, laboratory-provided estimates of measurement precision may be used in lieu of having the same sample analyzed seven times by two labs.

8.2. Detecting Changes in Sensitivity

We measure sensitivity via an estimate of measurement precision expanded uncertainty (MPEU). Measurement sensitivity will be evaluated by analysis of repeated measures of a normal environmental sample. This is essentially an estimate of precision but in a more rigorous sense based on a confidence interval. It differs from AMS+ (section 7.4) in that MPEU samples are made in a bucket, while AMS+ measurements are made in situ.

MPEU is calculated as

$$\text{MPEU} = t * \text{sd}_n$$

where

t = the 99% confidence middle t value for sample size n , and

sd_n = standard deviation of n replicate samples on a normal environmental sample.

When a set of paired measurements is made in such a way that seven or more measurements are taken on a single sample, the MPEU for each method should be reported in this SOP.

8.3. Detecting Measurement Bias

Measurement bias is a systematic difference between measurements made using different methods. Several methods may be used to detect measurement bias.

8.3.1. Significance Test

A significance test can be used if multiple measurements (7 or more) are made using both methods on a single sample. A t -test is performed to determine if the two sets of measurements came from the same population with the same mean. The t -test may be performed using any statistical software package or Microsoft Excel. While this test may be used to detect bias, it cannot be used to adjust data, as the level of bias at different parameter values is not explored.

8.3.2. Percent Difference

Percent difference is a measure of how different two measurements are expressed relative to the first measurement:

$$PD = ((q_2 - q_1) / q_1) * 100 \quad ,$$

where

q_1 = method 1 measurement value, and

q_2 = method 2 measurement value.

If only a small number of data pairs are available, then PD can be used to qualitatively assess bias. In particular, if the PD values are predominantly positive or negative then a large bias may be present.

If a large number of data pairs are available, then the standard deviation and 95% confidence interval of the PD values should be calculated. If the 95% confidence interval does not include 0, then the bias is statistically significant. However, the sign of the bias may change in different parameter ranges (e.g., sensor 1 may record higher pH values than sensor 2 in acidic environments but lower pH values than sensor 2 in basic environments). In this case, the distribution of PD values would include zero, so 95% confidence interval test described above would not detect the bias, and slope determination should be used.

8.3.3. Slope Determination

A full evaluation of bias requires the collection of paired measurements collected on different samples with a wide range of parameter values. These measurements will be plotted against each other, and a best-fit line will be calculated using any statistical software package or Microsoft Excel. Ideally, this best fit line would have a slope of one and an intercept of zero. Any statistically-significant deviation from these values is an indication of measurement bias that must be corrected for the analysis of long-term trends (Section 16.7).

9. Adjusting Data Correct for Cumulative Bias

The preferred method for dealing with bias is to adjust the laboratory method, instrument settings, or observer behavior to eliminate the bias. However, if these adjustments cannot be made, then the data must be adjusted prior to trend analysis. These adjustments are for the purposes of detecting long term trends only. Corrected data should never be recorded on a field sheet or uploaded to a database.

9.1. Before making adjustments

Before making adjustments to raw data a careful evaluation of the statistical results needs to be made in light of how the test was conducted. The offset, bias, slope, t-test, percent difference and sample size calculations are more meaningful when the test includes multiple springs. This type of test is more meaningful because it provides information about how the two observers, instruments or techniques compare across the expected range in field conditions. Without multiple springs (or perhaps multiple calibration standards) the data should not be adjusted.

Insufficient sample sizes result in data that are difficult to interpret. The sample size required to detect a difference can be evaluated using the methods described by Irwin (2008). If the sample size is insufficient, then the number of paired measurements should be increased, if possible.

9.2. Making adjustments

After determining that the means are not equal it is possible to adjust new results to correspond to old results such that measurement effects are subtracted from the new results. After adjustment temporal differences should only result from natural effects.

1. In Excel plot new method results on X-axis and old method results on Y-axis.
2. Determine the equation for the regression line.
3. Right click on a data point and click add trend line.
4. Make type be linear and under options select display equation and R-square value on chart.
5. Adjust data using the equation displayed on the chart.

9.3. Documentation

If adjustments are made they need to be carefully documented. It is exceedingly important that the original raw data and paired data be retained so that in the future evaluations can be made using other techniques. All adjustments made, along with any paired data used to evaluate cumulative bias, should be added to section 8, below. Additionally, if data in any database are adjusted a permanent record of the adjustment should be kept with the data in the comments field explaining why and how the adjustment was made.

10. Record of Paired Measurements Made to Control Bias

As of 2014, no paired measurements have been made for the purposes of bias control. Any measurements made in the future should be recorded here, along with any statistical analyses performed on them.

11. Literature Cited

Thoma, D., D. Sharrow, K. Wynn, J. Brown, M. Beer, and H. Thomas. 2009. Water quality vital signs monitoring protocol for park units in the Northern Colorado Plateau Network. National Park Service, Fort Collins, Colorado. Available online: <https://irma.nps.gov/App/Reference/Profile/2175498> (accessed 1 December 2014).

Standard Operating Procedure 15: Data Analysis and Reporting

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Introduction

This document details: 1) the methods used to process the data collected for this protocol, 2) the methods that will be used to detect long term trends in the data, and 3) the format and content of the reports that will be prepared.

2. Calculating Discharge from Quarterly Field Measurements

2.1. Volumetric Discharge Measurements

Volumetric measurements are converted to discharge by 1) dividing the volume of the container filled by the time needed to fill it, and 2) taking the mean of the repeated measurements. These steps will be automatically performed by the database at the time of data entry.

2.2. Stream Gaging Using a Flowmeter

Flowmeter measurements are collected using standard USGS stream gaging methods. For consistency, these data should be processed using the method described in *SOP 17: Data Analysis and Reporting* in the Streams and Lakes Protocol (Moret et al. 2012).

2.3. Portable Flumes and Weirs

The discharge in cubic feet per second through a Parshall flume (Q) is related to the water level in feet in the flume (h) by the equation:

$$Q = Ch^n \quad (1),$$

where C and n are empirically-determined parameters related to the width of the flume's throat (Table 15.1).

Table 15.1. Values of C and n for different flume sizes. Data from U.S. Bureau of Reclamation (2001).

Flume Throat	C	n
1 inch	0.338	1.55
2 inch	0.676	1.55
3 inch	0.992	1.55
6 inch	2.06	1.58

The discharge in cubic feet per second through a 90° V-notch weir (Q) is related to the stage of the weir pool in feet (h) minus the level of the weir notch (h_o , or the point of zero flow) by the equation:

$$Q = 2.5(h - h_o)^{2.5} \quad (2)$$

Discharge values will be automatically calculated in the database using equation (1) or equation (2).

3. Computing Continuous Discharge and Pool Stage Records

Continuous discharge and pool stage records are processed in Aquarius, a proprietary software package for the analysis of continuous data. In general, the procedures for record computation will be as follows:

1. Upload data to Aquarius server
2. Apply corrections to convert pressure transducer records to water level records
3. Convert Water level data to discharge using the Rating Curve Player in Aquarius (discharge records only).
4. Display the data graphically and compute summary statistics using Aquarius.

The NPS I&M Division has decided to develop national protocols for water data processing. MOJN will follow these protocols once they are developed.

4. Trend Analysis

As table 15.2 shows, trends will be analyzed using two different approaches: parametric trend testing using an R code written by L.A. Starceвич and non-parametric trend-testing using the R package “Kendall” (Macleod 2011). The model is implemented using R, a high-level computer language for data analysis. R can be downloaded for free at <http://cran.r-project.org/>.

The trend analyses should be undertaken by an experienced R user.

Table 15.2. Trend analysis procedures.

Data Type	Measureable Objective (Section 1.3.2)	Trend Analysis Method
Spring Discharge	Determine the status, trend, and natural range of variability in spring discharge	Parametric (mixed-model) trend testing and SKT testing for seasonally-weighted mean discharge for each spring, MKT for annual mean discharge.
Benthic Macroinvertebrates	Determine the status and trend in spring macroinvertebrate assemblages	MKT of basic indices for each spring
Water Quality and Water Chemistry	Determine the status, trend, and natural range of variability in spring water chemistry	SKT for water quality and MKT for water chemistry for each spring
Springsnails	Determine the status and trend in the population and spatial extent of springsnails	MKT for furthest downstream observation and mean population density. Qualitative evaluation of changes in population density vs. distance downstream.
Monitoring Wells	Determine the status and trend in the water levels in monitoring wells relevant to selected large springs	MKT trend testing for seasonally-weighted water level for each well.

SKT= Seasonal Kendall Test MKT= Mann-Kendall Test

4.1. Non-Parametric Trend Analysis Using Kendall Tests

As of 2014, the most convenient method for Kendall analysis of the Streams and Lakes data appears to be the R package “Kendall”. However, the protocol lead may use any convenient software package in the future. The script in the Supplementary Materials was written using version 2.2 of the “Kendall” package (McLeod 2011) and version 3.1.1 of R (R Core Team 2014).

4.1.1. Mann-Kendall Testing

The Mann-Kendall test is used to test for monotonic increase in time series data. In the SLS protocol, it will be used to test for trends in biennial data and annual mean values of continuous data (Table 15.2). A sample R script for Mann-Kendall testing is included in the Supplementary Materials (MannKendallRogersSpringDischarge.R). As the example shows, the input is a vector of the values to be tested (in this example, the mean annual discharges of Rogers Spring from 1986 to 2013). In the example, the trend in the data is slightly negative ($\tau = -0.0647$) but far from statistically significant ($p = 0.64843$).

4.1.2. Seasonal Kendall Testing

The seasonal Kendall test is used to test for monotonic trends in time series affected by seasonal variation. In the SLS protocol, it will be used to test for trends in quarterly data that exhibit seasonal variability. A sample R script for Mann-Kendall testing is included in the Supplementary Materials (SeasonalKendallSyntheticOpenWaterArea.R). As the example shows, the input is a time series object of the values to be tested (in this example, a synthetic data set with strong seasonal variation, a 5% annual increase in all seasons, and a random noise component) with a frequency of 4 (that is, quarterly data). Mann-Kendall testing of this data set does not detect a statistically significant trend ($p = 0.12$). In contrast, the seasonal Mann-Kendall trend detects a significant positive trend ($\tau = -0.727$, $p = 4.6 \times 10^{-11}$).

4.1.3. Censored Data

Mann-Kendall and Seasonal Kendall tests are non-parametric and based on ranked comparisons of data values, so censored data (data sets in which some measurements are below detection) can be used as long as all of the non-detect have the same detection limit (Hirsch et al. 1991). Commercial laboratories with well-established protocols seldom change their detection limits, and it is not clear how many non-detects will be encountered in the SLS data. However, over the long term, it is likely that it will be necessary to perform trend analyses on data sets with censored data collected with different detection limits. When that situation arises, the protocol lead will need to use trend analysis methods developed specifically for multiple detection limits (e.g., Lee and Helsel 2007).

4.1.4. Serial Correlation

Simple Kendall tests such as those used in the examples assume no serial correlation (that is, that each measurement is independent of the preceding and following measurements). Serial correlation is not generally found in quarterly or less frequently-sampled data (e.g., Harris et al. 1987), so it is not anticipated that it will pose a problem for the SLS protocol trend analyses.

4.2. Parametric Trend Analysis

The SLS protocol uses a linear mixed-model for parametric trend testing (VanLeeuwen et al., 1996; Piepho and Ogutu, 2002). The linear mixed-model trend test will be used for to test for trends in

biennial data and annual mean values of continuous data (Table 15.2). A sample R script for linear mixed-model testing is included in the Supplementary Materials (LMMRogersSpringDischarge.doc). As the example shows, the input is a matrix of the values to be tested (in this example, a text file of the monthly discharges of Rogers Spring from 1986 to 2013). In the example, the trend in the data is slightly negative ($\beta_1 = -0.0015$) but not statistically significant ($t' > t_\alpha$).

5. Reporting

Three types of reports will be produced using SLS protocol data: automated reports, biennial reports, and trend analysis reports.

5.1. Automated Reports

In an effort to make data available to park managers in a timely fashion, MOJN I&M will develop a web application for automated reporting. The application will allow park staff to select springs from a map, then produce plots or tables of discharge or water quality parameters over time. Certified data will be made available for reporting on a quarterly basis. The lists of parameters which will be available for automatic report generation for each spring are given in Table 15.3.

Initially, the data from DEVA that is collected by park staff in cooperation with WRD will not be included in the automated reporting. These data may be added to the system in the future.

The application will be developed using Rshiny, a web application package for R, and will be hosted on an NPS server in Fort Collins, Colorado. Initially, the application will only be accessible to NPS personnel.

Table 15.3. Parameters for automated reporting for selected large springs.

Park	Spring	Parameters
GRBA	Strawberry Source	Discharge, water quality parameters ¹
	Boiler	Discharge, water quality parameters
	Marmot	Discharge, water quality parameters
JOTR	49 Palms	Open water area, number of pools, water quality parameters
	Smith Water Canyon	Springbrook length, number of flowing outlets, water quality parameters
LAKE	Blue Point	Daily mean discharge, staff gage readings, water quality parameters
	Rogers Spring	Daily mean discharge, water quality parameters
MOJA	MC Spring	Daily mean pool stage, staff gage readings, water quality parameters
PARA	Pakoon	TBD
	Tassi	Discharge, water quality parameters

Water quality parameters= temperature, specific conductivity, dissolved oxygen, pH.

TBD = to be determined once spring rehabilitation is complete.

5.2. Biennial Reports

MOJN I&M will produce a biennial report for each park once data from the water chemistry and BMI laboratories are received. The report will include all the discharge, water quality, water

chemistry, BMI, and springsnail data produced in the park since the last report. Water levels collected at wells will also be included. Reports will be distributed to NPS-WRD, network staff, Resource Chiefs, MOJN Technical Committee, and the MOJN Water Resources Working Group. Reports will also be made available to interested park staff and the public via IRMA.

The biennial reports will include the following information:

- Description of field work in the park highlighting accomplishments
- Documentation of any deviations from the protocol, such as missed sites or samples
- Results from the past two years, including raw data, summary statistics and graphics
- Quality assurance and quality control analyses

The purpose of the biennial reports is to communicate SLS protocol results to park staff and the public in a timely way. They are not intended to provide in-depth analysis of the data. As such, they will be published in the NPS Natural Resource Data Series. A sample biennial report (Bailard et al. 2014) is included in the Supplementary Materials.

5.3. Data Synthesis Reports

Data synthesis reports will be prepared for each park every four years. In addition to summarizing the collected data, these reports will include the following information:

- Overview of the protocol status and major accomplishments
- Status and trend analysis results
- Discussion of results, including management implications
- In depth, quality assurance and quality control analysis and discussion
- Recommendations for future improvements.

The specific details of report content will be determined by the protocol lead at the time of report preparation.

6. Literature Cited

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- R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online: <http://www.R-project.org/> (accessed 19 November 2014).
- VanLeeuwen, D. M., L. W. Murray, and N. S. Urquhart (1996). A mixed model with both fixed and random trend components across time. *Journal of Agricultural, Biological, and Environmental Statistics* 1(4):435–453.

Standard Operating Procedure 16: Data Management

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

The following Data Management SOPs referred to in this section can be found in the MOJN I&M Data and Information Management Plan (MOJN-NPS 2007) or on the MOJN SharePoint Site:

1. MOJN-DM-SOP Database Naming Conventions
2. MOJN-DM-SOP Image Management
3. MOJN-DM-SOP Naming Conventions
4. MOJN-DM-SOP Directory Structure Non-Spatial
5. MOJN-DM-SOP Archiving
6. MOJN-DM-SOP Project Deliverables
7. MOJN-DM-SOP Season Closeout

Some content in this SOP was originally published as part of the NCPN Riparian Monitoring of Wadeable Streams Protocol (Weissinger et al. 2013).

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1. Database Design

MOJN I&M protocol databases are designed to be compliant with the standards set forth by the NPS Inventory and Monitoring Program's Natural Resources Database Template (NRDT), version 3.2 (National Park Service 2007). The database consists of two separate MS Access files. The 'front end' contains forms, linked tables, reports, queries, macros, and Visual Basic code while the 'back end' houses the data tables. This organization of the database allows new development and edits of forms and reports (housed in the front end) to proceed without hindering use of the data (housed in the back end). The link between frontend and backend files is managed by a utility that is programmed in the frontend database.

Data in the database are certified annually after quality assurance review. The database is then archived with the project files for the monitoring project. Archived files may include, but are not limited to, the database, data processed by proprietary software (e.g. continuous water quality summary data), photo links, GPS data, laboratory results, etc.

In addition to the SLS Database, ancillary data may be stored in geodatabases for geospatial data generated from field visits, and image management databases for photographs. The SLS database is the focus of this document.

1.1. Scope of the Database

The SLS Database is:

1. A relational MS Access database organized by subject-based tables and primary keys
2. Compliant with NRDT version 3.2
3. Designed to facilitate reporting and analyses of the data

The SLS Database can:

1. Manage summaries of continuous logger data
2. Provide quality control of data input
3. Provide quality assurance of discrete field data
4. Accommodate import of laboratory results
5. Accommodate annual data photo metadata
6. Accommodate export of water quality data and metadata that meets the NPS Common View and NPS EQuIS EDD requirements

The SLS Database cannot:

1. Manage large quantities of continuous logger data
2. Process continuous logger data for outliers and quality assurance
3. Store all data photos

1.2. Database Design Considerations

The following items were considered and included in the design of the database:

- Yes/No data types are not used; instead the field is set to Text data type, field size is limited to 4, Display control is Combo Box, Row Source Type is set to Value List, and the Row Source is “Yes;No”
 - Reason: Yes/No data types are check boxes in the database tables that may be true/false or binary (e.g. 0 or 1); therefore using text data type limits the data to a consistent value regardless of the software platform.
- Default values for Number data types are set to null to prevent the accidental inclusion of a zero value as data
- Non-integer numerical data are decimal data type, with appropriate scale and precision
- Use of enumeration tables for administrative information, e.g. Park unit codes, and water quantity and quality parameters that are not highly variable year to year
- Use of look-up tables for highly variable lists of information such as crew members and equipment tracking that must be updated and expanded annually
- Naming conventions of the database objects and fields follow the standards outlined in MOJN I&M Data Management SOP Database Naming Conventions

1.3. Database Design Summary

The following database tables and relationships were developed in a back-end master database based on the structure and standards of the I&M Natural Resources Database Template (NRDT), version 3.2. The unifying tables for most of the SLS springs data are tbl_Events and tbl_Data_Main for field data, and tbl_Event_Group for the summary data. Independent tables include tbl_1_Meta and tbl_1_Revisions which are used by the Network Data Manager to track the changes to and provide metadata for the database. Tables such as tbl_Equipment and tbl_Equip_Maint_Log document field equipment which is tracked using the equipment serial number along with the data collection and maintenance events. Cameras and GPS devices are not tracked with the equipment tables.

Due to the large size of the raw files generated from the continuous data loggers, raw and corrected continuous water quantity data are stored and archived in a text file format for a complete water year. These data are not stored in the SLS Database, but are uploaded and processed on an Aquarius server hosted by the NPS WRD.

Summary data derived from the continuous logger data may be stored and accessible in the database along with tracking records and descriptions of data flags and corrections derived from the processing of the data using Aquarius software.

Photographs associated with the protocol will not be stored in the database with the exception of annual site images for reference. MOJN I&M Data Management *SOP Image Management* documents procedures for organizing, cataloging, and creating metadata for all protocol photos.

1.4. Database Structure

Table 16.1 lists and describes the subject-based MS Access tables for the SLS Database. Tables include those that store field data, summary data from processed continuous logger files, calculated data fields, enumeration tables, and look-up tables.

Figure 16.1 through Figure 16.3 detail the tables, fields within the tables, and the relationships between the tables in the SLS database.

Table 16.1. Selected Large Springs database tables, MS Access format.

TableName	TableDescription
tbl_1_Db_Meta	Database description and links to I&M metadata tools
tbl_1_Db_Revisions	Database revision history data
tbl_Data_BMI	Field-collected data; Location and documentation of benthic macroinvertebrate samples collected in the field
tbl_Data_Chnl_Char	Field-collected data; Transect channel characteristics
tbl_Data_Discharge	Field-collected data; Gage readings for discharge calculations
tbl_Data_Discharge_Volumetric	Field-collected data; Volumetric measurements that are used to calculate discharge
tbl_Data_GPSField	Field-collected data; Field information as well as quality control coordinates comparison with tbl_Locations to ensure field crew are at the proper location
tbl_Data_Main	Field-collected data; Single measurement values collected during a sample event and may relate to other tables
tbl_Data_Photos	Field-Collected Data; Purpose and name of photographic images and their location on the MOJN I&M server
tbl_Data_Pressure	Field-collected data; Pressure transducer data-logger readings for quality control
tbl_Data_Springsnails	Field-collected data; Springsnail survey data and sample collections for species verification
tbl_Data_Well	Field-collected data; water well measurements
tbl_Data_WQ_AMSplus	Field-collected data; Discrete AMS+ data for water quality assurance assessment
tbl_Data_WQ_Pool	Field-collected data; Discrete water quality data for limnocrene springs without a springbox or a springbrook
tbl_Data_WQ_Springbox	Field-collected data; Discrete water quality data for springs with a springbox
tbl_Data_WQ_Springbrook	Field-collected data; Discrete water quality data for springs lacking a springbox but a springbrook is present
tbl_Equip_Maint_Log	Equipment maintenance log
tbl_Equip_Tracking	Log to track equipment used to collect field data

Table 16.1. Selected Large Springs database tables, MS Access format (continued).

TableName	TableDescription
tbl_Event_Details	Sampling event details
tbl_Event_Group	Event aggregations (e.g. summary metrics)
tbl_Events	Field-collected data; Basic sampling event information
tbl_Files_AquariusUpload	Process files exported from Aquarius software and associated with reporting
tbl_Files_Received	File names of digital PDF copies of field sheets and raw logger files; Entered here when files are downloaded to MOJN I&M server
tbl_Lab_BMI	Laboratory results; Benthic macroinvertebrate
tbl_Lab_BMI_Vouchers	Benthic macroinvertebrate voucher data
tbl_Lab_Chemistry	Laboratory results; Water quality chemistry data
tbl_Locations	Sampling unit locations; permanent geospatial coordinates that may be updated periodically or additional coordinates appended
tbl_Sum_WQ	Metrics for core water quality parameters; Summary data derived from processed continuous logger data using Aquarius software
tbl_Sum_WQ_AMSplus	Summary statistics for AMS+ data
tbl_Sum_Corrections	Corrections applied to the continuous logger data using Aquarius software
tbl_Sum_Flags	Flags generating during the processing of the continuous logger data using Aquarius software
tlu_Contacts	Contact data for project-related personnel
tlu_Enum_Admin	Enumerated lookup table for administrative variables
tlu_Enum_NPSEDD	Enumerated lookup table for EDD
tlu_Enum_Water	Enumerated lookup table for water quality and quantity variables
tlu_Equip	Equipment list and serial numbers
xref_Event_Contacts	Cross-reference table between events and contacts

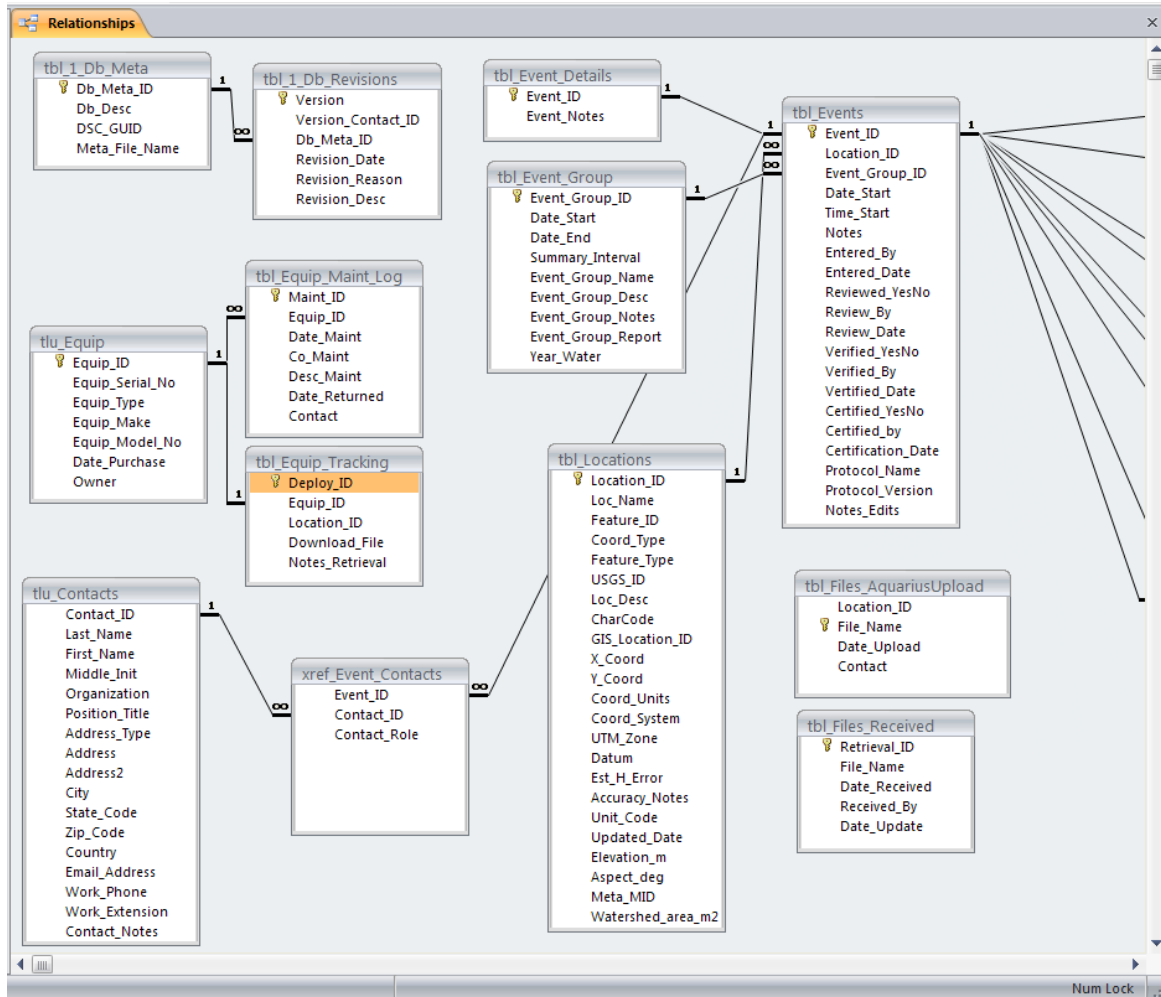


Figure 16.1. Administrative tables for Selected Large Springs database.

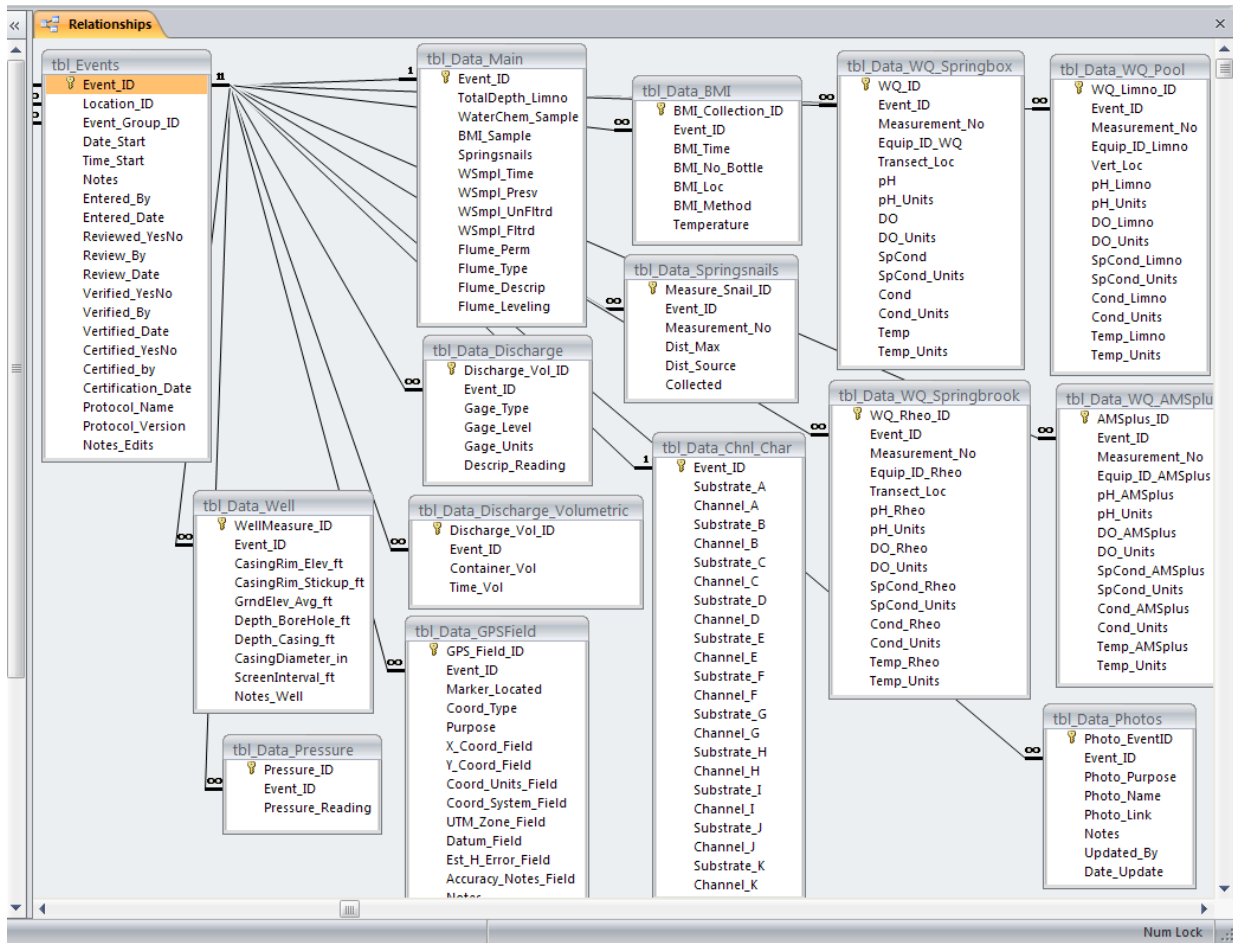


Figure 16.2. Field-collected data tables and relationships to **tbl_Events**. All tables except **tbl_Data_Main** and **tbl_Data_Chnl_Char** have a one-to-many relationship with **tbl_Events**.

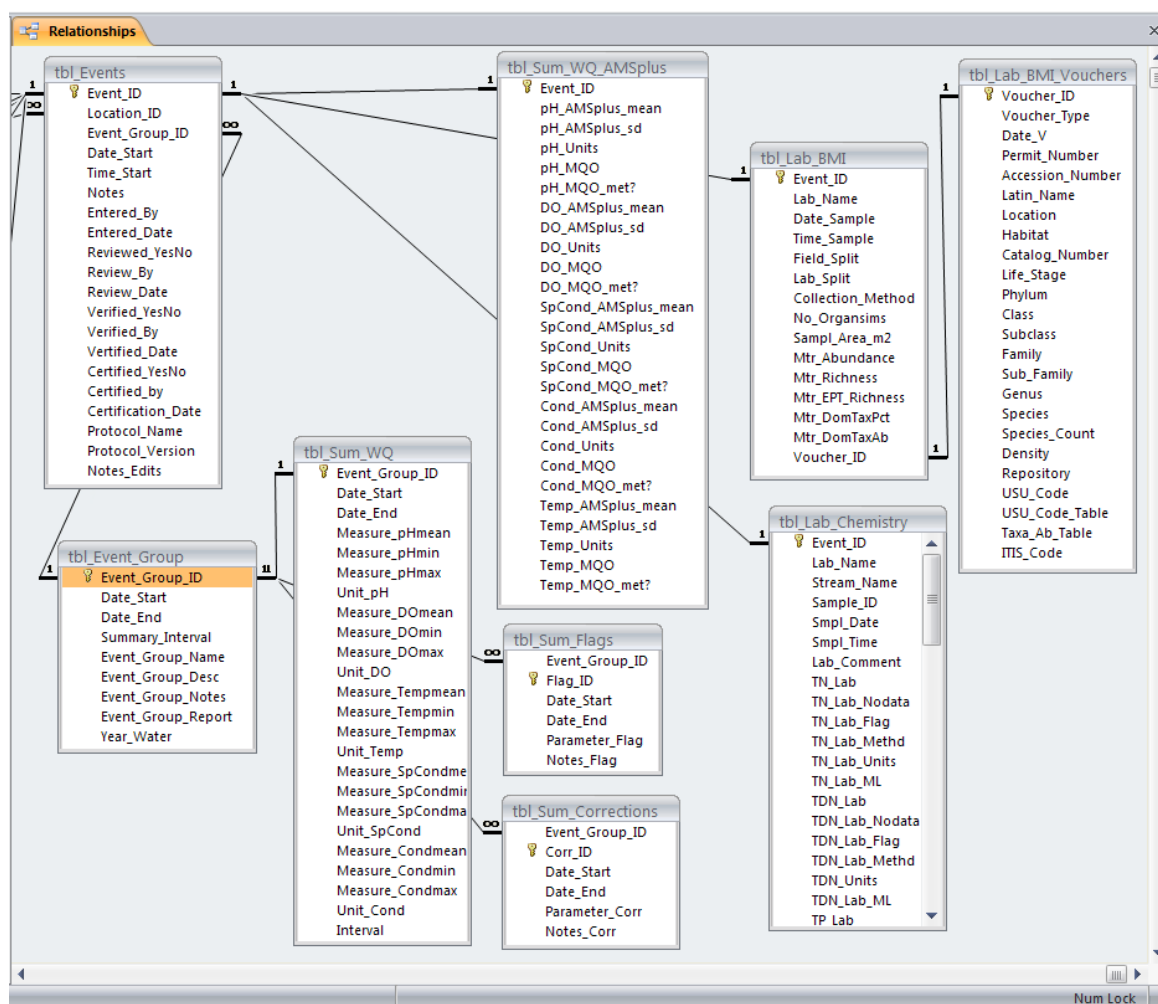


Figure 16.3. Laboratory (right) and data summary tables (lower left) and their relationships with tbl_Events and tbl_Event_Group.

1.5. Updating the Database Design

Lessons learned through years and updates to the protocol will require adjustments and additions to the database. Database changes are tracked using version controls in the tbl_1_Db_Revisions as well as a version number in the file name. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the structure and/or protocol methods. Version numbers will be incremented by tenths (e.g., Version 1.6 to Version 1.7) when there are changes to field names, field structure, data entry tables, queries, and any other minor modifications that do not affect the data.

2. Information Management Workflow

2.1. Introduction

Information Management workflow describes the numerous steps required to receive and process the data generated for Selected Large Springs (SLS) protocol. Schematics in Figures 16.4 and 16.5 provide the overall workflow for the entire project. SLS monitoring protocol is an integration of both

water quality (e.g. chemistry) and water quantity (e.g. discharge) procedures. Although the data for both procedures will be collected simultaneously in many instances, the processing workflows are distinctly different and are differentiated in this SOP. Information and data from USGS continuous discharge measurements at springs are managed according to the Streams and Lakes protocol. Because continuous discharge data for USGS monitoring sites at springs will be collected by the Streams and Lakes protocol crew and the data will be processed in a manner identical to the Streams and Lakes protocol, all USGS continuous discharge data from springs will be maintained in the Streams and Lakes database. Please refer to the Streams and Lakes protocol (Caudill et al. 2010) for more information. Following the two workflow schematics below are outlines of tasks that need to be accomplished in a timely manner throughout the lifecycle of the protocol.

2.2. Roles and Responsibilities

Information management tasks are the responsibility of the Data Manager and the Project Lead. While many of the tasks are carried out by field technicians, the ultimate responsibility for proper training and techniques is with the Project Lead. The Data Manager is responsible for ensuring that all information, primarily in the form of digital and non-digital data associated with the protocol is properly received, processed, stored, and archived.

2.3. Summary of Devices and Data Collections

SLS protocols couples both continuous and discrete data collection downloaded from devices in addition to field data collected from field measurements and devices that are recorded on hard copy field datasheets. The following is a list of general devices used for this protocol:

1. Camera
2. GPS unit
3. Fixed installation flowmeters
4. Water level/pressure transducer data-loggers
5. Container of known volume for volumetric discharge measurements
6. YSI water quality meter, handheld for discrete data collection
7. Water chemistry, BMI, and spring snail sample vials

2.4. Springs Discharge Data

Discharge is measured at variable frequency and with variable methods that depend on the type of spring. Refer to *SOP 7: Spring Discharge Monitoring* for more detailed information. Table 16.2 summarizes the data collected.

Table 16.2. Methods of discharge data collection and frequency for Selected Large Springs.

Type of Measurement	Continuous Data Logger	Frequency
USGS Stream gage	Yes	15 minutes
Volumetric	No	Quarterly
Flume/Weir – Pressure Transducer	Yes	Hourly
Pool stage – Pressure Transducer	Yes	Hourly
Open Water Area / Springbrook Length	No	Quarterly

Figure 16.4 summarizes the overall schema for data collection, analyses, archiving, processing, and storing SLS data.

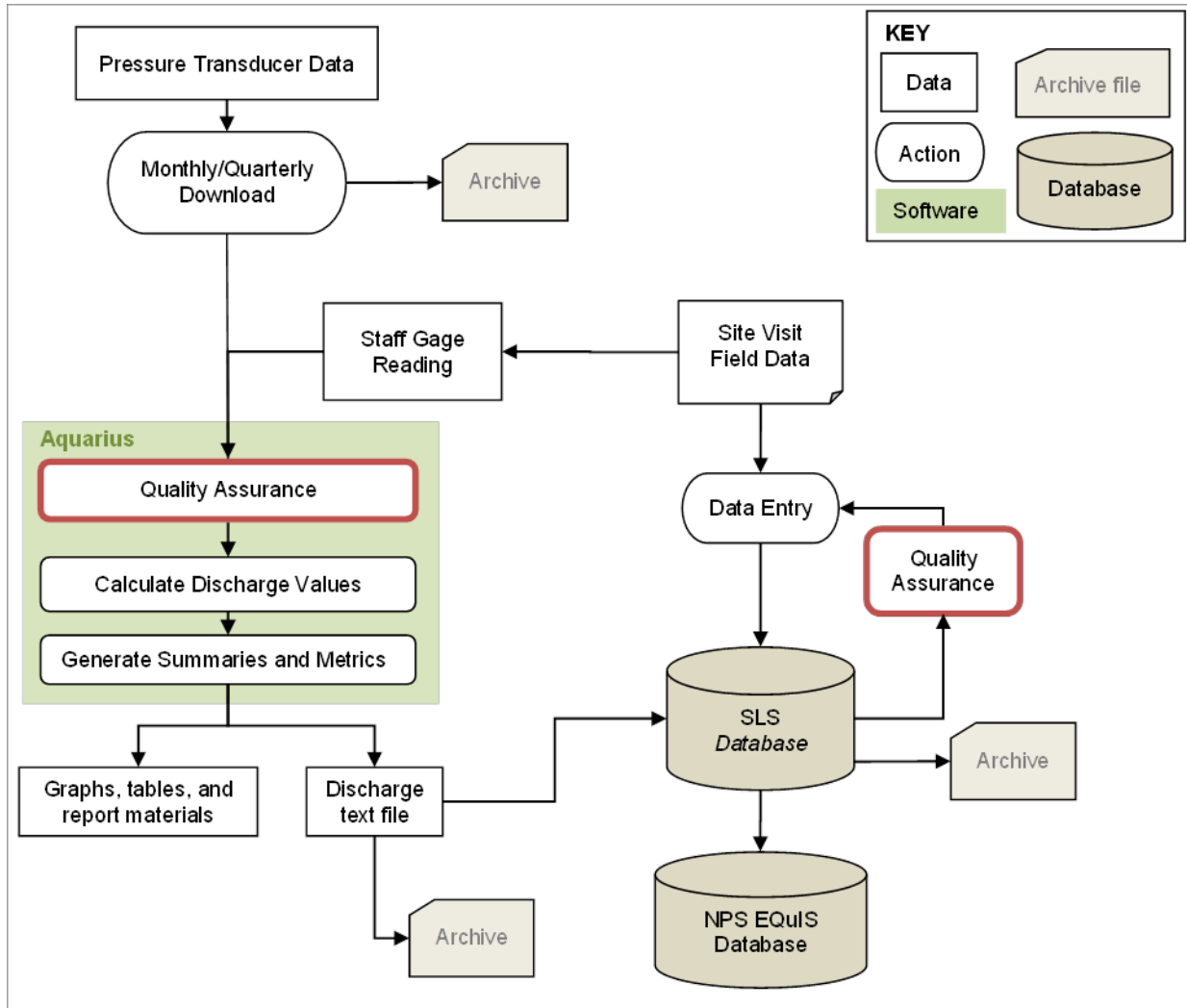


Figure 16.4. Information management work flow for springs discharge data, excluding USGS stream gage sites.

2.5. Springs Water Quality Data

Figure 16.5 presents the overall schema for water quality data collection, analyses, archiving, processing, and storing water quality data for selected large springs. Only discrete data are collected with this protocol.

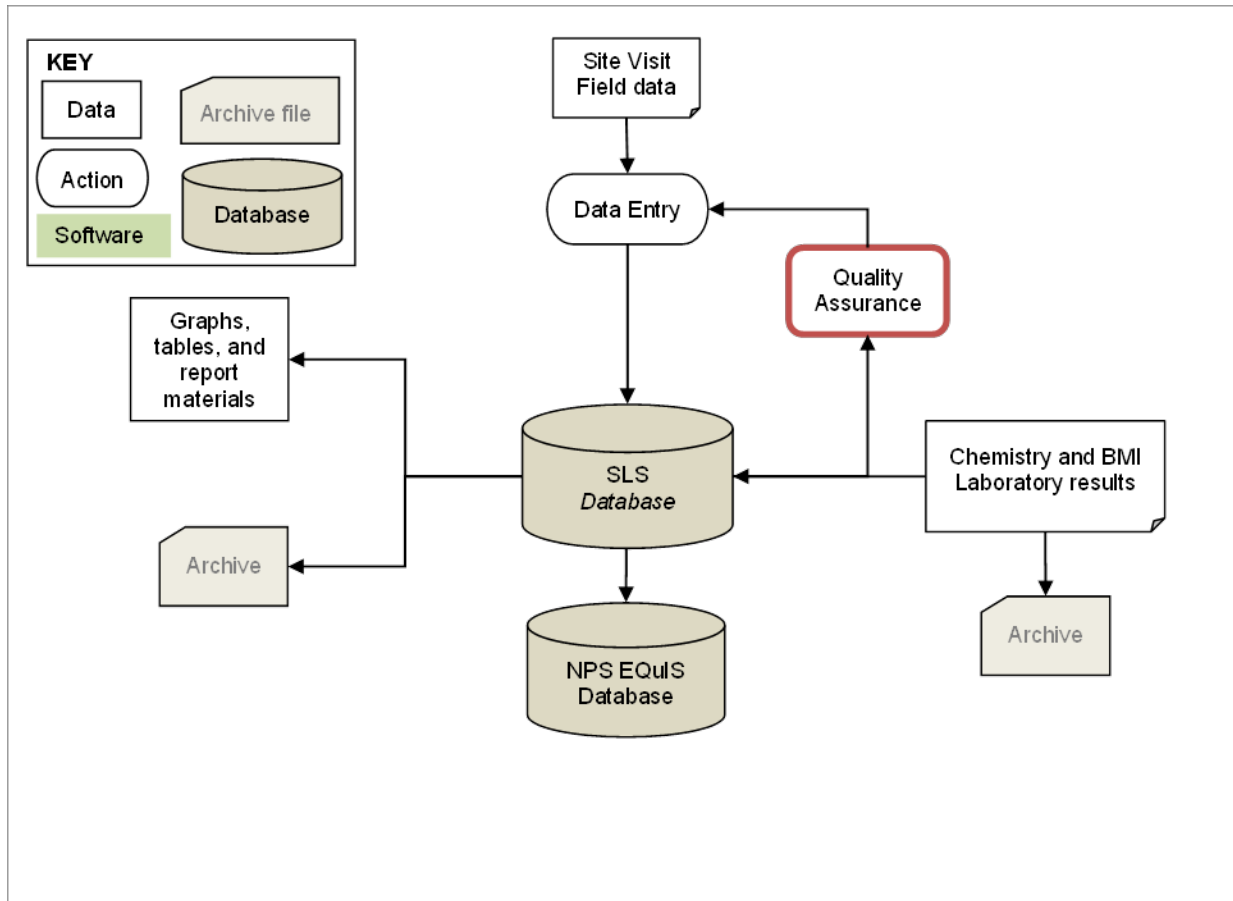


Figure 16.5. Information management workflow for water quality in Selected Large Springs.

2.6. Springs Data Acquisition and Initial Processing

Figure 16.6 details the data acquisition steps and products for discrete discharge (volumetric), staff gage level readings, and water quality data from springs site visits. All data are entered into the database for quality assurance review. Continuous data from pressure transducer loggers is downloaded and water levels are generated for further data processing and analyses with Aquarius software. Water levels from pressure transducer data-loggers from wells and or pools are not processed after export and are uploaded, with a correction history and flags, to the SLS Database.

Water level data are processed further using Aquarius software and the discrete water levels and discharge from the site visits to generate spring discharge (Figure 16.7). Products from Aquarius are subsequently uploaded with correction history and flags to the SLS Database. Finally, discrete water quality data are processed in the SLS Database to generate summaries that may be exported to a software program to generate presentation quality graphics for reports (Figure 16.8).

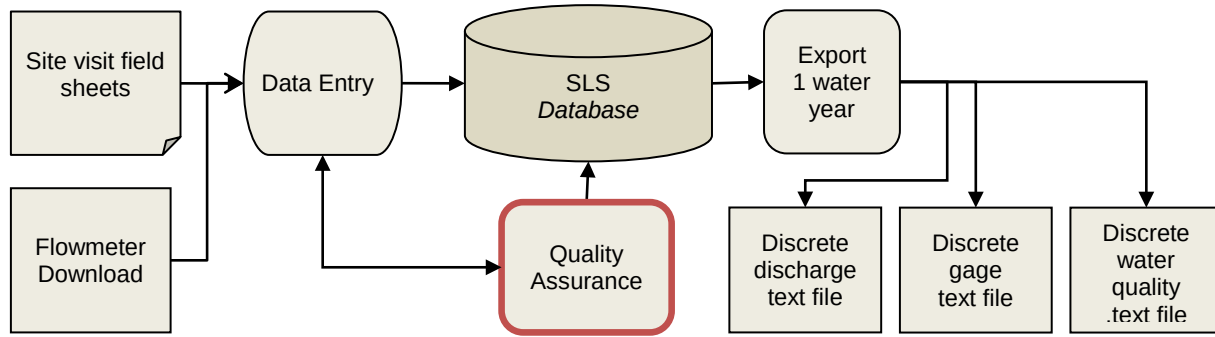


Figure 16.6. Upload and process discrete staff gage readings and water quality data for springs.

2.7. Process Water Level Data for Discharge

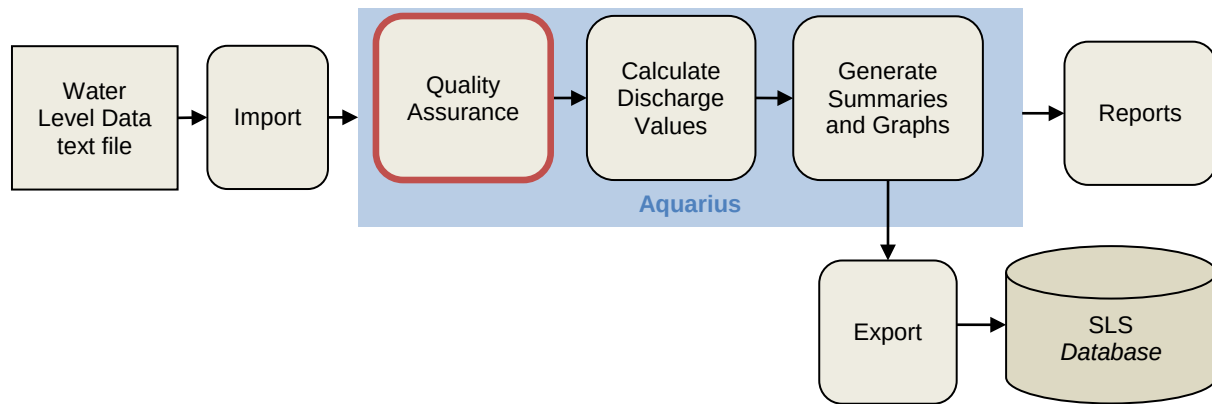


Figure 16.7. Converting water level to discharge.

2.8. Process Water Quality Data

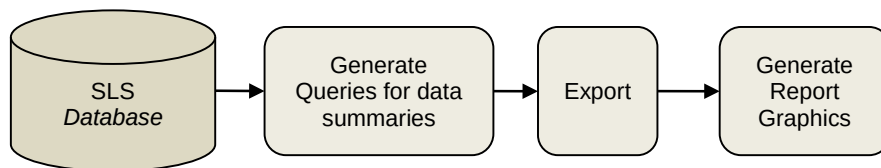


Figure 16.8. Discrete water quality processing steps for springs data.

2.9. Data Verification and Validation

To ensure that monitoring data are of the highest possible quality, verification and validation of the data will be performed. Data verification checks that data entered into a secondary (i.e., electronic) format match the source data, while data validation checks that the data make sense.

2.9.1. Data Verification

Data verification immediately follows data entry and involves checking the accuracy and completeness of the computerized records against the hard copy field records and identifying and correcting any errors. The following verification methods will be used to verify the data:

1. Visual review at data entry. The person doing data entry verifies each and every record after input and immediately corrects any errors.
2. Visual review after data entry. All records are compared to the original data source. Each data field on the corresponding electronic data entry form is compared with the original values from the hard copy, preferably by a second person who did not perform the data entry. Any errors that are discovered are corrected in the database as soon after data entry as possible.
3. Summary queries and tallies. Queries are run that detect broad errors such as duplicate or omitted records.
4. Visual review of spatial data. Using GIS, monitoring location data are visually inspected for accuracy. This review will take place at the end of the field season.

2.9.2. Data Validation

While many errors are prevented by including validation routines that function during data entry, additional review of the data by the project manager is needed to detect generic and specific errors that fall outside the scope of automated validation.

Invalid data commonly consist of slightly misspelled names, the wrong date, or out-of-range errors in parameters with well-defined limits (e.g., elevation). Other errors consist of unreasonable metrics or associations. For example, suppose a species was dominant on a reach during the current year's visit, but there was no observation recorded during the previous year's visit. Such data seem questionable and might indicate a species identification error. These types of logic errors (or potential errors) can be challenging to resolve, and in some cases it may not be possible to resolve them during the current year. Such questionable data will be flagged for future resolution.

Validation queries are of two types: one type presents tabular data in ways that allow records to be reviewed for content and context; the other type performs specific calculations or routines to detect logic or range errors. Corrections to errors detected during validation require notations in the original paper field records about how and why the data were changed. Modifications to the field records, whether made during data collection or subsequently, should be clear and concise while preserving the original data entries or notes. The original data entries should be crossed out with a single line and initialed - they should not be erased. Validation efforts should also include a check for the completeness of a data set since field sheets or other sources of data could easily be overlooked.

2.10. Reporting

There are 3 types of required reporting associated with the SLS protocol for which data are extracted and summarized:

1. Status (annual) and Trends (less frequent) reports
2. Investigator Annual Reports (IAR) to parks in which research permits were obtained
3. Water Quality reporting to NPS Water Resources Division

Data are summarized and provided to the Project Lead for the Status and Trends and IAR reports as needed in the format defined by the Project Lead. Water quality reporting is conducted annually by the Data Manager as required by NPS Water Resources Division. MOJN I&M will annually submit water quality and quantity data using the currently recommended transfer format (the NPS' EQuIS EDD format) to the EQuIS Data Processor for inclusion in the Servicewide EQuIS Database hosted by WRD. Once successfully uploaded to EQuIS, the data will be automatically transferred to the EPA STORET Data Warehouse.

2.11. Archiving

A critical aspect of data management for all MOJN I&M projects is the archiving of all data in a format that ensures future access and multiple locations as a safeguard to a catastrophic event. The standards and procedures are outlined in the MOJN I&M Data Management *SOP Archiving*. The following sections provide a general overview of how the different types of data generated for this protocol are handled.

2.11.1. Field Data

The SLS database is archived annually at season closeout. A text file of each data table is exported, named using a standardized convention, and saved in the appropriate archive location.

2.11.2. Continuous Logger Files

Files downloaded from the pressure data loggers are archived in their native CSV text format without any processing or changes to the original data. Following the Quality Assurance review in Aquarius, the flagged and corrected data are exported and archived again (Figure 16.9).

2.11.3. *Aquarius Archive Files, including Continuous Data*

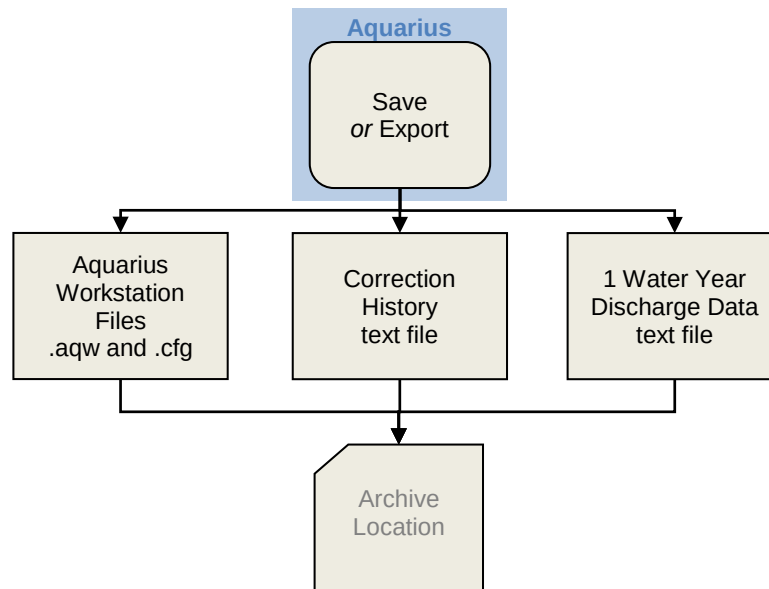


Figure 16.9. Aquarius archive files.

The following is a summary list of the data files that must be archived:

1. Pressure transducer raw data files, 1 per location per month/quarter
2. Annual water year stage and discharge records that have been QA'ed, 1-2 per location
3. Discharge Rating curves for a water year (tabular), 1 per location, update as needed
4. Correction History of the discharge data, 1 per location per year
5. Summary discharge or stage data (e.g. daily mean, daily max, etc) for a water year, 1 per location per year

2.12. Project Records Management

MOJN I&M records management is legally mandated as per NPS Director's Orders #19. Records management ensures all items pertaining to the operation of the Network are retained, preserved, and accessible according to law and regulations. Records are all documentary materials, including books, electronic data, maps, moving images, papers, photographs and sound recordings, made or received by the National Park Service during the transaction of public business. Network protocols and data are considered records. To facilitate efficient management of these records, MOJN I&M manages records using a structured workspace, and standardized procedures for file naming conventions, protocol deliverables and an end-of-season closeout, and archiving.

The project workspace is a hierarchical folder structure where all digital files are stored, including original templates, all project data, and reports. Hard copy files such as notebooks and field data

sheets may scanned to digital format; however, these hard copy records are be retained and managed according to NPS Director’s Order #19. The project workspace for the SLS protocol is structured as detailed in MOJN I&M Data Management *SOP Directory Structure Non-Spatial*.

MOJN I&M Data Management *SOP Naming Conventions* assists in the tracking of documents and data through the workflow. For instance, naming conventions for springs differentiate between raw, calibrated, and summary data obtained from a single data logger device. Specific files are archived permanently during the workflow as mentioned previously. Others files are submitted as project deliverables during the workflow and these may accumulate within a season, i.e. one water year, as a duplicate copy separate from the workspace on the MOJN I&M SharePoint site. Project deliverables may include laboratory data, field datasheets, camera images, Master databases, and geospatial data, to name just a few items. MOJN I&M Data Management *SOP Project Deliverables* lists the specifications and procedures for processing project deliverables. Project deliverables must also use the standardized naming conventions. At the end of the season, there is an annual closeout of the project files and data, during which all files are organized, reviewed for proper metadata and naming conventions, unnecessary files or duplicate files are destroyed in the project workspace and MOJN I&M SharePoint site, and all project deliverables are verified as received (refer to MOJN I&M Data Management *SOP Season Closeout*). The entire set of annual project deliverables is posted to the IRMA Data Store for dissemination to the parks and archived according to MOJN I&M Data Management *SOP Archiving*. A collection of project files is also maintained for long-term easy access during the project lifecycle in the project workspace.

3. Tasks and Schedule

Table 16.3 lists the major tasks associated with the Information Management work. Each task has an estimate of the task duration for the Data Manager, GIS Specialist, and Data Technician and a frequency for which this task is carried out.

Table 16.3. Information Management Tasks.

Task	DM Duration (hrs)	Responsibility	Frequency
Master Database			
Update structure (<i>tables & relationships</i>)	16	DM and Project Lead	Annually
Update data entry forms	28	DM and Project Lead	Annually
Data Acquisition (<i>field datasheets and logger data</i>)			
Standardize Location IDs; Update db tables	2	Project Lead and DM	Annually
Train data entry technician	8	DM	Annually
Data entry	6	DM Technician	Twice a month
Upload device data (loggers, camera, etc.) to db/folders	4	DM	Twice a month
GPS data download, quality assurance, and upload to gdb	2	GIS Specialist	Twice a month
Image Management (<i>download and process</i>)	3	Project Lead/DM	Twice a month

Table 16.3. Information Management Tasks (continued).

Task	DM Duration (hrs)	Responsibility	Frequency
Laboratory Results			
Reconcile sample events	4	DM	As received
Upload results from spreadsheets to database	4	DM	Annually
QA upload	4	DM	Annually
Reconcile permit, accession, and catalog numbers	4	DM	As received
Electronic Devices			
Pre-season equipment set-up	2	DM	Annually
Pre-season equipment set-up	8	GIS Specialist	Annually
Post-season close-out	4	DM	Annually
Quality Assurance (QA)			
Develop QA queries	16	Project Lead and DM	Annually
Implement QA queries, correct, and flag data	8	DM	Annually
Data certification	4	Project Lead and DM	Monthly
Transition data to Master db	16	DM	Annually
Data Delivery to Project Lead			
Develop output format and contents	8	DM	Annually
Generate data output	8	DM	Annually
Reporting			
Upload summary data from Aquarius and QA upload	16	DM	Annually
Populate EQuIS EDD and submit to the EQuIS Data Processor for inclusion in the Servicewide EQuIS database and transmission to the STORET Data Warehouse	16	DM and Project Lead	Annually
Maps and geospatial needs	24	GIS Specialist	Annually
Trend reporting needs (every 5 years, hours are 20% of total)	3	DM	Annually
Trend reporting needs (every 5 years, hours are 20% of total)	8	GIS Specialist	Annually
Project Deliverables			
Compile and disseminate project deliverables	4	DM	Annually
Post data and reports to NPS Info	2	DM	Annually
Close-out			
Season close-out (<i>organize and eliminate</i>)	32	DM and Project Lead	Annually
Season close-out (<i>organize and eliminate</i>)	8	GIS Specialist	Annually
Metadata for data, db, and archive files	8	DM	Annually
Metadata for geospatial data, db, and archive files	4	GIS Specialist	Annually
Archive	4	DM	Annually

4. Literature Cited

MOJN-NPS. 2007. Draft: Mojave Desert Network Data and Information Management Plan, Version 1.1. Mojave Desert I&M Network, National Park Service, Boulder City, Nevada. Available at <http://science.nature.nps.gov/im/units/mojn/index.cfm>.

National Park Service. 2007. Natural Resource Database Template Version 3.2 documentation. Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, Fort Collins, Colorado. Available online: <http://science.nature.nps.gov/im/apps/template/index.cfm>.

NPS Director's Order #19. Available at: <http://www.nps.gov/policy/DOrders/DOrder19.html>.

Standard Operating Procedure 17: Protocol Revision and Review

Version 1.0

Change History for this Document

Version #	Date	Revised By	Changes	Justification
1.0	11/20/2014	G. Moret	Original draft	

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Overview

[This SOP was adapted from Carson and Coopridge (2006)]

This Standard Operating Procedure explains how to make changes to the Selected Large Springs narrative and accompanying SOPs, and explains procedures for tracking these changes. MOJN personnel editing the Protocol Narrative or any SOP need to follow this procedure to eliminate confusion in data collection and analysis methods.

This SOP also contains Table 17.1, which lists the most current version of the protocol narrative and each of the SOPs. This will provide a single reference for ensuring that the most current documents are being used. Also included is a section containing comments from protocol review, responses to those comments and approvals. Information regarding the changes made in each revision is included in the “Version Information” section at the end of each SOP.

Table 17.1. Most current versions of MOJN Selected Large Springs documents.

Document	Current Version	Date	Author/Contact
Mojave Desert Network Selected Large Springs Protocol Narrative	1.00	4/15/2015	G. Moret
SOP 1: Safety	1.00	4/15/2015	G. Moret
SOP 2: Staff Training	1.00	4/15/2015	G. Moret
SOP 3: Spring Locations and Spring-Specific Procedures	1.00	4/15/2015	G. Moret
SOP 4: Field Mobilization and De-Mobilization	1.00	4/15/2015	G. Moret
SOP 5: Equipment Disinfection	1.00	4/15/2015	G. Moret
SOP 6: Handheld Water Quality Instrument	1.00	4/15/2015	G. Moret
SOP 7: Spring Discharge Monitoring	1.00	4/15/2015	G. Moret
SOP 8: Water Sampling, Benthic Macroinvertebrate Sampling, and Springsnail Monitoring	1.00	4/15/2015	G. Moret
SOP 9: Monitoring Water Levels in Wells	1.00	4/15/2015	G. Moret
SOP 10: Sample Handling	1.00	4/15/2015	G. Moret
SOP 11: Laboratory Analysis of Benthic Macroinvertebrates	1.00	4/15/2015	G. Moret
SOP 12: Laboratory Analysis of Water Chemistry	1.00	4/15/2015	G. Moret
SOP 13: Quality Assurance Project Plan	1.00	4/15/2015	G. Moret
SOP 14: Cumulative Measurement Bias	1.00	4/15/2015	G. Moret
SOP 15: Data Analysis and Reporting	1.00	4/15/2015	G. Moret
SOP 16: Data Management	1.00	4/15/2015	M. Lehman
SOP 17: Protocol Revision and Review	1.00	4/15/2015	G. Moret

2. Protocol Revision Procedures

The Selected Large Springs Protocol Narrative and accompanying SOPs are intended to incorporate the soundest methodologies for collecting and analyzing water quality and quantity data. However,

all protocols require editing as new and different sample collection, analysis, and data management techniques becomes available. Required edits should be made as soon as they are deemed necessary and appropriate reviews conducted.

All edits will be reviewed for grammatical and technical accuracy and overall clarity. Minor changes or additions to existing methods will be reviewed “in-house” by the protocol lead. However, if a complete change in methods is anticipated, then an outside review is required. Regional (Pacific West Region) and National staff (Water Resources Division) of the National Park Service familiar with water quality monitoring and data analysis will be utilized as reviewers. Also, outside experts in water quality monitoring and statistical methodologies may be utilized in the review process. A group of technical experts was utilized for the external peer review of the initial Selected Large Springs protocol; these individuals may be called upon again to provide input related to any significant revisions in methodology.

Edits and protocol revisions will be documented in the Revision History Log that accompanies the Protocol Narrative and each SOP. Only changes in the protocol narrative or specific SOP that has been edited will be logged. “Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02 ...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.

The MOJN Data Manager must be notified of any changes to the Protocol Narrative or SOP so that the new version number can be incorporated in the metadata of the protocol database. The Data Manager will then edit the database per any changes to the Protocol Narrative and SOPs.

New versions should be posted on the internet and forwarded to all individuals with a previous version of the Protocol Narrative or SOP.

When any significant changes in the sampling protocol occur such as changes in sample collection techniques or equipment, a change in analytical laboratory, or changes in staff, there should be an overlap of methods and personnel. The procedures for collecting and analyzing overlapping data are discussed in *SOP 14: Cumulative Measurement Bias*.

3. Protocol Review

The Protocol Review Checklist generated by the reviewers and the consolidated comments and responses from reviews are included in the Supplementary Materials. If significant changes to the protocol require additional review at a later date, then these comments and responses will also be included in the Supplementary Materials.

4. Version Information

Table 17.2. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

5. Literature Cited

Carson, R., and M. Coopridier. 2006. SFAN Freshwater quality monitoring protocol SOP #1: Protocol revision and review. *In* R. Carson and M. Coopridier. 2006. San Francisco Bay Area Network Freshwater Quality Monitor Protocol: Version 2.11 October 2006. Natural Resource Report. NPS/SFAN/NRR—2006/016. National Park Service. Fort Collins, California.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/131060, January 2016

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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