



Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River

Standard Operating Procedures

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Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ01

Safety—Version 1.4

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Summary

This standard operating procedure (SOP) explains the steps involved in handling an on-duty or job-related injury or illness. Read this SOP prior to conducting field work and keep a copy in all vehicles for quick reference.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Overview

The Appalachian Highlands Network (APHN) considers the occupational health and safety of its employees, cooperators, and volunteers to be of utmost importance. The network is committed to ensuring all people involved with monitoring activities receive adequate training on National Park Service (NPS) safety procedures, incident reporting, and emergency response, prior to conducting field work. Everyone is responsible for maintaining a safe work environment for themselves and their coworkers. This SOP and supporting appendices summarize safety issues to cover during training of field personnel for water-quality monitoring. The SOP and appendices are also a first reference in case of an incident. Topics covered include emergency procedures and contacts, incident reporting, field preparation, safe field procedures, vehicle safety, and workers compensation procedures. First Aid procedures are not covered in this SOP. The outline and some of the content of this SOP follow SOP 1 in the Northeast Temperate Network's forest monitoring protocol (Tierney et al. 2014). Procedural descriptions are adapted from Chapter A9 of the United States Geological Survey (USGS) National Field Manual for the Collection of Water Quality Data (Lane and Fay 1997).

A detailed job hazard analysis (JHA) has been developed for this protocol (see SOP CWQ02 *Job Hazard Analysis—Version 1.4*).

Responding to an Incident

Life-Threatening Medical Emergency

1. Personnel should call 9-1-1 or one of the emergency contacts in Appendix A of this SOP. Near Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI), use park radios to contact a park ranger or park headquarters. Directions to the nearest hospitals from each park and emergency numbers are provided in Appendix 1.
2. As soon as it is practical, personnel should inform their supervisor and the park's emergency contact (see Appendix A).
3. Workers Compensation paperwork should be completed (See <https://www.smis.doi.gov/smismain.cfm> to submit reports online).

Non-Emergency Incidents

1. Personnel should contact their supervisor immediately after incident.
2. Workers compensation paperwork should be completed (this must be done within 48 hours of the incident—See <https://www.smis.doi.gov/smismain.cfm> to submit reports online).

NOTE: Never discard original paperwork related to workers compensation claims (including information from doctor visits, CA-1, CA-2, CA-16 or CA-17 forms).

Field Preparation

Detailed steps for field preparation are provided in SOP CWQ07 *Operation and Maintenance Site Visit—Version 1.4*. Also, see USGS handbook 445-3-H: *Safety and Health for Field Operations* (USGS 2014).

Use safety checklists when preparing for a field trip. Examples of detailed checklists can be found in section 9.11 of the USGS national field manual (Lane and Fay 1997). Develop your checklists from existing site safety information and site reconnaissance (job hazard analysis or site safety plan).

Prior to commencing work, visit the field site, if possible, to ensure you and your equipment can access, sample, and leave the site safely. Confer with employees who have previously visited the site for valuable safety information.

Keep a field folder for each site at which water-quality data will be collected. The safety-related contents of a field folder include:

- Copies of the safety checklists.
- Site type (confined space, wading site, bridge site) and site description.
- Site location (include map, site sketch, and description).
- Additional information specific to the site (e.g., if it is open to hunting, what are season dates, and appropriate clothing such as orange safety vests).
- Emergency contact information for each park (see Appendix A), location and telephone numbers for nearest medical facilities (see Appendix A). Become familiar with this information before you are in the field and confronted with an emergency.

Personal Protective Equipment

Proper selection of personal protective equipment (PPE) is based on the hazards likely to be encountered, as well as compliance with regulatory safety requirements. Detailed recommendations of PPE for various water-monitoring operations are found in the USGS survey manual (USGS 2014).

Basic protective items:

- Personal flotation device (PFD), orange or other bright color
- Safety harness
- Walking stick or wading staff
- Wide-brimmed hat (hardhat, if working beneath bridges where falling debris or thrown items are a danger)
- Protective gloves

- Wading boots
- Wading belt (for chest waders)
- Safety glasses
- Sunglasses
- Sunscreen
- Fluids (water, sports drinks)
- Insect repellent
- Rain gear
- Temperature-modifying clothing
- Complete change of clothing, stored in dry area
- Bright-colored reflective vest

Additional safety equipment:

- Safety cones
- Flares
- Flashlight
- Flagging
- Bungee cords and tie-down straps (to secure loose articles)
- Fire extinguisher

First Aid Kits

Every APHN vehicle has a first aid kit that remains with the vehicle at all times. In addition to the vehicle first aid kit, a field first aid kit remains with the monitoring crew at all times while in the field. An inventory of first aid kits is performed at the beginning of each calendar year to ensure all medical supplies are in sufficient quantity and have not expired. Each first aid kit will have an inventory list of the supplies it should contain. Promptly replace any used items in first aid kits.

Standard first aid kit contents (quantity):

(8) Bandage, adhesive, fabric, 1" × 3" (2.5×7.6 centimeter [cm])

(2) Dressing, gauze, sterile, 2" × 2" (5×5 cm), pkg./2

- (3) Dressing, gauze, sterile, 4" × 4" (10.2 × 10.2 cm), pkg./2
- (3) Dressing, non-adherent, sterile, 3" × 4" (7.6×10.2 cm)
- (2) Gloves, nitrile (pair), hand wipe
- (1) Trauma pad, 5" × 9" (12.7 × 22.9 cm)
- (6) Moleskin, Pre-Cut and Shaped, or other blister plasters
- (1) Duct tape, two inch by five yard (5×457 cm)
- (1) Bandage, elastic with velcro, 3" (7.62 cm)
- (4) Acetaminophen (500 milligram [mg]), pkg./2
- (4) Antihistamine (Diphenhydramine 25 mg)—fast-acting chewable form
- (4) Ibuprofen (200 mg), pkg./2
- (6) After Cuts & Scrapes anesthetic/antiseptic wipe
- (2) Cotton tipped applicator, pkg./2
- (1) Tape, 1 inch by 10 yards (2.5 × 914.4 cm)
- (3) Triple antibiotic ointment, single use
- (1) Wound closure strips, 1/4" × 4" (0.64 × 10.2 cm), pkg./10
- (1) Sawyer venom extractor (for snakebites)
- (5) Pre-contact poison ivy towelettes
- (10) Post-contact poison ivy towelettes
- (2) Bottles of Sting-Kill or other bee-sting treatment
- (2) Bottles of eye drops
- (15) Band-Aids, assorted sizes

Daily Communication and Planning

Crews must plan their daily sample locations before going into the field. Leave a detailed itinerary with the APHN program manager or designated alternate. Crews will follow the InReach Operation SOP (see Appendix B) in the field. Crews will carry a charged APHN radio at all times in the field. If available, crews will carry cell phones. Radios and cell phones do not always get a signal in the river gorges. However, sometimes it is possible to send a text message even when there is no service. To the extent possible, crew members should familiarize themselves with “black out” zones before

going in the field and check for a signal once they arrive at the work site, so contingency plans can be made in case of an emergency. When crews work separately in the field, discuss the daily plans for each crew before splitting up. When working in split crews, employ transmitter or receiver units for local communication between crews. If plans change while in the field, crews must notify each other before changing work locations or rendezvous plans. At the end of the day, crews must notify the APHN program manager or designated alternate that they have returned from the field.

Personal Gear

Each crew member is responsible for ensuring they are wearing field-appropriate clothing and footwear such as long pants, a hat and hiking boots. Depending on the weather, crew members should take rain gear or warm clothing into the field, and keep an extra set of clothing in the vehicle. Crew members should take care to avoid overexposure to the sun by wearing sunscreen and protective clothing. Crew members should always carry ample water (2–3 liters or 0.5–0.8 gallons) and food when working in the field. To avoid dehydration, a serious condition that can cause complications if untreated, it is important to drink liquid frequently to maintain hydration on a warm day, even if you do not feel thirsty.

Field Safety

Slip, Trip, Fall Prevention

Uneven terrain, slippery rocks, dense brush, and fatigue are all hazards that could result in a slip, trip, or fall. Obey the following guidelines to avoid injury from slips, trips, or falls:

- Always wear appropriate footwear such as sturdy hiking boots.
- Pay attention to where you are going and remain alert to potential hazards.
- Walk at an appropriate pace and adjust pace for changes in terrain (e.g., slow down and take smaller steps on slippery surfaces).
- Do not cross frozen rivers by walking across the ice, even if it appears to be solid.
- When hiking long distances, take breaks to avoid excessive fatigue.
- Use a hiking staff on steep and rocky terrain, and for river crossings.
- When navigating to a location off-trail, choose the safest route (this may not be the shortest route). Whenever possible, avoid excessively steep terrain and sheer drop-offs. Always be careful when navigating over boulder fields or rocky banks and immediately alert others below of falling rocks.

Wading

Examine the section of a stream or river you plan to wade. Check the field folder for information relating to safety, including maximum depths in relation to stage (stream height), wading-section anomalies such as slippery conditions and drop-offs or holes (a wading rod can be used to help assess streambed conditions), and velocity curves for determining wadeable stages. **Do not attempt to wade a stream for which values of depth multiplied by velocity equal or exceed 10 square feet per second.** For example, a stream only two feet deep but with velocities of five feet per second or more can be dangerous to wade.

Wear a PFD during wading activities.

- Approved PFDs for wading include the standard jacket type and the suspender type. The PFD must fit properly, be rated for your weight, and be in good condition.
- The PFD should be dried and kept indoors between trips.

Wear hip boots or chest waders. Boots and waders provide protection from cold and pollutants, as well as from underwater objects.

- Be aware of the possibility of slipping and going underwater (feet up, head down) while wearing them.
- Avoid hip boots with tight ankles. These are difficult to remove in an emergency situation.
- Avoid chest waders that are tight-fitting at the top. Like tight-ankled hip boots, they are difficult to remove in an emergency situation. Wear a wading belt with chest waders to prevent waders filling with water. Whenever chest waders are worn, a PFD also must be worn.

Be aware of surrounding conditions.

- Watch for debris floating downstream, such as ice, logs, and aquatic vegetation.
- Watch for sand channels that can shift underfoot and entrap personnel.
- Watch the stream stage, especially when it could rise rapidly.
- When wading below a dam or control structure, contact the gate operator before entering the stream and communicate to them that crews will be working downstream and how long.

Proper use of Backpacks

Crew members will be expected to carry packs up to and in excess of 35 pounds (15.9 kilograms [kg]) over uneven terrain on a daily basis. It is important for crew members to understand appropriate ways to pack, lift and carry a heavy pack to avoid serious back, neck and shoulder injuries. Crew members must follow these guidelines:

- All crew members are expected to use a sturdy field pack with padded and adjustable hip and shoulder straps. Packs will be provided for each crew member.
- Pack heavy items in the center of the pack and close to your back.
- Distribute weight evenly from side to side.
- Once equipment is packed, tighten the compression straps to minimize movement inside the pack during travel.
- When picking up a heavy pack, use your legs to do the lifting, and use slow, smooth movements. Keep your back straight and keep the pack close to your body. Do not twist or bend at the waist and do not swing the pack quickly over one shoulder.
- Always carry a pack with both shoulder straps and with the hip belt and chest straps secured.
- Position the pack near the center of the back, with most of the weight resting on your hips.
- Keep your pack organized and only carry the necessary equipment, food, and water (to reduce weight).

Weather

Weather conditions on the Cumberland Plateau can be hazardous and change quickly. The crew is responsible for planning their day according to the local weather forecast and for being aware of their surroundings and changing conditions. This is particularly important when working in the bottom of the river gorges, where flash floods are common. Localized rainstorms in the headwaters can cause the rivers below to rise swiftly, even when no rain falls in the lower reaches. Crew members should always be alert for the sound of thunder or the presence of storm clouds in the watersheds upstream. A particularly illustrative example of this occurred in the spring of 2013, when a park visitor on Clear Creek (in OBRI) narrowly missed being swept away in a sudden flash flood rushing down the gorge. The gage recording at Lilly Bridge (Figure SOP1-1) which captured the event makes it clear that the term “wall of water” is sometimes not an exaggeration. The gage reading showed the river rose 5,000 cubic feet per second—from barely moving to a roaring flood—in less than 15 minutes! This event demonstrated how important it is for park and network staff to check on potential nearby precipitation events before setting out to work in a riparian zone and to stay alert to changing conditions.

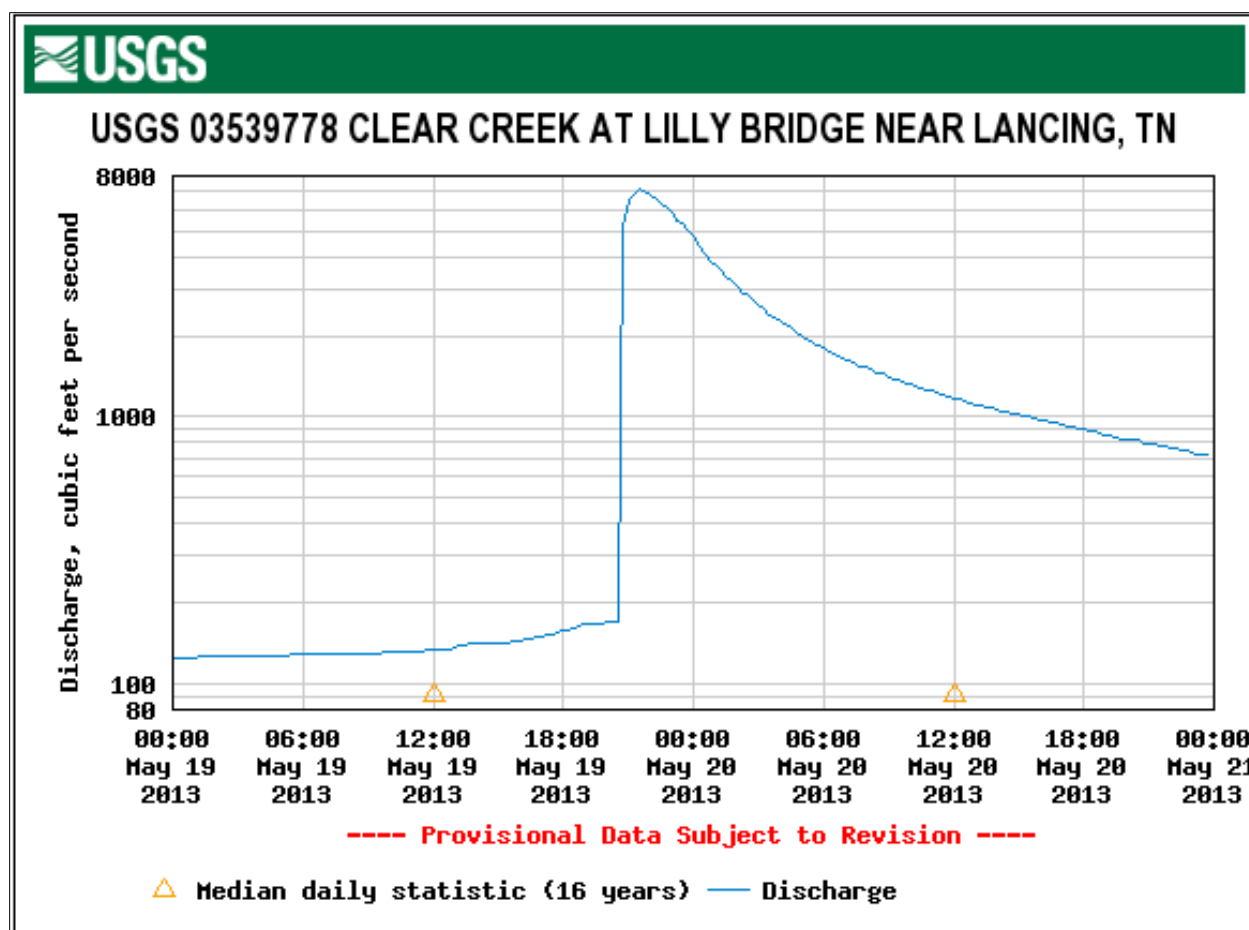


Figure SOP 1-1. Gage reading at Lilly Bridge, Clear Creek (OBRI) on 19 May 2013, showing a 5,000 cubic feet per second (cfs) increase in flow between 8:30 and 8:45 p.m. (the flood peaked within the hour at over 7,000 cfs).

Thunderstorms

Avoid dangerous storms that produce strong winds and lightning. If caught in a lightning storm, seek shelter in a building or car as soon as possible. If no shelter is available, spread out and move to an open space. Squat low to the ground on the balls of your feet with your hands on your knees (do NOT lie flat on the ground). Avoid high elevations, conductive materials, and tall structures such as trees or telephone poles. If you are in the open and feel your hair stand on end (indicating lightning is about to strike), immediately make yourself the smallest target possible and minimize contact with the ground.

Note: A person struck by lightning can often be revived by prompt administration of cardiopulmonary resuscitation (CPR) and oxygen.

Excessive Heat and Sun

Overexposure to heat and sun can cause dehydration, heat exhaustion, or heat stroke. All are serious conditions that can be life threatening. When working in hot weather, drink plenty of water and eat foods that can replace electrolytes. Wear loose and light colored clothing, including a hat to block the

sun's rays. It may help to shift the field schedule to avoid working outside during the hottest part of the day.

Warning: Signs of heat stroke include hot, red, or spotted (usually dry) skin, and the sufferer may be mentally confused, delirious, convulsing, or unconscious. If you suspect heat stroke, seek immediate medical attention. Precursors of heat stroke include heat cramps and heat exhaustion. The symptoms for both are:

- Heat cramps—the cause of heat cramps is initial exposure to high temperatures or physical exertion. Signs and symptoms of heat cramps usually include excessive sweating, fatigue, thirst, and cramps, usually in the stomach, arms, or legs. This condition is common in very hot weather or with moderate to heavy physical activity. You can usually treat heat cramps by drinking water or fluids containing electrolytes (e.g., Gatorade or other sports drinks), resting, and getting to a cool spot, like a shaded or air-conditioned area.
- Heat exhaustion—heat exhaustion occurs when you do not act on the signs and symptoms of heat cramps and your condition worsens. Signs and symptoms of heat exhaustion include headache, dizziness, lightheadedness, nausea, skin that feels cool and moist, and muscle cramps. Often with heat exhaustion, you can treat the condition yourself by following the same measures used to treat heat cramps, such as drinking cool, nonalcoholic beverages, getting into a cooler, shaded or air-conditioned area, or immersing yourself in cool water. If your symptoms persist, seek medical attention immediately.

Poor Air Quality

Summer ozone and particulate matter levels occasionally exceed federal health standards. Young children, seniors, and those suffering from asthma, chronic bronchitis, chronic obstructive pulmonary disease, or heart problems are especially sensitive to poor air quality and should minimize outdoor activity when poor air-quality warnings are posted. The risks of occasional exposure to ozone and fine particulate matter are minimal for healthy individuals. When poor air-quality warnings occur, it is advisable for the crews to avoid overly strenuous activity during the hottest part of the day (pollution levels tend to be lowest early in the morning) and to stick to lower elevations under a forest canopy.

To check local air-quality forecasts or learn more about health risks of air pollution, visit the AIRNow intergovernmental agency website: <http://www.airnow.gov/>.

Ticks

Several species of ticks are common in Cumberland Plateau park units. These include the deer tick (*Ixodes scapularis*), which is a known vector for Lyme Disease and Ehrlichiosis; the lone star tick (*Amblyomma americanum*), which can carry pathogens that cause Ehrlichiosis and Tularemia; and the American dog tick (*Dermacentor variabilis*), a vector for Rocky Mountain Spotted Fever and Tularemia. It is up to each crew member to take the following precautions to help minimize the chances of having an embedded tick, which could lead to illness:

- Clothes treated with permethrin are a fairly effective tick repellent. Therefore, crew members will be provided with permethrin and encouraged to treat their clothing with permethrin periodically throughout the summer. Crew members should carefully follow the application instructions on the spray bottles to ensure their safety. Repellent will remain active for several weeks and through several washings.
- Crew members should take additional precautions to protect themselves from ticks, including tucking pants in socks and tucking in shirts. Wearing long sleeves and gaiters has been found to help.
- Check clothes and skin for ticks at the end of every field day. Ticks typically need to be embedded for at least 24 hours for disease transmission to occur (4–6 hours for the American dog tick to transmit the bacteria that causes Rocky Mountain Spotted Fever); therefore, the earlier ticks are found and removed, the lower your chances are of acquiring a tick-borne illness.
- If you find a tick that is already embedded, use fine-tipped tweezers to firmly grasp the tick close to your skin. Slowly and steadily pull the tick's body away from your skin. Be careful not to crush the tick's body—this will minimize the chance that the tick will regurgitate fluids into the wound. Clean the bite area with soap and water once the tick is removed.
- If you receive a tick bite, fill out a complete record on the tick log (z:\Safety\Ticklog.xls). If you start to notice symptoms, file a workers' compensation report as soon as possible.
- Keep an eye out for any early symptoms of tick-borne diseases. Symptoms may include a bull's eye rash around the tick bite (this does not always occur), tingling or numbness in extremities, a spotted rash on extremities, bad headaches, high fever, muscle and joint aches, stiff neck, fatigue, or swollen glands. If you develop a combination of these symptoms soon after a tick bite, seek medical attention. If you have any unusual reaction to a tick bite, many physicians advise treating with antibiotics, regardless of the outcome of diagnostic tests for Lyme disease (which are often inaccurate). Early treatment is easier and more effective than treatment after the disease has become entrenched.

Chiggers

Chiggers are the larval form of a type of mite in the Trombiculidae family. They live on vegetation and are most commonly found close to the ground surface, as they require a high level of humidity for survival. Chiggers are barely visible to the naked eye (they measure less than 1/150th of an inch). They insert their feeding structures into the skin and secrete enzymes that cause destruction of host tissue. Hardening of surrounding skin cells results in the formation of a feeding tube called a stylostome. The itching caused by chigger bites is due to the presence of the stylostome and is usually most intense within one to two days after the bite. Symptoms include pronounced itching and a reddened, sometimes raised, area around the bite. Chigger bites themselves do not produce any long-term complications. However, because of the intense itching, prolonged scratching may cause skin wounds that can be infected by bacteria. Prevention and treatment measures include:

- Wash with soap and water after outdoor activity to remove any chiggers that may be migrating on the skin and prevent their bites. Likewise, wash any clothing worn outdoors to kill any chiggers remaining on the clothing.
- Pay attention to the outdoor temperature. Chiggers do not bite at colder temperatures (below 60°F [15.6°C]). You will not find chiggers in areas hotter than 99°F (37.2°C), so hot rocky areas on sunny days can provide chigger-free seats.
- As with mosquito bites, proper outdoor clothing can help prevent chigger bites. Long pants and long-sleeved shirts as well as thick socks and high shoes or boots can help prevent infestation. Tuck pant legs into shoes or boots if possible. All mosquito repellents (such as DEET), applied to skin and clothing, are effective at repelling chiggers.
- Focus treatment for chigger bites toward relieving the itching and inflammation. Use Calamine lotion and corticosteroid creams or diphenhydramine (Benadryl) spray to control itching. You may also use oral antihistamines, such as diphenhydramine, for symptom relief.

Mosquitos

Encephalitis is a mosquito-borne viral disease. As the name suggests, Eastern Equine Encephalitis occurs predominantly in the eastern half of the U.S. Because of the high case fatality rate, it is regarded as one of the more serious mosquito-borne diseases in the United States. West Nile virus is also a potentially serious illness. Experts believe West Nile virus is established as a seasonal epidemic in North America that flares up in the summer and continues into the fall. Most often, West Nile virus is spread by the bite of an infected mosquito.

The easiest and best way to avoid encephalitis and West Nile virus is to prevent mosquito bites. Avoid bites by employing personal and household protection measures, such as wearing protective clothing, taking precautions from dusk to dawn when mosquitoes are most likely to bite, and controlling standing water that can provide mosquito breeding sites. Field personnel should use insect repellent containing Meta-N,N-diethyl-meta-toluamide (DEET) or other EPA-registered active ingredient (CDC 2018). Follow the directions on the package.

CDC Reference: <http://www.cdc.gov/ncidod/dvbid/westnile/index.htm>

Dangerous Plants and Animals

For safety and protection of park resources, it is never advisable for crew members to eat wild plants while working in a national park, regardless of their confidence in plant identification. Crew members should also keep a safe distance from wildlife and never handle potentially dangerous wildlife.

Poison Ivy

Poison ivy (*Toxicodendron* spp.) is present in both Big South Fork NRR and Obed WSR and can be abundant in localized areas. Abundance of poison ivy is not a justification for excluding a plot. However, if a crew member is susceptible to extreme allergic reactions to poison ivy, this person should avoid working in infested areas, and all gear that has been near poison ivy should be carefully

cleaned. When working in areas with poison ivy, crew members should take precautions to avoid skin contact with any part of the poison ivy plant. Using a pre-exposure cream and wearing long sleeves and long pants, hats, and work or rubber gloves can help reduce the amount of skin contact. If needed, use poison ivy wipes after contact. Crew members should not rub their faces when working around poison ivy. After working in an area with abundant poison ivy, crew members should gently wash exposed skin in cool water with specially formulated poison ivy soap and should change into fresh field clothes. At the end of a field day, crew members should also wash potentially contaminated equipment (e.g., quadrat, DBH tape). If a crew member has a minor allergic reaction, use the provided cream. If a severe allergic reaction occurs, the crew member should seek medical attention, notify the supervisor as soon as possible, and file a workers' compensation claim.

Bees or Wasps

It is important to be prepared for any possible effects from an insect sting, whether it happens at work or at home. Most stings will only result in a temporary injury— pain, swelling, and skin redness around the sting. However, sometimes the effects can be more severe— even life-threatening, depending on where you are stung and what allergies you have. If you have experienced a severe allergic reaction to an insect sting in the past, you will likely experience a similar or worse reaction if stung again. Doctors will prescribe a bee sting kit (self-injectable syringe containing epinephrine) to allergic people so they can carry the medication with them at all times. For people who are hypersensitive to stings, wearing a medical alert bracelet will enable first responders to act promptly and appropriately, to a sting victim who is unconscious. Employers should be notified if a worker, especially one who works outdoors, has allergies to insect stings. Co-workers should be trained in emergency first aid, be aware of the signs of a severe reaction, and know how to use the bee sting kit (self-injectable epinephrine). People who have been stung multiple times (such as when fleeing from a swarm or nest) can sometimes suffer serious health effects. While rare, death may occur. If you do get stung many times at once, talk to your doctor. You may need to have your health monitored over the next few days or weeks.

Wasps and hornets do not leave their stinger, so they can sting repeatedly. Honey bees can sting only once and will leave the stinger (and venom sac plus some other parts) stuck in the skin at the sting site. The stinger, if present, should be removed right away since the venom can still be injected for up to a minute after the bee detaches. Try removing the stinger by scraping sideways with your fingernail, a credit card or other stiff card. Try **not** to squeeze the bee venom sac which will release more venom. You might have to use tweezers if the venom sac breaks off leaving the stinger in the skin. A normal (or "localized") reaction to the venom from a sting is redness of the skin, swelling, severe itching (pruritis), and a burning or stabbing pain. The longer the stinger is in the skin, the greater the effect of the venom being injected. An application of ice (wrapped in a towel to prevent freezing the skin), anti-itch cream or an antihistamine pill can help reduce the effects of the sting.

Bears

Seeing a bear in the wild is a special treat for any visitor to a national park. While it is an exciting moment, it is important to remember that bears in national parks are wild and can be dangerous. Their behavior is sometimes unpredictable. Although rare, attacks on humans have occurred,

inflicting serious injuries and death. Each bear and each experience is unique; there is no single strategy that will work in all situations and that guarantees safety. Most bear encounters end without injury. Following some basic guidelines may help to lessen the threat of danger. Your safety can depend on your ability to calm the bear.

Following the [viewing etiquette](#) prescribed by the National Park Service (NPS 2018) is the first step to avoiding an encounter with a bear that could escalate into an attack. Keeping your distance and not surprising bears are some of the most important things you can do. Most bears will avoid humans if they hear them coming. Pay attention to your surroundings and make a special effort to be noticeable if you are in an area with known bear activity or a good food source, such as berry bushes.

Once a bear has noticed you, additional strategies can help prevent the situation from escalating:

- Identify yourself by talking calmly so the bear knows you are a human and not a prey animal. Remain still. Stand your ground but slowly wave your arms. Help the bear recognize you as a human. It may come closer or stand on its hind legs to get a better look or smell. A standing bear is usually curious, not threatening.
- Stay calm and remember that most bears do not want to attack you; they usually just want to be left alone. Bears may bluff their way out of an encounter by charging and then turning away at the last second. Bears may also react defensively by woofing, yawning, salivating, growling, snapping their jaws, and laying their ears back. Continue to talk to the bear in low tones. This will help you stay calmer, and it will not be threatening to the bear. A scream or sudden movement may trigger an attack. Never imitate bear sounds or make a high-pitched squeal.
- Make yourselves look as large as possible (for example, move to higher ground).
- Do **not** drop your pack as it can provide protection for your back and prevent a bear from accessing your food.
- If the bear is stationary, move away slowly and sideways. This allows you to keep an eye on the bear and avoid tripping. Moving sideways is also non-threatening to bears. Do **not** run, but if the bear follows, stop and hold your ground. Bears can run as fast as a racehorse both uphill and down. Like dogs, they will chase fleeing animals. Do **not** climb a tree. Both grizzlies and black bears can climb trees.
- Leave the area or take a detour. If this is impossible, wait until the bear moves away. Always leave the bear an escape route.
- Be especially cautious if you see a female with cubs. Never place yourself between a mother and her cub, and never attempt to approach them. The chances of an attack escalate greatly if she perceives you as a danger to her cubs.

Bear attacks are rare. Most bears are only interested in protecting food, cubs, or their space. Being mentally prepared can help you have the most effective reaction. Every situation is different, but below are guidelines on how brown bear attacks can differ from black bear attacks. Help protect others by reporting all bear incidents to a park ranger immediately. Above all, keep your distance from bears. If a black bear attacks you, **do not play dead**. Try to escape to a secure place such as a car or building. If escape is not possible, try to fight back using any object available. Concentrate your kicks and blows on the bear's face and muzzle.

Bear pepper spray is important to carry when exploring the back country. It is used defensively to stop an aggressive, charging, or attacking bear. Although it is used in the same manner, bear pepper spray and human pepper spray are not the same. Make sure you select an EPA-approved product that is specifically designed to stop aggressive bears. It is not a repellent so do not apply to your body or equipment. Check with your national park to see if bear pepper spray is recommended or even allowed.

Venomous Snakes

Two species of venomous snakes may occur in Big South Fork NRRA and Obed WSR: copperheads (*Agkistrodon contortrix*) and timber rattlesnakes (*Crotalus horridus*). Of these, the rattlesnake has the more life-threatening bite. Avoid all snakes by keeping them at a safe distance. When in venomous snake country, pay attention to where you put your hands and feet, especially around rock piles and bedrock outcrops. Do not reach into crevices or put your feet into places where you cannot clearly see what is there. In thick vegetation, use a long stick to part the vegetation so you can see the ground. Wear snake leggings in thick vegetation where there could be significant numbers of venomous snakes. Should you receive a bite from a potentially venomous snake, move to a safe area, wash the bite area and dress the wound. Use a venom extractor within minutes to be effective. Immobilize the bite area with a splint, remove any rings, watches or other items that could constrict blood flow as the bite area swells, and immediately seek medical attention. Remain calm, and if emergency services cannot reach you, walk slowly to a place where you can be picked up. Note that many snake bites are purely defensive and contain no venom. Bites from immature snakes are more likely to contain a dangerous amount of venom than bites from adult snakes.

Vehicle Safety

Responsibilities of NPS Vehicle Operators

Crew members are responsible for inspecting their vehicles before every use to ensure the vehicles are in safe working condition. This includes visually checking tire pressure, adjusting mirrors, and making sure equipment is secure. Crew members must perform preventative maintenance in a timely manner (e.g., having oil changed by a qualified mechanic) and report any potential hazards or needed repairs to their supervisor.

Rules that must be followed when operating an NPS vehicle:

- Everyone in a government vehicle is required to wear a seat belt.

- Texting and other cell phone uses while driving are strictly prohibited. If you must answer or make a call, first pull over to a safe location off the road.
- Only NPS employees or authorized cooperators and contractors are allowed to operate a government vehicle.
- Individuals who are not NPS employees, authorized cooperators or contractors, or other authorized individuals on government business, are generally forbidden from riding in a government vehicle.
- Drivers must adhere to all federal and state vehicle regulations, including all posted speed limits.

Trailer towing precautions

- Towing a trailer or equipment with your vehicle requires additional planning, caution, and proficiency in driving.
- Vehicles and trailers vary in maximum load capacity. Do not exceed the maximum recommended load capacity. (Check owner's manuals or contact vehicle or trailer manufacturers for this information.)
- Vehicles and trailers must be compatible and have a matching hitch ball and coupling.
- Trailers are required to have standard safety equipment such as safety chains (placed in an "x" under the coupling), lights, brakes (if applicable), and load-securing devices. Be aware that air turbulence from passing vehicles can cause your trailer to sway.
- Drive slower when towing. Maintain extra following and stopping distance to allow for the increased load. Balance loads.
- Disengage the vehicle's automatic "overdrive gear" option when towing.

Procedures for reporting a motor vehicle accident

Instructions and forms are in the vehicle's glove compartment and include the following: SF91—Motor Vehicle Accident Report; SF94—Statement of Witness, and SF95—Claim for Damage, Injury, or Death. In case of a motor vehicle accident, use the following procedures:

- Stop immediately.
- Take steps to prevent another accident at the scene.
- Call a doctor or ambulance if necessary.
- Notify police if outside the park. If inside the park, notify a ranger.
- **Do not** sign any paper or make any statement as to who was at fault (except to your supervisor or to a federal government investigator).

- Get the name and address of each witness. Ask each witness to complete a Standard Form 94, Statement of Witness, contained in the envelope in the vehicle's glove compartment.
- State your name, address, place of employment, name of your supervisor, and upon request, and show your operator's permit.
- Complete Standard Form 91, Motor Vehicle Accident Report (or reporting form required by your agency) at the scene. If conditions prevent this, make note of the following:
 - Registration information for other vehicle(s), owner's name, tag number and state, vehicle description and serial number
 - Information on other driver (name, address, operator's permit number, and expiration date)
 - Name and address of each person involved and extent of injury, if any
 - Name and address of company insuring other vehicle(s) and insurance policy number
 - General information such as location, time, weather, and damage.
- As soon as possible, notify your supervisor and the chief of Resource Management.
- Submit all reports and data to your supervisor within one working day.
- Process injuries through your agency personnel office using <https://www.smis.doi.gov/smismain.cfm> to submit reports online.

Chemical Safety

Conductivity and pH sensors on APHN datasondes are calibrated with a chemical solution. Material Safety Data Sheets (MSDS) for these solutions are kept on file. These liquids are generally classified as non-toxic, non-corrosive and non-flammable. Contact with eyes or skin may cause irritation. Flush irritated eyes or skin with water for 15 minutes. Ingestion may cause nausea or diarrhea and should be treated by dilution, which is achieved by drinking water. Seek medical attention if symptoms persist. Inhalation may cause irritation, requiring removal of the affected person from the exposure area and possible medical assistance.

The National Park Service must follow applicable federal, Department of Transportation (DOT), Environmental Protection Agency (EPA), and supplemental state guidelines when transporting chemicals and chemical wastes. Chemical transportation guidelines are summarized in the following paragraphs.

- The National Park Service will transport small quantities of chemicals for use in field and office laboratory procedures. The National Park Service is not considered a commercial carrier which, by definition, transports materials in commerce or in the furtherance of a commercial enterprise (transporting for profit).

- Because the National Park Service transports small quantities of chemicals and wastes, the EPA and DOT small-quantity exemption rules apply. According to these guidelines, the National Park Service is exempt from many industry handling and shipping regulations and training requirements. Check your state's laws on intrastate transport of small quantities of chemicals in a federal government vehicle.
- It is not necessary to placard your vehicle when transporting small quantities of chemicals. Placarding a vehicle informs enforcement and emergency response personnel the vehicle contains large amounts of the material indicated on the placard. *(For their own safety, first-response teams might not immediately approach a wrecked vehicle with placards signaling a highly dangerous or reactive material.)*

Safe Containment and Transport of Chemicals

- Protect yourself and passengers in the vehicle by stowing and securing chemicals away from the passenger compartment and behind a safety screen or barrier.
- Avoid unnecessary exposures and spills. Never place chemical containers where they can be knocked over.
- Try to transport chemicals in their original DOT-approved shipping containers with the package correctly sealed. If the original packaging is not available, use a container that will resist and contain the material in the event of an accident. Use of an overpack container, such as an ice chest, is recommended to further protect against breakage and spills.
- Carry spill kit(s) appropriate for the chemicals being transported.
- Label packages with their contents and remove old, inappropriate labels from containers that are being reused.
- Keep a chemical inventory list in the glove box or side door pocket of the vehicle. This list should also have an emergency contact name and phone number. Keep a copy of each chemical's MSDS here as well.
- Transport waste products in the same safe and approved manner as other hazardous materials. The container must be of adequate composition and strength and labeled with the type and concentration(s) of chemical(s).

Chemical and waste disposal requirements and exemptions are federally regulated by the EPA. You must also follow supplemental state guidelines. Contact your safety officer or waste disposal representative for details and follow these general disposal guidelines:

- Do not indiscriminately dump chemicals or pathogens down sinks, toilets, or drains, and **do not discard wastes into the environment.**

- Do not let chemical wastes accumulate in your vehicle, office, or laboratory. Waste disposal storage areas should be established and used.
- Do not mix incompatible wastes. Waste disposal companies have strict and costly requirements for accepting mixed wastes.
- Always label the storage container of a waste product to indicate its contents.
- The dilute acid solution used for equipment cleaning can be prepared for safe disposal by following procedures described by Horowitz et al. (1994).

Appropriate Personal Protective Equipment

Select PPE appropriate to the chemical(s) to be in contacted with. Personal protective equipment can be designed for specific chemicals. For example, wear gloves that will provide adequate protection. Vinyl gloves are used for handling inorganic acids and bases. Latex gloves are used for handling relatively mild organic solvents, such as methanol and acetone. Nitrile gloves can be used for some stronger organic solvents.

Contaminated water

Water samples might be contaminated with pathogens or hazardous chemicals. Use caution and extra protection when working with water known or suspected to contain high concentrations of pathogens.

Waterborne, disease-causing organisms (pathogens) are found in nearly all surface-water systems and occur in some ground-water systems as well. Most pathogens originate from the body fluids and feces of animals and humans. Pathogens enter surface-water resources primarily through sewage discharges and spills, storm and agricultural runoff, and direct contact. Microorganisms are also transported on small particles such as dust or aerosols (gaseous suspension of very fine particles). Pathogens enter ground water through infiltration from septic tank effluent, leachate from fields and ponds, and from faulty well seals and casings. Bacteria, viruses, and other pathogenic organisms can occur in the most pristine environments.

To minimize exposures to and effects from contaminated water:

- Never drink sample water, no matter how pristine the environment appears.
- Receive required inoculations. Contact your safety officer about receiving appropriate inoculations before you sample.
- Use personal protective equipment, including respiratory equipment (certification required) when working over turbulent, polluted flows, and in shelters containing evidence of excrement (see Water Resource Division [WRD] Memorandums 94.30 and 95.06 (USGS, 1994, USGS, 1995)). Pathogens can enter your body through many openings such as your mouth, eyes, nose, cuts, scrapes, or chapped skin.

- Wear rubber boots, gloves, and splash protection (a disposable dust mask offers splash and dust protection at a very low cost).
- Do not ingest pathogens or other contaminants. Never eat or drink while sampling or put pencils or other items in your mouth.
- Carry antibacterial soap; wash before leaving the site. Remember to wash again after unloading supplies.
- Disinfect all contaminated surfaces as soon as possible.

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- U.S. Geological Survey (USGS). 2014. Safety and health for field operations. Handbook 445-3-H. Chapter 26. pp 303-304. Available at: <http://www.usgs.gov/usgs-manual/handbook/hb/445-3-h.pdf> (last accessed February 2016).

Appendix A: Emergency Contact Information

APHN Program Manager

Brian Witcher

Cell: (828) 484-6331

Telephone: (828) 407-5654

Email: brian_witcher@nps.gov

APHN Hydrologist

Jim Hughes

Telephone: (423) 569-2404 x 248

Email: james_d_hughes@nps.gov

BISO Chief of Resource Management

Tom Blount

Telephone: (423) 569-2404 x 252

Email: tom_blount@nps.gov

BISO Botanist

Marie Kerr Tackett

Telephone: (423) 569-2404 x 251

Email: marie_tackett@nps.gov

BISO Chief Ranger

Randy Scoggins

Telephone: (423) 569-2404 x 263

Email: randy_scoggins@nps.gov

BISO Safety Officer

Kenny Gilreath Telephone: (423) 569-2404 x 317

Email: kenneth_gilreath@nps.gov

OBRI Natural Resource Specialist

Rebecca Schapansky

Telephone: (423) 346-8901 x 27

Email: rebecca_schapansky@nps.gov

OBRI Chief Ranger

Matt Hudson

Telephone: 423-346-8901 x 22

Email: matt_hudson@nps.gov

Table SOP 1A-1. Emergency Contact Numbers.

Agency	Phone Number
Scott County Hospital	(423) 569-8521 (CLOSED as of 3/2013)
Jamestown Regional Medical Center	(931) 879-8171
Scott County Sheriff (Huntsville)	(423) 663-2245
Fentress County Sheriff	(931) 879-8142
McCreary County Sheriff	(606) 376-2322
Scott County Ambulance	(423) 569-6000
Fentress County Ambulance	(931) 879-8147
McCreary County Ambulance	(606) 376-5062
Morgan County Sheriff	(423) 346-6262

Medical Facilities Near BISO and OBRI—Hospitals and Urgent Care Clinics

Compiled by Brian T. Watson, 2011 APHN Intern

Harriman

Ambulatory Care Center of Roane County

2497 S. Roane St. # 110

Harriman, TN 37748-8666

(865) 882-2909

Monday–Friday 8 a.m.–5 p.m.

Approximate coordinates:

35.894218, -84.617647

+35° 53' 39.18", -84° 37' 3.53"

UTM: 715021.7 E, 3974837.6 N; 16 S

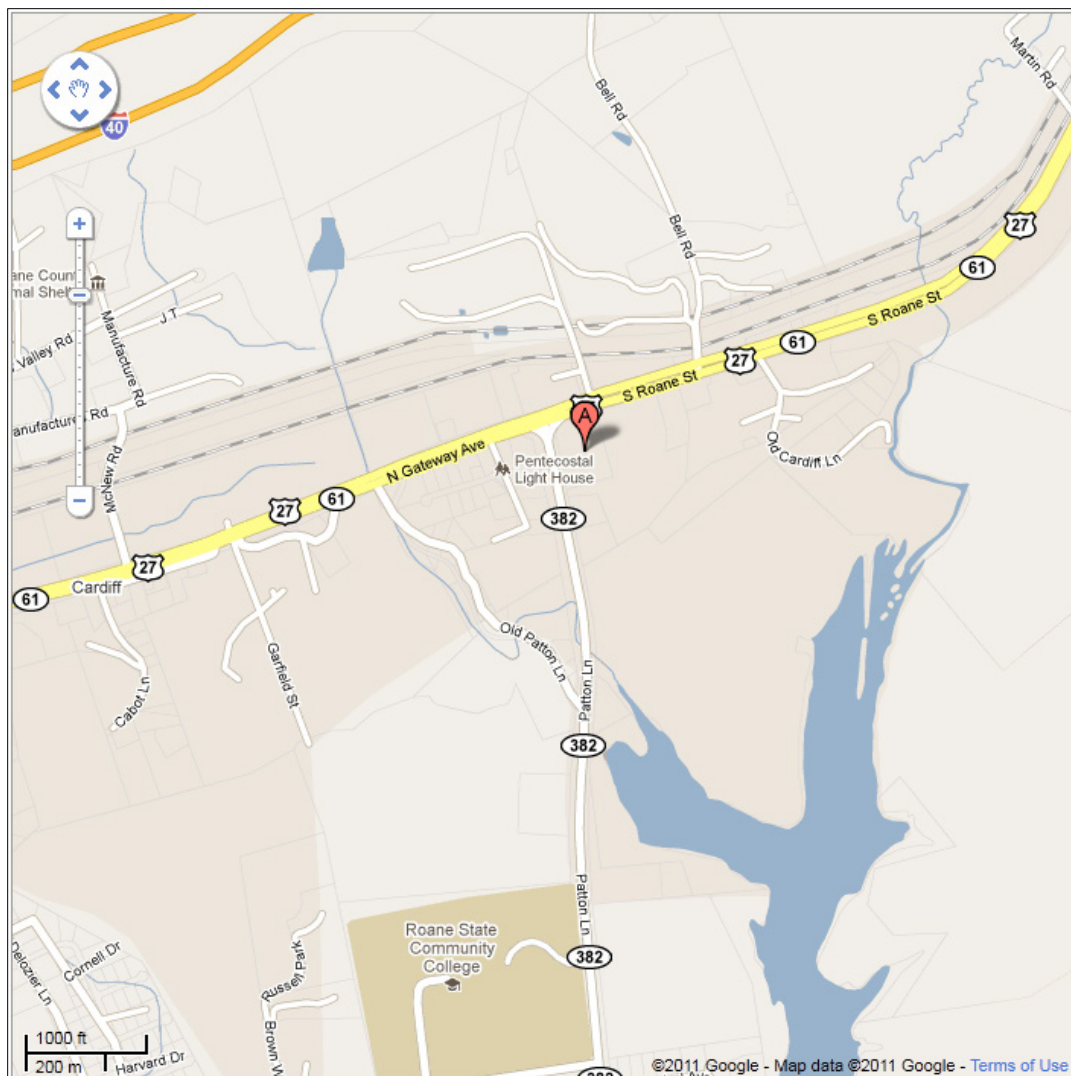


Figure SOP 1A-1. Location of Ambulatory Care Center of Roane County.

Roane Medical Center

412 Devonian Street

Harriman, TN 37748

(865) 882-1323

24 hours a day

Approximate coordinates:

35.934797, -84.551364

+35° 56' 5.27", -84° 33' 4.91

UTM: 720892.4 E, 3979487.6 N; 16 S



Figure SOP 1A-2. Location of Roane Medical Center.

Oneida

Ambulatory Care Center of Scott County

16050 Scott Highway

Oneida, TN 37841

(423) 286-3292

Monday–Friday 8 a.m.–5 p.m.

Approximate coordinates:

36.472324, -84.542854

+36° 28' 20.37", -84° 32' 34.27"

UTM: 720148.6 E, 4039145.2 N; 16 S

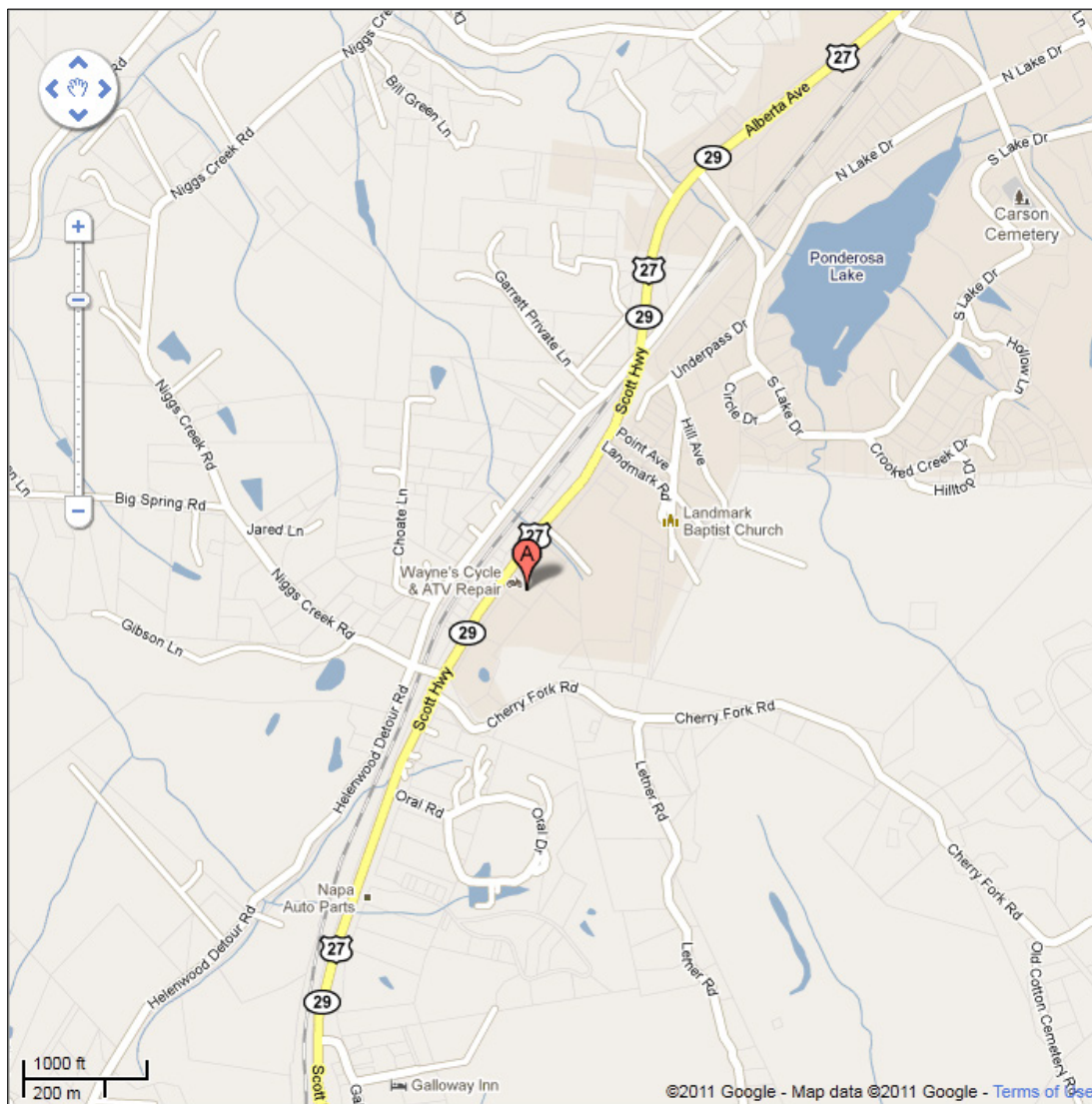


Figure SOP 1A-3. Location of Ambulatory Care Center of Scott County.

Jamestown

Jamestown Regional Medical Center

436 Central Avenue West

Jamestown, Tennessee 38556

(931) 752-5762

Open 24 hours a day

Approximate Coordinates:

36.431802, -84.943782

+36° 25' 54.49", -84° 56' 37.62"

UTM: 684318.3 E, 4033808 N; 16 S

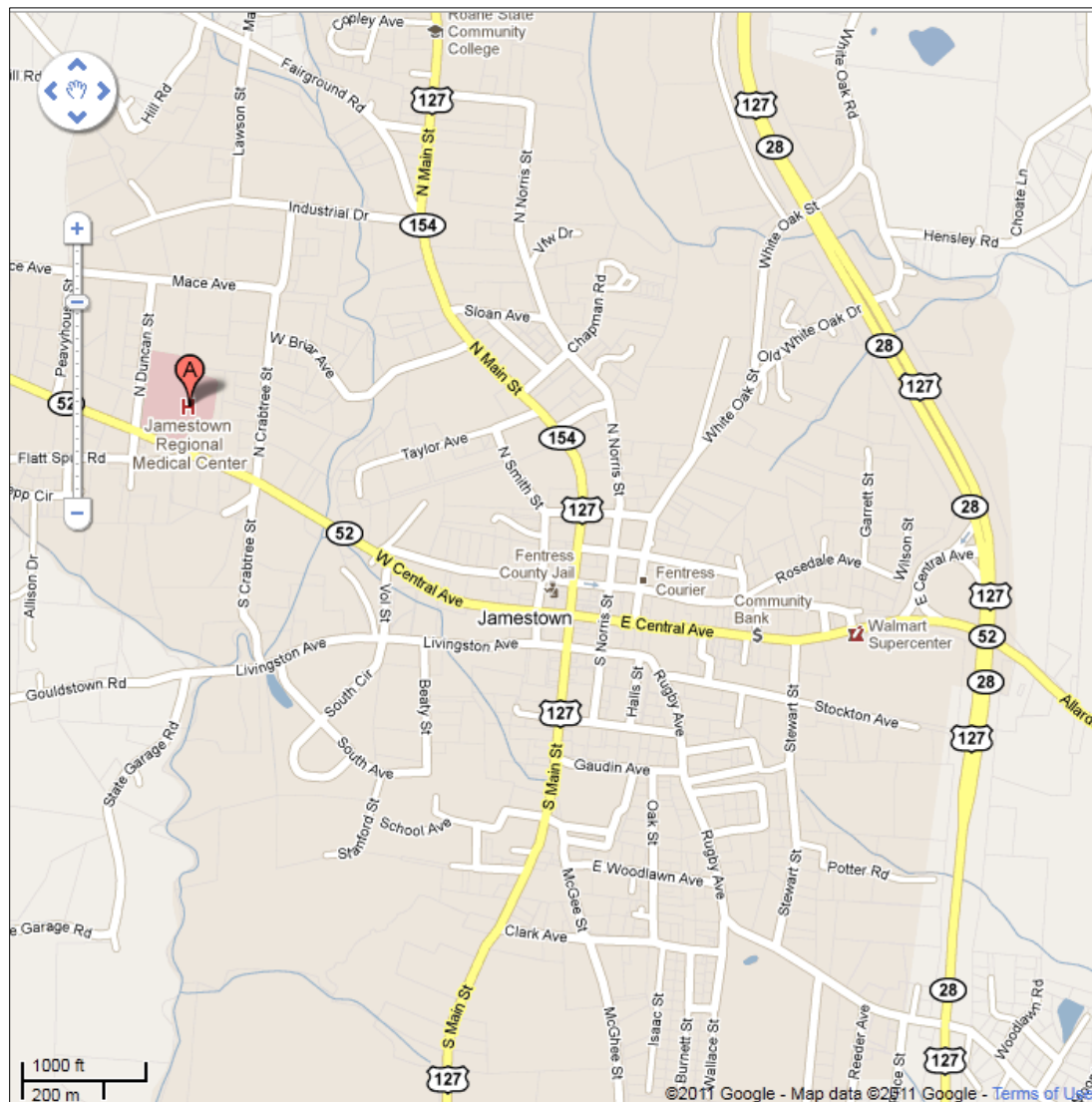


Figure SOP 1A-5. Location of Jamestown Regional Medical Center.

Oak Ridge

Park Med Urgent Care Center

115 B South Illinois Avenue

Oak Ridge, TN 37830

(865) 483-4040

Monday–Friday: 8 a.m.–6 p.m.

Saturday: 8 a.m.–2 p.m.

Approximate coordinates:

36.009093, -84.265916

+36° 0' 32.73", -84° 15' 57.30"

UTM: 746417.3 E, 3988415.1 N; 16 S

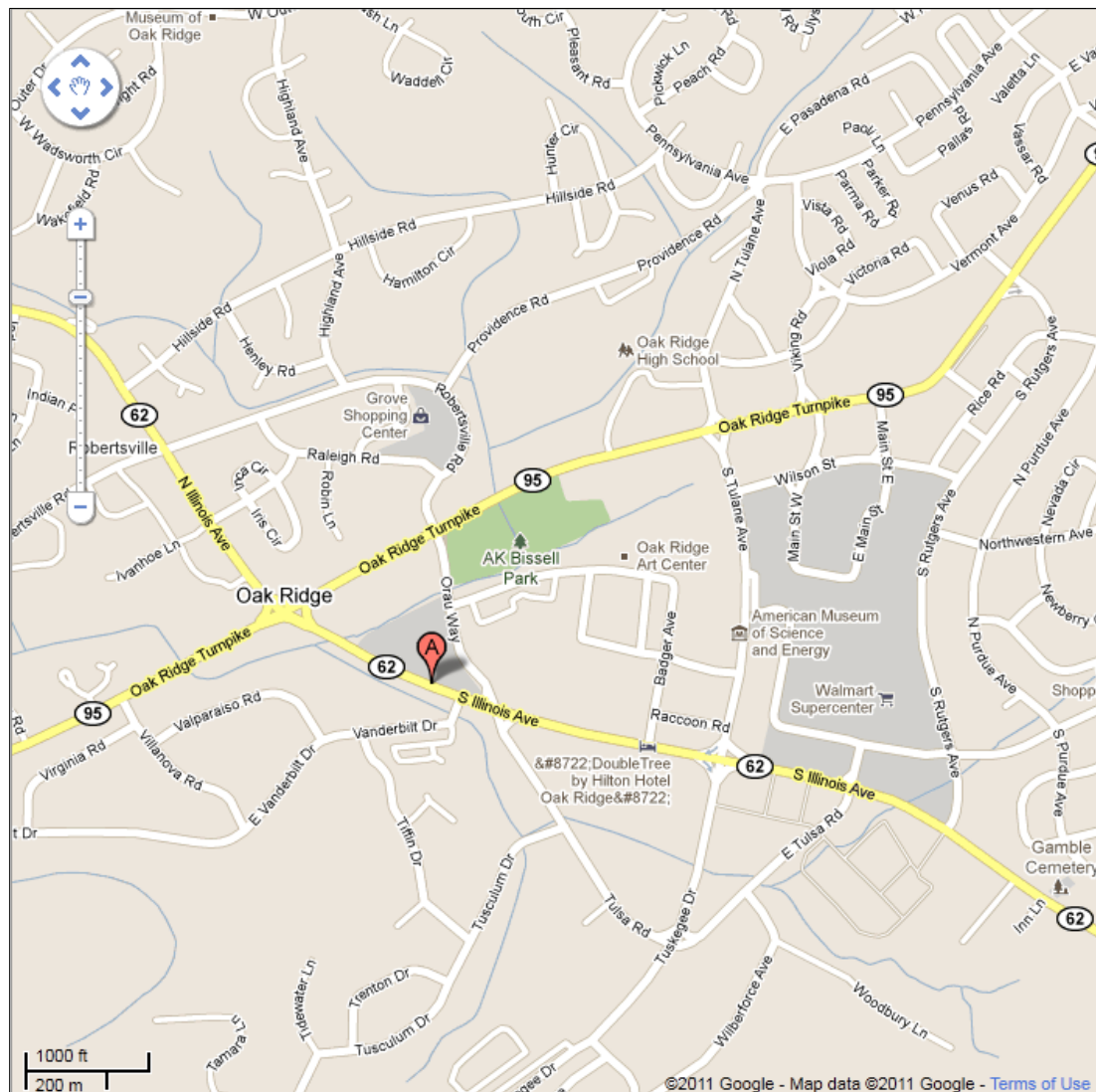


Figure SOP 1A-6. Location of Park Med Urgent Care Center.

Methodist Medical Center of Oak Ridge

990 Oak Ridge Turnpike

Oak Ridge, TN 37831

(865) 835-1000

Open 24 hours a day

Approximate coordinates:

36.024239, -84.242481

+36° 1' 27.26", -84° 14' 32.93"

UTM: 748482.4 E, 3990155.2 N; 16 S

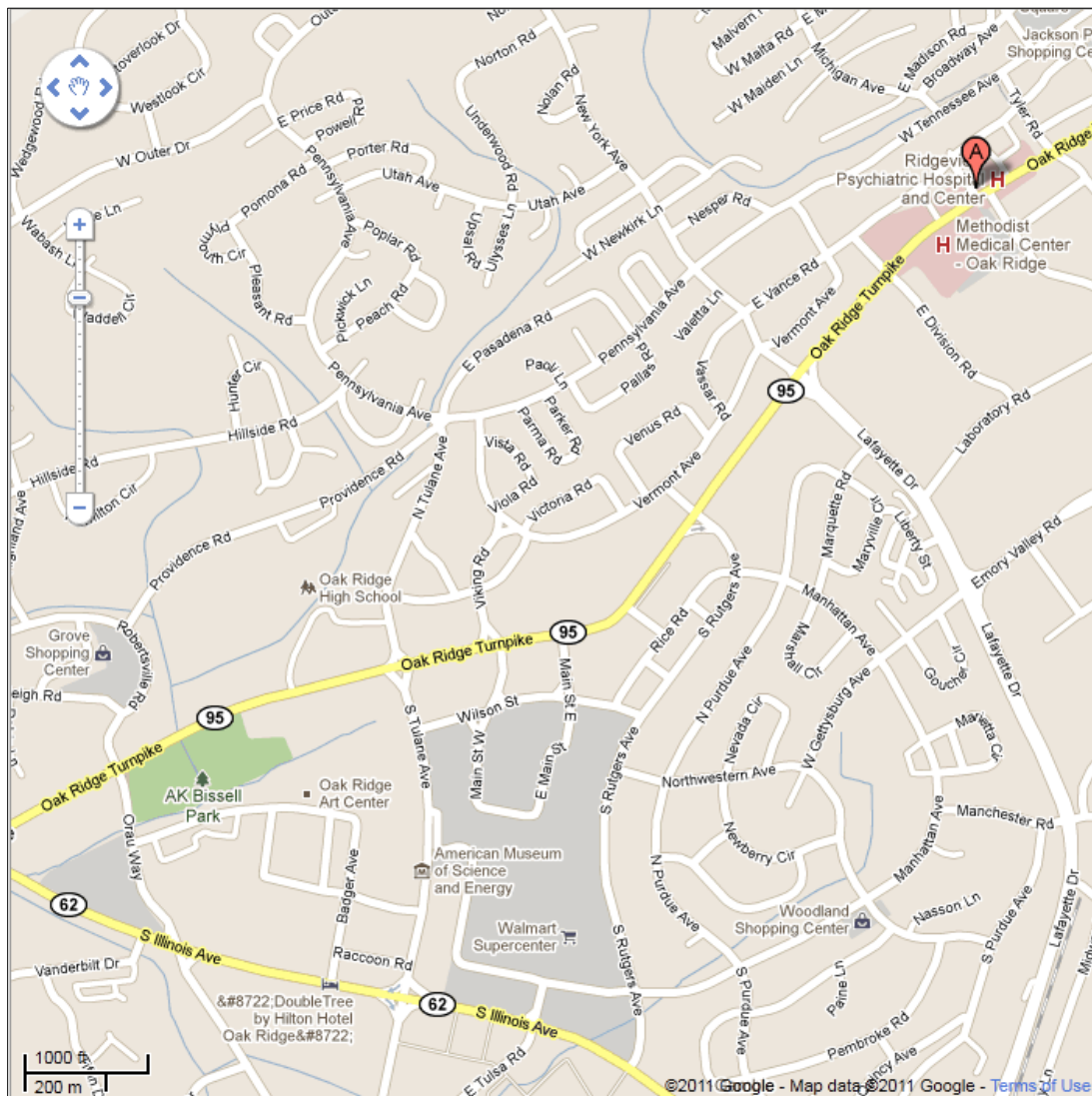


Figure SOP 1A-7. Location of Methodist Medical Center of Oak Ridge.

Wartburg

Ambulatory Care Center of Wartburg

1236 Knoxville Highway; PO Box 368

Wartburg, TN 37887

(865) 882-2909

Monday–Friday 8 a.m.–5 p.m. (stops accepting patients at 4)

Approximate coordinates:

36.103734, -84.580482

+36° 6' 13.44", -84° 34' 49.74"

UTM: 717799.4 E, 3998164.9 N; 16 S

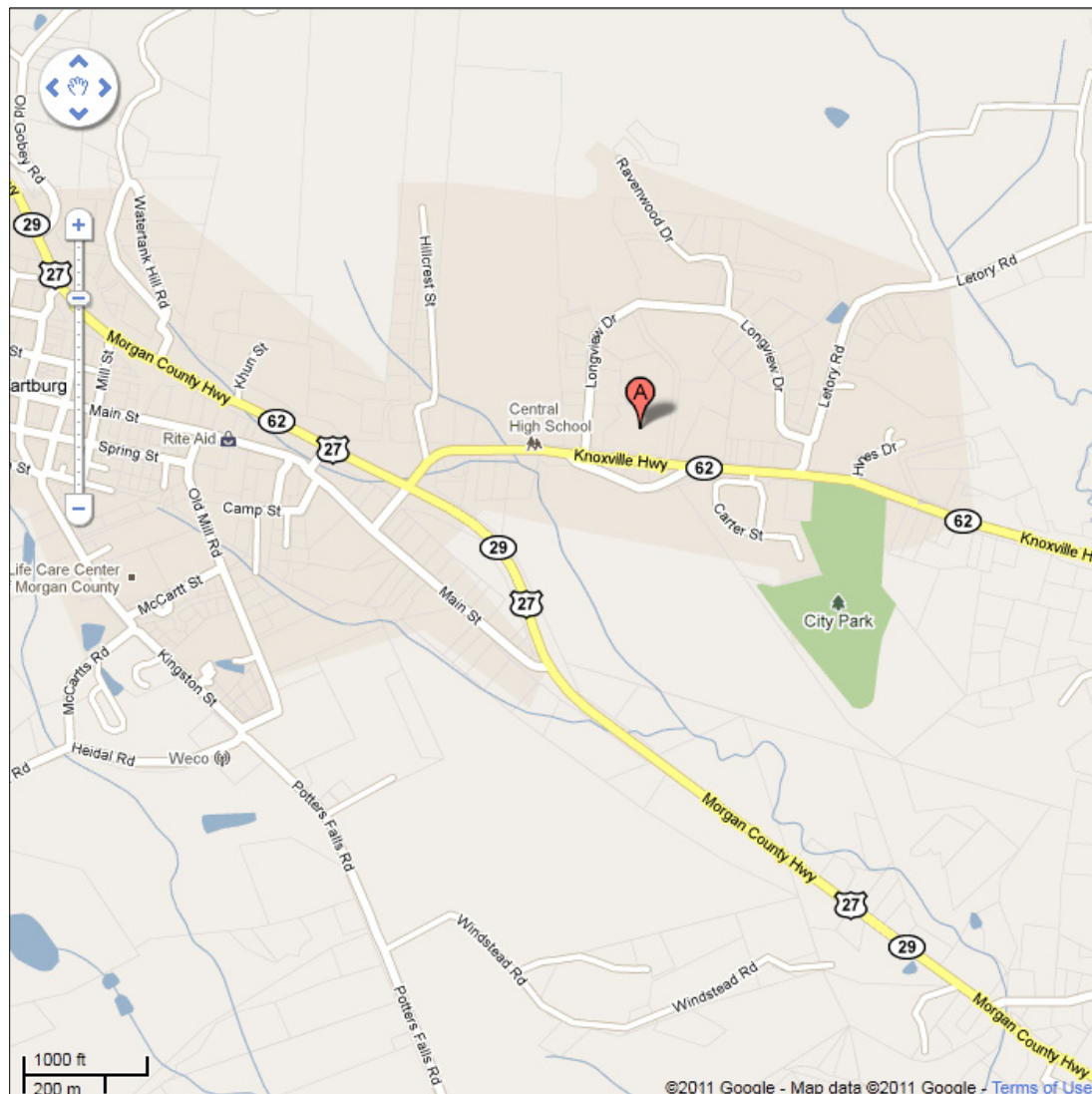


Figure SOP 1A-8. Location of Ambulatory Care Center of Wartburg.

Also, see Harriman Hospital and Oak Ridge Hospital facilities.

Whitley City, Kentucky

See Oneida, Tennessee

Knoxville, Tennessee

North Knoxville Medical Center (Tennova Healthcare)

7565 Dannaher Drive

Powell, TN 37849

(865) 859-8000

Open 24 hours a day

Approximate coordinates:

36.053523, -83.996637

+36° 3' 12.68", -83° 59' 47.89"

UTM: 230064.7 E, 3994041.7 N, 17S

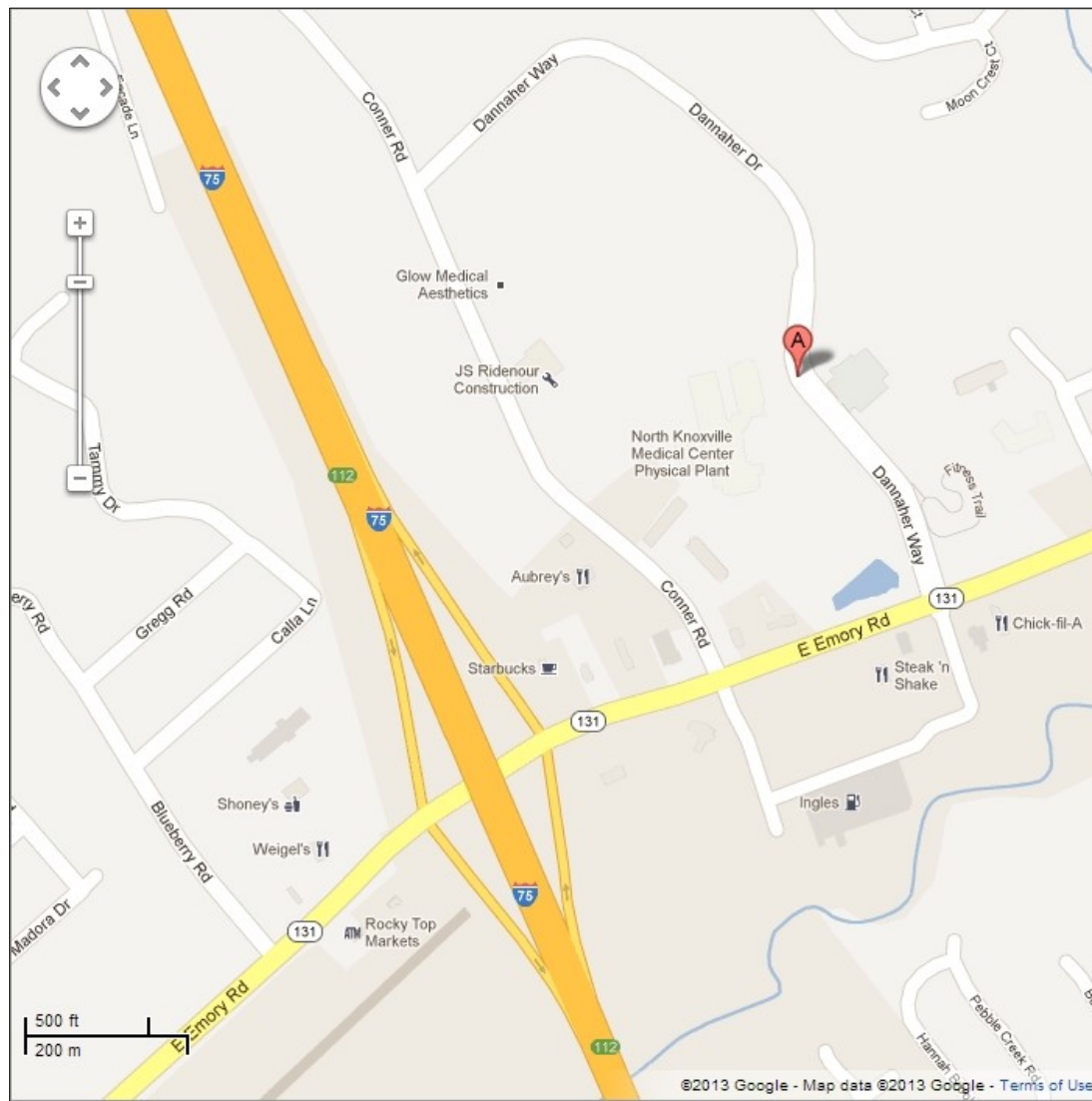


Figure SOP 1A-9. Location of North Knoxville Medical Center (Tennova Healthcare).

Appendix B: InReach Operation

Big South Fork National River and Recreation Area /Obed Wild and Scenic River

Start of the Day

1. Send email or text message to APHN Program Manager or designated alternate indicating itinerary and estimated time you will be returning to office.
2. Send InReach message: “I&M in the park” at the start of the day and at each site that you visit.
3. Turn InReach tracking on.

List of individuals receiving emails:

- amanda_little@nps.gov
- beverly_chase@nps.gov
- brian_mitchell@nps.gov
- brian_witcher@nps.gov
- evan_raskin@nps.gov
- james_d_hughes@nps.gov
- matt_hudson@nps.gov
- robert_emmott@nps.gov
- randy_scoggins@nps.gov
- tom_blount@nps.gov

End of the Day

1. If crew is working in the field past anticipated return time, send InReach preset message “I&M delayed but everything is OK.”
2. At the end of the day, upon returning to the BISO Resource Management office or your place of lodging, send InReach message: “I&M leaving the park” and turn tracking off.

Crews failing to check-in via InReach

If you fail to check in at your stated time, the APHN Program Manager or designated alternate will do the following:

- Check their email for the latest InReach Message.
- Contact the crew via InReach Beacon.
- Contact the crew via cell phone.
- Contact crew via radio.
- If contact cannot be made by the above methods, the APHN program manager or designated alternate will login to <https://explore.delorme.com/> and track location of the crew. Login procedures include:

- Email address: brian_witcher@nps.gov
- Password: Aphnbiso1!

If the last tracked location is not safely outside the park, the APHN program manager or designated alternate will contact Park Dispatch and ask that resources be sent to ascertain the status of the field crew.

Blue Ridge Parkway

Start of the Day

1. Contact Park Dispatch via radio 800 or phone (828) 298-2491.
2. Identify using radio call number.
3. Provide the following:
 - a. Project you will be working on (i.e., vegetation, water quality);
 - b. Start time;
 - c. Expected end time;
 - d. Number of people in party;
 - e. Vehicle information;
 - f. Mile post range (e.g., 20–70) where you will be working.
4. Send InReach message: “I&M in the park” at the start of the day and at each site that you visit.
5. Turn InReach tracking on.

List of individual receiving emails:

- bambi_teague@nps.gov
- brian_mitchell@nps.gov
- brian_witcher@nps.gov
- BLRI_Communications@nps.gov
- debra_flowers@nps.gov
- evan_raskin@nps.gov
- neal_labrie@nps.gov
- robert_emmott@nps.gov

End of the Day

1. If crew is working in the field past anticipated return time, send InReach preset message: “I&M delayed but everything is OK.”

2. At the end of the day, send InReach message: “I&M leaving the park” and turn off InReach tracking.
3. Radio Park Dispatch, identify yourself using your radio call number, state that you are: “Out of service.”

Crews failing to check-in with Park Dispatch

If you fail to check in at your stated time Park Dispatch will do the following.

- Contact you via radio
- Check their email for the latest InReach Message.
- Contact the APHN program manager, or designated alternate, via phone and email

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ02

Job Hazard—Version 1.4

Please cite this as:

Appalachian Highlands Network. 2018. Job hazard analysis—Version 1.4. Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—CWQ02. Appalachian Highlands Network Asheville, North Carolina.

Summary

All Appalachian Highlands Network (APHN) staff are required to review and sign this Job Hazard Analysis (JHA) each year before going into the field to collect monitoring data. The JHA is presented here in altered format, to improve readability and ensure compliance with section 508 of the Rehabilitation Act.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

JOB HAZARD ANALYSIS (JHA)

Date: 24 March 2014

New or Revised JHA: New JHA

Park Unit: APHN

Division: SER I&M

Branch: APHN

Location: Obed Wild and Scenic River (OBRI, Tennessee) and Big South Fork National River (BISO, Tennessee and Kentucky)

TASK TITLE: Continuous water-quality monitoring instrument maintenance and data download.

Job Performed By: Network Hydrologist and/or Technician/Intern

Analysis By: Jim Hughes

Supervisor: Network Program Manager

Approved By: Brian Witcher, Network Program Manager

Required Standards and General Notes: Read the entire water-quality monitoring protocol, including SOP CWQ01 *Safety—Version 1.4*. Drive and hike carefully. Bring all necessary equipment into the field.

Required Personal Protective Equipment: Hiking boots, long pants, wading shoes, insect repellent, rain gear, sunscreen, wide-brimmed hat, safety goggles, food, water, first aid kit, Sawyer Extractor snakebite kit, radio, cellular phone. If boating: personal flotation devices, throw rope, and helmets.

Recommended/Optional Equipment: Snake leggings, walking stick, poison ivy protection (pre- and post-contact), wasp/hornet spray, antihistamine, water filter or treatment.

Tools and Equipment: Field data sheets, clipboard, pencils, compass, map, GPS unit, flagging, chest waders, wading boots, personal locator beacon, and personal protective equipment (PPE).

Pre-trip Planning: Advise appropriate personnel of trip agenda. Sign out on sign out boards. Carry InReach beacon, cellular phones, 2-way radios, or other communication devices.

Table SOP 2-1. Job Hazard Analysis.

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Driving to/from site	1a. Car accident	Wear seatbelt at all times while vehicle is in motion. Drive only on established roads, follow all driving laws, and park in a safe location that will not obstruct traffic. Do not use cell phone or other device while driving. Avoid traveling during inclement weather. Slow down where large animals may be present to allow for reaction time.
	1b. Unimproved roads	Maintain a safe speed for the road condition. Use 4WD when necessary. Move sharp rocks out of road. Ensure that tires are properly inflated and check for tire damage regularly. Always have a fully inflated spare tire and all equipment necessary for changing a tire.
	1c. Fatigue	Do not drive if fatigued. Pull over to rest or have another member of the crew drive.
Traveling to/from site	2a. Steep, rugged, or slippery terrain.	Wear sturdy, well-fitting boots with good traction. Use established trails when possible. When walking off-trail, take care to assess terrain conditions in order to determine the safest route. Move slowly and deliberately through steep areas, using trees and solid rocks as handholds when available. Check footholds before using them. Walking sticks may help to increase stability. Fall into the slope if you slip or slide. Never be directly above or below someone on a loose or unstable slope. Be especially cautious on stream banks, which are often steep and slippery.
	2b. Loss of orientation	Ensure all crew members are knowledgeable with map and compass, as well as with GPS. Keep track of current position, vehicle location, and pay attention to landmarks along your way. Use established trails when possible.
	2c. River crossing and working in water	Check river gages for safe levels before crossing or working in streams. Never cross a river alone. Use walking sticks to aid stability, making sure to stabilize one foot before moving the other. Avoid stepping on slippery or teetering rocks. Wear wading shoes or waders—never cross barefoot due to potential for stepping on glass or other sharp objects. For deep, swift crossings, an inflatable kayak or raft should be used to cross (see 4a). Be aware of changes in water level (see 5b: “Inclement Weather.”
Boating to/from site	3a. Entrapment; overturning; falling overboard	Check river gages and weather forecasts to ensure that flow levels are low enough for safe crossing. Have personal flotation devices, a throw rope, and helmets. Avoid submerged trees and large boulders to prevent entrapment or overturning.

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Traveling to/from and performing maintenance at a site	4a.. Poison ivy	Make sure all crew members are able to identify and avoid contact with poison ivy. Wear long sleeves when weather permits, and use pre-exposure lotions or wipes (e.g., Tecnu, IvyX) to prevent exposure. Wash with Tecnu's poison ivy soap immediately after returning from the field. Wash field clothes separately from other laundry.
	4b. Bees/Wasps/Hornets	Carry hornet spray, antihistamines, and Epipens (if prescribed by physician). Be aware of the ground where you step, looking out for and avoiding bees or hornets at ground level. Also watch for hornets in tree canopies (especially river birch).
	4c. Ticks	If bitten by a tick, remove it and fill in a report on the network's tick log in the event that symptoms of Lyme or other tick-related diseases eventually appear.
	4d. Mosquitoes	Wear bug repellent and long sleeves when weather permits. Be aware of West Nile virus symptoms. (http://www.cdc.gov/ncidod/dvbid/westnile/ga/symptoms.htm)
	4e. Snakes	Wear snake leggings and leather boots. Inspect the ground and tap logs and rocks before stepping over them. Do not put hands or feet in places you cannot see. If in dense vegetation, walk slowly and use walking stick to thump the ground ahead of you. Carry the Sawyer Extractor snakebite kit and familiarize yourself with it in order to allow for rapid use if needed. Be able to identify venomous snakes and lookalikes.
	4f. Black Bears	If you encounter a black bear, keep your distance. If you encounter a sow with cubs, leave the area and return when the bears are gone. Upon meeting a bear in close proximity, back up slowly. If a bear charges, look big, raise your arms and make a lot of noise. If attacked aggressively, fight back. More info online at: https://www.nps.gov/biso/planyourvisit/foodstorage.htm .
	4g. Encounters with strangers	Report uncomfortable encounters with strangers to a supervisor/park ranger as soon as possible. Report apparent illegal activities to a park ranger. Avoid confrontation with other people in the park. Do not cross into private property without first obtaining permission from the landowner.
	4h. Broken glass	Broken glass is often found on the river bottom and along banks. Wear sturdy shoes at all times and look out for broken glass and other sharp debris. Use a walking stick to feel your way through dense vegetation.

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Exposure to environmental variables while traveling to/from and performing monitoring at a site	5a. Sun, heat	If possible, do not work on excessively hot days (Above 100°F or 37.8°C). To prevent sunburn, use sunscreen and lip balm of 30+ SPF. Hat, sunglasses and long-sleeved shirt are also recommended to prevent burning. Carry plenty of water (and filter) and electrolytes. Wear broad-brimmed and ventilated hats, and sunglasses. When possible, crew members may switch off tasks so that they can take turns being in the shade vs. sun. Watch others for signs of heat stress and heat-related illness (See SOP CWQ01— <i>Safety-Version 1.4</i>) and treat accordingly by getting to shade and water.
	5b. Inclement weather	Obtain weather forecasts daily and, if possible, avoid working on days with potentially hazardous weather. Always carry rain gear and stay clear of tall trees as storms approach. Pay attention to distant thunder and rising water levels to allow for safe river crossing. Where river crossings are involved, if the water level begins to rise quickly, evacuate the site before the river becomes too swift to cross.
	5c. Giardia	Giardia may be present in the parks. Do not drink from any stream, river, or other body of water unless the water has been properly filtered or treated.
Use of calibration standards	6a. Contact with skin, eyes, ingestion, inhalation.	Chemical solutions are used to calibrate conductivity and pH sensors on APHN datasondes. Material Safety Data Sheets for these solutions are kept on file. These liquids are generally classified as non-toxic, non-corrosive and non-flammable. Gloves and goggles should be worn during use. Contact with eyes or skin may cause irritation and should be flushed with water for 15 minutes. Ingestion may cause nausea or diarrhea and should be treated by dilution by drinking water. Seek medical attention if symptoms persist. Inhalation may cause irritation, requiring removal from the exposure area and medical assistance should irritation persist.
Office work	7a. Computer use fatigue	Take appropriate breaks, getting up from your desk to walk around and/or stretch. If possible, intersperse computer tasks with other job duties, trade appropriate and assigned duties with co-worker, apply work/rest ratio guidelines.
	7b. Computer use eye strain	In addition to recommendations under 7a above, ensure proper placement of screen for ergonomic viewing (top of screen at eye level). Use a non-glare screen or an anti-glare device on screen and avoid placing screen in front of a bright background (such as a sunny window). Adjust screen refresh rate as needed to eliminate screen flicker (if using a CRT monitor). Individuals requiring prescription eye wear should ensure proper focal distance is achieved without having to tilt the head.
	7c. Carpal Tunnel Syndrome	In addition to recommendations under 7a above, periodically stretch hands and do wrist exercises, ensure proper keyboard position, and adjust chair height so that forearms are parallel to the work surface.

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Office work (continued)	7d. Electrical cords and electrical hazards	Do not overload outlets. Use surge protection for computer equipment and keep cords organized and out of walkways. Never use personal space heaters in government buildings unless approved by facility maintenance supervisor.
	7e. Inadequate lighting and poor air circulation	Take appropriate breaks. Alternate indoor and outdoor activities, if possible. Adjust thermostat, open windows and/or use a fan, as needed. Turn lights on or off to achieve adequate lighting.

JHA Instructions

The JHA Shall:

Identify the location of the work project or activity, the name of personnel involved in the process, the date(s) of acknowledgment, and the name of the appropriate supervisor approving the JHA. The supervisor acknowledges that personnel have read and understand the contents, have received the required training, and are qualified to perform the work project or activity.

Identify all tasks and procedures associated with the work project or activity that have potential to cause injury or illness to personnel and damage to property or material. Include emergency evacuation procedures (EEP).

Identify all known or suspected hazards associated with each respective task or procedure listed. For example:

1. Research past accidents or incidents.
2. Research the Health and Safety Code or other appropriate literature.
3. Discuss the work project or activity with participants.
4. Observe the work project or activity.
5. A combination of the above.

Emergency Evacuation Instructions

Work supervisors and personnel are responsible for developing and discussing field emergency evacuation procedures and alternatives in the event an individual becomes seriously ill or injured at the worksite.

Be prepared to provide the following information:

1. Nature of the accident or injury (avoid using victim's name)
2. Type of assistance needed, if any (ground, air, or water evacuation)
3. Location of accident or injury, best access route into the worksite (road name/number), identifiable ground/air landmarks
4. Radio frequencies
5. Contact person
6. Local hazards to ground vehicles or aviation
7. Weather conditions (wind speed and direction, visibility, temperature)
8. Topography
9. Number of individuals to be transported
10. Estimated weight of individuals for air/water evacuation

The items listed above serve only as guidelines for the development of emergency evacuation procedures.

JHA and Emergency Evacuation Procedures Acknowledgment

I, the undersigned participant, acknowledge participation in the development of this JHA (as applicable) and accompanying emergency evacuation procedures. I have read them thoroughly and understand the provisions of these documents.

PRINT NAME

SIGNATURE

DATE

_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ03

Training Field Personnel—Version 1.4

Please cite this as:

Appalachian Highlands Network. 2018. Training field personnel—Version 1.4. Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—CWQ03. National Park Service, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) explains the steps involved in training field personnel. Read this SOP prior to conducting fieldwork.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Suggested Reading

Wagner, R.J., R.W. Boulger Jr., C.J. Oblinger, B.A. Smith. 2006. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51

Overview

This SOP generally describes topics and some specific presentations or courses that should be considered for training field personnel. Personnel should refer to this SOP for general guidance but should also seek additional information from the suggested references and through hands-on training courses provided by the National Park Service (NPS) and outside vendors.

The protocol lead or an appropriately-trained surrogate will conduct or provide all field-techniques training required to implement this protocol, including training in the principles of water resource field and laboratory data collection, and data handling techniques. Training will be required for each network staff member and park field technician before they participate in field sampling. Untrained personnel may assist in the presence of trained personnel.

Training Topics

Safety

Before field crews and park staff assist with monitoring, they must certify they have read SOP CWQ01 *Safety—Version 1.4* and SOP CWQ02 *Job Hazard Analysis—Version 1.4* for this protocol. National Park Service “Operational Leadership” is a required course for network personnel, as is “Wilderness First Aid.” Field crews should be briefed on network-specific safety procedures and potential hazards before conducting monitoring. These procedures include proper use of radios and emergency signaling using the InReach personal beacon tracking devices carried by network field crews. Briefings will occur in the office and at tailgate safety talks during each site visit.

YSI 6920-V2 Multi-Parameter Water-Quality Datasonde Operation

The protocol lead will assume primary responsibility for the operation and maintenance of water-quality datasondes deployed at United States Geological Survey (USGS) streamflow gages in the Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI) systems. Other network or resource management staff at Big South Fork NRRRA and Obed WSR may provide logistical support and will occasionally respond to and correct fouling or deployment issues, which are indicated by real-time display on the internet. The protocol lead will train other APHN staff and resource management staff at individual parks on field techniques used to address fouling issues at each continuous monitoring station.

Additional personnel must be competent in methods for sensor installation and care, accurate calibration, and proper maintenance for YSI datasondes and sensors. Therefore, the protocol lead will periodically train network staff, resource management staff, and other field personnel on those procedures. In general, the most effective training technique for sensor installation and datasonde

calibration is provision of written documentation of techniques, supplemented by hands-on demonstration. Demonstration and training of personnel will follow the procedures outlined in the YSI 6-Series Operations Manual, the YSI Calibration and Maintenance Tips white paper, and SOPs *CWQ05 Equipment and Calibration—Version 1.4* and *CWQ06 Linking YSI 6920 Datasondes to USGS Gages—Version 1.4*. Network and resource management staff at each park will be provided with copies of the YSI 6-Series Multiparameter Water-Quality Datasonde User Manual, YSI 650MDS data display and logger, and pertinent SOPs developed for calibration of field equipment.

During training, field personnel will use the YSI 650MDS handheld unit to perform calibrations under the guidance of the APHN hydrologist. This will familiarize trainees with navigation of 650MDS calibration menus and address any issues or questions. Documentation of calibration and site visits is an important component of continuous water-quality monitoring, and the NPS-USGS partnership necessitates that the National Park Service adopt USGS procedures for thorough documentation of calibration, operation and maintenance site visits, and QA/QC of data. Training will be provided on that aspect of the process as well. Field personnel who are responsible for calibration and data retrieval will be updated on procedures annually.

Internal Datasonde Firmware Setup and Interface with USGS Gages

YSI 6920 datasondes must be set up to communicate with USGS hardware at the gaging stations (see SOP CWQ06 for details). That setup is conducted with the YSI 650MDS handheld unit. The protocol lead will provide training as necessary on the settings required for gage interface and navigation of appropriate 650MDS menus to change settings. The protocol lead will also provide training on use of Sutron Satlink Communicator software (Sutron, 2009), which is used to communicate with USGS data collection platform (DCP) dataloggers and to set up sampling order, frequency, and measurement units for data export to the National Water Information System (NWIS).

Data Retrieval and Management

To date, the Appalachian Highlands Network has logged water-quality data collected by YSI 6920 water-quality datasondes externally to USGS DCP hardware at water-quality stations associated with stream gages. Through an informal agreement with USGS, these data are exported via USGS telemetry and geostationary operational environmental satellite (GOES) to the USGS National Water Information System (NWIS). Broadcast of data to the internet necessitates that those data be monitored and maintained to minimize the period of time that inaccurate data (such as might occur in response to sensor fouling) are displayed online. The protocol lead corrects these data weekly at a USGS workstation utilizing the USGS version of Aquarius software resident on the USGS NWIS server. To provide duplicate capabilities for correction of data, the network data manager will be trained on the use of Aquarius [Aquatic Informatics 2016], once USGS completes their transition to the new system (spring of 2017) for processing and editing of continuous time-series data.

Suggested Formal Training

To provide a sound foundation in sampling techniques, the following USGS field training courses are required for the protocol lead:

1. USGS QW 1028: Field Water-Quality Methods for Groundwater and Surface Water

2. USGS SW 1286: Introduction to Surface Water Records Computation
3. USGS SW 2298: Standard Procedures for Continuous Water-Quality Monitors

Literature Cited

Aquatic Informatics. 2016. Aquarius Time Series Water Quality software.

Sutron Corporation. 2004. Satlink 2 Logger and Transmitter Operations and Maintenance Manual (Satlink version 2.6.07 and Satlink Logger version 5.09). Sterling, Virginia.

Wagner, R.J., R.W. Boulger Jr., C.J. Oblinger, B.A. Smith. 2006. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51

YSI, Inc. 2010. Calibration, Maintenance and Troubleshooting Tips for YSI 6-Series Datasondes & Sensors. Available at: <https://www.ysi.com/File%20Library/Documents/Tips/YSI-Calibration-Maintenance-Troubleshooting-Tips-6-Series-Datasondes-2-8-10.pdf> (last accessed March 2018).

YSI, Inc. 2011. YSI 6-Series Multiparameter Water Quality Datasondes User Manual. Yellow Springs Instruments, Yellow Springs, OH 45387

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ04

Disinfection Procedures for Aquatic Resource Sampling— Version 1.4

Please cite this as:

Appalachian Highlands Network. 2018. Disinfection procedures for aquatic resource sampling—
Version 1.4. Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—
CWQ04. Appalachian Highlands Network, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) describes disinfection procedures relating to aquatic resource sampling. Read this SOP prior to conducting fieldwork and keep a copy in all vehicles for quick reference.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Background and Scope

Staff and cooperating researchers of the Appalachian Highlands Inventory and Monitoring Network (APHN) routinely conduct field activities that include sampling of water and associated aquatic and riparian resources within and adjacent to APHN park units. These resources include a variety of sensitive aquatic ecosystems that are dispersed across a broad geographic area. Consequently, the network must guard against the transport of non-native species and biological contaminants on field equipment, vehicles, and boats. To meet that obligation, the network will implement decontamination procedures to minimize the risk of spreading nuisance species and contaminants.

This SOP provides standardized methods for cleaning and disinfecting all equipment used to collect samples from APHN waters in a manner that will prevent the spread or introduction of disease-causing pathogens and invasive algae, plant, and animal species. These methods are consistent with the decontamination procedures of other entities conducting water-resource sampling activities in Virginia, North Carolina, Tennessee, and Kentucky. Confirmed and potential pathogens of concern in APHN waters include but are not limited to chytrid fungus (*Batrachochytrium dendrobatidis*), ranavirus (*Ranavirus* spp.), *Ribeiroia* spp., *Saprolegnia* spp., *Proteocephalus ambloplitis* and other fish pathogens. Invasive aquatic plant and alga species of concern include but are not limited to variable water milfoil (*Myriophyllum heterophyllum*), Eurasian water milfoil (*Myriophyllum spicatum*), hydrilla (*Hydrilla verticillata*), curly-leaved Pondweed (*Potamogeton crispus*), and didymo (*Didymosphenia geminata*).

Applicability

This SOP applies to all aquatic and riparian monitoring activities conducted by Appalachian Highlands Network. This SOP also applies to state, federal, and academic partners that conduct water-resource investigations supported or coordinated by the network. Protocols and programs that encompass activities to be conducted under APHN disinfection guidelines include, but are not limited to:

- Continuous Water-Quality Monitoring Protocol
- Discrete Water-Quality Monitoring Protocol
- Freshwater Mussel Monitoring Protocol
- Rare Fish Monitoring Protocol
- Long Term Monitoring Protocol for Cobblebar Communities
- Benthic Macroinvertebrate Monitoring Protocol
- All water-resource inventory and monitoring activities conducted by APHN collaborators

The methods described herein will be used unless more stringent program or project decontamination protocols are mandated by other state, federal, or local entities. This SOP applies to all types of sampling equipment (waders, wetsuits, nets, seines, datasondes, handheld meters, handheld or reel mounted water samplers, electrofishing equipment, boats and trailers) that directly contact a waterbody during collection of water-quality or biological samples from APHN park waters.

Description of Disinfection Measures

The required decontamination equipment and chemicals will be housed in NPS laboratories and offices and will also be available in field vehicles. These procedures will be followed when field activities necessitate the movement of personnel and equipment between waterways and watershed basins. All susceptible equipment moved between watersheds should be properly cleaned and disinfected, especially in situations where aquatic invasive species (AIS) are known or suspected to occur.

Field staff should be aware of infestations in their management areas and assess whether direct contact with the waterbody is necessary. Information on distribution of some aquatic invasive species can be found at: <http://nas.er.usgs.gov/>. Contact your local or agency AIS specialist for additional information. If an infestation of a water body is questionable, proceed as if the waterbody is infested. If in-water work cannot be avoided, identify ways to minimize contact with water, plants, or sediments, and follow the Dedicate, Clean, and Decontaminate procedures:

Dedicate

When working in infested waterbodies, field staff should ideally maintain unique sets of equipment and clothing dedicated to those waters, and should use the unique sets in a manner that will prevent the transfer of aquatic invasive species to uncontaminated areas. Dedicated equipment does not need to be cleaned or decontaminated after each use but must be labeled and kept isolated to avoid cross-contamination with other equipment. **Dedicated equipment should never be used in another waterbody.** If dedicated equipment is impractical or cost-prohibitive, field staff must follow the Clean and Decontaminate practices described below.

Clean

Before leaving a water-resource sampling location, field staff should visually inspect all clothing and equipment for any foreign material, including plant fragments, animals, or sediment. Remove all material at the site and properly dispose of in an upland area. Disinfect equipment before field staff leaving the site to sample another waterbody. Always re-inspect clothing and gear before entering another water body in case it was not properly cleaned after its last use.

Decontaminate

Field clothing, equipment, and vehicles that have been used in a waterbody should be cleaned as above and then should be decontaminated using a temperature or chemical treatment prior to use elsewhere. There are a number of acceptable disinfecting agents, but the preferred treatment in APHN waters is a 1% solution of Virkon Aquatic®, a disinfectant/virucide containing potassium peroxymonosulfate and sodium chloride as the active ingredients. Virkon Aquatic has been clinically

demonstrated to be effective against viruses, fungi, and bacteria. Virkon is non-toxic when used as recommended and degrades quickly in the environment. It is the principal disinfectant used by Great Smoky Mountains National Park and Conservation Fisheries, Inc. (Knoxville, Tennessee), both organizations with extensive experience in the aquatic resource conservation field.

Virkon® Aquatic—Directions for General Use

A 1% Virkon Aquatic solution is recommended for cleaning and disinfecting all equipment that comes in contact with aquatic resources in APHN parks, including: meters, nets, boots, waders, dive suits, boats, vehicles and other equipment. A container of Virkon solution, mixed at the recommended dilution, will accompany field crews involved in activities that require contact with aquatic resources.

Dilution Instructions

Virkon Aquatic is available in individual 1.3-ounce (37 grams) packets or in bulk tubs that include a 1.3-ounce measuring scoop. A 1% solution is obtained by mixing 1.3 ounces (37 grams) of Virkon/ powder with 1 gallon (3.8 liters) of water. Practice the following procedures when using Virkon Aquatic:

- For heavily soiled surfaces, clean with an appropriate detergent prior to disinfection. A scrub brush may be useful to facilitate cleaning.
- Do not apply Virkon Aquatic powder directly on surfaces you are trying to disinfect. Always mix with water first.
- Always prepare the Virkon Aquatic solution in a clean container of known volume.
- If using bulk product, measure the correct amount of Virkon Aquatic powder using the provided measuring scoop. The scoop holds approximately 1.3 ounces (37 grams) of Virkon Aquatic powder which, when added to a gallon of water, will make a 1.0% disinfectant solution. **Always use safety goggles and a dust mask when mixing dry Virkon Aquatic with water.**
- Stir or agitate the mixture to dissolve the Virkon Aquatic powder.
- After application of the solution to the surface(s) to be disinfected, allow a minimum of two minutes contact time and follow up with a clean water rinse. One gallon of solution is sufficient to disinfect approximately 135 square feet (12.6 square meters).
- Virkon® Aquatic solutions are stable for up to seven days. Test strips are available to determine the mixed solution's strength.

Safety Precautions for Virkon Aquatic

Virkon Aquatic is a disinfectant in the peroxygen (hydrogen peroxide) family. It is 99.9% biodegradable, breaks down to water and oxygen, and is not corrosive at the working dilution (1% solution). Virkon Aquatic is available from Western Chemical (contact number 1-800-283-5292).

Skin Contact

Virkon Aquatic diluted in water according to package directions (1% solution) is not a skin irritant. Skin contact with dry powder may cause skin burns or ulceration. In rare cases for sensitive individuals, skin contact with dry powder may cause an allergic skin reaction. Use **rubber gloves when mixing dry powder with water**. If skin irritation occurs after accidental contact with dry powder, take off contaminated clothing. Rinse skin immediately with plenty of water for 15–20 minutes. Call a Poison Control Center or doctor for further treatment advice.

Eye Contact

Virkon Aquatic diluted in water according to package directions (1% solution) is not an eye irritant. Eye contact with dry powder may cause eye corrosion or ulceration. Severe eye damage may result if not immediately treated. **Always use safety goggles when mixing dry Virkon Aquatic with water**. If accidental contact of dry powder with eyes occurs, hold eyes open and rinse slowly and gently with water for 15–20 minutes. Remove contact lenses, if present, after five minutes, then continue rinsing eyes. Call a Poison Control Center or doctor for further treatment advice.

Inhalation

Inhalation of this product may cause nose bleeding or irritation of the upper respiratory passages, resulting in coughing, sneezing, runny nose and sore throat. Gross overexposure may cause ulceration of mucous membranes. **Use a dust mask when mixing dry powder with water**. If accidental inhalation occurs, move the victim to fresh air. If a person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth. Call a Poison Control Center or doctor for further treatment advice.

Ingestion

Ingestion of this product may cause gastritis, with stomach pain, nausea, vomiting, diarrhea, headache or weakness; possibly progressing to necrosis or hemorrhage with gross overexposure. If accidental ingestion occurs, call the American Association of Poison Control Centers (Tel: 1-800-222-1222) or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by the Poison Control Center or doctor. Do not give anything by mouth to an unconscious person.

Summary

Always wear a dust mask and eye protection when mixing powder. Wear rain gear and gloves if spraying and position personnel upwind from the spray. When handling or spraying 1% Virkon Aquatic disinfectant, wear protective equipment (mask, gloves, goggles, rain gear, etc.) and use in a well-ventilated area. Follow precautions on the Material Safety Data Sheet (available at <https://www.pharmacal.com/MSDS/Completed%20SDS/VirkonS%20Powder.pdf>).

General Guidance for Control of Aquatic Invasive Species

- At the beginning of a sampling effort, all stream, river, and lentic surveys should be conducted with thoroughly dry or disinfected equipment.
- Staff should never become complacent and assume that aquatic invasive species are absent from waterways or all locations within a given watershed. Only properly-treated gear should be used during each survey if a risk of transporting aquatic invasive species to a new location is present.
- If possible, staff should purchase extra boots, nets, and other gear to ensure disinfected or dry equipment is available during the height of the field season. If a high percentage of field efforts are to be conducted in waters with aquatic invasive species or other potentially harmful organisms, staff should consider dedicating certain gear for use only in those waters. In situations when both infected and non-infected waters are to be sampled, then non-infected waters should be sampled prior to infected waters. If duplicate gear is not practical or is cost prohibitive, then all sampling gear should be properly treated prior to use, especially when both infected and non-infected waterways are scheduled for sampling. Do not sample infected water first.
- Staff should identify waters in their respective regions or areas of responsibility where aquatic invasive species or other potentially harmful organisms occur so that precautionary measures can be taken to prevent translocations of these organisms into non-infected waters.
- For water resource investigations where the status of potentially harmful organisms is unknown, sampling should start at the uppermost reach and then proceed in a downstream or down-lake direction. This will ensure that non-motile organisms are not transported on boots or other gear to uninfected upstream or remote lake locations.

Gear-Specific Disinfection Guidance

- Personal protective gear: Personal protective gear includes rain gear, gloves, boots, waders, wetsuits, and snorkeling gear. Remove all organic material from gear after exiting a waterbody. Spray personal protective gear with a 1% solution of Virkon Aquatic disinfectant and allow a minimum of two minutes contact time. The spray method is particularly useful when sampling multiple locations during the course of a day (e.g., discrete water-quality sampling). Alternately, gear can be immersed for a minimum of two minutes in a tub of 1% Virkon Aquatic. Rinse with clean water or water from the next waterbody. Personal gear may be steam cleaned or dried thoroughly for five days after cleaning with soap and water if visiting only one site as part of an isolated single-day field effort.
- Water-quality datasondes and water-quality sensors: After a datasonde is removed from deployment, it should be returned to a laboratory environment for servicing in accordance with SOP CWQ07 *Operation and Maintenance Site Visit*—Version 1.4. Sensors should be

removed from the datasonde as part of that maintenance, and sensors' ports should be sealed with port-specific plugs. At that time, the datasonde body can be sprayed with a 1% Virkon Aquatic solution for a minimum of two minutes contact time, then rinsed with distilled or tap water and allowed to dry. If a field meter or datasonde is used at multiple locations during the course of a field day, the sensor guard can be filled with chlorinated tap water between sites, and the datasonde body can be disinfected with Virkon as described above. Note that water-quality sensors, probes and sensitive electronic equipment can be damaged by disinfectants and should only be rinsed with tap water, then stored in appropriate sensor storage solutions.

- Dip nets, measuring boards, and other sampling gear—To disinfect small nets and other sampling gear, immerse them in a 1% solution of Virkon Aquatic disinfectant for a minimum of two minutes contact period. Rinse, hang to dry, or use immediately. Alternately provide a soaking spray of Virkon and allow two minutes contact time.
- Large sampling nets and other gear—Organic debris should be removed prior to disinfection. Power washing is effective but not required to remove debris. Nets may be sprayed with a garden hose if available to assist with debris removal. Nets may then be steam cleaned, washed, and dried thoroughly for five days or treated with a 1% solution of Virkon Aquatic for a minimum of two minutes contact time in the following manner.
 - Option One: The gear can be sprayed with Virkon disinfectant and a wet surface maintained for the appropriate contact time. The gear should be rinsed with clean water or water from the next waterbody before it is used again.
 - Option Two: Fill a tub with disinfectant and place all equipment in the tub for the appropriate contact time. The gear should be rinsed with clean water or water from the next waterbody before it is used again.
 - Option Three: Use a new set of gear for each waterbody sampled throughout the work day or work week. Disinfect all gear at the end of the survey day or week using option one or two.

Boats, Trailers, and Other Gear

When arriving at and departing from a waterbody, use the following procedures for boats, trailers, and all other gear that comes in contact with the water. Inspect and remove all visible aquatic plants, animals, mud, and other organic material from your boat, trailer, equipment, and gear at the sampling location. If you suspect a new occurrence of an invasive plant or animal, save a specimen for identification and report the sighting (specimen collection kits should be available on all surveys).

- When departing from a boat launch, drain all water from your boat, motor, live well, bilge, transom well, and all equipment and gear that came in contact with, or stored ambient water. This includes trailers, tubs, buckets, electrofishing droppers and cross supports, boots, hoses, pumps, and all other items that could serve as potential water holdings for aquatic species.

- Do not knowingly transfer any aquatic animals, plants or water from one waterbody to another.
- Dispose of unwanted aquatic plants and animals an appropriate distance away from any waterbody.
- Do not store dissolved oxygen probes or other water chemistry gear in lake water. Use chlorinated tap water to rinse probes, and empty all containers and samplers used during chemical or vertical profile assessments.

Disinfect boat trailers s after the boat is launched in waters where aquatic invasive species are known to exist. A garden sprayer with a 1% solution of Virkon Aquatic should be kept in the vehicle so the driver can treat the trailer bunks after the boat is deployed.

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ05

Equipment and Calibration—Version 1.4

Please cite this as:

Appalachian Highlands Network. 2018. Equipment and calibration—Version 1.4. Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—CWQ05. Appalachian Highlands Network, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) explains the steps involved in maintaining and calibrating Appalachian Highlands Network (APHN) equipment. Read this SOP prior to conducting field work. Detailed descriptions of methodologies required to operate continuous monitors in accordance with USGS criteria can be found in *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Record Computation, and Reporting* (Wagner et al. 2006). See SOP CWQ07 *Operation and Maintenance Site Visit—Version 1.4* for procedures for conducting operation and maintenance site visits in accordance with those procedures.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Appalachian Highlands Network Field Water-Quality Monitoring Equipment

Water-quality monitoring equipment available to the Appalachian Highlands Network includes the following instruments (including equipment that belongs to the network and to Big South Fork National River and Recreation Area and Obed Wild and Scenic River):

1. Eight (8) **YSI 6920-V2 multi-parameter water-quality datasondes** equipped with standard YSI 6560 temperature and conductivity sensors. Additional sensors routinely used by the network include YSI 6589 fast response amplified pH sensor, YSI 6150 ROX optical dissolved oxygen sensor, and YSI 6136 optical turbidity sensor. Standard and optical ports can optionally be equipped with a variety of alternate sensors. The 6920 datasondes are used for extended deployment in the field, either with United States Geological Survey (USGS) gages or at remote deployment locations. The YSI 6920 datasondes can also be used in tandem with Teledyne Isco (ISCO) automated water-quality samplers. The 6920 datasondes can communicate with the USGS gage interface [Data Collection Platform (DCP) and telemetry] via SDI-12 connection, with YSI 650 MDS display, or with a personal computer. The YSI 6920 datasondes can be externally powered or may be internally powered by AA batteries during stand-alone remote deployment and internal data logging. Calibration and data download from datasondes is facilitated with two (2) **YSI 650 Multiparameter Display System (MDS) data loggers** equipped with barometer and extended memory. Direct data download from datasondes is also available via personal computer interface.
2. One (1) **YSI 600XL multi-parameter datasonde**. An older, non-logging water-quality datasonde that is compatible with the YSI 650 MDS display. It was previously used by Big South Fork NRRRA and Obed WSR as a field meter during routine field investigations and water-resource monitoring. The 600XL is not currently in use, but can be placed into operation by replacement of the pH and dissolved oxygen sensors and by calibration of the existing specific conductance and temperature sensor.
3. One (1) **In-Situ Inc. Troll 9500 XPS** multi-parameter water-quality monitor/logging instrument and **Rugged Reader** data display and logging meter. The Troll 9500 is equipped with sensors for pH, specific conductance, temperature, dissolved oxygen (rapid pulse polarographic), and optical turbidity. Use the Troll 9500 as a stand-alone for extended remote deployment and in tandem with ISCO samplers.

Operation and Maintenance

Detailed descriptions of methodologies required to operate continuous monitors in accordance with USGS criteria can be found in *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Record Computation, and Reporting* (Wagner et al. 2006). Requirements for operation and maintenance of continuous monitors include:

1. Review equipment function daily on the internet. If fouling or calibration drift is apparent, conduct a site visit to resolve the issue.
2. At least monthly, perform routine maintenance in accordance with Wagner et al. (2006). The most efficient frequency of maintenance is difficult to predict. The environment into which monitoring equipment is deployed greatly influences the ability to maintain calibration and collect representative data. Changing seasons will require different maintenance schedules. The monitoring station may also be vulnerable to vandalism and weather events and may require maintenance and repair on an irregular schedule.
3. Datasonde calibration.
4. Complete and archive datasonde maintenance log field forms as part of the operation and maintenance schedule, fouling checks, and calibration.

Calibration of Multi-Parameter Water-Quality Monitors

Calibration Location

It is best to conduct datasonde calibration in a laboratory environment prior to deployment. Datasondes that serve as “field meters” during monthly operation and maintenance site visits (see SOP CWQ07) will be calibrated prior to the site visit. It is advantageous to have one to three spare datasondes calibrated so the “monitors” (deployed datasondes) can be rotated in and out of service. If monthly site visits do not indicate appreciable fouling or calibration drift of the deployed monitor, the monitor can remain deployed with calibration in the field as necessary. Note that turbidity sensors are particularly prone to calibration error in the field, primarily because of issues with minor contaminants that skew the zero point calibration. The YSI 6920 datasonde sensors are replaceable in the field, and it is acceptable to calibrate pH, dissolved oxygen, and specific conductance in the field. If field maintenance indicates turbidity calibration drift, it is advisable to replace the entire datasonde rather than install and field calibrate a turbidity sensor.

Calibration Order

Calibration of multi-parameter datasonde sensors should follow a consistent order. Because network park waters are generally of low ionic strength, conductivity calibration will typically use calibration standards of relatively low conductivity [447 microsiemens per centimeter ($\mu\text{S}/\text{cm}$)] that bracket the anticipated specific conductance of the sample. For this reason, calibrate specific conductance sensors first to avoid fouling of the conductivity sensor when high conductivity calibration standards are used for pH and turbidity calibrations. Where warranted in those limited situations where higher ionic strength waters are encountered, 1000 $\mu\text{S}/\text{cm}$ standards will be utilized. Perform the three-point calibration of dissolved oxygen as described in the “Dissolved Oxygen Calibration” section of this SOP last to allow for equilibration of the sensor with water-saturated air or air-saturated water.

In summary, calibrate multi-parameter instruments in the following order:

1. Specific conductance

2. pH
3. Turbidity
4. Dissolved oxygen

Further detailed instructions can be found in the YSI manuals for YSI 6 series datasondes (YSI Inc. 2010; YSI Inc. 2011; YSI Inc. Undated).

Specific Conductance Calibration

1. Air check: When the sensor is removed from an aqueous medium and exposed to atmospheric air, specific conductance should read 0.0. Note the inside of the conductivity cell may need to be dried with a chemwipe to get a true 0 reading.
2. Distilled water check: When the conductivity sensor is placed in distilled water, specific conductance should theoretically read 0.0 microsiemens per centimeter ($\mu\text{S}/\text{cm}$). If distilled water conductance varies by more than 5 $\mu\text{S}/\text{cm}$ from 0.0, the distilled water source should be evaluated or the sensor recalibrated.
3. Specific conductance calibration (single point):
 - a. Never calibrate with conductivity standards less than 100 ($\mu\text{S}/\text{cm}$). You are setting the slope on a linear device so a good strong conductivity signal will give you the best performance. Always calibrate with a conductivity standard that exceeds the anticipated values encountered during the period of deployment. In the majority of cases utilization of a 447 $\mu\text{S}/\text{cm}$ calibration standard will be acceptable for waters of the Cumberland Plateau. In limited instances, a conductivity standard of 1,000 $\mu\text{S}/\text{cm}$ should be utilized (e.g., Obed River at Adams Bridge and New River at New River stations) during low flow seasons, when ionic strength of waters is greater. Always conduct a post calibration check against a low calibration standard. **Note: Because of the linear slope on specific conductance curves, YSI recommends the use of 1,000 $\mu\text{S}/\text{cm}$ standard for all fresh waters.**
 - b. Pre-rinse the calibration cup and sensor two times with a small amount of distilled water and discard in the waste container.
 - c. Pre-rinse the calibration cup and sensor two times with the calibration standard and discard in the waste container.
 - d. Fill the calibration cup with a sufficient volume of the standard to ensure the conductivity sensor is completely submerged in the standard. The vent hole in the side of the sensor must be under the solution. It is important to avoid entrapment of bubbles in the cells. Gently shake the datasonde to help dislodge any air bubbles that may be trapped in the conductivity sensor.

- e. Enter the calibration menu for the meter/datasonde. Calibrate in accordance with the operating instructions for the individual meter.
- f. If a meter or datasonde reports “Out of Range” after the calibration, investigate the cause! Never override a calibration error message without knowing the reason. Typical causes for this error message are incorrect entries (entering 1,000 $\mu\text{s}/\text{cm}$ instead of 1.0 ms/cm), low solution level, air bubbles in the probes cell, calibrating in conductivity mode instead of specific conductance mode, and/or bad standard.
- g. With YSI datasondes, check the conductivity cell constant which can be located in the datasonde’s “Advanced Menu” under “Cal Constants.” The acceptable range for the 6560 probe is 5 ± 0.45 . Numbers outside of this range indicate a problem in the calibration process or with the standard that was used.
- h. Calibration frequency for specific conductance: Based on field experience, specific conductance sensors are very stable following calibration. Nevertheless, specific conductance should be checked for biofouling and then with a calibration standard during site visits at least monthly. Individual deployments may require more frequent calibration and maintenance.

pH Calibration

Calibrate the pH sensor at each field site. A minimum of two pH buffers that bracket the anticipated pH of the sample should be used to properly calibrate the pH sensor (use pH 7 buffer and either pH 4 or 10 buffer, depending on the anticipated sample pH). A third buffer can be used to check instrument system performance over a larger range, and three-point calibration is the preferred method under the APHN continuous monitoring protocol. The pH of the buffer solution is temperature dependent: pH 10 buffers change more per unit change in temperature than do pH 4 buffers. Note that all APHN sensors are automatic temperature compensated (ATC), negating the need for temperature correction factors. Calibration and operating procedures differ to some degree depending on the brand and model of the instrument. Check the manufacturer’s instructions in the operating manual. For further emphasis: **calibration of datasondes deployed under this continuous monitoring protocol will be based on three-point pH calibration.**

All pH monitoring equipment used by the network in the field and laboratory utilize ATC sensors. The ATC sensors have reliable auto-calibration functions and will automatically compensate for buffer temperatures and indicate Nernst slope. For these meters, **follow the manufacturer’s calibration instructions precisely—do not take shortcuts.**

1. Check the records of electrode performance before each calibration and field day. Optimum electrode response is between approximately 98 and 99.5% of the theoretical Nernst slope. A slope of 94% indicates possible electrode deterioration. **At 90% slope, the electrode cannot be used.**
2. Check the temperature sensor at least annually by comparing the readings against a NIST-traceable or NIST-certified glass thermometer side by side in the same sample. Record the

sensor ID and date of check in the pre-printed *USGS Water-Quality Meter Calibration and Maintenance Log* field book. Temperature certification needs to be done over a range of temperatures (ice water bath to maximum water body temperatures observed (~30 or more degrees °C). The water bath needs to be insulated to limit temperature gradients across the water bath with both sensors in close proximity. Several temperature sensors of datasondes can be checked simultaneously and compared. Temperature is a key parameter to have accurately measured because most sensors are now temperature compensated so temperature affects measurement accuracy of the other sensors. Do not rely on the ATC function of a pH meter if the temperature sensor has not been certified within the past 12 months.

3. Record calibration in the instrument log book and on field forms at the time of instrument calibration. Back up with internal logging on equipment with internal logging capability. Millivolt (mV) values for pH buffers should fall within the following range. If mV values do not fall within the indicated range, either the buffers or the sensor should be discarded.
 - a. Buffer 4.0 = $+180 \pm 50$ mV
 - b. Buffer 7.0 = 0 ± 50 mV
 - c. Buffer 10.0 = -180 ± 50 mV
4. Calibration frequency for pH: Water-quality datasondes should be maintained, spot checked for calibration drift at least once a month, and re-calibrated if necessary. Individual deployments may require more frequent maintenance.

pH Sensor Calibration Steps

Allow equilibration of sensors and buffers to field temperature. This is recommended even if using an automatic temperature compensating (ATC) meter. Bring the pH buffers, thermometer (if applicable), and electrode to the temperature of the sample. Allow 15 minutes for the buffers to adjust to the field sample temperature. To equilibrate to stream temperature, place the buffer bottles in a minnow bucket or mesh bag and suspend them in the stream.

1. Inspect the pH electrode.
 - a. Check for damage to the electrode bulb, body, or cables.
 - b. Rinse any precipitate off of the electrode with deionized water (the measurement can be affected if precipitate falls into the buffer or sample).
 - c. Rinse the sensor twice with distilled or deionized water.
 - d. Slide the protective sleeve up or down to uncover the filling hole (if applicable).
 - e. Gently shake or tap the electrode to dislodge and remove air bubbles trapped in the sensing tip of the electrode and to remove excess deionized water. Do not wipe the bulb of the sensor.

2. Perform three-point calibration (pH 7, 4, and 10).
 - a. pH 7.0 calibration: Note—Always initiate three-point calibrations with pH 7.0 buffer, then follow with either 4.0 or 10.0 in any order.
 - i. Rinse: Rinse sensor and calibration chamber twice with deionized water. Then, rinse the pH electrode and thermometer or automatic temperature compensating (ATC) sensor twice with pH 7.0 buffer. Discard the used pH buffer into a waste container.
 - ii. Calibrate: Pour fresh pH 7.0 buffer into the buffer-rinsed container that holds the electrode. Allow the instrument to equilibrate for one minute (if necessary). Swirl the sample gently or stir carefully with the electrode. If using a magnetic stirrer, stir slowly enough to avoid creation of a vortex. Calibrate to pH 7.0 in accordance with the manufacturer's operating instructions for the instrument. Discard the buffer into a waste container. The bulb of the pH electrode must not touch the bottom or side of the container. Add enough pH buffer solution to cover the reference junction.
 - iii. Record the temperature, the initial pH value, and the post-calibration pH and millivolt values in the dedicated calibration notebook specific to the instrument.
 - b. pH 10.0 calibration:
 - i. Rinse: Rinse twice between calibration standards with deionized water. Then rinse twice (with pH 10.0 buffer) the pH electrode and thermometer or automatic temperature compensating sensor. Also twice, rinse the calibration cup or another container large enough to hold the sensors and buffer. Discard the used pH buffer into a waste container.
 - ii. Calibrate: Pour fresh pH 10.0 buffer into the buffer-rinsed container that holds the electrode. Allow the instruments to equilibrate for one minute (if necessary). Swirl the sample gently or stir carefully with the electrode. If using a magnetic stirrer, stir slowly enough to avoid creation of a vortex. Calibrate to pH 10.0 in accordance with the manufacturer's operating instructions for the instrument. Discard the buffer into a waste container. The bulb of the pH electrode must not touch the bottom or side of the container. Add enough pH buffer solution to cover the reference junction.
 - iii. Record the temperature, the initial pH value, and the post-calibration pH and millivolt values in the dedicated calibration notebook specific to the instrument.
 - c. pH 4.0 calibration:

- i. Rinse: Rinse twice between calibration standards with deionized water. Then rinse the pH electrode and thermometer or automatic temperature-compensating sensor twice with pH 4.0 buffer. Also twice, rinse the calibration cup or another container large enough to hold the sensors and buffer. Discard the used pH buffer into a waste container.
- ii. Calibrate: Pour fresh pH 4.0 buffer into the buffer-rinsed container that holds the electrode. Allow the instruments to equilibrate for one minute (if necessary). Swirl the sample gently or stir carefully with the electrode. If using a magnetic stirrer, stir slowly enough to avoid creation of a vortex. Calibrate to pH 4.0 in accordance with the manufacturer's operating instructions for the instrument. Discard the used buffer into a waste container. The bulb of the pH electrode must not touch the bottom or side of the container. Add enough pH buffer solution to cover the reference junction.
- iii. Record the temperature, the initial pH value, and the post calibration pH and millivolt values in the dedicated calibration notebook specific to the instrument.

3. Slope Adjustment.

- a. Upon completion of three-point calibration, internal software in datasondes and field meters calculates the slope of the pH/millivolt relationship. Rinse the electrode and thermometer or ATC sensor thoroughly with deionized water.

Turbidity Calibration

Turbidity—the measurement of the content of suspended solids (cloudiness) in water—is typically determined by shining a light beam into the sample solution and then measuring the light that is scattered off the particles which are present. For turbidity systems capable of field deployment, the usual light source is a light emitting diode (LED) which produces radiation in the near infrared region of the spectrum. The detector is usually a photodiode of high sensitivity. The angle between the emitted and detected light varies (usually between 90 and 180 degrees) depending on the probe used. The International Organization for Standardization (ISO) recommends the use of a light source with a wavelength between 830 and 890 nanometers and an angle of 90 degrees between the emitted and detected radiation (ISO 1990).

Calibration Solutions

All APHN turbidity sensors must be calibrated using standard reference suspensions with reproducible light-scattering properties. The calibration of all YSI and InSitu turbidity sensors must be done with either YSI distributed standards, Hach StablCal, or commercially available polymer suspension standards that have been prepared according to the instructions in Section 2130B of the American Public Health Association's Standard Methods manual (APHA 2012). Formazin standards will be used by the network to calibrate turbidity sensors. The resulting calibration coefficients take into account the light-scattering properties of the suspensions and the sensor optics.

Note: For the YSI-prepared and AMCO-AEPA turbidity standards, the value entered during the calibration protocol is DIFFERENT depending on which YSI or InSitu turbidity sensor (6026 or 6136) is being calibrated. AMCO standards and their calibration values are presented by probe in Table SOP 5-1.

Table SOP 5-1. Formazin standards and calibration values for YSI and InSitu sensors.

Standard Value	YSI 6136 sensor	InSitu sensor
0.0	0.0	0.0
10.0	12.7	10.0
100	126	100
800	1000	800
1000	NA (out of range of sensor)	1000
2000	NA (out of range of sensor)	2000

Calibration of YSI 6920 Datasondes/6136 Turbidity Sensors

The turbidity system available as an option for use with YSI 6-series datasondes consists of a probe which conforms to the above ISO recommendations. The output of the datasonde turbidity sensor is processed via the datasonde software to provide readings in nephelometric turbidity units (NTUs). The Model 6136 turbidity sensor has been the only turbidity probe sold by YSI since 2002 and it is characterized by relatively large optics compared to previously used sensors. These larger optics result in deeper penetration of the light beam into the sample, requiring the use of a longer probe guard. This is a slight disadvantage. However, the larger optical cell volume of the sensor has two significant advantages: (1) there is less background noise associated with the turbidity readings and (2) the absolute values of the readings are significantly closer to those from typical laboratory turbidimeters (such as the Hach 2100AN) which use a large cell volume. If a 6136 sensor is selected in the “Sensor” menu of the datasonde, the turbidity will automatically be reported in the units “turbid+ NTU.”

The YSI datasonde software offers the option of one-point, two-point, or three-point calibration procedures for turbidity. For most applications, a two-point calibration at 0 and approximately 100 NTU is sufficient for the 6136 sensor. However, as standard operating procedure, the network will use three-point calibration with 0 NTU, 12.7 NTU, and 126 NTU for datasonde deployment within the Obed Wild and Scenic River system. Because the New River and other tributaries to the Big South Fork carry a heavy sediment load during runoff events, three-point calibrations within the Big South Fork watershed will use 0 NTU, 126 NTU and 1000 NTU standards to provide maximum accuracy over the entire normally encountered environmental turbidity range (0–1000 NTU). If the range of turbidity in the environmental sample is well known, standards of other turbidity values can be used (in either three-point or two-point routines). **However, in all calibration procedures, one of the standards must be 0 NTU, and this should be the first calibration point.**

Calibration of turbidity is preferably conducted in a laboratory environment to reduce the potential for error introduced by field conditions. It is preferable (but not always possible) to post-calibrate a datasonde back in the lab rather than to attempt the calibration of an optical probe in the field.

Preparation for Turbidity Calibration:

1. First, confirm that the turbidity probe is functioning properly. Confirm that the wiper parks correctly. It should be positioned at approximately 180° opposite the optics. The wiper must reverse direction during the wipe cycle. The output of the probe must increase when you place your finger in front of the optics. If the wiper does not park correctly or reverse direction, then make sure that the underside of the wiper is clean and free of mud, sediment, or other fouling. Replace the wiper or pad with a spare if needed. If the probe does not show an increase in output or the wiper does not park correctly, stop the calibration and determine the cause of the problem.
2. All turbidity calibration should be conducted with a clean laboratory dedicated sensor guard in place on the datasonde. Never use plastic or glass containers as calibration vessels for your calibration unless the sensor guard is installed on the datasonde. During calibration, submerge the turbidity sensor (with sensor guard in place) in the calibration and storage cup supplied with the datasonde to assure accurate calibration.
3. Always ensure that the submerged parts of the datasonde and wipers are clean before beginning any turbidity calibration. Remove any brush wipers and replace with a clean, standard wiper pad. Sediment or other contaminants will compromise the standard if not removed prior to calibration. Make especially sure the optics are clean—no fingerprints.
4. **Always start with the zero (0) NTU standard first!!!**

Three-Point Turbidity Calibration for YSI 6920 Datasondes/6136 Sensor

1. Rinse twice with 0.0 NTU calibration standard. Then, pour the 0 NTU calibration standard (distilled and filtered water) into the calibration cup. Pour down the side to avoid aeration of the sample. Secure the datasonde **with the sensor guard** in the calibration cup. Use the 650 MDS display/logger to navigate to the datasonde “calibrate” menu, select optical turbidity, then select “three-point calibration.” Enter 0 as the standard value. Verify there are no air bubbles on the probe face, run the wiper at least once, and wait until the end of the probe’s sampling period before accepting the first calibration point.
2. After accepting the 0 calibration point, the 650 MDS menu will prompt for the next value. Enter 12.7 at Obed WSR and 126 at Big South Fork NRRRA. Rinse the calibration cup and sensor twice with the appropriate standard and pour a sufficient volume of standard into the calibration cup to submerge the turbidity sensor. Again ensure that no bubbles are present, engage the wiper at least once, and calibrate as described above. Discard the used turbidity standard into a waste container.

3. After accepting the previous calibration point, the meter will again prompt for the next value (126 NTU at Obed WSR and 1000 at Big South Fork NRRRA). Rinse the calibration cup and sensor twice with distilled water, rinse the calibration cup and sensor twice with the appropriate turbidity standard, then fill the calibration cup with the final standard and complete calibration as before. Discard used turbidity standard into a waste container.
4. Exit the calibration menu by using the escape key on the 650 MDS.
5. Calibration frequency for YSI turbidity sensors: Datasondes should be calibrated before extended deployment in a laboratory environment and the calibration should be checked during routine maintenance and cleaning in accordance with the schedule described by Wagner et al. (2006). If datasondes are used as field meters during routine water resource investigations (instead of for extended deployment), turbidity sensors should be calibrated at the beginning of each field day in the lab.

Calibration of In-Situ Troll 9500 XPS Turbidity Sensor

Factory Calibration

The turbidity sensor has been factory-calibrated to achieve a sensor accuracy of $\pm 5\%$ or 2 NTU (whichever is greater). The sensor is calibrated over its full range, 0 to 2000 NTU, using polymer standards. The resulting calibration coefficients are written to the sensor memory where they are stored permanently. They may be overlaid by performing a field calibration, or they may be recalled from the sensor memory at any time.

The TROLL 9500's turbidity sensor is ready to measure turbidity without any user intervention. It is advisable to take a turbidity reading first in your own calibration solution(s) as a check to ensure the accuracy is within your operational standards and requirements. If this result is satisfactory, a field calibration is not required.

Field Calibration

Field calibration (or "user calibration") of the In Situ Troll 9500 is an overlay function that can be applied after the factory calibration is done. The factory calibration applies across the entire range of NTU and can be altered in the field with a one- to four- point calibration procedure (later in this section) to compensate for effects of sensor fouling and other factors. For best results, calibrate as close to field temperature as possible.

For most applications, a two-point calibration at 0 and approximately 100 NTU is sufficient for the sensor. However, as standard operating procedure, the network will use a three-point calibration with 0 NTU, 12.7 NTU, and 126 NTU for datasonde deployment within the Obed Wild and Scenic River system. Because the New River and other tributaries to the Big South Fork carry a heavy sediment load during runoff events, three-point calibrations within the Big South Fork watershed will use 0 NTU, 126 NTU and 1000 NTU standards to provide maximum accuracy over the entire normally encountered environmental turbidity range (0–1000 NTU). If the range of turbidity in the environmental sample is well known, standards of other turbidity values can be used (in either three-

point or two-point routines). **However, in all calibration procedures, one of the standards must be 0 NTU, and this should be the first calibration point.**

Calibration of turbidity should be conducted in a laboratory environment, prior to field use, to reduce the potential for error introduced by field conditions. It is preferable (but not always possible) to post-calibrate a water-quality sensor in the lab rather than to attempt the calibration of an optical probe in the field.

You will need:

1. In-Situ TROLL 9500 with turbidity sensor with wiper.
2. The sensor guard and removable sensors (if any) that will be installed when turbidity is measured.
3. The calibration cup supplied with the Troll 9500.
4. One or more calibration standards for the region in which you wish to calibrate. Several ranges from Very Low to Full are suggested in the Calibration Wizard.
5. An InSitu Rugged Reader handheld computer equipped with PocketSitu software, or a personal computer equipped with WinSitu software.

Procedure:

1. Connect the MP Troll 9500 to the Rugged Reader or personal computer and establish connection with PocketSitu or WinSitu software.
2. Rinse the MP TROLL 9500 sensor bank with clean water. Shake gently to remove the rinse water. Dry external surfaces (not the optical windows) with a clean tissue.
3. Rinse the sensor and calibration cup twice with initial calibration standard, then fill the calibration cup until the windows of the turbidity sensor are immersed at least a quarter of an inch deep in the solution. **Always start with the zero (0) NTU standard first!!!**
4. Gently agitate the instrument to dispel any air bubbles.
5. Using the software, select the MP Troll 9500 in the navigation tree. The installed sensors will be displayed—including the turbidity wiper, if installed in port P3. Click to select **Turbidity** in the **Parameters** list. The sensor serial number (S/N) and recent calibration information will be displayed. Select **Calibrate**.
6. The Turbidity Calibration Wizard will start. Select the type of calibration you wish, and select **Use Default Coefficients** to use factory defaults or enter the values with which you wish to calibrate

7. Select **Standard Calibration**, then select an operational range target. The ranges are suggestions only; a one- to four-point calibration may be performed in any range, using any standards. *Note:* If the software detects a turbidity wiper accessory, pressing the **Wipe** button will result in one complete wipe cycle of the turbidity sensor optics.
8. Select **Next** to continue, then select the number of calibration points for the calibration, and the turbidity value (in NTU) of the calibration solution for each point. One to four points (solutions) may be selected for any operational range target selected in the previous screen.
9. For a multi-point calibration, the value of the first solution will be displayed in the calibration wizard. When the sensor is situated in the calibration medium, select **Run** to begin the stabilization. The display will continuously update as readings are taken and compared against the stabilization criteria. Stabilization criteria for selected field parameters are provided in Table SOP 5-2.

Status indicators:

- a. **NOT TESTED** is displayed until you begin the calibration by selecting **Run**.
 - b. **UNSTABLE** indicates the sensor response does not meet the criteria for a valid calibration point.
 - c. **NOMINAL** indicates the sensor deviation meets early stabilization criteria.
 - d. **STABLE** is displayed when the readings have stabilized sufficiently to take a valid calibration point. The calibration proceeds automatically to the next screen. As a standard operating practice, APHN calibration of InSitu turbidity sensors will only be accepted when the **Stable** status is met for each turbidity standard throughout the range of multipoint calibrations.
10. The **Accept** button becomes available when nominal stability is achieved. The software allows you to accept the early value, but you should wait for complete stability. If you accept the early value, the calibration point will be designated “USER SET” in the calibration report. (For more on calibration reports, see “Calibration History” in Section 10 of the Troll 9500 Operations Manual [In-Situ Inc. 2009]) The **Sensor Reading** will display the current sensor response in NTU, the **Sensor Deviation** (the change in sensor response between the last two readings), and the **Temperature**.
 11. Discard the first solution into a waste container, rinse the beaker and the front end of the instrument thoroughly, wipe off excess water, refill the beaker with the second solution, and insert the MP TROLL 9500 as before.
 12. Select **Run** to begin the stabilization for the second calibration point. Status indicators and controls are the same as for the first calibration point (step 9).

13. Again wait for stabilization, dump, rinse twice with distilled water then the new standard, dry, refill, Run, as many times as necessary to collect a stable calibration point in each solution.
14. The final screen in the calibration wizard indicates the sensor slope and offset, as calculated during the calibration. A slope and offset will be shown for each calibration point. “Pivot” designates the point at which the slope characteristics change with a multi-point calibration. The correct slope for the turbidity values being monitored will automatically be applied.
15. Select **Finish** to program the sensor with the newly calculated calibration coefficients.

Table SOP 5-2. Stabilization criteria for recording standard direct field measurements (Wagner et al. 2006).

Field Measurement	Method or Threshold	Stabilization criteria
Temperature	Thermistor thermometer	$\pm 0.2^{\circ} \text{ C}$
	Liquid in glass thermometer	$\pm 0.5^{\circ} \text{ C}$
Conductivity	When $< 100 \mu\text{S/cm}$	$\pm 5\%$
	When $> 100 \mu\text{S/cm}$	$\pm 3\%$
pH	Meter displays to 0.01	± 0.1 unit
Dissolved Oxygen	Atmospheric method	$\pm 0.3 \text{ mg/L}$
Turbidity	Turbidimetric method, in NTU	$\pm 10\%$

Temperature Check

For most instruments, there is no calibration procedure for the temperature sensor. However, periodically check the temperature sensor to verify its accuracy. Perform an accuracy check at least once per year and log the results of the accuracy check in the field calibration logbook specific to each instrument. If the accuracy check date and information is not included with the instrument or the last check was over a year ago, check the temperature sensor accuracy at the beginning of the sampling event. If the instrument contains multiple temperature sensors, check each sensor in using this procedure:

1. Allow a container filled with water to equilibrate with room temperature.
2. Place a thermometer that is traceable to the National Institute of Standards and Technology (NIST) and the instrument’s temperature sensor into the water and wait for both temperature readings to stabilize. Both sensors should be in close proximity to each other.
3. Compare the two measurements. The instrument’s temperature sensor must agree with the NIST certified reference thermometer measurement within the accuracy of the sensor (usually $\pm 0.15^{\circ}\text{C}$). If the measurements do not agree, the instrument may not be working

properly and the manufacturer needs to be consulted. Check at low end of temperature range in an ice water bath and at the upper end (30°C) of anticipated ambient water temperature.

Dissolved Oxygen Calibration

Dissolved oxygen (DO) sensors are calibrated by using either water-saturated air or air-saturated water as the calibration medium. If **water-saturated air** is used as the calibration medium, make certain that both the DO reading and the temperature have stabilized before starting the calibration sequence by allowing a minimum of **15 minutes** exposure to the medium. If **air-saturated water** is used, assure that the water is truly saturated with oxygen by sparging the water at least **one hour** with an aquarium air pump and air stone. Regardless of the medium, calibrations can be made to either 100% saturation or by imputing a dissolved oxygen value in milligrams per liter (mg/L) that represents 100% saturation at the known temperature and barometric pressure indicated by field meters. The saturated DO value at different temperature and barometric pressure values can be obtained from published dissolved oxygen tables in the *Dissolved Oxygen Handbook* (YSI Inc. 2009), available at www.YSI.com/weknowDO. **To assure accurate calibration, turn the meter on at least 15 minutes prior to calibration.**

DO Calibration in Water-Saturated Air (100% Saturation)

1. Gently dry the temperature sensor according to manufacturer's instructions.
2. Place a wet sponge on the bottom of the calibration cup or other calibration container for meters that are not equipped with a calibration cup. **A recommended alternative to use of the calibration cup is use of the field sensor guard (YSI 556 and 6920 datasondes, and In Situ Troll 9500) wrapped in a wet towel** (See Figure SOP 5-1). Note the towel should be light colored or white and the calibration should be made inside or in a shaded area.

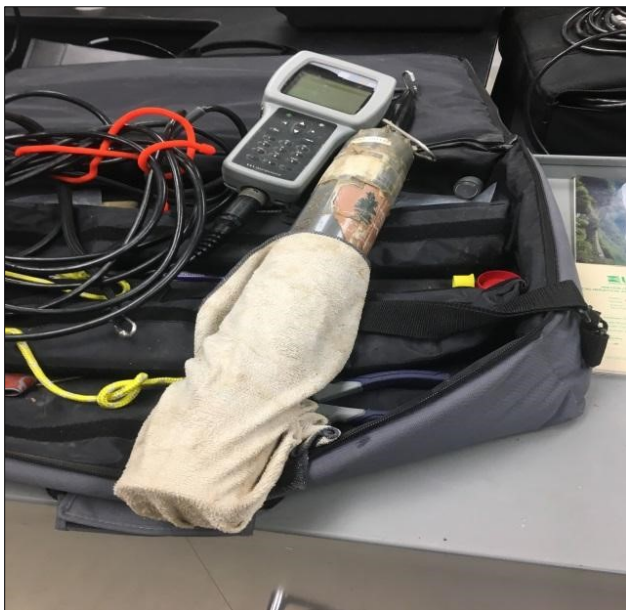


Figure SOP 5-1. YSI 6920 datasonde dissolved oxygen calibration.

3. Place the DO probe into the calibration cup or sensor guard without the probe coming in contact with the wet sponge or towel. Calibration cups should be loosely fitted to the datasonde or meter bulkhead to allow continued inflow of atmospheric oxygen. Refer to operation manuals for each instrument for details.
4. Allow the confined air to become saturated with water vapor (saturation occurs in approximately 10 to 15 minutes). During this time, turn on the instrument to allow the DO probe to warm up. Select monitoring/run mode. Check temperature readings. Readings must stabilize before continuing to the next step.
5. Select calibration mode, then select “DO %” (preferred option). You can also select DO mg/L if calibration is made by inputting values from DO tables.
6. Enter the local barometric pressure (usually in millimeters [mm] of mercury [Hg]) for the field sampling location into the meter. This measurement must be determined from an on-site barometer. Do not use barometric pressure obtained from the local weather service unless the pressure is corrected for the elevation of the sampling location. **The YSI 556 Multi-meter, YSI 650 MDS data display/data logger for the YSI 6920 datasondes, and the In Situ Troll 9500/Rugged Reader are equipped with barometers that automate input of barometric pressure.** Refer to the operating manuals for these instruments for a detailed description of the calibration sequence (*Note: inches of mercury times 25.4 mm per inch equals mm of mercury; or consult the “Oxygen Solubility at Indicated Pressure” chart [Appendix A in this SOP] for conversion at selected pressures*).
7. The instrument should indicate the calibration is in progress. The instrument will take approximately one minute to calibrate. After calibration, the instrument should display percent saturated DO.
8. Select monitoring/run mode. Compare the DO mg/L reading to the “Oxygen Solubility at Indicated Pressure” chart (Appendix A). The numbers should agree. If they do not agree to the accuracy of the instrument (usually ± 0.2 mg/L), repeat the calibration. If this does not work, change the membrane and electrolyte solution (for polarographic sensors) or use the “clean optics” option on the YSI 650 MDS for 6920 datasonde optical sensors.

DO Calibration in Air-Saturated Water (100% Saturation)

1. Fill the calibration chamber with water of sufficient depth to cover the oxygen sensor.
2. Activate the bubbler for a minimum of one hour (the longer the better). See Figure SOP 5.2.



Figure SOP 5-2. InSitu dissolved oxygen calibration chamber with aquarium pump and oxygen stone.

3. Turn on the meter to allow the sensor to warm up. Place the DO probe into the calibration chamber (See Figure SOP 5.2).
4. Allow a minimum of 15 minutes for temperature to stabilize. Check temperature readings. Readings must stabilize before continuing to the next step.
5. Select calibration mode; then select “DO %” (preferred option). You can also select DO mg/L if calibration is made by inputting values from DO tables.
6. Enter the local barometric pressure (usually in mm of mercury) for the field sampling location into the meter. **The YSI 556 Multi-meter, YSI 650 MDS data display/data logger for the YSI 6920 datasondes, and the InSitu Troll 9500/Rugged Reader are equipped with barometers that automate input of barometric pressure.** Refer to the operating manuals for these instruments for a detailed description of the calibration sequence. (*Note: inches of mercury times 25.4 mm per inch equals mm of mercury or consult the “Oxygen Solubility at Indicated Pressure” chart [Appendix A in this SOP] for conversion at selected pressures*).
7. The instrument should indicate the calibration is in progress. The instrument will take approximately one minute to calibrate. After calibration, the instrument should display percent saturated DO.
8. Select monitoring/run mode. Compare the DO mg/L reading to the “Oxygen Solubility at Indicated Pressure” chart (Attachment 1). The numbers should agree. If they do not agree to the accuracy of the instrument (usually ± 0.2 mg/L), repeat the calibration. If this does not work, change the membrane and electrolyte solution (for polarographic sensors) or use the “clean optics” option on the YSI 650 MDS for 6920 datasonde optical sensors.

Two-Point DO Calibration (100% Saturation and Zero Oxygen Solution)

Typically, one-point dissolved oxygen calibration as described above will be the standard operating procedure except as follows. To be consistent with USGS recommendations, the Appalachian Highlands Network will purchase commercially available zero oxygen solution and will check zero

calibration of sensors on an annual basis to assure that ROX optical DO sensors are accurate throughout the range that may be encountered in response to diurnal fluctuation. Two-point calibrations involve calibration to 100% saturation as described above and calibration to zero oxygen using commercially available zero oxygen solution. Note: YSI does not recommend the two-point calibration for ROX optical DO sensors unless: (a) you are certain that the sensor does not meet your accuracy requirements at low DO values; and (b) you are operating under conditions where you are certain that you can generate a medium truly free of oxygen or you can purchase a certified zero oxygen solution commercially.

1. Remove the probe from the container and place it into a 0.0 mg/L DO standard (see note above). The standard must be filled to the top of its container and the DO probe must fit tightly into the standard's container (no head space). Check temperature readings. They must stabilize before continuing.
2. Wait until the "mg/L DO" readings have stabilized. The instrument should read 0.0 mg/L or to the accuracy of the instrument (usually ± 0.2 mg/L). If the instrument cannot reach these values, it will be necessary to clean the probe, and change the membrane and electrolyte solution. If this does not work, prepare a new 0.0 mg/L DO standard. If these measures do not work, contact the manufacturer.
3. Flush the sensor with copious amounts of tap or distilled water to remove all zero-oxygen solution.
4. Calibrate to 100% saturation by either water-saturated air or air-saturated water methods as described for one-point calibration.
5. Record the temperature, initial DO value, and post-calibration DO (mg/L) and DO (% saturation) millivolt values in the calibration notebook specific to the instrument.
6. Calibration frequency: YSI recommends dissolved oxygen calibration of polarographic dissolved oxygen sensors once at the start of a field day. The meter may be powered off and on during the course of the day with no effect on the calibration. YSI optical sensors used for extended deployment are very stable over long periods of time. They should be calibrated before deployment and the calibration checked during routine operation and maintenance.

Field Instrument Calibration Records

Field-measurement data and other field information must be recorded on paper or electronically, while in the field (see SOP CWQ07 *Operation and Maintenance Site Visit—Version 1.4*, Figure SOP 7-1, and Figure SOP 7-2). Record field-measurement data, methods and equipment selected on USGS Continuous Monitor Field Forms (Wagner, et al. 2006) and in dedicated log books for each instrument (Figure SOP 5-3). Calibration information from field forms and logbooks should be converted to electronic format as described in SOP CWQ07. Field personnel must be familiar with the instructions provided by equipment manufacturers. This SOP either provides generic guidelines for equipment use and maintenance or focuses on a particular instrument or instruments that currently in use in the National Park Service. Various field instruments are available, and field

instruments are continuously updated or replaced as newer technologies become available. Field personnel are encouraged to contact equipment manufacturers for answers to technical questions. Hardcopy excerpts and links to full electronic copies of manufacturers' equipment manuals are also provided for specific equipment that is currently used by the Appalachian Highlands Network for field and laboratory measurements.

5

Date 4/6/15 Name ATG battery voltage _____

Calibration Location: BISO Lab

TEMPERATURE CHECK						Sensor ID:
Date of last 2 3 5 pt check:			Date of NIST/ASTM Certification:			
NIST/ASTM Traceable	Instrument	NIST/ASTM Traceable	Instrument	NIST/ASTM Traceable	Instrument	

SPECIFIC CONDUCTANCE						Sensor ID:
Standard Value	Lot #	Exp. Date	Standard Temp.	Initial Reading	Adjusted Reading	
1000			21.7	884	100	
100	10403	8/14	21.14	104	100	

DISSOLVED OXYGEN						Sensor ID:
Calibration Method: _____ Air Calibration Chamber in Water						
_____ Water-Saturated Air _____ Air-Saturated Water						
_____ Air Calibration Chamber in Air _____ Winkler						
Wiper replaced? Y N						
Barometric Pressure	Temperature	100% Saturation from Chart	Initial Reading	Adjusted Reading	Reading in Zero Sol'n	
725	20.01	8.45	8.60			
Barometer ID:		Date of last barometer check:		Charge:	Gain:	

pH CALIBRATION						Sensor ID:	
Buffer	Lot #	Exp. Date	Buffer Temp	Buffer corrected for Temp.	Initial pH	Adjusted pH	mV
7.00	C25432	—	21.7	—	6.0	7.0	-8
4.0	C25426	—	21.6	—	3.9	4.0	154
10.0	C03604	—	21.4	—	9.82	10.0	742
%							

Figure SOP 5-3. Pre-printed USGS Water-Quality Meter Calibration and Maintenance Log.

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Appendix A Oxygen Solubility Table

Table SOP5A-1a. Oxygen Solubility at Indicated Pressure (in mg/L, Porfert 2010) for barometric pressure between 730–760 mmHg (28.74–29.92 inHg) in fresh water.

°C	760/29.92	755/29.72	750/29.53	745/29.33	740/29.13	735/28.94	730/28.74
0	14.57	14.47	14.38	14.28	14.18	14.09	13.99
1	14.17	14.08	13.98	13.89	13.79	13.70	13.61
2	13.79	13.70	13.61	13.52	13.42	13.33	13.24
3	13.43	13.34	13.25	13.16	13.07	12.98	12.90
4	13.08	12.99	12.91	12.82	12.73	12.65	12.56
5	12.74	12.66	12.57	12.49	12.40	12.32	12.23
6	12.42	12.34	12.26	12.17	12.09	12.01	11.93
7	12.11	12.03	11.95	11.87	11.79	11.71	11.63
8	11.81	11.73	11.65	11.57	11.50	11.42	11.34
9	11.53	11.45	11.38	11.30	11.22	11.15	11.07
10	11.28	11.19	11.11	11.04	10.96	10.89	10.81
11	10.99	10.92	10.84	10.77	10.70	10.62	10.55
12	10.74	10.67	10.60	10.53	10.45	10.38	10.31
13	10.50	10.43	10.36	10.29	10.22	10.15	10.08
14	10.27	10.20	10.13	10.06	10.00	9.93	9.86
15	10.05	9.98	9.92	9.85	9.78	9.71	9.65
16	9.83	9.76	9.70	9.63	9.57	9.50	9.43
17	9.63	9.57	9.50	9.44	9.37	9.31	9.24
18	9.43	9.37	9.30	9.24	9.18	9.11	9.05
19	9.24	9.18	9.12	9.05	8.99	8.93	8.87
20	9.06	9.00	8.94	8.88	8.82	8.75	8.69
21	8.88	8.82	8.76	8.70	8.64	8.58	8.52
22	8.71	8.65	8.59	8.53	8.47	8.42	8.36
23	8.55	8.49	8.43	8.38	8.32	8.26	8.20
24	8.39	8.33	8.28	8.22	8.16	8.11	8.05
25	8.24	8.18	8.13	8.07	8.02	7.96	7.90

°C	760/29.92	755/29.72	750/29.53	745/29.33	740/29.13	735/28.94	730/28.74
26	8.09	8.03	7.98	7.92	7.87	7.81	7.76
27	7.95	7.90	7.84	7.79	7.73	7.68	7.62
28	7.81	7.76	7.70	7.65	7.60	7.54	7.49
29	7.68	7.63	7.57	7.52	7.47	7.42	7.36
30	7.55	7.50	7.45	7.39	7.34	7.29	7.24
31	7.42	7.37	7.32	7.27	7.22	7.16	7.11
32	7.30	7.25	7.20	7.15	7.10	7.05	7.00
33	7.08	7.13	7.08	7.03	6.98	6.93	6.83
34	7.07	7.02	6.97	6.92	6.87	6.82	6.78
35	6.95	6.90	6.85	6.80	6.76	6.71	6.66
36	6.84	6.79	6.76	6.70	6.65	6.60	6.55
37	6.73	6.68	6.64	6.59	6.54	6.49	6.45
38	6.63	6.58	6.54	6.49	6.44	6.40	6.35
39	6.52	6.47	6.43	6.38	6.35	6.29	6.24
40	6.42	6.37	6.33	6.28	6.24	6.19	6.15
41	6.32	6.27	6.23	6.18	6.14	6.09	6.05
42	6.22	6.18	6.13	6.09	6.04	6.00	5.95
43	6.13	6.09	6.04	6.00	5.95	5.91	5.87
44	6.03	5.99	5.94	5.90	5.86	5.81	5.77
45	5.94	5.90	5.85	5.81	5.77	5.72	5.68

Table SOP5A-1b. Oxygen Solubility at Indicated Pressure (Porfert 2010) for barometric pressure between 690–725 mmHg (27.17–28.54 in Hg).

°C	725/28.54	720/28.35	715/28.15	710/27.95	705/27.76	700/27.56	695/27.36	690/27.17
0	13.89	13.80	13.70	13.61	13.51	13.41	13.32	13.22
1	13.51	13.42	13.33	13.23	13.14	13.04	12.95	12.86
2	13.15	13.06	12.97	12.88	12.79	12.69	12.60	12.51
3	12.81	12.72	12.63	12.54	12.45	12.36	12.27	12.18
4	12.47	12.39	12.30	12.21	12.13	12.04	11.95	11.87
5	12.15	12.06	11.98	11.89	11.81	11.73	11.64	11.56
6	11.84	11.73	11.68	11.60	11.51	11.43	11.35	11.27
7	11.55	11.47	11.39	11.31	11.22	11.14	11.06	10.98
8	11.26	11.18	11.10	11.02	10.95	10.87	10.79	10.71
9	10.99	10.92	10.84	10.76	10.69	10.61	10.53	10.46
10	10.74	10.66	10.59	10.51	10.44	10.36	10.29	10.21
11	10.48	10.40	10.33	10.28	10.18	10.11	10.04	9.96
12	10.24	10.17	10.10	10.02	9.95	9.88	9.81	9.46
13	10.01	9.94	9.87	9.80	9.73	9.66	9.59	9.52
14	9.79	9.72	9.65	9.68	9.51	9.45	9.38	9.31
15	9.58	9.51	9.44	9.58	9.31	9.24	9.18	9.11
16	9.37	9.30	9.24	9.17	9.11	9.04	8.97	8.91
17	9.18	9.11	9.05	8.98	8.92	8.85	8.79	8.73
18	8.99	8.92	8.86	8.80	8.73	8.67	8.61	8.54
19	8.81	8.74	8.68	8.62	8.56	8.49	8.43	8.37
20	8.63	8.57	8.51	8.45	8.39	8.33	8.27	8.21
21	8.46	8.40	8.34	8.28	8.22	8.16	8.10	8.04
22	8.30	8.24	8.18	8.12	8.06	8.00	7.95	7.89
23	8.15	8.09	8.03	7.97	7.91	7.86	7.80	7.74
24	7.99	7.94	7.88	7.82	7.76	7.71	7.65	7.59
25	7.85	7.79	7.74	7.68	7.60	7.57	7.51	7.46
26	7.70	7.65	7.59	7.54	7.48	7.43	7.37	7.32
27	7.57	7.52	7.46	7.41	7.35	7.30	7.25	7.19

°C	725/28.54	720/28.35	715/28.15	710/27.95	705/27.76	700/27.56	695/27.36	690/27.17
28	7.44	7.38	7.33	7.28	7.22	7.17	7.12	7.06
29	7.31	7.26	7.21	7.15	7.10	7.05	7.00	6.94
30	7.19	7.14	7.08	7.03	6.98	6.93	6.88	6.82
31	7.06	7.01	6.96	6.91	6.86	6.81	6.76	6.70
32	6.95	6.90	6.85	6.80	6.70	6.70	6.64	6.59
33	6.83	6.78	6.73	6.68	6.83	6.58	6.53	6.48
34	6.73	6.68	6.63	6.58	6.53	6.48	6.43	6.38
35	6.61	6.56	6.51	6.47	6.42	6.37	6.36	6.27
36	6.51	6.46	6.41	6.36	6.31	6.27	6.22	6.17
37	6.40	6.35	6.31	6.26	6.21	6.16	6.12	6.07
38	6.30	6.26	6.21	6.16	6.12	6.07	6.02	5.98
39	6.26	6.15	6.11	6.06	6.01	5.97	5.92	5.87
40	6.10	6.06	6.01	5.96	5.92	5.86	5.83	5.78
41	6.00	5.96	5.91	5.87	5.82	5.78	5.73	5.69
42	5.91	5.86	5.82	5.77	5.73	5.69	5.64	5.60
43	5.82	5.78	5.73	5.69	5.65	5.60	5.56	5.51
44	5.72	5.68	5.64	5.59	5.55	5.51	5.46	5.42
45	5.64	5.59	5.55	5.51	5.47	5.42	5.38	5.34

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ06

Linking YSI 6920 Datasondes to USGS Gages—Version 1.4

Please cite this as:

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National Park Service, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) explains the steps involved in linking a YSI datasonde to a United States Geological Survey (USGS) gage. Read this SOP prior to implementing field work.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Scope

This SOP describes procedures used to link YSI 6920 water-quality monitoring datasondes with onsite data collection platforms (DCPs) at USGS streamflow monitoring gages. The SOP provides details of YSI 6920 setup using a YSI 650 MDS (Multiparameter Display System) handheld meter, SDI-12 communication interface between YSI datasondes and USGS Sutron® dataloggers/controllers, and communication with Sutron dataloggers via Sutron® Satlink Communicator software that can be installed on laptop or handheld computers. A description of ancillary hardware at USGS gages relevant to the datasonde/DCP interface is also provided.

USGS Gage Infrastructure

Typical USGS gage infrastructure consists of:

- Gage housing structures, which contain and protect the DCP, batteries and solar regulator, and constant flow bubbler system. These structures vary at gages where APHN continuous water-quality monitors are deployed and include historic USGS stilling towers, concrete block sheds, and pole-mounted utility toolboxes (see Figures SOP 6-1 to SOP 6-3).
- An external mast-mounted solar panel wired to a solar regulator and battery.
- A Sutron® or equivalent bubbler/pressure sensor system (see Figure SOP 6-4). This system draws in atmospheric air with suction, routes the air through a desiccant canister, and then forces the dry air into the water column via a bubbler line equipped with an orifice at its terminus. The bubbler line is housed within metal conduit (pipe) and affixed at a known depth to a boulder or other structure within the stream channel. The pressure required to force the air into the water column is proportional to the depth of water. Water depth, measured at 15-minute intervals, is used in conjunction with the rating curve for each station to derive stream discharge in cubic feet per second (cfs).
- A communications antenna connected to the DCP/transmitter. The antenna transmits logged data via the Satlink 2 interface from the datalogger (DCP) to an orbiting satellite (GOES [Geostationary Operational Environmental Satellite]; Figure SOP 6-5). These data are broadcast in near-real time to the internet.
- Additional deployment infrastructure (at USGS gauging stations equipped with NPS continuous water-quality (WQ) monitors). Continuous water-quality monitor infrastructure includes buried PVC conduit to house datasonde communication cables and slotted vertical PVC riser conduits with threaded caps to house the YSI 6920 datasondes. The risers and conduit are affixed and braced to suitable boulders or piers within or adjacent to the stream channel.



Figure SOP 6-1. USGS 03538830: Obed River at Adams Bridge gage housing.



Figure SOP 6-2. USGS 03409500: Clear Fork near Robbins stilling tower.



Figure SOP 6-3. USGS 03509600: Daddys Creek near Hebbertsburg tool box housing.

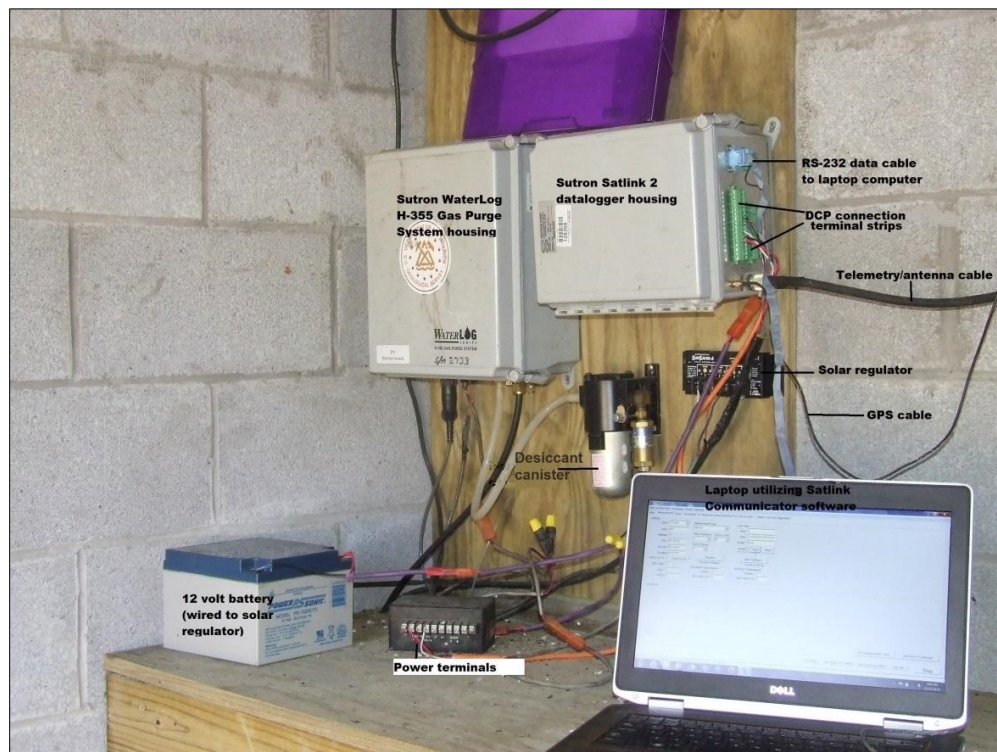


Figure SOP 6-4. Typical stage/discharge and continuous water quality (QW) monitoring hardware (USGS 03538830: Obed River at Adams Bridge).



Figure SOP 6-5. Open cabinet view of Sutron Waterlogger H-355 and Satlink 2 DCP.

YSI 6920 Datasonde Setup for Deployment at USGS Gages

The setup of YSI datasondes for deployment in tandem with USGS gages and dataloggers is relatively simple. Setup primarily involves selecting the parameters to be reported within the datasonde firmware using the YSI 650 MDS handheld meter. The handheld meter is also used for calibration in accordance with SOP CWQ05: *Equipment and Calibration—Version 1.4*. Because calibrations use additional parameters not reported by active continuous monitoring, the operator must change the report format in the YSI datasonde internal firmware prior to deployment. For example, pH is calibrated with both pH standard units and pH in millivolts, but only pH in standard units is reported at the QW stations.

Refer to the YSI User Manual for 6-Series Datasondes for detailed description of datasonde setup and deployment (YSI Incorporated 2011). To set up the datasonde for deployment, connect the datasonde to the YSI 650 MDS with a YSI field communication cable. Turn on the YSI 650 MDS handheld and scroll through the Main Menu, which includes the following options:

- Sonde Run
- Sonde Menu
- File
- Logging Setup
- System Setup

Use the keypad arrows to scroll down to the **System Setup** menu, then hit the return key (↵). First, scroll to the date/time format and choose any of the formats according to your preference. Note date and time will not be included in the report that is sent by the datasonde to the USGS datalogger. Instead, Satlink software records the time (see discussion below). Second, assure the **Power sonde** box is checked. Third, assure the baud rate to the datasonde is set at 9600 (the default). Use the escape key (twice) to return to the main menu.

At the main menu, use the keypad arrows to scroll to the **Sonde Menu** option. Using the arrow keys, scroll down to the **System** submenu. Choose **Date and Time** and set the date and time. Then escape back to the **System** submenu, scroll down to **SDI-12 address**, and manually set the address to “1” using the numeric keypad on the 650MDS. Hit escape once, then scroll to the **Report** submenu and hit the return key (↵) to choose the report setup. In the **Report** submenu, be careful to disable parameters such as date/time, pH mv, or ODOsat % that may have been activated during calibration. If extra parameters are included in the report, the Satlink software will send the data to the wrong parameter location (e.g., pH values reported as turbidity). **Only the following radio buttons should be highlighted** prior to datasonde deployment in the field at USGS gages. Toggle the individual choices on or off until the following parameters are reported:

- Temp °C
- SpCond µs/cm @ 25°C.
- pH
- Turbid+ NTU
- ODO mg/L

Connecting NPS YSI 6920 Continuous Monitors to the USGS DCP Interface

The communication interface between NPS YSI 6920 datasondes and the USGS DCP requires the following hardware:

- YSI 6920 datasonde with pH, specific conductance/temperature, optical turbidity, and ROX optical dissolved oxygen sensors installed. If desired, alternate sensors can be enabled in accordance with YSI 6920 operation requirements.
- YSI 6190-series field communication cables (varied lengths depending on site-specific deployment requirements).
- YSI 6096 flying lead adaptor (15-foot length). The flying lead is used to connect the 6190 field cable to the USGS data collection platform (DCP).
- USGS Sutron DCP (or equivalent) and associated gage infrastructure.

The YSI 6096 flying lead adaptor (Figure SOP 6-6) has nine separate wires for communication and powering of YSI 6920 datasondes. Only three of these are needed to connect the datasonde to the USGS DCP, as follows:

- Black (ground)
- Red (power)
- Purple (SDI-12 interface/data)



Figure SOP 6-6. YSI 6096 flying lead adaptor (connected directly to datasonde).

The flying lead wires identified above are connected to the Sutron Satlink 2 datalogger (DCP) via terminal strips at the back of the DCP housing (Figure SOP 6-7).

- Board A is used for both the USGS Waterlog Gas Purge System and the YSI datasonde SDI-12 and power interface. Both the USGS Waterlog and YSI 6920 systems connect to the DCP via SDI-12 communication. The three SDI-12 interface terminal strips on board A (with connected wires) can be unplugged and moved between DCP units, facilitating replacement operations in the event of DCP failure.
- The left set of SDI connections is SDI address # 0, which is wired to USGS Waterlog hardware.
- The middle set of SDI-12 connections (SDI-12 address # 1) is used to connect to YSI 6920 datasondes via the flying lead adapter. Connect the YSI 6096 flying lead to the DCP by wiring (from left to right on the connector strip): red to the **PWR** slot, black to the **GND** slot, and purple to the **DATA** slot.
- The third set of SDI-12 connections (empty SDI-12 address # 2 in Figure SOP 6-7) can be used to connect additional sensors, datasondes, or other SDI-12 compatible hardware.
- The event connection on board A can be used to connect a rain gage or other event monitoring hardware.



Figure SOP 6-7. Sutron datalogger showing connection boards on rear panel (red annotation added).

Satlink Communicator2® Software

After the internal firmware for YSI 6920 datasondes is configured and the datasonde communication cables are wired to the Sutron DCP as described above, the interface with the YSI datasonde must be configured. Use the Sutron Satlink Communicator2 software to complete this task. The QW station operator should download the software and the *Satlink2 Logger and Transmitter: Operations and Maintenance Manual* from the Sutron website at: <http://www.sutron.com/downloads.htm>. (Sutron Corporation 2009). Install the software to a laptop computer and save the operations manual to the laptop for field reference. It is useful to drag a shortcut for the Satlink2 software onto the desktop or other convenient location on the laptop.

Once the software is installed on the laptop, connect the computer to the RS-232 communication port on the Satlink2 DCP (Figure SOP 6-7) and click the Satlink Communicator shortcut icon (). The opening screen (Figure SOP 6-8) for the software will appear. Click on the **Connect to Satlink directly** radio button and click OK.

This will cause the program to search for a Satlink Logger on one of its communication ports. Once a Satlink has been found, the program will load that Satlink's setup to the visual interface, which provides a quick status summary (Figure SOP 6-9).

If Satlink was malfunctioning at either a USGS stage/discharge or NPS QW station, errors would be identified at this initial interface (Figure SOP 6-10).

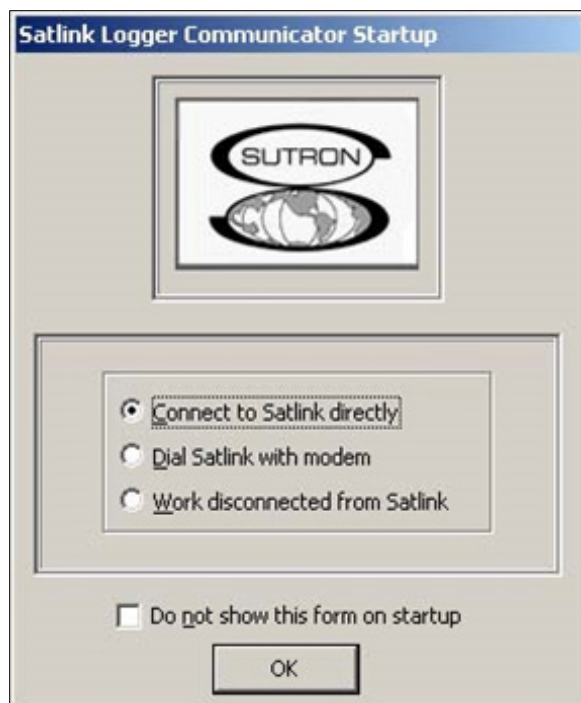


Figure SOP 6-8. Satlink2 startup screen.



Figure SOP 6-9. Satlink visual interface screen.



Figure SOP 6-10. Satlink interface indicating system malfunction.

Figures SOP 6-9 and SOP 6-10 indicate one and ten active measurements, respectively. Typically, a standard USGS stage and discharge gage will indicate two active measurements (gage height and battery voltage). The Appalachian Highlands Network continuous monitoring QW stations typically indicate seven active measurements on the summary screen visible after login (gage height, voltage, temperature, pH, conductance, dissolved oxygen, turbidity). Note the various options available in Figures SOP 6-9 and SOP 6-10: **Download log, Refresh, Graph, and Disconnect and Close. To begin setting up the QW station, choose Proceed to Setup.**

Proceed to Setup will navigate to the **Main Tab** of the Satlink Communicator Software (Figure SOP 6-11), which provides a system summary. Note the status of the GPS sync. A common cause of transmission failures is a malfunctioning GPS unit. If the GPS sync remains active for an extended period of time but does not successfully sync, transmissions to the orbiting GOES satellite will ultimately fail. Data will continue to be saved to the DCP, but webpages will not be updated. In these situations, USGS QA/QC systems will send an email notification to USGS and NPS staff to inform appropriate personnel of system issues, prompting a site visit to troubleshoot and repair the station. Daily review of data on webpages will also identify servicing needs. The GPS should be replaced to restore transmissions (typically by USGS technicians, though NPS occasionally provides assistance).

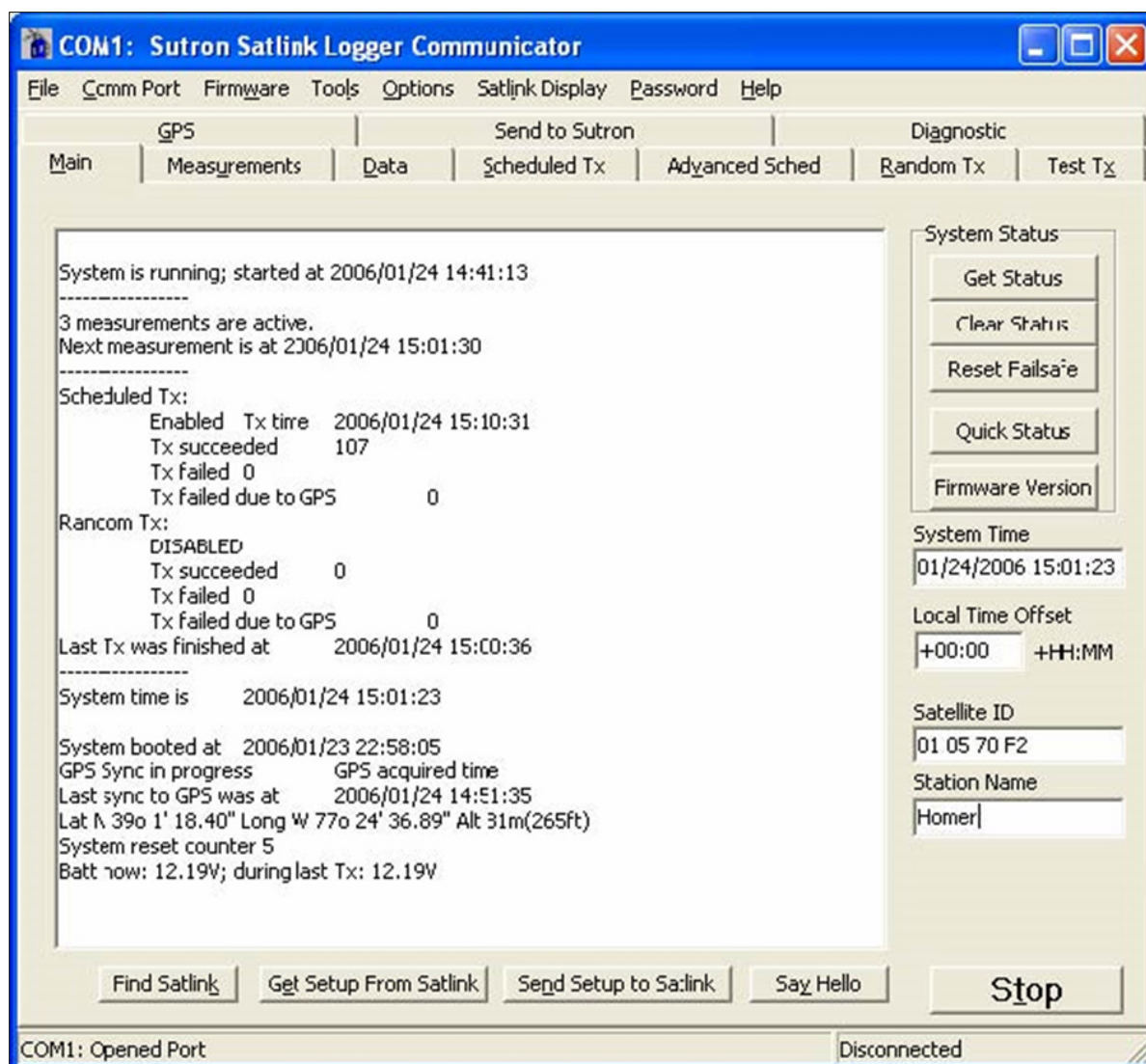


Figure SOP 6-11. Satlink Communicator Main Tab screen.

After reviewing the status of the system at the Main Tab, select the **Data** tab to review recent data collected by the system (Figure SOP 6-12). By default, Satlink navigates to the **Single** option of the **Show Measurements** box (Figure SOP 6-12). In the single measurement option, the HG (gauge height) measurement is identified by default at a USGS gage, and the most recent six hours of 15-minute-frequency gage height measurement values are displayed. To view the most recent six hours of data for a different (single) measurement, choose the parameter of interest by clicking the dropdown arrow in the *Index* box. To view all active measurements at one time, choose the Multiple option in the **Show Measurements** box; this will display the most-recent single measurement for all sensors (Figure SOP 6-13).

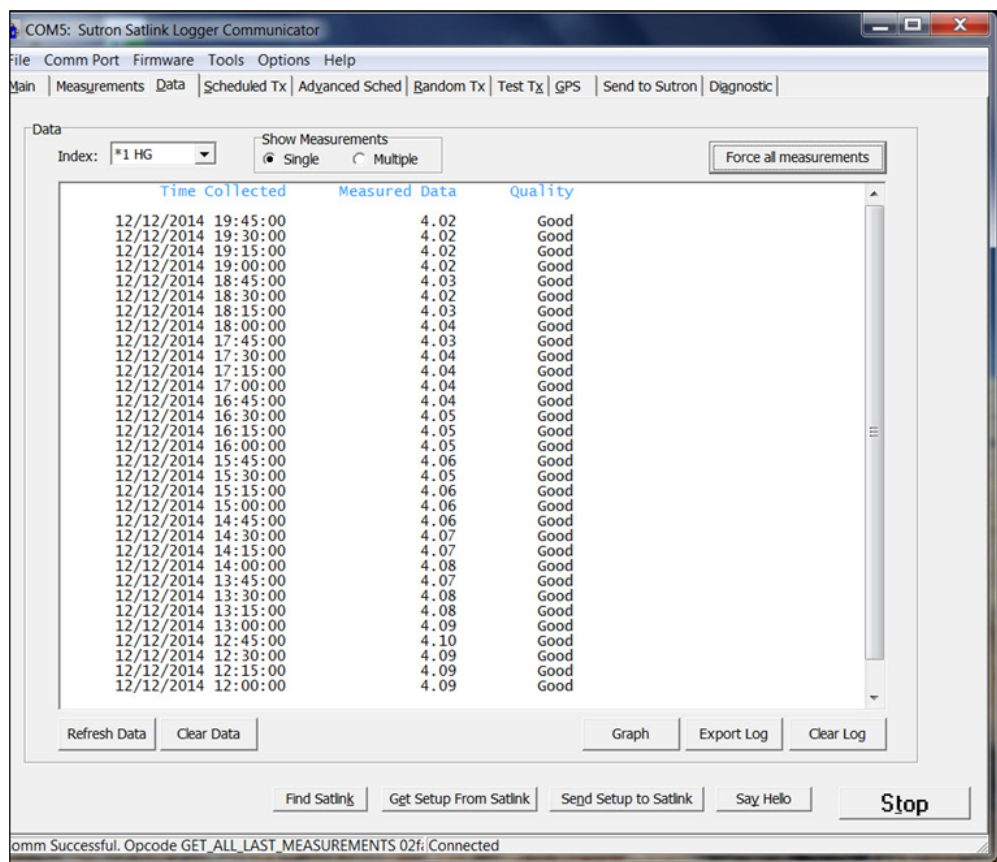


Figure SOP 6-12. Satlink Communicator Data Tab screen (single measurement choice for New River at New River).

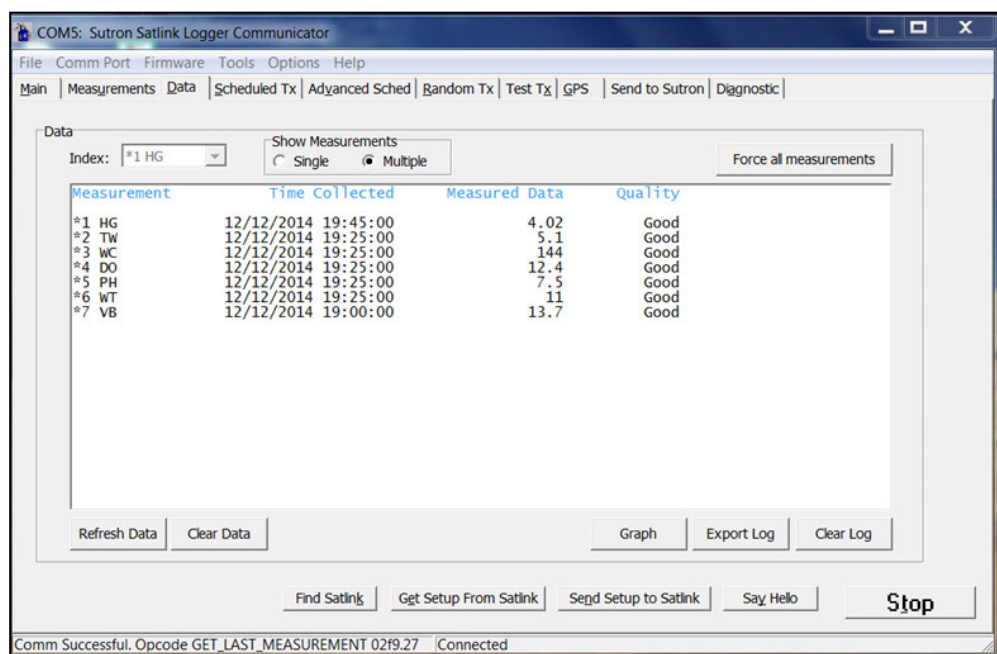


Figure SOP 6-13. Data Tab displaying multiple measurements option (New River at New River).

At established USGS gages, only USGS measurements transmitted via the zero (0) SDI-12 address will be displayed until the linking of the YSI 6920 datasonde at SDI-12 Address 1 is complete. To complete this linking, select the **Measurements** tab (Figure SOP 6-14). Once the flying lead is connected, the Satlink software will recognize the SDI-12 address (1) sensors. YSI 6920 sensors are indexed variably at individual stations but are labeled consistently as follows in NWIS:

- Sensor: (Temp °C)—NWIS Label **TW**
- Sensor: (SpCond µs/cm)—NWIS Label **WC**
- Sensor: pH—NWIS Label **PH**
- Sensor: Turbid+ NTU—NWIS Label **WT**
- Sensor: (ODO mg/L)—NWIS Label **DO**

Typically, the USGS gage height sensor will be indexed as *1HG. No adjustment of settings will be required for this sensor, but its setup can be reviewed as follows: In the index dropdown box in the left column of settings under the **Measurements Tab**, select [*1HG]. Observe in the left column of settings that the label is HG with two digits to the right. Note in the middle column that the sensor reports at SDI-12 Address 0 and is SDI-12 parameter number 1 for SDI-12 Address 0.

To set up YSI sensors and to index, label, and set SDI-12 parameter numbers for those sensors, input appropriate information as indicated in Tables SOP 6-1 to SOP 6-5 for the individual QW stations. Check the **Active** box and set **Sampling Interval** to [00:28:30]. This offsets the QW measurements slightly to assure that both NPS QW measurements and USGS gage height measurements fit into the transmission window. (This offset may have to be adjusted in the field during initial setup in concert with USGS). Set the number of digits to the right of the decimal to report in the **Right** digits box.) APHN reports turbidity and specific conductance with zero digits to the right; remaining parameters are reported with one digit to the right). Set **slope** to [1] and offset to [0].

In the middle column of settings, choose SDI-12 under the dropdown arrow in the **Measurement Type** box. Then choose the appropriate SDI-12 address as indicated below in the SDI-12 **address** dropdown box. Set SDI-12 **Cmd** to M! (for measure) for each water quality sensor. Select the appropriate SDI-12 **Param**: [number 1, 2, . . . n] using the dropdown arrow. Set **Num vals** to **transmit** at [4] in both scheduled and random transmissions. Repeat the above steps for each sensor, assigning the appropriate NWIS labeling nomenclature identified above.

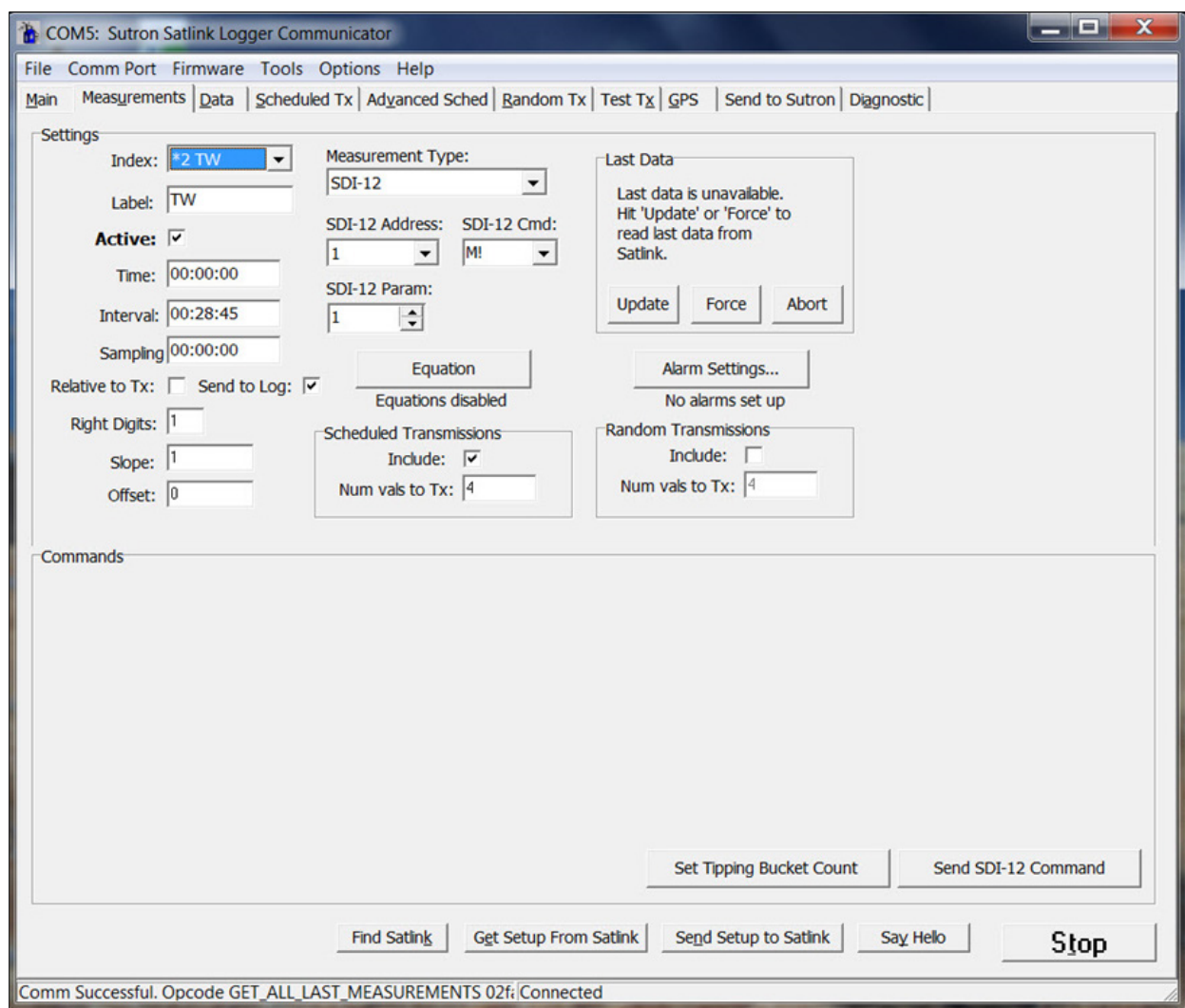


Figure SOP 6-14. Satlink Communicator Measurements Tab screen (03408500: New River at New River).

Table SOP 6-1. Station 03408500, New River at New River (7 measurements active).

Index	SDI-12 Address	SDI-12 Parameter #
*1HG	0	1
*2TW	1	1
*3WC	1	2
*4DO	1	5
*5PH	1	3
*6WT	1	4
*7VB	Satlink Batt Voltage	--

Table SOP 6-2. Station 03538830, Obed River at Adams Bridge (8 measurements active).

Index	SDI-12 Address	SDI-12 Parameter #
*1HG	0	1
*2TW	1	1
*3ORP1	1	4
*4WC	1	2
*5DO	1	6
*6PH	1	3
*7WT	1	5
*8VB	Satlink Batt Voltage	--

Table SOP 6-3. Station 03409500, Clear Fork near Robbins (8 measurements active).

Index	SDI-12 Address	SDI-12 Parameter #
*1HG	0	1
*2PC	Analog	TB Rain Gage
*3VB	Satlink Batt Voltage	--
*4TW	1	1
*5WC	1	2
*6PH	1	3
*7WT	1	4
*8DO	1	5

Table SOP 6-4. Station 03539600, Daddys Creek near Hebbertsburg (8 measurements active).

Index	SDI-12 Address	SDI-12 Parameter #
*1HG	0	1
*2TW	1	1
*3ORP1	1	4
*4WC	1	2
*5DO	1	6
*6PH	1	3
*7WT	1	5

Index	SDI-12 Address	SDI-12 Parameter #
*8VB	Satlink Batt Voltage	--

Table SOP 6-5. Station 03539778, Clear Creek at Lilly Bridge (7 measurements active).

Index	SDI-12 Address	SDI-12 Parameter #
*1HG	0	1
*2TW	1	1
*3WC	1	2
*4PH	1	3
*5WT	1	4
*6DO	1	5
*7VB	Satlink Batt Voltage	--

¹ Legacy place holder

Linking NPS QW Data to USGS NWIS Internet Webpages

At this point, YSI 6920 datasondes and sensors have been linked to USGS dataloggers, which transmit data via GOES to USGS NWIS servers. NPS data are now being stored in the NWIS system. To complete the real time link to internet webpages, contact USGS Information Technology personnel to configure the internet display (for the Appalachian Highland Network, these contacts are located at the USGS Lower Mississippi-Gulf Water Science Center).

The current USGS contact for the Appalachian Highlands Network is:

Rick Jenkins
U.S. Geological Survey
Lower Mississippi-Gulf Water Science Center
Suite 100, 640 Grassmere Park
Nashville TN 37211
Tel: (615) 837-4725
rjenkins@usgs.gov

Literature Cited

Sutron Corporation. 2009. Satlink 2 Logger and Transmitter Operations and Maintenance Manual. LOGGER AND TRANSMITTER OPERATIONS & MAINTENANCE MANUAL Standard. Revision 6.0.40. October, 2009.

YSI Incorporated. 2011. 6-Series multiparameter water quality datasondes user manual. Yellow Springs, Ohio, Revision H, 377 p.

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ07

Operation and Maintenance Site Visit—Version 1.4

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Appalachian Highlands Network, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) describes laboratory preparation, field methods, and records documentation associated with routine operation and maintenance (O&M) site visits for continuously deployed water-quality monitoring datasondes. The methodologies described herein follow United States Geological Survey (USGS) guidance found in Wagner et al. (2006).

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Scope

Definitions: In accordance with USGS nomenclature, a “field meter” is a laboratory-serviced and calibrated datasonde used during a site visit to evaluate the accuracy of data provided by the “monitor.” The “monitor” is the datasonde that has been deployed for an extended period at the continuous monitoring station.

Activities associated with continuous monitoring station operations and maintenance site visits include:

- Daily review of online water-quality data for each station.
- Laboratory calibration of field meters in accordance with SOP CWQ05: *Equipment and Calibration—Version 1.4*.
- Site visit to continuous monitoring stations, to clear fouling and evaluate calibration drift of individual sensors. If fouling or calibration drift of the deployed monitor exceeds acceptable limits (Table 7-1), the “monitor” datasonde will be replaced by the “field meter” datasonde during the site visit, becoming the new “monitor”. The previously deployed monitor is returned to a lab environment for servicing and recalibration. Conversely, if sensor calibration drift of the monitor falls within acceptable limits, the monitor can be cleaned and recalibrated in the field and will remain deployed. **Note: because of the need for precise 0.0 NTU calibrations, turbidity sensors should be calibrated in a laboratory environment.**
- Field calibration of monitor sensors, or replacement of a deployed monitor datasonde with the field meter datasonde.
- Entry of calibration drift and fouling data on the “USGS/APHN Continuous Water Quality Monitor Field Form” (Figures SOP 7-1 to SOP 7-4).
- Upon return to office, transfer USGS/APHN Continuous Water Quality Monitor Field Form data into USGS Continuous Hydrologic Instrumentation Monitoring Program (CHIMP) software on personal computer or handheld computer.

Frequency of Operation and Maintenance Site Visits to Continuous Monitoring Stations

The variable fouling rates of sensors, sensor type, and water quality and hydrologic characteristics of individual monitoring stations influence the frequency of site visits. Optical turbidity and dissolved oxygen sensors are most prone to fouling by debris and sediment accumulation, while pH sensors are more prone to biofouling and sensor drift. All of these sensors (pH, turbidity, dissolved oxygen) may exhibit calibration drift over extended periods of time. Specific conductance and temperature sensors are less prone to calibration drift and fouling error. To ensure accuracy in the monitoring record, visit continuous water-quality monitoring stations at least monthly for full maintenance and servicing of

instrumentation as described in this SOP. Monthly O&M site visits should ensure that subtle calibration drift and biofouling error are addressed expeditiously.

Frequent O&M site visits are needed to resolve issues such as debris fouling or instrument failure. A daily review of online water-quality data for each monitoring station by the protocol lead or other personnel can identify those issues. Conducting a daily review of online data, especially during runoff events when datasondes are subject to fouling, provides an opportunity for a quick response. Field personnel should mobilize to address operational concerns associated with fouling, sensor failure, or other issues. On these occasions, servicing of the continuous monitoring station may be limited to clearing of fouling, verification of sensor accuracy of the deployed monitor (with a field meter), and recording of activities on the USGS/APHN field form.

Lab Preparation and Equipment List for Datasonde Maintenance

1. Calibrate field meter datasonde(s) in accordance with SOP CWQ05.
2. Load field meter datasonde(s), communication cables, and two YSI 650 MDS handheld data loggers into the field vehicle.
3. Assemble the field kit with a supply of calibration standards for pH, specific conductance, and turbidity adequate to conduct field calibrations (if necessary) for all stations to be visited during the day. Include several liters of distilled water to rinse sensors during the calibration process. **Note: It is generally not recommended that turbidity sensors be calibrated in the field, and the network will generally not calibrate turbidity in the field in most cases. But, field calibration may be effective if care is taken to avoid errors in zero calibration (0.0 NTU), including special attention to cleaning of the sensor, wiper replacement, and use of a sensor guard dedicated to turbidity calibration (YSI 2010).**
4. Assemble a supply of calibration materials for field calibration (if necessary) of optical dissolved oxygen sensors. Supplies should include cloth rags to wrap the sensor guard, bungee cord or rubber bands to secure cloth rags to the sensor guard, spray bottles for distilled water rinse of sensor optics, replacement wipers, and dissolved oxygen saturation tables (hardcopy or electronic).
5. Assemble a supply of replacement sensors (pH, conductance/temperature, dissolved oxygen, and turbidity), sensor removal tools, sensor cleaning supplies (rags, Q-tips, 5-gallon rinse bucket, cleaning brushes), and replacement optical wipers and wiper installation hex wrenches for dissolved oxygen and turbidity sensors.
6. Pack a laptop or handheld computer equipped with Satlink Communicator software and RS232 communication cables. Pack a supply of field data forms (“USGS/APHN Continuous Water Quality Monitor Field Form”) and a handheld or laptop computer with USGS CHIMP software.

7. Pack a tool kit with a supply of screwdrivers, pipe wrenches, and channel lock wrenches for removal of threaded datasonde housing caps and sensor communication connections.
8. Schedule and follow trip planning procedures outlined in SOP CWQ01 *Safety—Version 1.4* and SOP CWQ02 *Job Hazard Analysis—Version 1.4*. Review field folder contents for each continuous monitoring station.

Field Maintenance Procedures at the Continuous Monitoring Station

Fouling Checks

1. Deploy the field meter at a location and depth immediately adjacent to the currently deployed monitor. Ideally, the field meter should be affixed to the outside of the vertical PVC deployment structure that houses the monitor datasonde. Allow the field meter to equilibrate with ambient water for a minimum of 15 minutes (longer if possible).
2. After equilibration, use the YSI 650 MDS handheld unit to initiate field meter measurements (first use the “clean optics” function to wipe dissolved oxygen and turbidity sensors). Wait for stabilization and then record both field meter and monitor readings on the “Monitor Fouling Checks” section of the USGS/APHN continuous monitoring field form (“Before Cleaning”). Obtain the monitor readings by first connecting a laptop to the USGS datalogger at the streamflow gage. Then use Satlink Communicator software to “force” all measurements (located within the “data” tab of the software) by choosing the “Show Measurements Multiple” and “Force All Measurements” options (use of the Satlink Communicator software is described in SOP CWQ06 *Linking YSI 6920 Datasondes to USGS Gages—Version 1.4*). Record time and other required information on the field form (Figure SOP 7-1). After recording field meter and monitor observations, leave the field meter deployed in the stream.
3. Remove the deployed monitor datasonde from the deployment housing and examine it for obvious fouling (including debris and mud). Record observation notes on the field sheet. Remove the sensor guard from the monitor and clear debris from the sensor guard by hand, to the extent possible. Agitate (swish) the sensor guard in a 5-gallon (18.9 liter) bucket filled with ambient water from the stream and use a coarse-bristled bottle or utility brush suitable to clean the 2.75-inch (or 6.9 centimeter diameter) datasonde sensor guard.
4. In a 5-gallon (18.9 liter) bucket filled with ambient stream water, agitate the datasonde (with the sensor guard removed) to remove the majority of debris or mud fouling the sensors. Avoid impacts between the datasonde and the sides of the bucket which could damage the sensors. Use microfiber cloths to gently clean the outside plastic housings for each sensor, being careful to avoid direct contact with pH sensor bulbs and optical windows for dissolved oxygen and turbidity sensors.

5. For the pH sensor, use the trigger spray bottle to spray distilled water onto the sensor bulb to clear as much biofilm as possible from the bulb.
6. Examine the optical dissolved oxygen and turbidity sensors to assure that wipers have remained operative since the last site visit (the optical windows should be clean). If unsure, force a measurement with the Satlink Communicator, and observe the operation and parking of sensor wipers. If wipers are in poor condition, replace them in the field in accordance with YSI procedures described in the YSI 6920 operator manual. Use the trigger spray bottle to direct a strong mist of distilled water onto the optical windows of each sensor.
7. For conductance/temperature sensors, use the squirt bottle or syringe to spray distilled water into the sensor ports. Use the YSI conductivity sensor cleaning brush for additional cleaning of sensor ports, then rinse the ports again with distilled water. Use the microfiber cloth to gently clean biofouling from temperature sensors on the combined conductance/temperature probe.
8. Replace the sensor guard on the monitor datasonde. Redeploy the monitor in the deployment housing structure. Allow 15 minutes (more if possible) for the datasonde to equilibrate with ambient water in the stream.
9. Record the field meter and monitor readings in the “Monitor Fouling Checks—After Cleaning” section of the USGS/APHN field form. When data are processed for analysis, they will be corrected to account for fouling and drift error. Data correction will only occur if fouling and drift corrections fall outside pre-defined criteria (Table SOP 7-1). The data correction process is more thoroughly discussed in SOP CWQ10 *Continuous Water Quality Record Processing—Version 1.4*.

Table SOP 7-1. Criteria for water-quality data corrections, modified from Wagner et al. 2006. [$\mu\text{S}/\text{cm}$ —microsiemens/centimeter; mg/L —milligrams per liter].

Parameter	Calibration / Data Correction Criteria ¹
Temperature	$\pm 0.2\text{ }^{\circ}\text{C}$ when checked with another meter $\pm 0.5\text{ }^{\circ}\text{C}$ when checked with NIST thermometer
Specific Conductance	$\pm 5\text{ }\mu\text{S}/\text{cm}$ or $\pm 3\%$ of the measured value, whichever is greater
Dissolved Oxygen	$\pm 0.3\text{ mg}/\text{L}$
pH	0.2 pH units

¹ Apply correction when the sum of the absolute values for fouling and calibration drift error exceeds the value listed.

Calibration Drift Checks

Following evaluation of fouling error, field personnel should conduct calibration checks for each of the sensors on the deployed monitor datasonde. Calibration checks should be completed in the

following order for specific conductance, pH, turbidity, and dissolved oxygen sensors, in accordance with procedures described in detail in SOP CWQ05.

1. Remove the monitor datasonde from the deployment housing. Disconnect the datasonde from the USGS data collection platform and connect it to a YSI 650 MDS handheld unit. Remove the YSI 6920 sensor guard and install the YSI 6920 calibration cup.
2. In accordance with methodologies in SOP CWQ05, evaluate the accuracy of the specific conductance sensor by comparing values with those of a known calibration standard (usually 447 $\mu\text{S}/\text{cm}$). If the error exceeds the calibration criteria (the greater of 5 microsiemens per centimeter [$\mu\text{S}/\text{cm}$] or 3% of measured value), recalibrate the sensor. Under the “Calibration Drift Check” section of the USGS field form, record “calibration check” and “recalibration” values, times, and any comments.
3. Record pH calibration check values for buffers 7, 4, and 10. If the error exceeds the calibration criteria (± 0.2 pH units), recalibrate the sensor in accordance with methodologies described in SOP CWQ05 and record values in pH and millivolts (mV) on the USGS field form, along with additional requested information. **Note: If millivolt values for individual buffers exceed the following criteria, either replace the sensor in the field (if the monitor will remain deployed) or deploy the field meter as the monitor at the end of the site visit.**
 - a. Buffer 4.0 = $+180 \pm 50$ mV
 - b. Buffer 7.0 = 0 ± 50 mV
 - c. Buffer 10.0 = -180 ± 50 mV
4. Conduct three-point calibration check in the field and record “calibration check” information on the USGS field form. The YSI 6136 optical turbidity sensor typically remains stable and accurate throughout long deployments but is prone to fouling. Because precise zero (0.0 NTU) calibration is difficult in the field, it is recommended turbidity calibration be conducted in a laboratory environment. If it is necessary to calibrate turbidity in the field, follow procedures described in detail in SOP CWQ05 to conduct a three-point calibration that brackets the anticipated values encountered during deployments. Record calibration data on the USGS field form. The New River at New River continuous monitoring station should be calibrated with 0.0 NTU, 126 NTU, and 1000 NTU calibration standards. All remaining continuous monitoring deployments should use 0.0 NTU, 12.7 NTU, and 126 NTU standards. Follow detailed procedures described in SOP CWQ05, including use of a clean sensor guard dedicated to turbidity calibration.
5. The YSI ROX optical dissolved oxygen sensor typically remains stable and accurate throughout long deployments. If the field meter/deployed monitor comparisons indicate unacceptable error (> 0.3 milligrams per liter [mg/L]), recalibrate the sensor. To calibrate, secure a white wet cloth or towel around the sensor guard, place the datasonde in a shaded area, and wait a minimum of 15 minutes. Then calibrate in accordance with SOP CWQ05 by

entering the calibration menu of the YSI 650 MDS and choosing “one point” calibration and “saturation.” Accept the barometric pressure reading indicated by the 650 MDS barometer and press “calibrate” and “continue.” Compare the dissolved oxygen reading to theoretical oxygen saturation at the indicated temperature and barometric pressure on the dissolved oxygen table (SOP CWQ05, Appendix A). Record “calibration check” and “recalibration,” and other required information on the USGS/APHN field form.

Final Field Meter and Monitor Readings

After recalibrating the monitor, it can either be redeployed in the station deployment infrastructure (PVC housing) or replaced by the field meter, which is deployed as the monitor. Base the decision on the condition of the previously-deployed monitor and whether recalibration meets acceptable standards of accuracy. It is advisable to replace monitors every two months to allow thorough servicing of datasondes in a laboratory environment. Before replacing, the field technician should record the final field meter and monitor readings in the USGS/APHN field form “Final Readings” section at the bottom of page 1–2.

Cross-Section Survey

The data objectives for continuous water-quality monitoring stream sites require placing the sensors at locations representative of average measurements in the stream cross sections. Prior to selection of a final deployment location at each monitoring site, conduct cross-section surveys of field parameters to ensure deployment locations are representative of the entire (well-mixed) waterbody rather than of an anomalous condition. Where possible, choose a monitoring site characterized by well-mixed streamflow in order to eliminate the necessity for correction of the water-quality record to account for heterogeneous water-quality conditions across the section. Specific conductance and turbidity are the most critical parameters evaluated during cross-section surveys because they are most susceptible to large variations in unmixed waters (Wagner et al. 2006).

A sufficient number of cross-section surveys representing different flow conditions is required to determine if discharge or seasonal changes significantly affect mixing in the cross section for the field measurement(s) being monitored. Prior to initial deployment of continuous monitors, a minimum of two cross-section surveys per year is required to verify or revise results from previous surveys. Cross-section surveys of the parameters being monitored are conducted both at base flow and during a runoff event near the maximum safe wading stage, and the results are compared with those at the deployment location. At locations with high stream velocities or depth, it may be necessary to attach the datasonde to a sounding weight/B-reel assembly and sample the cross-section from a bridge utilizing a bridge board or bridge crane. Temporal changes in cross-section variability, if indicated at individual stations, may require surveying more frequently. Following deployment, documentation of cross-section mixing is required at least once per year at a minimum.

The most effective means of obtaining cross-section surveys is with a calibrated datasonde that can measure the identical field parameters being recorded by the monitor. The APHN procedure for selecting measurement points for making a cross-section survey and calculating a cross-section mean value is to divide the stream cross section into increments using the equal width increment (EWI) method. These multiple measurements also establish the horizontal cross-section variability of a

measured field parameter. Make mid-depth measurements at the midpoint of equal-width increments to determine an area-weighted mean value. A minimum of 10 and a maximum of 20 equal-width increments across a large stream or river are needed to establish the area-weighted mean value and horizontal cross-sectional variability of a field parameter. Examples of both area- and discharge-weighted cross-section average calculations are given in Wilde and Radtke (2005). Repeat cross-section analyses annually to verify deployment locations continue to be representative of site conditions.

Cross-section Survey Methods Using In Situ EWI Field Measurements

In situ measurements made by immersing a field-measurement sensor directly in the waterbody are used to determine a profile of variability across a stream section. Measurements made directly (in situ) in the surface-waterbody are preferable in order to avoid changes that result from removing a water sample from its source. Follow the steps below to quantify the cross-section mixing at the deployment location.

1. Test, calibrate, and check field instruments.
2. Divide cross section into minimum of 10 and no more than 20 equal width increments. At each increment:
 - a. Locate the mid-point of the increment.
 - b. Lower sensors to mid-depth of the vertical.
3. Allow minimum of one minute for readings to stabilize. Then record field measurements on USGS Continuous Water-Quality Monitor Field Form for each vertical.
4. Calculate area weighted cross-section value for each parameter. Table SOP 7-2 provides an example of field notes and area weighted cross-section calculation for specific conductance.

Table SOP 7-2. Example of field notes and calculations for an area-weighted conductivity determination by in situ EWI measurements.

Increment # C1	Vertical Location - C2 (ft. from LEW)	Width of section – C3 (ft)	Depth of vertical – C4 (ft)	Area of section – C5 (ft ²)	Conductance - C6 (µs/cm)	C5 * C6
LEW	0	---	---	---	---	---
1	2	4	1.0	4.0	145	580
2	6	4	2.0	8.0	146	1,168
3	10	4	2.6	10.4	148	1,539
4	14	4	3.2	12.8	148	1,894
5	18	4	3.5	14.0	149	2,086
6	22	4	4.0	16.0	149	2,384
7	26	4	4.2	16.8	148	2,486
8	30	4	4.4	17.6	148	2,605
9	34	4	4.0	16.0	148	2,368
10	38	4	3.7	14.8	149	2,205
11	42	4	4.1	16.4	149	2,444
12	46	4	4.6	18.4	148	2,723
13	50	4	3.5	14.0	148	2,072
14	54	4	1.4	5.6	148	829
15	58	4	1.0	4.0	148	592
REW	60	---	---	---	---	---
Σ	--	--	--	188.8	--	27,976

Calculation of weighted conductance: sum of values in last column (27,976) divided by total sum of area (C5) (188.8) = 148.

Cross-section Data Variability Criteria

If the difference between discharge-weighted values of measured field parameters and the measured values at the sonde locations exceeds the data-correction criteria (Table SOP 7-1), the deployment location may not be representative of the waterbody. If this occurs, relocate the measurement point to a more representative location in the cross section. Consider moving the monitor to a better site if a representative measuring point cannot be found. Location of the monitoring site, however, may be required for regulatory reasons, cooperator's objectives, or other data-quality objectives. Another option to consider before applying cross-section corrections is downgrading the rating of accuracy for a monitoring record. If cross-section data show the site is not representative of particular flows or seasons, these portions of the record

could be downgraded in ratings of accuracy. Professional judgment and observations in the field logs will aid in evaluating the need for the application of cross-section corrections. Document the analysis and statistical summaries of cross-section variability in the annual station analysis.

Disposition of Field Maintenance Records

At the end of the site visit, pages 1–4 of the USGS/APHN field form should be complete. The form should be reviewed for accuracy, scanned, and archived as described in SOP CWQ09 *Data Management—Version 1.3*. Information from the field form will be input into the USGS CHIMP software on laptop or handheld computers. Use that program to edit the water-quality record in the USGS NWIS system as described in SOP CWQ10.

Sample Field Form from Datasonde Fouling Check

USGS/APHN CONTINUOUS WATER QUALITY MONITOR FIELD FORM

Station No. 03539778

Station No. 03539778 Station Name Clear Cr @ Cal. Bridge
 Monitor Inspected By ADH Date 10/2/13 Watch Time 1045 Time Datum _____
 Gage Ht 3.88 (Rising, Falling, Steady, Peak) Channel Conditions Clear/light algae
 Monitor Make/Model YSI 6920 Monitor Serial No. 161 102596
 Field Meter Make/Model YSI 6920 Field Meter Serial No. 118 102209
 Weather Cold ☒ Warm Hot Rain Mist Sleet Snow Humid Dry Cloudy ☒ Pt Cloudy Overcast Clear Windy Gusty Breeze Calm
 Comments:

MONITOR FOULING CHECKS

Parameter	Before Cleaning		After Cleaning	
	Recorded/ Live Value	Field Meter	Recorded/ Live Value	Field Meter
Temp (°C)	13.5	13.48	13.5	13.5
pH (units)	7.3	7.15	7.2	7.1
DO (mg/L)	8.5	8.2	8.6	8.4
SC (µS/cm)	91	87	90	87
Turbidity (☒ FNU ☐ FNMU ☐ FBU) Method code _____	-0.3	-0.12	-0.1	-0.3
Other _____				

CALIBRATION DRIFT CHECKS

TEMPERATURE	Calibration Check	Recalibration
Calibration Criteria: ± 1 percent or ± 0.5 °C for liquid-filled thermometers; ± 0.2 °C for thermistors	Time <u>1030</u>	Time _____

Comments:

SPECIFIC CONDUCTANCE
 Calibration Crite ia: the greater of 5 µS/cm or 3% of measured value

				Calibration Check			Recalibration		
				Time <u>1050</u>			Time <u>1057</u>		
STD VALUE	STD LOT NO.	STD TYPE KCl; NaCl	EXP. DATE	STD TEMP	SC READING	Error %	STD TEMP	SC READING	Error %
100	1041e3	KCL	7/2014		97	3%		100	0
Cell range =	Reading in air = (should be zero)								

Comments: Recalibrate (at truck), cleaned sensor ports w/ brush & DW

Monitor form ver. 3.0

Figure SOP 7-1. USGS/APHN continuous water-quality monitoring field form, page 1 of 4.

DISSOLVED OXYGEN				Calibration Check				Recalibration					
Calibration Criteria: ± 0.3 mg/L				Time <u>1105</u>				Time _____					
TEMP °C	BARO PRES mm Hg	DO TABLE READING mg/L	SALINITY CORR. FACTOR	DO READING	ERROR %	Reading in zero DO sol'n	TEMP °C	BARO PRES mm Hg	DO TABLE READING mg/L	SALINITY CORR. FACTOR	DO READING	ERROR %	Reading in zero DO sol'n
SALINITY:		SALINITY CORRECTION APPLIED? <u>Y</u> <u>N</u>		DO CHARGE:			DO GAIN:		Date Barometer Calibrated:				
COMMENTS: <u>DID NOT RECALIBRATE; replaced wiper, compared well w/ Field meter</u>													

pH				Calibration Check			Recalibration				
Calibration Criteria: ± 0.2 pH units				Time _____			Time _____				
pH BUFFER	THEO- RETICAL pH FROM TABLE	BUFFER LOT NO.	BUFFER EXP DATE	TEMP	pH READ- ING	ERROR %	TEMP	pH READ- ING	ERROR %	SLOPE	MILLI- VOLTS
pH 7		<u>C256321</u>			<u>7.1</u>						
pH <u>4</u>		<u>C25426</u>			<u>4.15</u>						
pH <u>10</u>		<u>C035689</u>			<u>9.9</u>						
Comments: <u>DID NOT RECALIBRATE; cleaned bulb w/ DIW spray</u>											

TURBIDITY			Calibration Check			Recalibration		
Calibration Criteria: ± 0.5 Turbidity Units or $\pm 5\%$			Time _____			Time _____		
	Lot no. or Date Prepared	CONC	TEMP °C	READING	ERROR %	TEMP °C	READING	ERROR %
Stock Turbidity Standard								
Zero Standard (DIW)	<u>DIW</u>	<u>0.0</u>		<u>1.0</u>	<u>—</u>		<u>0</u>	
Standard 1	<u>C282799</u>	<u>12.7</u>		<u>14.6</u>	<u>10.4</u>		<u>12.7</u>	
Standard 2	<u>C302395</u>	<u>126</u>		<u>119</u>	<u>5.5</u>		<u>12.6</u>	<u>0</u>
Standard 3								
Turbidity Sensor Limit: <u>1000 FNU</u>		Comments: <u>Replaced wiper RECALIBRATE @ check w/ clean sensor gear</u>						

FINAL READINGS						Time _____	
Parameter	Recorded/ Live Value	Field Meter	Parameter	Recorded/ Live Value	Field Meter		
Temp (°C)	<u>13.6</u>	<u>13.55</u>	Turbidity (<u>FNU</u> FNMU FBU)				
pH (units)	<u>7.3</u>	<u>7.15</u>	METHOD CODE <u>00</u>	<u>0.0</u>	<u>-0.3</u>		
DO (mg/L)	<u>8.4</u>	<u>8.4</u>	Other _____				
SC (µS/cm)	<u>91</u>	<u>89</u>					

Figure SOP 7-2. USGS/APHN continuous water-quality monitoring field form, page 2 of 4.

Station No. _____

CROSS-SECTION SURVEY INFORMATION

Method ☐ EVM ☐ EDI ☐ Other _____ No. of Verticals _____

Measurement Location: _____ ft upstream downstream of monitor

Stream Mixing: ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments _____

Station	Time	Ft from left bank (00009) or ft from right bank (72103)	Depth to bottom at meas. loc. ft (81903)	Measurement depth ft (00003)	Temp °C (00010)	pH units (00400)	SC µS/cm (00095)	DO mg/L (00300)	Turbidity () ()	Other () ()	NWIS Record No.
Gage ht =											
At monitor											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
At monitor											
Gage ht =											

CROSS-SECTION COMPARISON AT _____ CFS

Parameter	Cross-section median	Point value	Indicated coefficient
Water Temp	°C	°C	
pH	units	units	
SC	µS/cm	µS/cm	
DO	mg/L	mg/L	
Turbidity			
Other _____			

Figure SOP 7-3. USGS/APHN continuous water-quality monitoring field form, page 3 of 4.

Station No. _____

MAINTENANCE RECORD FOR CONTINUOUS MONITOR

Correction factors applied to field meter readings? YES ☒ NO

Battery changed? YES ☒ NO Voltage _____ volts

Sensors cleaned? ☒ YES NO Type of fouling light biofilm on pH & sk/tem

Calibration check: ☒ WT ☒ SC ☒ pH ☒ DO ☒ TURB Recalibrated: ☒ WT ☒ SC ☒ pH ☒ DO ☒ TURB optical check

Sensor changed? SC YES ☒ NO Sensor ID _____

pH YES ☒ NO Sensor ID _____

DO YES ☒ NO Sensor ID _____

Turbidity YES ☒ NO Sensor ID _____

Sonde Changed? YES ☒ NO New Sonde No. _____ Old Sonde No. _____

DO Membrane changed? YES ☒ NO Date Changed: _____ Membrane allowed to relax _____ hrs

Comments _____

Reference (Field) Meter(s)	Make/Model	Serial No.	Corr. Factor Applied?
Multi-Meter	YSI 6920	110102209	☒ None Yes No
Temperature			☒ None Yes No
Conductivity			☒ None Yes No
pH			☒ None Yes No
Dissolved Oxygen			☒ None Yes No
Turbidity (1)			☒ None Yes No
Turbidity (2)			☒ None Yes No
Other			☒ None Yes No

COMMENTS/OBSERVATIONS:

Turbidity method codes are available at: http://water.usgs.gov/bwq/FieldManual/Chapter6/6.7_contents.html

Figure SOP 7-4. USGS/APHN continuous water-quality monitoring field form, page 4 of 4.

Literature Cited

- Wagner, R.J., R.W. Boulger Jr., C.J. Oblinger, B.A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting. U.S. Geological Survey Techniques and Methods 1–D3, p. + 8 attachments.
- Wilde, F.D., and D. B. Radtke. 2005, General information and guidelines: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.0, 36 p. YSI Incorporated. 2009. The dissolved oxygen handbook. YSI, Inc., Yellow Springs, Ohio.
- YSI Incorporated. 2010. Calibration, maintenance & troubleshooting tips For YSI 6-Series Datasondes & Sensors. YSI, Inc., Yellow Springs, Ohio.
- YSI Incorporated. 2011. 6-Series multiparameter water quality datasondes user manual. Yellow Springs, Ohio, Revision H, 377 p.

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ08

Quality Assurance/Quality Control—Version 1.4

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Summary

This standard operating procedure (SOP) describes step-by-step quality assurance/quality control (QA/QC) procedures for ensuring that data collected under this protocol are of known quality, pertinent to monitoring objectives, and useful to future investigations. The general content and format of this SOP is based on SOP 12 from Starkey et al. (2016), SOP 7 from Sharrow et al. (2007), Part B Lite (Irwin 2008) and the U. S. Environmental Protection Agency (EPA) National Coastal Assessment Quality Assurance Project Plan 2001–2004 (EPA 2001).

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.4

Measurement Quality Objectives (MQOs) for Water Chemistry

Modified from Sharrow et al. (2007)

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 data are:

- Consistent over time and consistent between staff members,
- Collected and analyzed using standardized and acceptable techniques,
- Comparable to data collected in other assessments using the same methods, and
- Used appropriately to make decisions based on sound statistics.

Data Quality Objectives (DQOs)

Modified from Sharrow et al. (2007)

Data Quality Objectives are the quantitative and qualitative terms that describe the data quality required to meet project objectives.

- Target population
- Representativeness
- Completeness
- Data comparability
- Measurement sensitivity and accuracy.
- Measurement systematic error/bias

Target Population

This protocol targets surface waters in the major rivers and creeks that flow through Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI). Monitoring stations are located in the upstream sections of the larger rivers and tributaries designated for protection by park legislation. These monitoring locations were chosen as index sites that represent physical and chemical water-quality conditions “delivered” to park waters from upstream areas of their respective watersheds.

Representativeness

For this protocol, frequency and timing of sampling were important considerations in designing a sampling program that would generate representative samples across the hydrograph. Samples taken during high-flow conditions may have significantly different properties than those taken during base-

flow conditions. Much of the annual mass transport for a basin may occur in just a few storm events during the year. The fixed-frequency sampling design called for in this protocol reflects a comprehensive range of flow conditions over time. To monitor temporal variability in water-quality conditions in individual watersheds, sampling is year round at 30-minute intervals (Wagner et al. 2006). Monthly calibrations and error checks ensure quality data for the duration of the monitoring program.

Cross-section surveys of field parameters were conducted prior to selection of a final deployment location at each monitoring site, to ensure that locations were representative of the entire (well-mixed) water body rather than of an anomalous condition. Generally, the most critical parameters to evaluate during cross-section surveys are specific conductance and turbidity, because they are most susceptible to large variations in unmixed waters (Wagner et al. 2006). Sufficient measurements were made at each cross section to determine the degree of mixing and to quantify variability at each site. Cross-section surveys of the parameters to be monitored were conducted at base flow and during a wadeable runoff event, and the results were compared with those at the potential deployment location. Cross-section analyses will be repeated annually as described in the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI): Quality Assurance Plan* (Hughes et al. 2018) to verify that deployment locations continue to represent site conditions.

Completeness

Modified from Starkey et al. (2016) and Sharrow et al. (2007)

The ability to monitor the performance of our deployed datasondes in real-time and make repairs quickly minimizes errors in the data set. However, it is not reasonable to expect all sites will be accessible at all times, especially when water levels are high. Given our minimum detectable differences and calculated statistical power, our sampling objective of 90% completeness of annual and seasonal data sets should ensure large-enough sample sizes to provide acceptable power of detectable change. However, we will continue to target 100% completeness.

Data Comparability

The Appalachian Highlands Network (APHN) seeks to generate water-quality data easily integrated with data obtained by other agencies and projects. Easily-integrated data will facilitate a greater understanding of watershed conditions and issues. The network will generate such data by adopting sampling procedures and quality checks recommended by the United States Geological Survey (USGS) whenever possible. Site selection, sampling frequency, calibration criteria, and correction criteria will follow guidelines recommended by USGS (Wagner et al. 2006). In addition, the network is measuring a set of core parameters (temperature, pH, specific conductance, dissolved oxygen, and turbidity) which are widely reported and have broad utility for assessing water quality.

Measurement Sensitivity and Accuracy

Modified from Starkey et al. (2016) and Sharrow et al. (2007)

The network uses YSI 6920-V2 multi-parameter datasondes for continuous water-quality monitoring. The range, accuracy, and resolution of each sensor as provided by the manufacturer (YSI, Inc.) are presented in Table SOP 8-1.

Table SOP 8-1. Range, accuracy, and resolution of the YSI 6920-V2 datasonde, as defined by YSI, Inc.

Sensor	Range	Accuracy	Resolution
Temperature	-5 to 50 °C	± 0.15 °C	0.01 °C
Specific Conductance	0 to 100,000 µS/cm	± .5% of reading or ± 1 µS/cm, whichever is greater	1 µS/cm
pH	0 to 14 units	± 0.2 units	0.01 units
Dissolved Oxygen	0 to 50mg/L	± 0.1 mg/L for 0 to 20 mg/L; ± 15% of reading relative to calibration gases for 20 to 50 mg/L	0.01 mg/L
Self-cleaning Turbidity	0 to 1000 NTU	± 2% of reading or 0.3 NTU, whichever is greater	0.1 NTU

Measurement Precision and Repeatability

Modified from Starkey et al. (2016) and Sharrow et al. (2007)

Relative Percent Difference (RPD)—Precision Plus (+)

Precision+ is the variability of repeated measures of two samples collected in close proximity. It is a less rigorous measure of sensitivity than Alternate Measurement Sensitivity (AMS) (Thoma et al. 2012) by using a sample size of 2 rather than 7, but is used more frequently to ensure measurements are in “control,” especially for laboratory analyses in which inclusion of 7 duplicates is not always practical (Sharrow et al. 2007). Precision+ is expressed through RPD, calculated as:

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

S1 = the larger test result value

S2 = the smaller test result value

As described in SOP CWQ05 *Equipment and Calibration—Version 1.4* and CWQ06 *Linking YSI 6920 Datasondes to USGS Gages—Version 1.4*, deployed monitor datasondes will be calibrated and checked against a calibrated field meter datasonde. The network will record the values obtained from comparing the deployed monitor and the calibrated field meter on the USGS/APHN continuous monitoring field forms. Then, the data is entered into electronic USGS CHIMP files and converted by USGS SiteVisitAq into Aquarius readable files. The network will drag and drop site visit files into

NWIS based Aquarius software for automated correction (shifting) of data based upon site visit measurements. Automated reports available within Aquarius will document and summarize correction of the data record, including RPD.

The application of data corrections allows recorded data to be adjusted for instrument calibration drift and sensor-fouling errors that occurred during the interval between servicing visits because of environmental or instrumentation effects, and for other factors. Errors occur primarily from fouling of sensors (most notably turbidity sensors) and from sensor calibration drift. A data correction is required when the combined absolute values for fouling and calibration drift error exceed the criterion for water-quality data corrections as described in detail in SOP CWQ10 *Continuous Water Quality Record Processing—Version 1.4* (Table SOP 10-3):

$$ET = |Ef| + |Ed|,$$

where

ET = total error,

Ef = sensor fouling error, and

Ed = calibration drift error.

For example, assume the fouling error for a dissolved oxygen (DO) sensor is + 0.2 milligrams per liter (mg/L). If the calibration error (the difference between the theoretical value for 100% DO saturation and actual reading in 100% DO saturation) is 0.2 mg/L, the sum of the absolute value of the errors (0.4 mg/L) exceeds the data-correction criterion for DO (± 0.3 mg/L; Table SOP 10-3). Thus, the data must be corrected. These data-correction criteria are minimum requirements for data corrections. More stringent data-correction criteria may be needed to meet the data objectives of the project or specific hydrologic and chemical environments. The decision to apply data corrections when total errors are smaller than the data-correction criteria or to correct for other factors is up to protocol lead.

All data corrections have a starting date and time and an ending date and time that delineate the data-correction period. A data-correction period typically begins and ends on a servicing date. Calibration drift is assumed to occur at a constant rate throughout the correction period. Characteristics of individual waters influence fouling rates, and sensor fouling may begin as soon as the datasonde is deployed in the aquatic environment. Environmental or hydrologic events, such as a rise in gage height (affecting turbidity, for example) can be identified as significant fouling events, and may be used to delineate the start or end date for a fouling correction. Thus, a zero correction is applied at the start of the correction period, the full correction is applied at the end of the correction period, and corrections to the data between the start and end dates are linearly interpolated (Bartholoma 2005). If fouling is severe, it is sometimes necessary to delete individual sensor data.

Measurement Systematic Error and Bias

Modified from Starkey et al. (2016 and Sharrow et al. (2007)

Systematic error and bias is the systematic or persistent distortion of a measurement process that causes errors in only one direction (high or low). Results for systematic error and bias are usually expressed as a percent recovery; the correct or expected answer is 100%, with an acceptable range of 90–110% for core parameters (Sharrow et al. 2007; Irwin 2008). During each monthly site revisit or calibration, the network determines the amount of error caused by fouling and calibration drift as described in SOPs CWQ05 and CWQ06. The raw values for systematic error and bias are recorded on the USGS/APHN continuous monitoring field form as “drift correction” and “fouling correction.” Percent difference will be calculated for each parameter based on data obtained during the assessment of fouling and drift corrections, as: $PD = [(Y - X) / X] * 100$.

PD for Fouling

X = the concentration in stream water after fouling is removed from the sensors

Y = the concentration in stream water before fouling is removed from the sensors

PD for Drift

X = the known concentration of a standard solution

Y = the measured concentration of a standard solution

The result will be 2%-difference values for each parameter (with the exception of pH and temperature, for which absolute difference will be reported) for each month (deployment interval)—one value accounts for percent drift and the other accounts for percent fouling.

When data are processed for analysis, they will be corrected to account for fouling and drift error. Data correction will only occur if drift and fouling corrections fall outside of pre-defined criteria (Table SOP 8-2). The process of data correction is more thoroughly discussed in SOP CWQ10.

Besides percent difference, the degree of data bias will be reflected in the grade or rating that data will receive based on the amount of correction that has been applied. Rating criteria are listed in Table SOP 8-3 and discussed in SOP CWQ10. Data grades will be applied on a monthly (deployment period) basis. Data may be unusable because of uncorrectable turbidity fouling or sensor failure. In those cases, the protocol lead will remove the data from the corrected record in Aquarius, and the data will be excluded from analyses. Note that raw data will remain in Aquarius and that a record of data gaps will also be maintained in Aquarius.

Table SOP 8-2. Criteria for water-quality data corrections, modified from Wagner et al. 2006. Corrections are applied when the sum of the absolute values for fouling and calibration drift error exceeds the value listed in the “Calibration/Data Correction Criteria” column.

Parameter	Calibration / Data Correction Criteria
Temperature	± 0.2 °C when checked with another meter ± 0.5 °C when checked with NIST thermometer
Specific Conductance	± 5 μ S/cm or $\pm 3\%$ of the measured value, whichever is greater
Dissolved Oxygen	± 0.3 mg/L
pH	± 0.2 pH units
Turbidity	± 0.5 turbidity units or $\pm 5\%$ of the measured value, whichever is greater

Table SOP 8-3. USGS accuracy ratings of continuous water-quality records or “data grade” (modified from Wagner et al. 2006). Ratings are based on combined fouling and calibration drift corrections applied to the record and include ratings of “excellent,” “good,” “fair,” and “poor.”

Parameter	Excellent	Good	Fair	Poor
Water Temperature	$\leq \pm 0.2$ °C	$>\pm 0.2$ – 0.5 °C	$>\pm 0.5$ – 0.8 °C	$>\pm 0.8$ °C
Specific Conductance	$\leq \pm 3\%$	$>\pm 3$ – 10%	$>\pm 10$ – 15%	$>\pm 15\%$
Dissolved Oxygen	$\leq \pm 0.3$ mg/L or $\leq \pm 5\%$, whichever is greater	$>\pm 0.3$ – 0.5 mg/L or $>\pm 5$ – 10% , whichever is greater	$>\pm 0.5$ – 0.8 mg/L or $>\pm 10$ – 15% , whichever is greater	$>\pm 0.8$ mg/L or $>\pm 15\%$, whichever is greater
pH	$\leq \pm 0.2$ units	$>\pm 0.2$ – 0.5 units	$>\pm 0.5$ – 0.8 units	$>\pm 0.8$ units
Turbidity	$\leq \pm 0.5$ NTU or $\leq \pm 5\%$, whichever is greater	$>\pm 0.5$ – 1.0 NTU or $>\pm 5$ – 10% , whichever is greater	$>\pm 1.0$ – 1.5 NTU or $>\pm 10$ – 15% , whichever is greater	$>\pm 1.5$ NTU or $>\pm 15\%$, whichever is greater

Pre and Post Mobilization Check to Minimize Bias

Conduct pre- and post-deployment calibration and error checks in the APHN lab to ensure all sensors are functional and ready before deployment. During pre- and post-mobilization calibrations, all sensors must calibrate and remain within the calibration criteria during error checks, as defined in Table SOP 8-2. Should any sensors fail to calibrate, or sensor measurements of standard solutions consistently fall outside of the calibration criteria, replace or return the sensors to the manufacturer for service.

Field Calibration to Minimize Bias

Monthly calibration will minimize bias in measurements by deployed datasondes as described in SOP CWQ05 and SOP CWQ07 *Operation and Maintenance Site Visit—Version 1.4*. All calibrations will be recorded on the USGS/APHN continuous monitoring field form. In general,

if measures of standard solutions fall outside of the calibration criteria as defined by Wagner et al. (2006), the sensor needs to be re-calibrated. If values consistently fall outside of the criteria or exceed the maximum allowable limits (SOP CWQ05), the sensor needs to be replaced or returned to the manufacturer for repair. Consistent staff training (SOP CWQ03 *Training Field Personnel—Version 1.4*) and strict adherence to the procedures in SOP CWQ05 will help limit bias caused by personnel.

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Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ09

Data Management—Version 1.3

Please cite this as:

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Summary

This standard operating procedure (SOP) explains the data management procedures for continuously collected water-quality data.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
10/26/2017	APHN	Addressing peer review comments.	Addressing peer review comments.	1.3

Overview

The Appalachian Highlands Network (APHN) manages data, graphics, summaries, reports, and numerous other information products to report and interpret monitoring results in the context of APHN long-term monitoring objectives. Proper management and quality control of data sets, and the products derived from them, is critical for effective analysis and interpretation of water-quality monitoring data. It also provides managers, policy makers and researchers with information necessary for making decisions regarding the use and conservation of the parks' water resources.

The types of data produced by continuous water-quality monitoring include raw field data (fouling and calibration drift; cross-section water quality) collected at frequent intervals, corrected data, and metadata. Metadata includes documentation of systematic corrections made during routine instrument calibration, as well as corrections made to eliminate transient errors in the data record due to fouling or instrument malfunction. Field data, corrected data, and metadata will be archived for later evaluation and analysis by APHN staff, managers, and researchers.

Aquatic Informatics' Aquarius software, supported by the National Park Service (NPS) Water Resources Division (WRD) and adopted by the United States Geological Survey (USGS), will be the principal program used by the Appalachian Highlands Network to analyze water-quality data and produce summary statistics and graphics. The National Water Information System (NWIS), managed by USGS, will be the main repository for continuous water-quality data—for both raw and corrected data files. Backup copies of these files will be stored in Aquarius. Annual summary reports will provide detailed information on the status of water quality at each monitoring site. Trend and synthesis reports will be completed every three to seven years to place monitoring results in a broader context, both in space and time. Detailed procedures for data analysis and reporting are provided in SOP CWQ11 *Data Analysis and Reporting—Version 1.4*.

Aquarius Time-Series Software

The NPS Water Resources Division provides networks access to and technical support for Aquatic Informatics' Aquarius time-series software for archiving and analyzing continuous water-quality monitoring data. The USGS recently adopted Aquarius as its primary system for data handling and analysis. The USGS is in the process of migrating its offices to the new system. Aquarius is a database and a collection of tools that allows APHN data sets to be stored and manipulated in various ways. Data processing tools facilitate quality checking and correcting time-series data. Numerous built-in routines calculate both summary statistics and sophisticated statistical analyses. Graphics tools are able to display continuous data in various forms, which allow ready interpretation. Basic data processing steps in Aquarius are described in more detail in SOP CWQ10 *Continuous Water Quality Protocol Revision—Version 1.4*.

Data Acquisition

Figure SOP 9-1 shows the flow for continuous water-quality monitoring data. Table SOP 9-1 summarizes routine annual data management tasks. For this protocol, data are collected every 30 minutes for five water-quality parameters at each of five monitoring sites. Data are automatically transmitted to NWIS, displayed on the internet, and archived in near real-time. Backup data logs are collected and stored on a shared APHN storage drive during monthly visits to calibrate each datasonde. After each calibration, data files are corrected and certified in NWIS, and copies of uncorrected and corrected data files are archived in NPS Aquarius for eventual analysis.

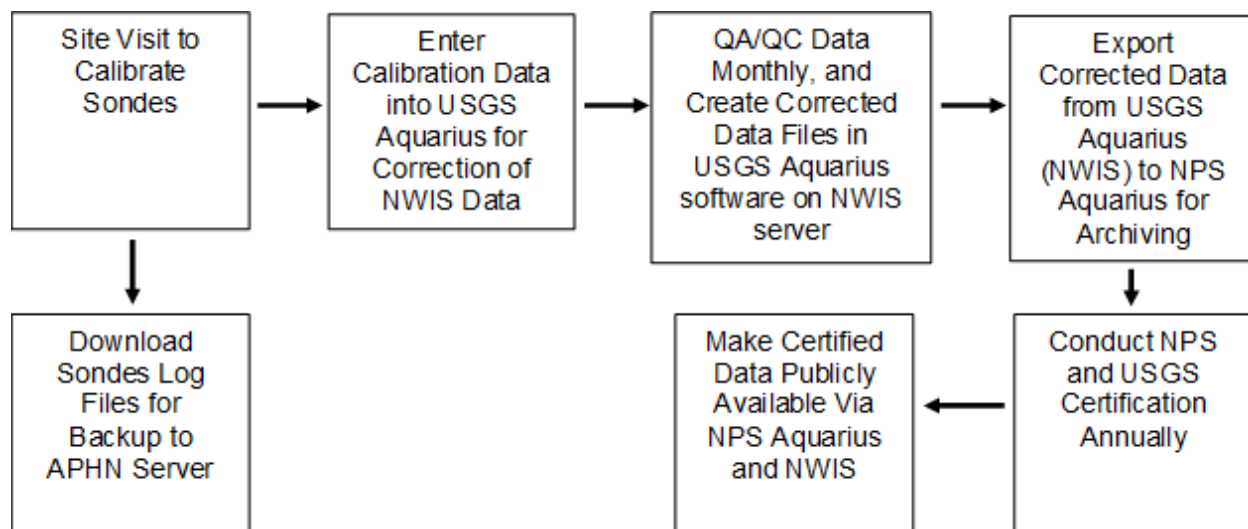


Figure SOP 9-1. Process flow chart for management of continuous water quality monitoring data.

Data Entry

Manual editing of data is routinely required to remove spikes or fill gaps in the data record caused by fouling or instrument malfunction. Online editing is done utilizing USGS's NWIS server to access the USGS licensed version of Aquarius time series software. During monthly operation and maintenance site visits, appropriate fouling, calibration, and other measurements are recorded on paper. Within one week, site visit data are entered into laptop or handheld versions of the USGS Continuous Hydrologic Instrumentation Monitoring Program (CHIMP) files. At the date of this writing, CHIMP files must be converted into Aquarius readable files by utilizing the USGS SiteVisitAQ software. Upon conversion, electronic site visit files can be dragged and dropped into Aquarius for automated shifting and correction of data based upon O&M site visit measurements, depending on how much fouling or calibration drift has occurred in the previous period. The protocol lead or other designated personnel, enter corrections into the Aquarius software (permissions required). Data verification, validation and certification are completed by the protocol lead after calibration corrections have been entered. The protocol lead or protocol tech archives and scans the calibration data sheets into PDF format following drift corrections.

Verification and Validation

Calibration, along with O&M site visit data are verified during data entry in a process that involves checking the accuracy of computerized records against the original source—mainly paper field calibration data sheets. Data entry personnel check 100% of the records against the original data sheets. The protocol lead performs validation subsequent to verification. The purpose of validation is to identify generic errors in the data record such as missing, mismatched, or duplicate records.

Data Certification

After the calibration and O&M site visit data are verified and validated, the protocol lead certifies that all data meet quality standards and marks the time-series data with the “approved” status in Aquarius. Site visit data sheets, generated during operation and maintenance site visits, are scanned and archived. The certified electronic data are used for subsequent data analysis and reporting. The altered data sheets are scanned and archived along with the original versions should the data sheets require editing in the future.

Metadata

For long-term projects such as this one, metadata creation is most time consuming the first time it is developed. Most information then remains static from one year to the next. The protocol lead and the data manager (or data technician) work together to create a continuous water-quality monitoring metadata record and upload this record to NPS’s Integrated Resource Management Applications Portal (IRMA). The metadata record will be updated annually as new data are collected, and to describe any changes in collection methods, analysis methods, current publications, references, contact information, data disposition and quality. Edits within the metadata record will be tracked so changes are obvious to future users or editors of the XML metadata file.

Data Archiving

Raw field data and corrected certified data sets are stored in NWIS with backup copies maintained in NPS Aquarius. The Appalachian Highlands Network digitally archives data sheets from the calibration process and photographs from site visits. These files are stored on a shared network storage device, which has daily and weekly routine backup procedures. Paper copies of field data sheets are stored in permanent files immediately following data entry, verification and validation.

Table SOP 9-1. Schedule of tasks associated with collection and analysis of time-series data.

Project Stage	Task Description	Responsibility	Status/Schedule
Preparation	Install datasonde deployment infrastructure	APHN staff (with USGS assistance)	Completed (2009 – 2013)
	Develop field calibration procedures	Protocol Lead	Completed
	Attend USGS Continuous Monitoring Training	Protocol Lead	Completed (2010)
	Complete Aquarius training	Protocol Lead/Data Manager	In progress. Regular annual updates completed in Jan–Feb
Deployment and Data Acquisition	Deploy datasondes	Protocol Lead	Completed (2009–2013)
	Service datasondes/acquire data logs (5 stations)	Protocol Lead	Monthly
Data Handling	Complete routine data editing	Protocol Lead	As needed
	Complete data corrections associated with calibration drift	Protocol Lead	Monthly
	Export corrected and uncorrected data files from USGS Aquarius and upload to NPS Aquarius	Protocol Lead/Data Manager	Quarterly
	Conduct NPS/USGS data quality review; upload certified data to NPS Aquarius; make certified data publicly available	Protocol Lead/Data Manager	Annually
Data Analysis and Reporting	Prepare graphics and data summaries using NWIS and Aquarius	Protocol Lead/Data Manager	Nov–Dec
	Submit draft briefings and reports to network program manager for review	Protocol Lead	Jan–Feb
	Submit reports to Parks	Network Program Manager	March
Posting and Distribution	Upload completed reports to IRMA Data Store and Network website	Data Manager	March
	Archive completed reports on APHN shared drive	Data Manager	March
Project Review	Meet to discuss the recent field season; document needed changes to the protocol	Network Program Manager/Protocol Lead/Data Manager	Jan–Feb

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ10

Continuous Water-Quality Record Processing—Version 1.4

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Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—CWQ10.
Appalachian Highlands Network, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) is a guide for processing records from Appalachian Highlands Network (APHN) continuous water-quality monitoring stations at Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI).

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments	Addressing peer review comments	1.4

Overview

This SOP is a guide for processing records from continuous water-quality monitoring stations at Big South Fork NRR and Obed WSR. The types of data produced by continuous water-quality monitoring include raw field data collected at frequent intervals, corrected data, and metadata. This data will be archived for later evaluation and analysis by APHN staff, managers, and researchers.

The National Water Information System (NWIS), managed by the United States Geological Survey (USGS), will be the main repository for APHN continuous water-quality data, both raw and corrected data files. Data is processed in NWIS through Aquatic Informatics' Aquarius software, which is supported by the National Park Service (NPS) Water Resources Division (WRD). Aquarius will be the principal program used by the network to analyze water-quality data and produce summary statistics and graphics. Backup copies of raw and corrected data files will also be stored in Aquarius. Figure SOP 10-1 shows the general workflow for this process.

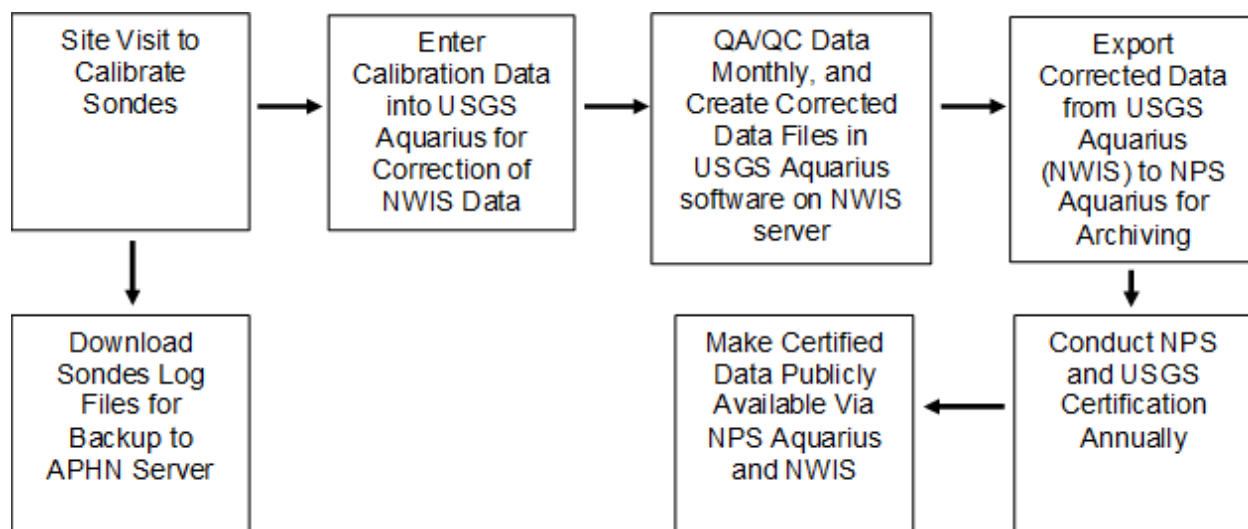


Figure SOP 10-1. Process flow chart for management of continuous water-quality monitoring data.

Continuous Records Processing Procedures

This SOP contains some of the basic procedures for carrying out data corrections in the USGS instance of Aquarius.

Table SOP 10-1. USGS station numbers.

Park	Water Body Name	Location	Station Name/Number
BISO	New River	New River, Tenn.	USGS 03408500
BISO	Clear Fork	Robbins, Tenn.	USGS 03409500
OBRI	Obed River	Adams Bridge, Crossville, Tenn.	USGS 03539778
OBRI	Daddys Creek	Hebbertsberg, Tenn.	USGS 03539600
OBRI	Clear Creek	Lilly Bridge, Lancing, Tenn.	USGS 03538830

Table SOP 10-2. USGS NWIS parameter codes for utilized in Aquarius.

Sensor	NWIS Parameter Code
Temperature (°C)	TW
Specific conductance (µs/cm)	WC
pH (standard pH units)	PH
Turbidity (NTU)	WT
Optical Dissolved Oxygen (mg/L)	DO

Data Processing Procedures

Systematic corrections are often necessary during routine visits to calibrate datasondes. The following sections detail systematic data correction steps.

Initial Data Evaluation

Appalachian Highlands Network monitoring sites at USGS gages are equipped with transmitters that provide hourly satellite downloads of data from the field to NWIS. The initial data evaluation is conducted to verify raw field data (instrument readings) have been accurately transferred to NWIS, and to evaluate and identify erroneous data.

Sensors, recorders, transmitters, receivers, relays, transmission systems, or unforeseen events can all produce erroneous data. The data record should be processed and plotted immediately after the service visit to confirm the accurate transfer of data and to detect instrument or sensor error.

USGS/APHN Continuous Monitor Field Form

As part of routine site visits to maintain datasondes, APHN staff will complete the USGS/APHN Continuous Water-Quality Monitoring Field Form (see Figure SOP 7-1) which provides a workflow to compare deployed datasondes (“monitor”) with datasondes (“field meter”) that have been recently calibrated in a laboratory environment. The field form provides a comprehensive list of data fields for recording site visit information. Use of the field form encourages consistency and helps to avoid omission of critical information. Field form data is transferred to electronic format utilizing USGS CHIMP software, a correction autoloader for raw data contained in Aquarius.

Application of Data Corrections

The application of data corrections allows recorded data to be adjusted for instrument calibration drift and sensor-fouling errors that occurred during the interval between servicing visits because of environmental or instrumentation effects, and other factors. Errors occur primarily from fouling of sensors (most notably turbidity sensors) and from sensor calibration drift. A data correction is required when the combined absolute values for fouling and calibration drift error exceed the criterion for water-quality data corrections (Table SOP 10-3):

$$ET = |Ef| + |Ed|,$$

where

ET = total error,

Ef = sensor fouling error, and

Ed = calibration drift error.

For example, assume the fouling error for a dissolved oxygen (DO) sensor is + 0.2 milligrams per liter (mg/L). If the calibration error (the difference between the theoretical value for 100% DO saturation and actual reading in 100% DO saturation) is 0.2 mg/L, the sum of the absolute value of the errors (0.4 mg/L) exceeds the data-correction criterion for DO (± 0.3 mg/L; Table SOP 10-3). So, the data must be corrected. These data-correction criteria are minimum requirements for data corrections. More stringent data-correction criteria may be needed to meet the data objectives of the project or specific hydrologic and chemical environments. The decision to apply data corrections when total errors are smaller than the data-correction criteria or to correct for other factors is left to the protocol lead.

Table SOP 10-3. Criteria for time-series water-quality data correction (Wagner et al. 2006). [C—Celsius; $\mu\text{S}/\text{cm}$ —microsiemens per centimeter; mg/L —milligrams per liter].

Measured field parameter	Data-correction criteria ¹
Temperature (may affect other field parameters)	$\pm 0.2\text{ }^{\circ}\text{C}$
Specific conductance	$\pm 5\text{ }\mu\text{S}/\text{cm}$ or $\pm 3\%$ of the measured value, whichever is greater
Dissolved oxygen	$\pm 0.3\text{ mg}/\text{L}$
pH	$\pm 0.2\text{ pH unit}$
Turbidity	± 0.5 turbidity units or $\pm 5\%$ of the measured value, whichever is greater.

¹ Apply correction when the sum of the absolute values for fouling and calibration drift error exceeds the value listed.

All data corrections have a starting date and time and an ending date and time that delineate the data-correction period. A data-correction period typically begins and ends on a servicing date. Calibration drift is assumed to occur at a constant rate throughout the correction period. Characteristics of individual waters influence fouling rates, and sensor fouling may begin as soon as the datasonde is deployed in the aquatic environment. Environmental or hydrologic events, such as a rise in gage height (affecting turbidity, for example) can be identified as significant fouling events, and may be used to delineate the start or end date for a fouling correction. Thus, a zero correction is applied at the start of the correction period, the full correction is applied at the end of the correction period, and corrections to the data between the start and end dates are linearly interpolated (Bartholoma 2005). If fouling is severe, it is sometimes necessary to delete individual sensor data.

Sometimes, data corrections start in between site visits. Data corrections for fouling, calibration drift, and cross-section variability are based on measurements made during servicing. In Aquarius, corrections are applied using one of three data-correction sets. Data-correction set one is for sensor fouling, data-correction set two is for calibration drift, and data-correction set three is for “other” data adjustments. Each data-correction set may be used to apply constant data corrections, or one-, two-, or three-point variable data corrections. Variable data corrections are prorated by time over the correction interval. Two- and three-point variable data corrections also are prorated by the amount of correction over the correction interval.

Automated Data Correction Procedures

The USGS has developed software tools to streamline and automate water-quality time-series records processing to improve record quality and consistency, and decrease costs. These tools include the USGS handheld software package, called the Continuous Hydrologic Instrumentation Measurement Program (CHIMP), which collects field data during site visits. Data collected in CHIMP are converted into electronic site visit files and uploaded to the USGS Aquarius software for automated data corrections to the record. Within Aquarius, report templates are available to document corrections and shifts to the data record.

Record Processing in Aquarius

Introduction to Aquarius Software

By default, Aquarius software opens in the “Springboard” view, where data from individual sampling stations within NWIS can be loaded for processing. The Data Correction Tool (DCT) is utilized to edit raw data and provides a number of correction tools to process time series water-quality data. While this system sounds complex, it adds great flexibility to the ways data can be processed and viewed. The National Park Service supports Release 3.8 of this software, and USGS has converted to Aquarius, replacing ADAPS as its primary data processing system.

The NPS Water Resources Division provides access to and technical support for Aquatic Informatics’ Aquarius time-series software for inventory and monitoring networks. Aquarius is specifically designed for archiving and analyzing continuous water-quality monitoring data. Aquarius includes data processing tools for importing and merging data streams, flagging and editing of data spikes, application of sensor drift corrections, built-in routines for calculating summary statistics, as well as sophisticated statistical analyses. Graphics tools can display continuous data in various forms allowing for ready interpretation.

The best way to learn how to operate Aquarius is by using the customized NPS training publications and videos at <http://nrdata.nps.gov/Programs/Water/Aquarius/AquariusVideos.htm>, or by accessing the vendor-supplied user manual and videos, both of which can be found by clicking the “Help” menu within Aquarius or by going to <http://aquaticinformatics.com/support>. The following information was taken from NPS WRD-supplied training materials and from Starkey et al. (2016).

Table SOP 10-4 lists the primary toolboxes to be familiar with before starting record processing in Aquarius. Set up a workspace whiteboard and explore the functionality of each toolbox before loading the APHN Aquarius Workflow and importing new data.

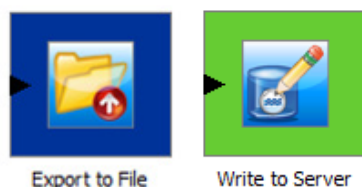
Table SOP 10-4. Primary toolboxes used to process water-quality monitoring data.

Data Process	Relevant Aquarius Toolbox(es)
Data input	 Read from Server
Flagging and QA/QC	 Auto QA/QC
Visualization and reporting	   Quick View Charting Reporting
Data pre-processing	  Signal Joining Signal Trimming
Correction	 Data Correction
Math and statistics	 Descriptive Statistics

Data Process

Relevant Aquarius Toolbox(es)

Data output



General Whiteboard and Workflow Setup

The Appalachian Highlands Network has developed a general whiteboard or workflow to use when processing each park's water-quality data. Process data from continuous monitors immediately following the deployment period (monthly). Whiteboards will likely need to be modified or re-arranged to address differences in data from various parks or monitoring concerns. All major changes to the workflow should be revised in this SOP. Figure SOP 10-2 shows the general workflow for each parameter. Note each row represents one deployment interval and has a corresponding Calibration and Maintenance Log. For each deployment period, data is appended to the station time series and then the deployment period is selected and processed. This signal can then be flagged for values over regulatory thresholds and wired into a descriptive statistics toolbox or a graphing toolbox.

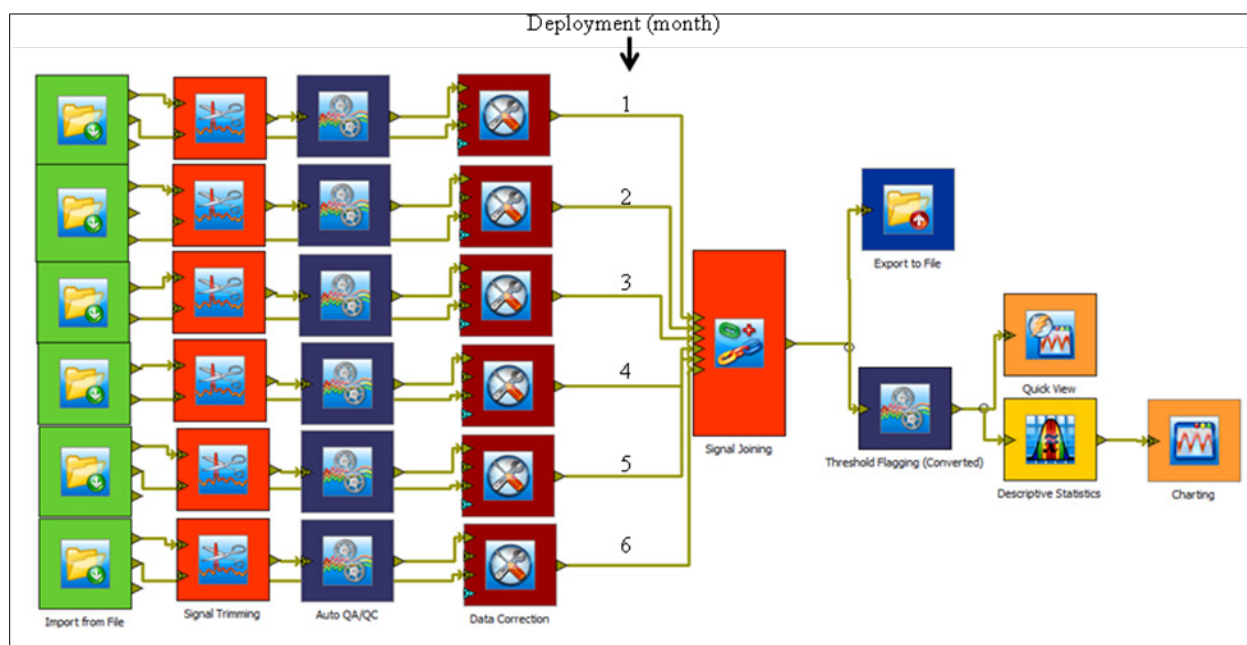


Figure SOP 10-2. General workflow for one core water-quality parameter. Each row corresponds to a specific deployment period (one month). This workflow should be repeated for each of the five core parameters (temperature, specific conductance, dissolved oxygen, pH, and turbidity).

Procedures

Importing from a File

It is important that datasonde log files be configured in a consistent format. This will greatly reduce the time and effort required to successfully import data to Aquarius. Note the same configuration file will be used to import each parameter (i.e., one configuration file/whiteboard).

1. **If you have an existing whiteboard skip to step 3.** Set up the whiteboard as illustrated in Figure SOP 10-2. Repeat this design for each core parameter (temperature, specific conductance, dissolved oxygen, pH, and turbidity). You should have five groups that look exactly like the general workflow in this figure. A separate whiteboard is necessary for each stream/monitoring station. You will not be able to wire toolboxes together until data have been read.
2. Double click the **“Read from Server”** toolbox. A “Read from Server” icon will appear on the whiteboard (Figure SOP 10-3).
3. Double click the **“Read from Server”** icon. A **“Location Manager”** toolbox will appear (Figure SOP 10-4).
4. Select the data set you wish to read and click the **“Location Manager”** icon (Figure SOP 10-4).
5. Edit the URL box to set the Start and End date for the period you would like to use (Figure SOP 10-5).
6. Click on “File,” then “Save and Exit.”

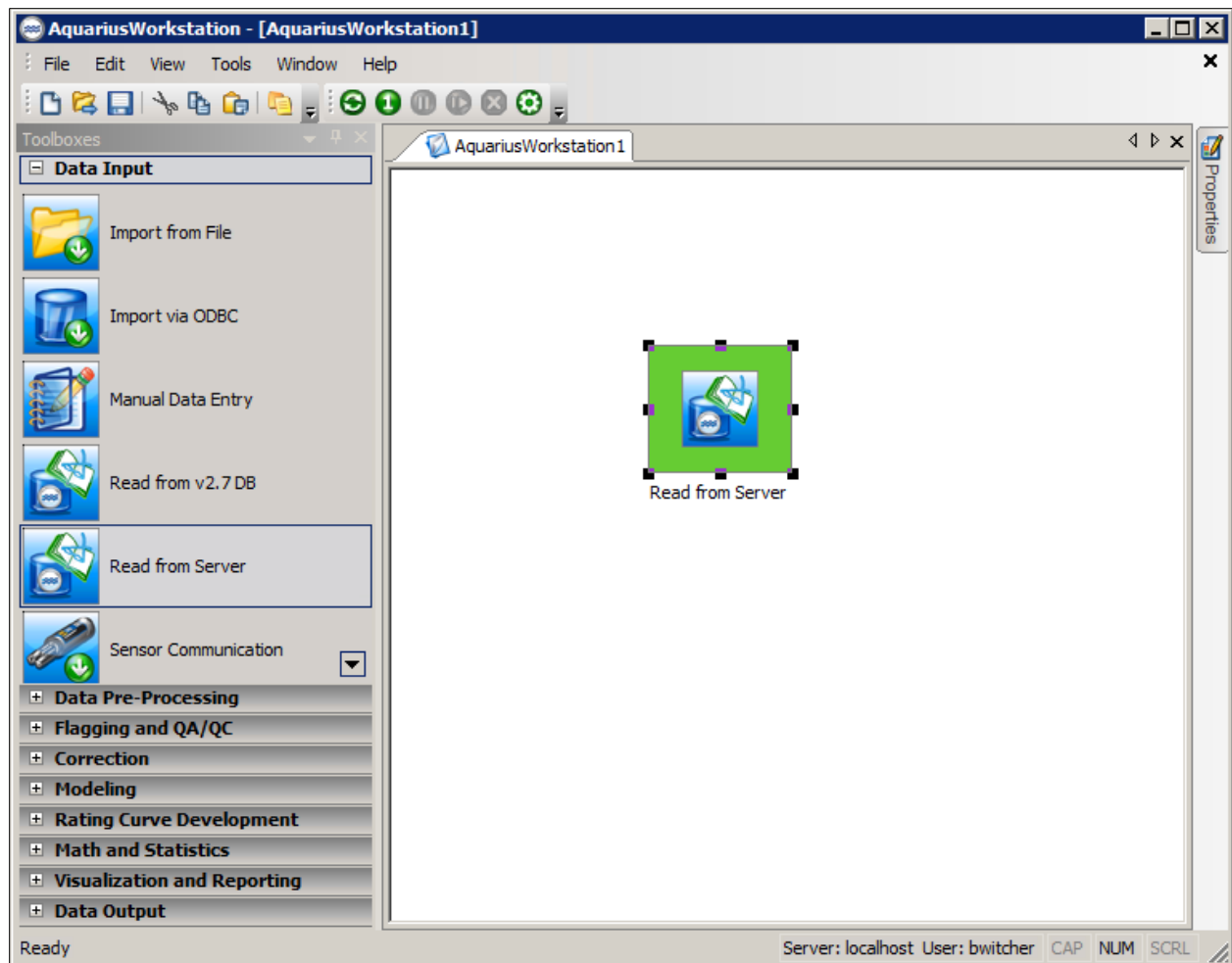


Figure SOP 10-3. Read from server.

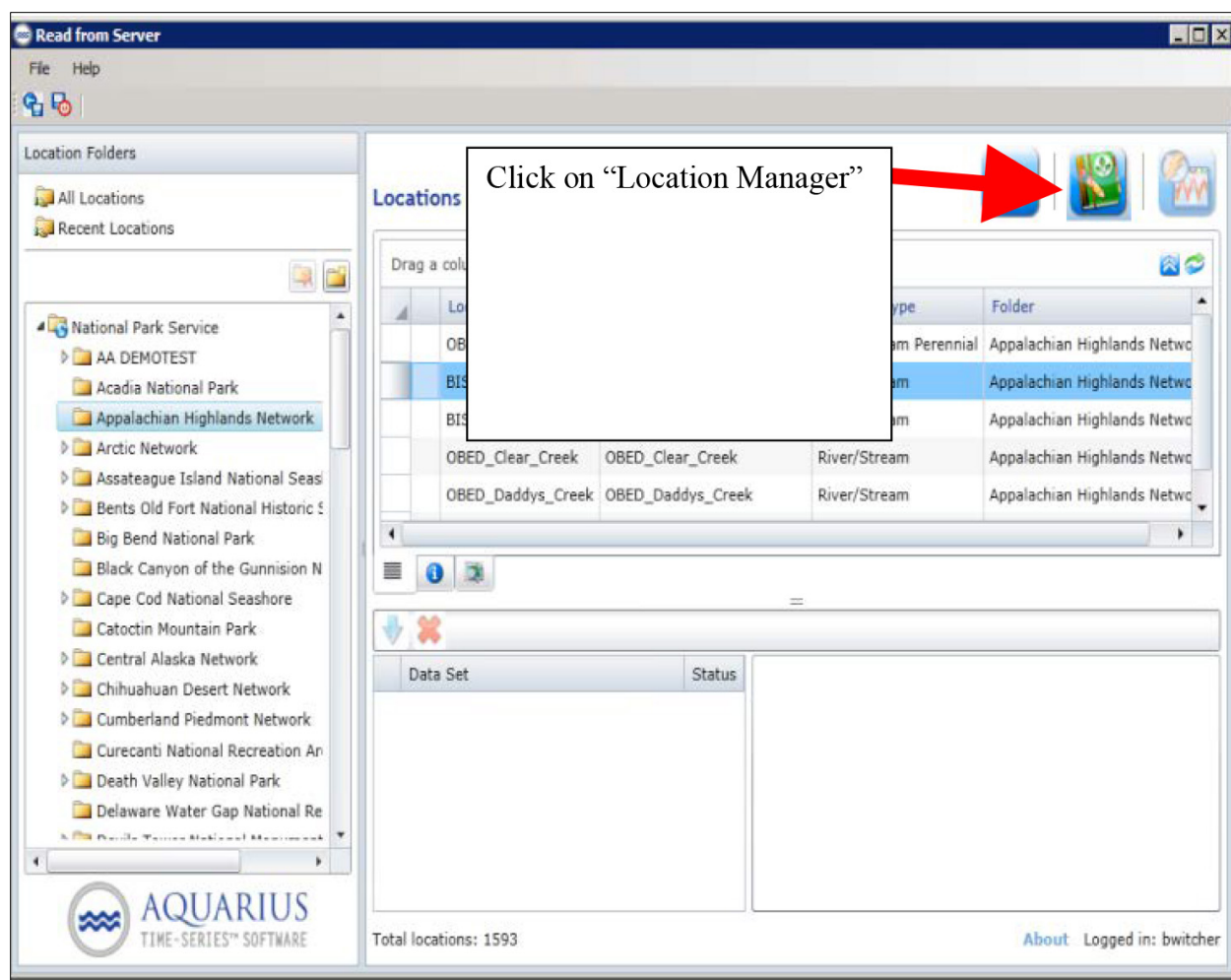


Figure SOP 10-4. Location Manager.

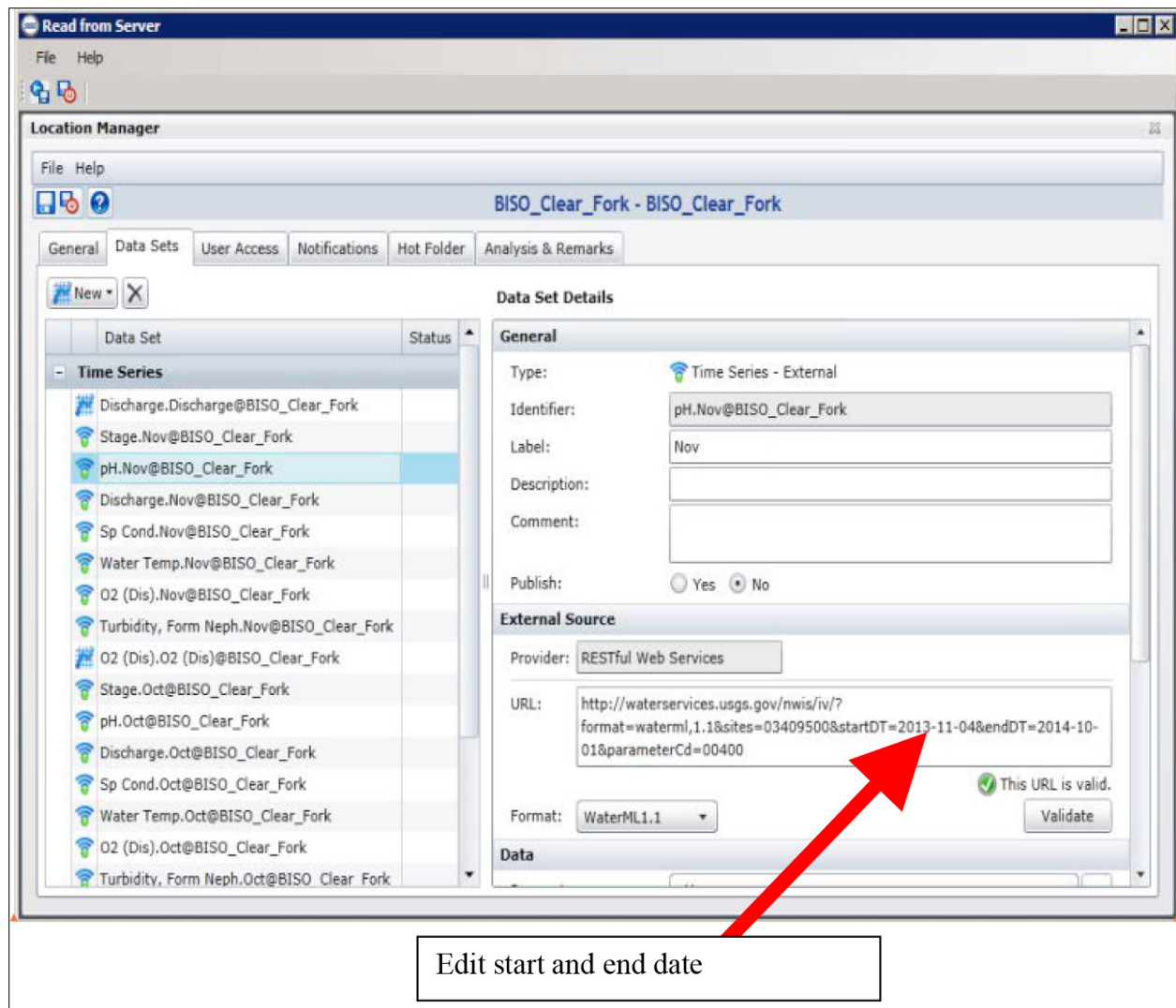


Figure SOP 10-5. URL box.

Signal Trimming

The Signal Trimming toolbox allows you to remove outliers, trim dates, and interpolate small gaps. This toolbox is helpful in certain situations and can greatly speed up the processing of a record. The “Signal Trimming” toolbox should be placed before the “Auto QA/QC” and “Data Correction” toolboxes.

Note the following about the signal trimming toolbox: The Signal Trimming Toolbox performs special corrections on one or more input signals and creates a new output signal for each one. It works as follows: Corrected data from input + new corrections = new raw data in output. The original raw data and correction history are not preserved, so using this toolbox on previously corrected signals is not recommended. For this reason, the Signal Trimming toolbox should not be used for outlier removal or interpolation.

1. After successfully loading one parameter and % battery, your “Read from Server” toolbox should have two triangular output ports. **Click on the first output port (►) and drag a wire to the input port on the “Signal Trimming” toolbox (Figure SOP 10-6). Next, connect the second output port (should be % battery) to the surrogate signal input port labeled with an “O” on the “Data Correction” toolbox.** You can determine the right output port by placing the mouse cursor over the port and waiting for several seconds to see a dialog box that describes the data. The data you read is now connected to the signal trimming toolbox.

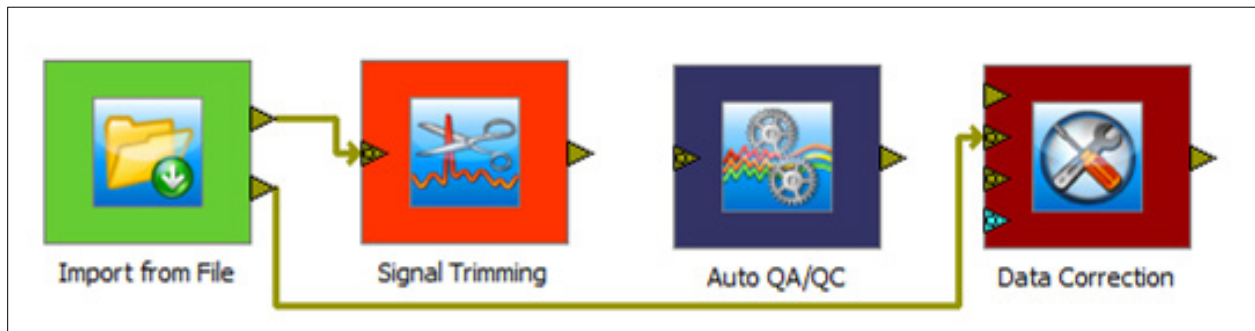


Figure SOP 10-6. “Read from Server” toolbox successfully connected to the “Signal Trimming” and “Data Correction” toolboxes.

2. Double click the “**Signal Trimming**” toolbox.
3. If the data **do not require trimming** click “Run” and return to the whiteboard. Click “**OK.**”
4. If the data **do require trimming**, enter the values and date range you wish to keep. Everything outside of the range you specify will be trimmed.
5. Click “**Apply,**” then click “**Run.**” To return to the whiteboard click “**OK.**”
6. You should now have an active output port on the “Signal Trimming” toolbox.

Auto QA/QC

The “Auto QA/QC” toolbox allows the user to automatically flag data that exceed a specified threshold or rate of change. Individual data points flagged using this toolbox can be viewed in the “Quick View” toolbox and the “Data Correction” toolbox. In addition, options under the “Correctives” tab (Figure SOP 10-7) allow for the automatic removal and correction of flagged data. This toolbox can also be used to assist in the identification of outliers. Basic steps for running data through this toolbox are:

1. Wire the “**Signal Trimming**” toolbox to the auto QA/QC input port.
2. Double click the “**Auto QA/QC**” toolbox.
3. When the toolbox first opens you will notice the fields in the “**Input Port View**” (left column in Figure SOP 10-7) are populated with data. The “**Output Port View**” will remain empty until you run the toolbox.

- a. Enter any data-flagging thresholds or correctives (center column in Figure SOP 10-8). Exact thresholds depend on the parameter, time of year, and monitoring station. Professional judgment should be used to determine appropriate thresholds and corrective measures. Threshold flagging allows the user to input values that should be flagged for review or that exceed a specified criteria. This function is especially useful for indicating values that fall above individual state regulatory thresholds.
 - b. When in doubt, it may be easier to visually identify outliers and other data anomalies in the subsequent “Data Correction” toolbox.
4. Once all thresholds and correctives have been input, click the **“Run Toolbox”**  button. The **“Output Port View”** should now be populated (right column in Figure SOP 10-11). This view allows you to quickly see how many flags have been applied and other summary information about the output signal.
 5. Click the **“Save Output Port and Exit”** button  to exit the “Auto QA/QC” toolbox.

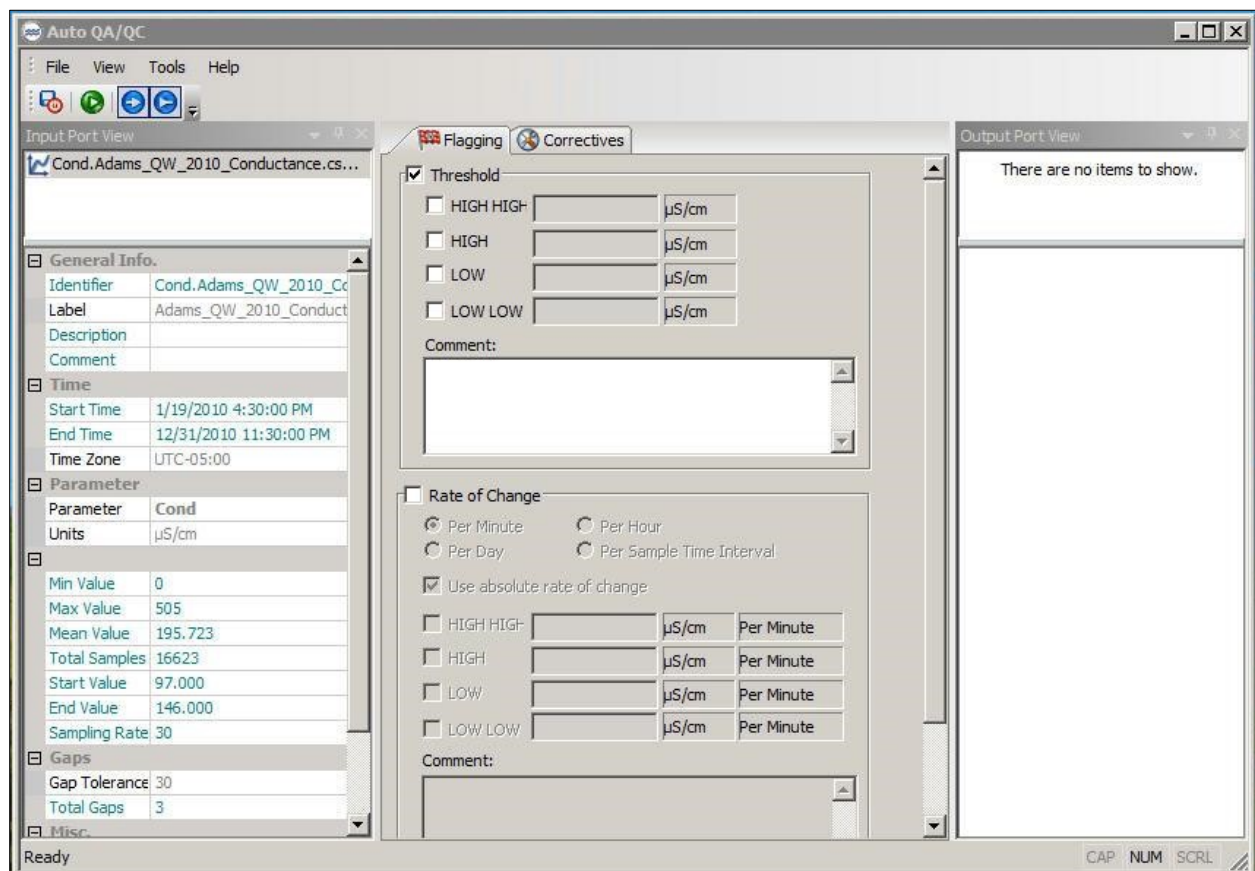


Figure SOP 10-7. The Auto QA/QC Toolbox flagging tab.

Data Corrections

In Aquarius, data corrections and data grading are completed in the same toolbox. For information on data grading refer to the next section. To complete data corrections you should have prior knowledge about the deployment location (i.e., discharge, weather, basin geology). This knowledge allows you to interpret the data and look for false spikes or outliers versus real spikes. Some parameters may be interpreted more easily by looking at several parameters simultaneously (i.e., dissolved oxygen, water temperature). Removal of false spikes and corrections relies on professional judgment.

1. Wire the “**Auto QA/QC**” toolbox to the “**Data Corrections**” toolbox. Also make sure to connect any other parameters of interest to the surrogate signal input port. Surrogate signals can aid in the interpretation of data. Examples of when surrogate signals are useful include:
 - a. Data for a specific parameter may show erratic readings near the end of a deployment but the cause may be unknown. If you look at the time series for the parameter and % battery power (surrogate signal) you may be able to tell if the erratic readings are associated with low battery power.
 - b. If you notice a large spike in turbidity that you suspect might be erroneous, you might want to view specific conductance or stream discharge as surrogate signals. The surrogate signals may help determine if the spike was due to actual conditions in the stream or sensor fouling.
2. Double click on the “**Data Correction**” Toolbox. You will see the data correction window open with a graph of the parameter you loaded (Figure SOP 10-12). If you connected a surrogate signal, it will be graphed below the main time series. Next, look at your data and visually determine which values are suspected outliers or erroneous data. Outliers not removed in the “Auto QA/QC” toolbox should be removed here manually (step 3).
 - a. *Delete Region*—Note: In Aquarius the data is never permanently deleted, it is removed from the working or “Corrected” copy of the data. A correction history log tracks all changes made to the raw data.

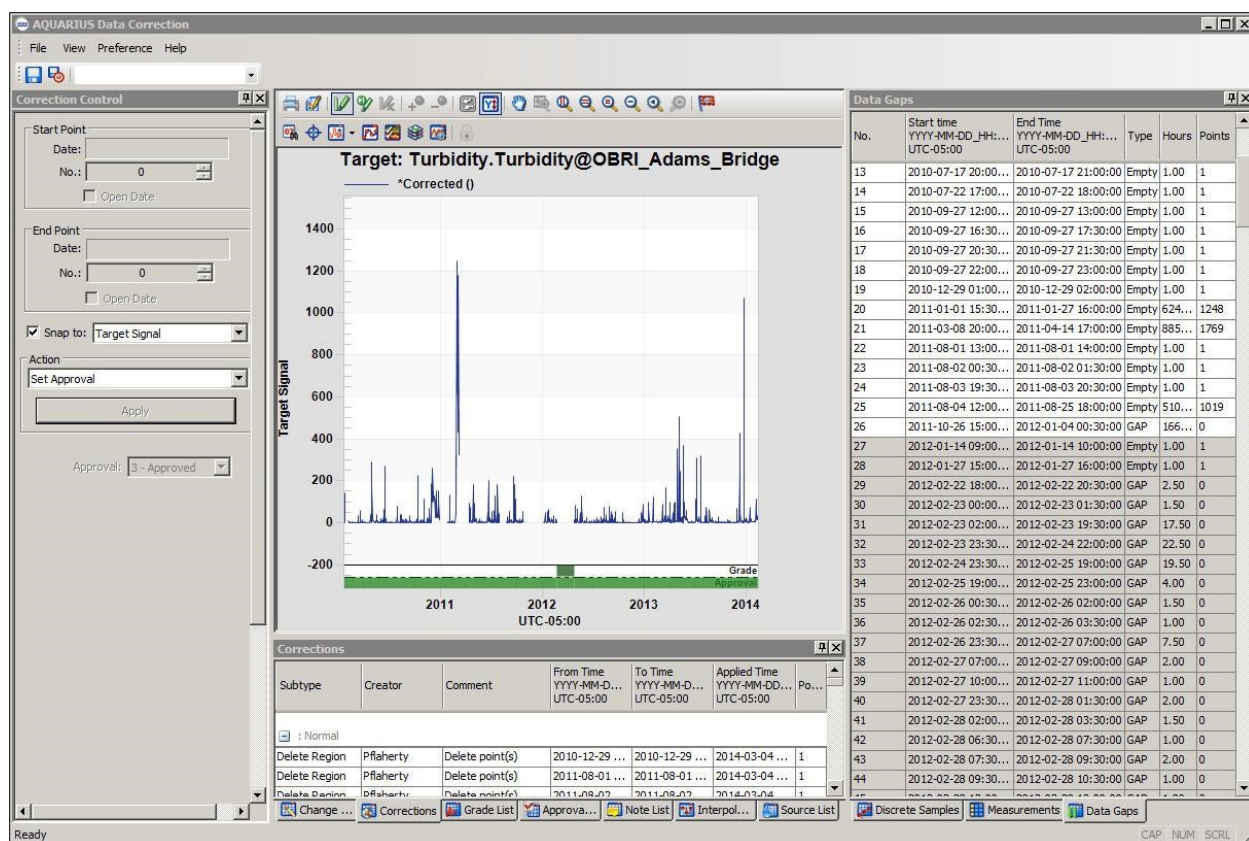


Figure SOP 10-8. Data Correction toolbox. Graph of raw turbidity data, ready for corrections.

- To remove data points (outliers, erroneous data) click the **“Mark Region”**  tool from the toolbar and **highlight the section of data you wish to remove. Double check you have selected the correct region.** Zoom in on the specific segment you want to remove. Make sure you have selected the correct data by checking the time-series grid on the right side of the window (Figure SOP 10-8). **Click the drop-down menu under “Action”** (left side in the Correction Control pane). **Select “Delete Region”** then click **“Apply”** under the drop down menu. An “Apply Correction” window will open (Figure SOP 10-9).
- Fill out the **“Apply Correction”** window (Figure SOP 10-9). Make sure to add a comment describing the reason you have removed the data. Save the comment to the list for future use. If you have already added comments to the list, they can be selected from the “Saved Comments” box. All deletions or corrections are logged in the correction history manager. If you have made an error, these deletions can be un-done from the correction history tab at the bottom of the data correction window. Reasons for deletion might include a low battery, sensor spikes, etc.

Figure SOP 10-9. Apply Correction window.

Fouling and Drift Corrections

1. **Skip this step if no correction is necessary** (see Figure SOP 7-1 USGS/APHN Continuous Water-Quality Monitoring Field Form you completed for the deployment period you are processing). Applying drift and fouling corrections is done by highlighting the entire data set.



Click the “Mark All Region” icon from the toolbar to select the entire time period. Next, **click the drop-down menu under “Action”** (left side in the Correction Control pane). **Select “Drift Correction.”** If needed, enter the **calibration drift** (sensor drift) and **fouling drift**. These can be found on the USGS/APHN Continuous Water-Quality Monitoring Field Form. Make sure **to include a negative sign if necessary**. Click “Apply” under the drop-down menu. The “Apply Correction” window will appear. The amount of correction applied is automatically listed in the comment field. Be sure to **add additional comments if necessary**. Click **“OK.”** You will see a second signal within the graph—this is the corrected data.

2. This toolbox is also the place to make other corrections such as: offset, percent, multi-point, and clock drift. These types of corrections are described in the Aquarius Data Correction toolbox manual. Find the manual in the “Help” menu within the “Data Correction” toolbox.
3. After double-checking that all corrections have been made, continue with data grading. Do not close the “Data Correction” toolbox.

Data Grading

The ability to grade or assign a quality rating to data is built into the “Data Correction” toolbox. Data grades are indicated by the color below the time-series graph and by the “Grade” column in the time-series grid (Figure SOP 10-10).

1. The **“Data Correction”** toolbox should still be open following data corrections. If the “Data Correction” toolbox is not open, follow steps 1 and 2 from the “Data Correction” section.
2. The Appalachian Highlands Network is applying a data grade for the entire deployment period (back to the previous calibration). **Click the “Mark All Region” icon**  from the toolbar to select the entire time period. Next, **click the drop-down menu under “Action”** (left side in the Correction Control pane). **Select “Set Grade.”**
3. Next, **select the appropriate data grade from the “Grade” drop-down menu**. These data grades are pre-set in the NWIS Aquarius software based on the USGS rating criteria found in Wagner et al. 2006 (Table SOP 10-5). **Click “Apply.”**
4. The “Set Grade” window will appear.
5. Add any necessary comments in the comments field. **Click “OK.”**
6. After double checking that all corrections have been made, continue by setting the approval code (see next section). Do not close the “Data Correction” toolbox.

Table SOP 10-5. USGS accuracy ratings of continuous water-quality records or “data grade” (modified from Wagner et al. 2006).

Measured field parameter	Rating of accuracy (data grade) ¹ Excellent	Rating of accuracy (data grade) ¹ Good	Rating of accuracy (data grade) ¹ Fair	Rating of accuracy (data grade) ¹ Poor
Water Temperature	$\leq \pm 0.2\text{ }^{\circ}\text{C}$	$>\pm 0.2\text{--}0.5\text{ }^{\circ}\text{C}$	$>\pm 0.5\text{--}0.8\text{ }^{\circ}\text{C}$	$>\pm 0.8\text{ }^{\circ}\text{C}$
Specific Conductance	$\leq \pm 3\%$	$>\pm 3\text{--}10\%$	$>\pm 10\text{--}15\%$	$>\pm 15\%$
Dissolved Oxygen	$\leq \pm 0.3\text{ mg/L}$ or $\leq \pm 5\%$, whichever is greater	$>\pm 0.3\text{--}0.5\text{ mg/L}$ or $>\pm 5\text{--}10\%$, whichever is greater	$>\pm 0.5\text{--}0.8\text{ mg/L}$ or $>\pm 10\text{--}15\%$, whichever is greater	$>\pm 0.8\text{ mg/L}$ or $>\pm 15\%$, whichever is greater
pH	$\leq \pm 0.2$ units	$>\pm 0.2\text{--}0.5$ units	$>\pm 0.5\text{--}0.8$ units	$>\pm 0.8$ units
Turbidity	$\leq \pm 0.5\text{ NTU}$ or $\leq \pm 5\%$, whichever is greater	$>\pm 0.5\text{--}1.0\text{ NTU}$ or $>\pm 5\text{--}10\%$, whichever is greater	$>\pm 1.0\text{--}1.5\text{ NTU}$ or $>\pm 10\text{--}15\%$, whichever is greater	$>\pm 1.5\text{ NTU}$ or $>\pm 15\%$, whichever is greater

¹ Based on combined fouling and calibration drift corrections applied to the record.

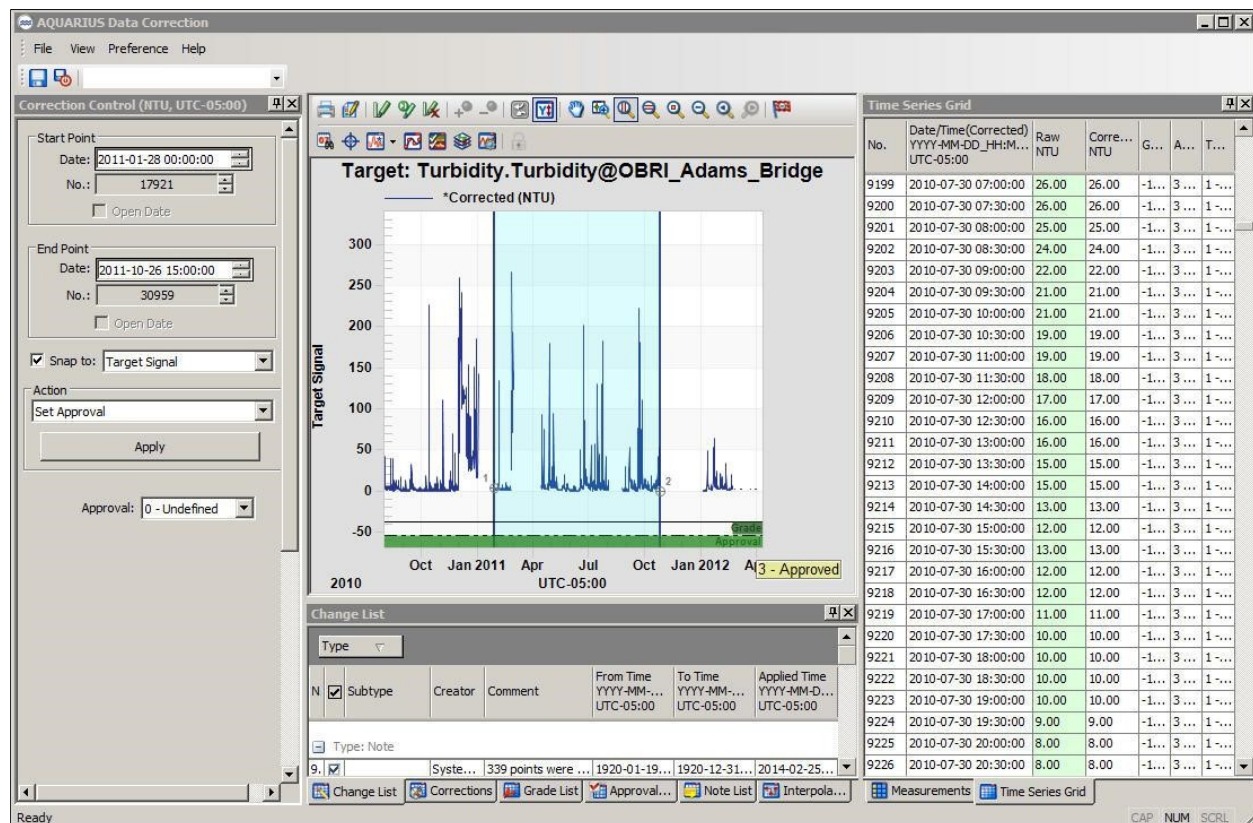


Figure SOP 10-10. Data Correction toolbox indicating the portion of turbidity data ready to be approved.

Approval Codes

Approval codes help define the status of the data relative to data processing. The codes indicate if the data are “working,” “in review,” or “approved.” These categories help with quality assurance and are important if multiple users will be reviewing and processing the data. For example, a hydrologic

technician could enter and process the data in Aquarius and set the approval code as “in review.” After the data has been checked by a supervisor, the approval code could be switched to “approved.” Note that the approval codes can be changed to meet individual user needs. For instance, rather than “working” the user might want the approval code to read “provisional.” The process for changing the approval codes can be found in the Aquarius help Manual under the heading “Aquarius Local Data Manager.” The help manual is available from the Help menu.

1. The **“Data Correction”** toolbox should still be open following data grading. If the “Data Correction” toolbox is not open, follow steps 1 and 2 from the “Data Correction” section above.
2. Click the **“Mark Region”**  tool from the toolbar and **highlight the section of data to which you would like to set the approval code. If you wish to set the same approval code for the entire deployment period use the “Mark All Region” tool**  **to select the entire data range.**
3. Next, **click the drop-down menu under “Action”** (left side in the Correction Control pane). **Select “Set Approval.”**
4. Next, **select the appropriate approval code from the “Approval” drop-down menu.** The assigned approval code depends on the data’s status. Use the following as a guide to choosing an approval code.
 - a. Working: The data have been imported to Aquarius but have not been reviewed, error-checked, corrected, or graded.
 - b. In Review: The data are being processed and checked for errors and outliers. The data may have been corrected and graded but have not been double-checked by a supervisor or received subsequent analysis.
 - c. Approved: The data have been corrected, graded, and error-checked. The data are certified and ready for export and analysis.
5. After double-checking the approval code, data grade, and data corrections, click the **“Save data to output ports and exit”** icon . You should now have one active output port on the “Data Correction” toolbox.

Signal Joining

The “Signal Joining” toolbox allows you to join the signals from multiple deployment periods. Joining signals allows the user to perform descriptive statistic functions on the entire season’s data set or on a monthly basis. **Signal joining requires multiple signals. If you have only one signal you will need to bypass this step and wire the output port from the “Data Correction” toolbox directly to the input port on the “Descriptive Statistics” toolbox.**

1. **Connect multiple deployment signals to the signal joining input ports.** If you need additional input ports, right click on the “Signal Joining” toolbox and select **“Properties Pane”**. Change the number of input ports. If you have more input ports than signals the toolbox will not function.
2. Double click the **“Signal Joining”** toolbox.
3. The “Signal Joining” window will appear (Figure SOP 10-11). Each signal (deployment period) will appear as a different color on the graph. Make sure the check boxes are selected under **“Include Corrections?”** in the “Signal Joining Properties” section of the “Time Series Manager” pane.
4. Click the **“Save data to output ports and exit”** icon  on the toolbar. You should now have one active output port on the “Signal Joining” toolbox.

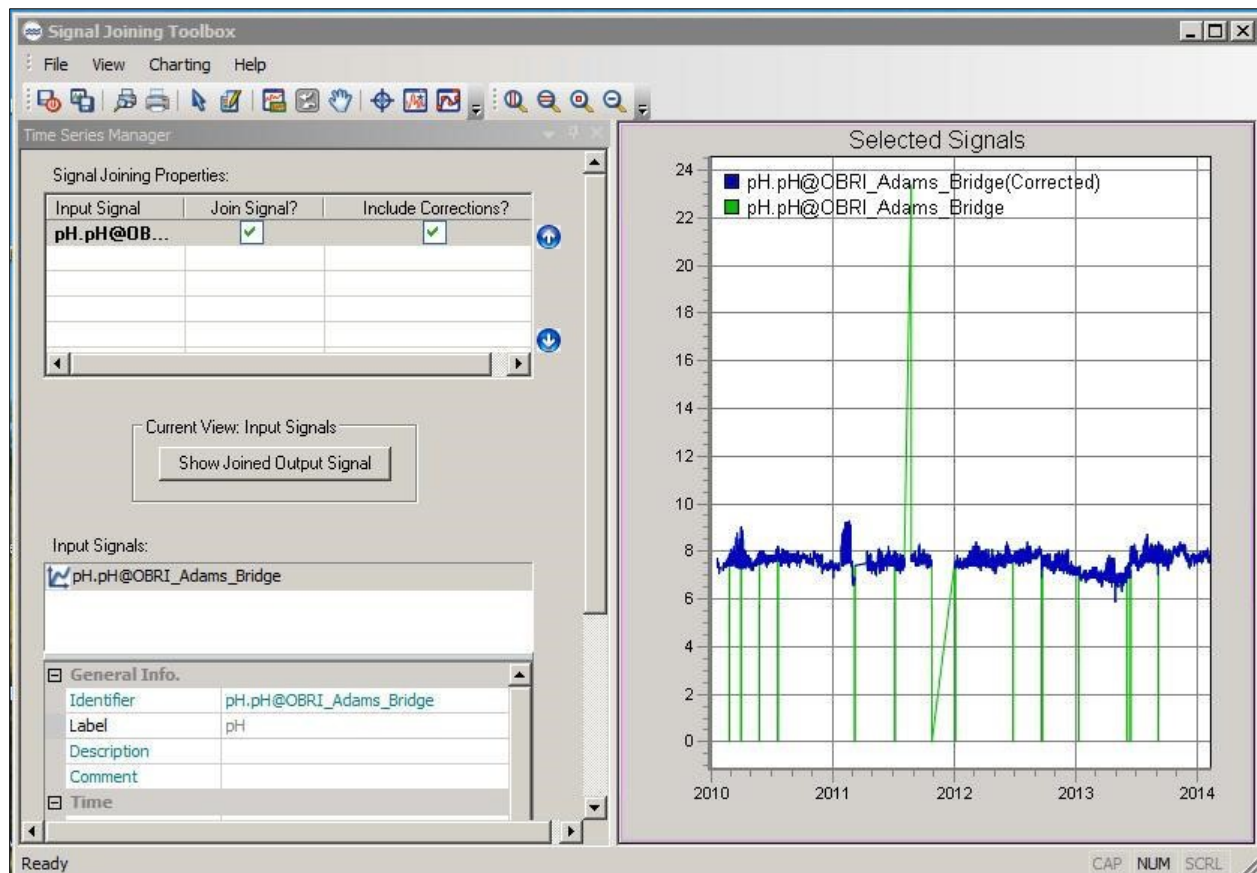


Figure SOP 10-11. Signal joining toolbox.

Write to Server

The “Write to Server” toolbox allows you to write results back to the server.

1. **Connect the “Signal Joining” output port to the “Write to Server” toolbox.**

2. Double click the **“Write to Server”** toolbox.
3. The **“Write to Server”** window will appear (Figure SOP 10-12). Under “Data Set” you will find the data sets that have been corrected. Each will have a status of “Found.” Click on the Blue arrow above Data Set to “update selected item in database.” Once the data set has been updated the status will change to “Updated.”
4. Click **“File”** then **“Exit.”**

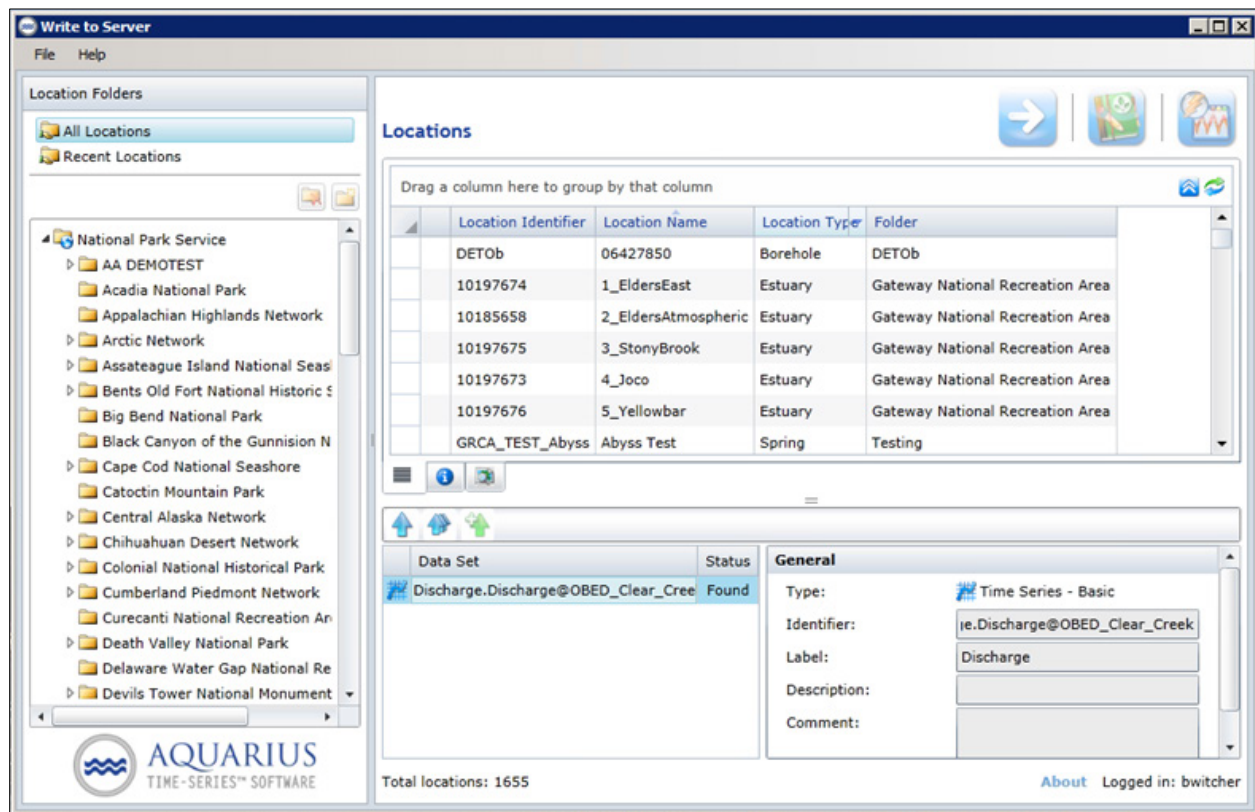


Figure SOP 10-12. Write to Server toolbox.

Graphing

Two toolboxes allow the user to produce a graph suitable for export to a publication. The “Quick View” toolbox is the easiest to use, yet it does not have the flexibility of the “Charting” toolbox. The user can decide which toolbox will work best for specific graphical needs. It is important to note a user can either graph the entire set of raw or corrected data, or can analyze the data with the “Descriptive Statistics” toolbox first and subsequently graph summarized data (i.e., daily max, min, mean). The order of operations depends on specific needs. The following graphing instructions are to be used once data has been corrected and written back to the server.

Quick View:

1. Begin with a new Whiteboard and add a **“Read from Server”** toolbox. Double click and select the data set that you would like to graph. Connect the **“Read from Server”** toolbox to the **“Quick View”** toolbox, **or** right click the **“Read from Server”** output port, and select **“Quick View”** (if you choose this option skip to step 3).
2. Double click the **“Quick View”** toolbox.
3. The **“Quick View”** graphing window should open. You can zoom to specific dates or graph the entire time period. Graph options can be edited by going to the **“Charting”** menu, then by clicking **“Properties.”**
4. For reports, change the grid lines to black and the frame to white.
5. Threshold flags initially established in the **“Auto QA/QC”** toolbox (prior to data correction) are not maintained after the data has been processed in the **“Data Correction”** toolbox. If you would like to view threshold flags after the signal has been joined, you must connect the **“Signal Joining”** toolbox to another **“Auto QA/QC”** toolbox and re-enter the flagging thresholds (see the Auto QA/QC section above). The **“Auto QA/QC”** toolbox can then be connected to the **“Quick View”** toolbox.
6. To view the threshold flags within the quick view window, click the **“Select Active Flag”** icon  from the toolbar. Then choose the threshold rule you established in the **“Auto QA/QC”** toolbox.
7. To export the graph, go to the **“File”** menu and select **“Save Chart Image.”**

Charting:

1. Begin with a new Whiteboard and add a **“Read from Server”** toolbox. Double click and select the data set that you would like to graph. Connect the **“Read from Server”** toolbox to the **“Charting”** toolbox.
2. Double click the **“Charting”** toolbox.
3. The **“Charting”** window should open. It will automatically graph both the raw and corrected data. The raw or corrected signals can be turned on and off by going to the **“Chart”** menu and selecting **“Show/Hide Series.”**
4. To customize the chart, go to the **“View”** menu and select **“Chart Options.”**
5. If you want to add an additional Y axis, go to the **“Chart”** menu and select **“Multiple Y-Axis.”**
6. Note that no threshold flagging option is available from this toolbox.

7. After you have formatted the graph, save the settings as a template for future use. This will help you produce standardized graphs for each parameter. To save the template go to the **“File”** menu and select **“Save as Template.”**
8. To export the graph, go to the **“File”** menu and select **“Save Chart Image.”**
9. **Note:** If you close the **“Charting”** toolbox you will lose your graph.

Descriptive Statistics

1. Begin with a new Whiteboard and add a **“Read from Server”** toolbox. Double click and select the data set that you would like to graph. Connect the **“Read from Server”** toolbox to the **“Descriptive Statistics”** toolbox.
2. Specify the time period and the types of statistics to report by filling in the appropriate fields and checking the appropriate boxes. Checking the left box next to each statistic will generate an output port. For example, if both boxes were checked next to mean, minimum and maximum, and the time period was set at “daily,” it would generate three output ports. These output ports contain the daily mean, minimum and maximum. Those values could then be graphed using the **“Quick View”** or the **“Charting Toolbox.”**
3. It is also possible to specify thresholds in this toolbox and calculate the **“number of days”** the parameter exceeded the threshold. The **“Days Above”** and **“Days Below”** values are calculated based on the number of hours the parameter exceeded the threshold and not the actual number of days the parameter peaked above or below that threshold. For example, (Figures SOP 10-13 and SOP 10-14), if dissolved oxygen was below 6 mg/L during eight samples (one sample per hour) Aquarius would say it was below the threshold 0.333 days (eight-hourly samples per 24 hours). Dissolved oxygen was actually below the threshold on four separate days. This is important when compiling annual reports.
4. Within the **“Input Time Series Control”** pane you can specify that you would like to run statistics on days with a specific grade and data coverage. These settings are described in detail in the Aquarius user manual. This manual can be accessed by clicking on the **“Help”** menu and selecting **“Descriptive Statistics Toolbox Manual.”**
5. Click **“Compute”** and the results will be displayed within the same window.
6. To save the results to the output port, click the icon **“Save Data to Output Ports and Exit”**



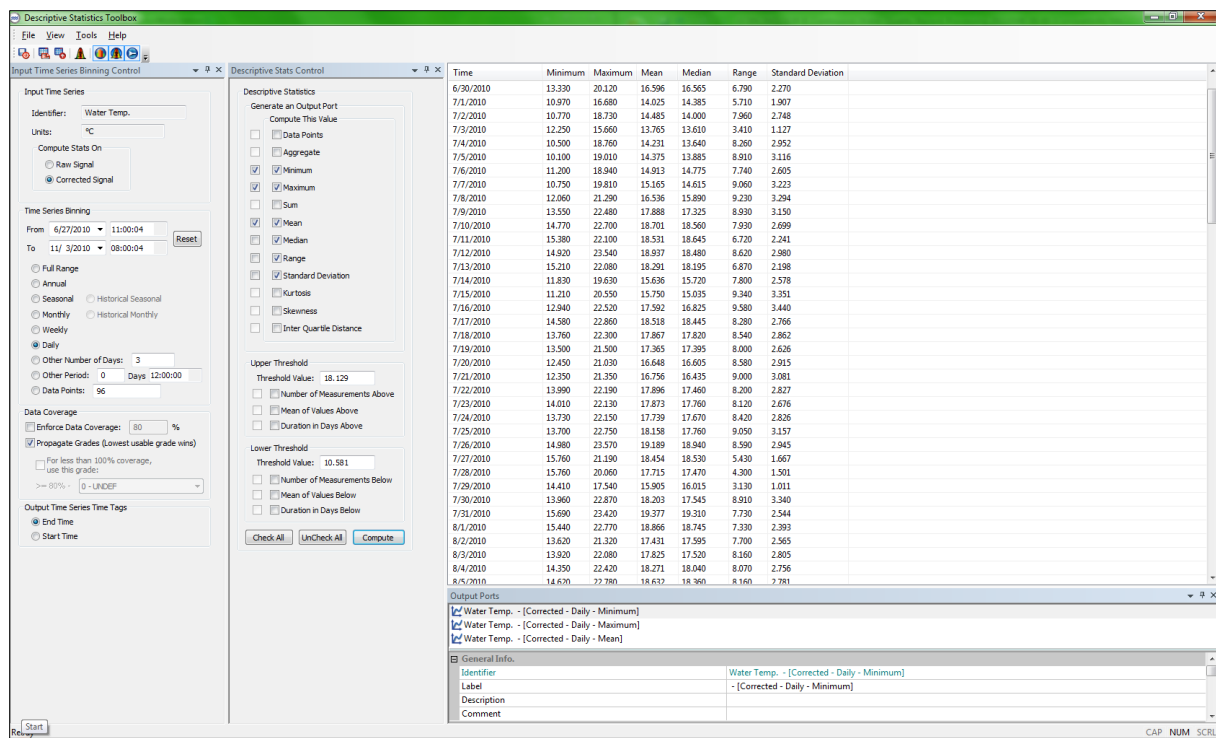


Figure SOP 10-13. Descriptive statistics toolbox.

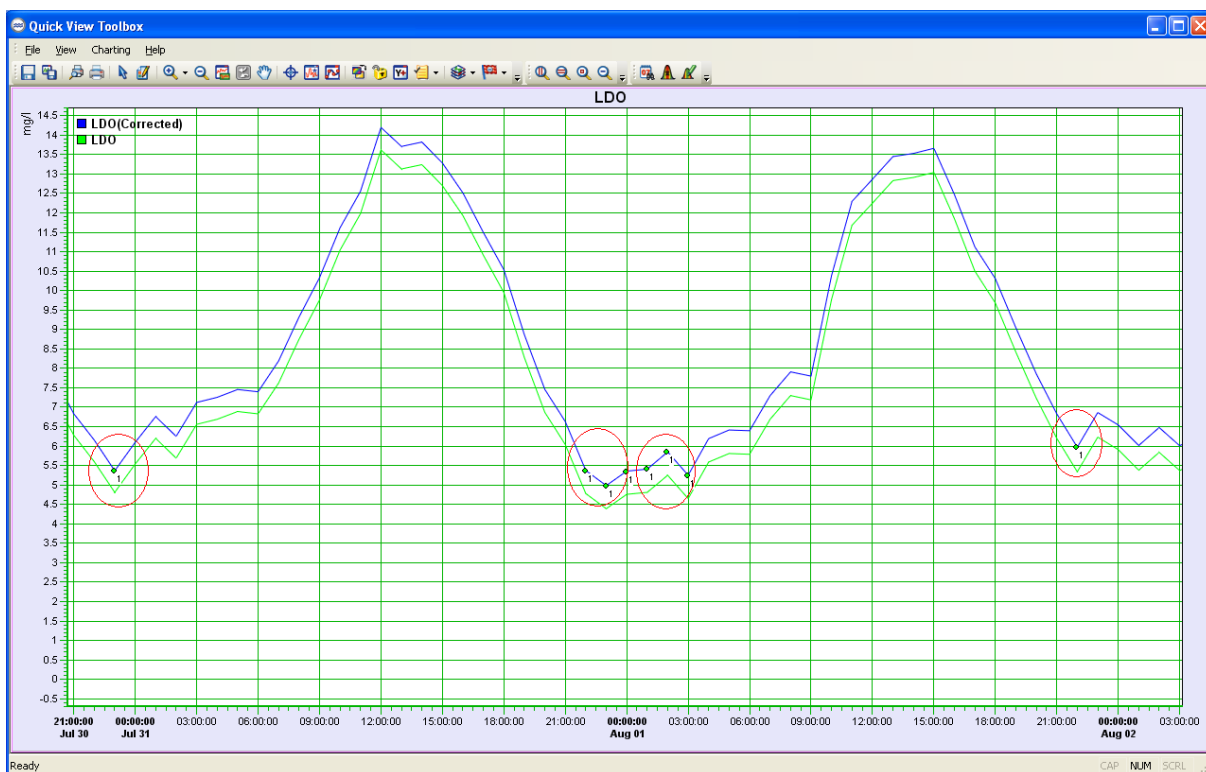


Figure SOP 10-14. Illustration of threshold flagging for dissolved oxygen. Values below 6.0 mg/L are flagged with green dots. Red circles indicate the days when dissolved oxygen was below 6.0 mg/L.

Export

At the end of each season, a cumulative file of all stations should be exported and saved on the APHN server:

1. Aquarius Output File (AOP) for each parameter—Aquarius-specific file (carries all data corrections and grading)
2. Corrected data file (will include all parameters)—CSV format
3. Correction history file for each parameter—CSV format
4. Data grade/rating file for each parameter—CSV format

Other files that do not require export but should be copied and saved on the APHN server include:

1. Workstation file for each monitoring station—Aquarius-specific file
2. Configuration file for each monitoring station—Aquarius-specific file
3. Site inspection summary worksheets for each deployment/station

The procedure for exporting the AOP and corrected data files is:

1. Wire the **“Signal Joining”** toolbox for each parameter to the **“Export to File”** toolbox. Adjust the number of input ports on the “Export to File” toolbox by right clicking the toolbox and selecting **“Properties Pane.”** Once this pane opens, change the number of input ports to match the number of parameters on your whiteboard.
2. Double-click the **“Export to File”** toolbox. The “Export to File” window will open (Figure SOP 10-15).

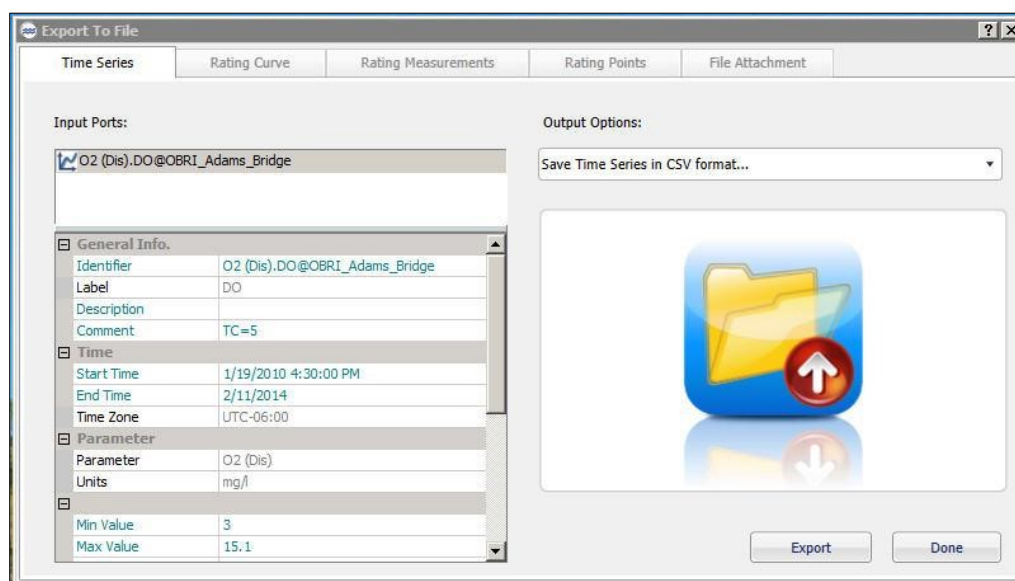


Figure SOP 10-15. Export to file toolbox.

3. Make sure all of the parameters are listed in the “Input Ports” box.
4. Click on the first parameter in the list of input ports.

AOP File:

1. To export the AOP file select “**Save Selected Time Series in AOP Format**” from the drop-down menu under “**Output Options.**” Then click “**Export.**” Save the AOP file using established naming conventions (e.g., Water Temp. BISO_NewRiver_Temp_20100626-20101103). Repeat for each parameter.

Corrected/Raw Data File:

1. To export the corrected or raw data file select “**Save Time Series in CSV Format**” from the drop down menu under “**Output Options.**” Then click “**Export.**” The “Export to CSV” window will appear (Figure SOP 10-16).
2. Select the radio button for “**Entire Range.**”
3. **Select the first parameter from the list on the left.** When you have selected the first parameter, the “Available Columns” box should be populated.
4. **Select each column under the “Raw Data” tab and click “Add.”** Selected columns will become part of the data that will be exported.
5. **Click the “Corrected Data” tab.**
6. Select the first parameter from the list on the left again. When you have selected the first parameter, the “**Available Columns**” box should again be populated, but this time with the corrected data.
7. **Select each column under the “Corrected Data” tab and click “Add.”** The selected columns will become part of the exported data.
8. When all columns for both raw and corrected data have been added, click the checkboxes next to “**Append Time Series Statistics**” and “**Append Metadata Glossary.**”
9. To avoid this process in the future, save these settings as a configuration file by clicking “**Save Config.**”
10. Next, click “**Export**” and save the CSV file using established naming conventions (e.g., BISO_NewRiver_Output_All_Data_2010). Files are saved to Z:\Monitoring\WaterQuality\WQ_Protocol_Continuous_Sampling_Data. On an annual basis these files are uploaded to IRMA.
11. When finished, click “**Done.**”

Identifier	Units	Samples	Time Zone	Location Identifier
Turbidity.Turbidity@OBRI_Adams_Bridge	NTU	66704	UTC-05:00	OBRI_Adams_Bridge

Data Reporting Range

Time Zone: UTC-05:00

Start Date: 1/1/2011

End Date: 12/31/2011

Data Processing

Processing Type: (None)

Resampling Interval: Hourly

Starting Time: 12:00 AM

Advanced... Export to Chart Export to CSV Cancel

Figure SOP 10-16. Export to CSV window.

Correction History File:

1. Connect the **“Signal Joining”** toolbox for a single parameter to a new **“Data Correction”** toolbox.
2. Double click the **“Data Correction”** toolbox. The data correction window should open.
3. Check that the entire season’s data are displayed in the graph. Below the graph, there should be a series of colors indicating each deployment period’s data grade.
4. Go to the “File” menu. Select **“Export Corrections List”**. Save the file using established naming conventions (e.g., BISO_BigSouthFork_001_Correction_history_of_SpCond_2010).
5. Repeat steps 1–4 for each parameter.
6. Do not close this toolbox. Continue by exporting the data grade or rating file.

Data Grade or Rating File:

1. After exporting the correction history file, you should still be within the “**Data Correction**” toolbox for a given parameter.
2. Go to the “File” menu. Select “**Export Grade List.**” Save the file using established naming conventions (e.g., BISO_BigSouthFork_001_Grade_List_SpCond_2010).
3. Repeat steps 1 and 2 for each parameter.
4. When finished, click the icon  “**Save Data to Output Ports and Exit.**”

Other Notes

It is important to save the whiteboard for future use. The naming convention for whiteboards should indicate the park, stream and last date of modification (e.g., OBRI_DaddysCreek_Workstation_20081103.aqw). If multiple datasondes are deployed within the same stream, it may be necessary to add the instrument or station number to the file name.

Literature Cited

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Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ11

Data Analysis and Reporting—Version 1.4

Please cite this as:

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Summary

This standard operating procedure (SOP) explains the procedures for analysis and reporting of Appalachian Highlands Network (APHN) data.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments	Addressing peer review comments	1.4

Overview

Perhaps the most critical task the Appalachian Highlands Network performs is evaluate long-term monitoring data and interpret the results for management, within the context of the APHN long-term monitoring objectives. The key audience for APHN monitoring results is park management, because managers are directly responsible for the monitored resources. The primary concern for the network is to present monitoring results in a timely fashion, in formats which best meet park needs. Where appropriate, monitoring results are shared as broadly as possible with park partners, National Park Service (NPS) staff and the public.

The task of analyzing data and interpreting results is ongoing. In the short-term, water quality anomalies can be viewed as they happen, allowing timely investigation and—when warranted—follow-up action by park managers. Over the regular reporting cycle, annual reports provide summary information on the status of water quality at each monitoring site. Trend and synthesis reports will be completed every five years, to place monitoring results in a broader context, both in space and time.

Alerts

Datasonde data will be evaluated daily, and events of concern that require further investigation will be described and forwarded to park managers as soon as it is practical. (Figure SOP 11-1). When possible, APHN staff will assist parks in identifying the sources of pollution events and describing their effects.

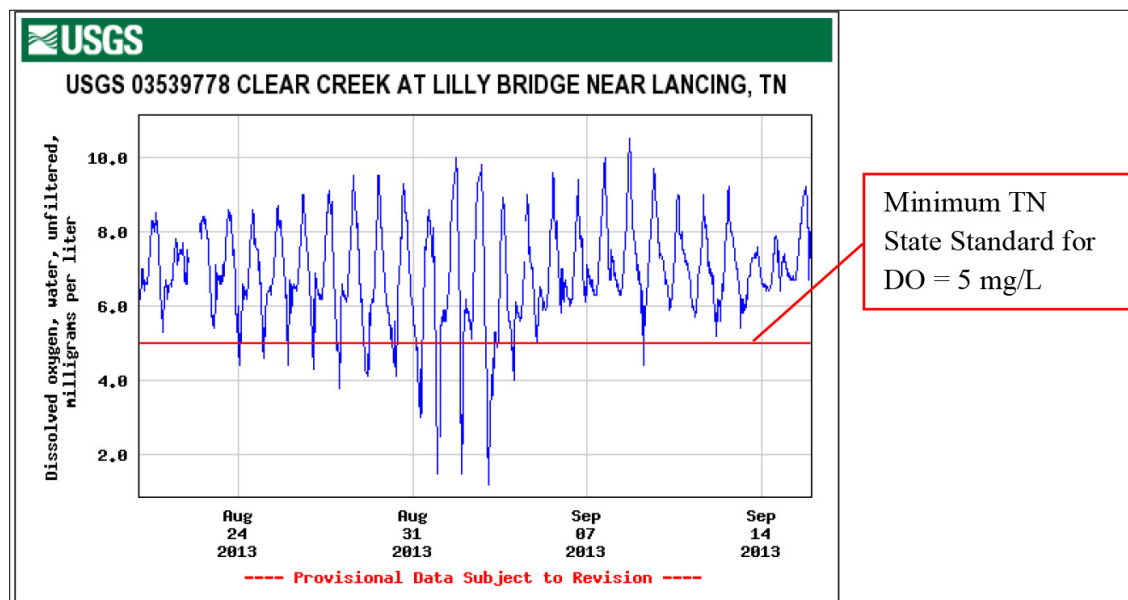


Figure SOP 11-1. Graph showing dissolved oxygen dipping below state standards for 12 consecutive nights, and below 2 mg/L for 3 nights, in late summer 2013. This was an extremely unusual event for this station, which is downstream of the most pristine watershed in Obed WSR. A field visit did not reveal fish kills or other evident biological effects. Oxygen sags during evening hours are related to respiration of macrophytes and algae and may reflect nuisance nutrient enrichment of surface waters.

Annual Reports

The Appalachian Highlands Network will provide annual reports to Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI) in two primary forms: annual status reports and resource briefs. Annual status reports will be published in the NPS Natural Resource Publications Management (NRPM) Natural Resource Reports (NRR) series and will receive an appropriate level of peer review. Status reports describe and summarize the results of monitoring efforts conducted during the previous water year (October 1 through September 30). The reports interpret results, supported by summary statistics and graphics; identify areas of concern; and provide a brief discussion of issues for management consideration. Data summaries will be provided in appendices. One challenge the network faces is to adequately characterize water quality in the parks in the absence of clear state standards for some water-quality constituents, or in situations where state standards are not appropriate for waters of the Cumberland Plateau. An example summary table and provisional water-quality standards are provided in Tables SOP 11-1 and SOP 11-2, respectively. The primary audience for annual status reports includes park superintendents and resource managers, as well as park staff, partners and the general public, as appropriate. These reports will be produced during the first quarter of the year following monitoring.

Resource briefs are short (two to four pages) annual summaries written for park managers, staff and park partners, in brochure or newsletter form, that summarize the status of water quality during the past year, and provide highlights of findings. These briefs will be completed as soon as possible after the end of the water year (September 30) so that findings will be current. To the extent possible, resource briefs will be illustrated with graphs, maps and photos and will incorporate a brief narrative about water quality in the parks that may be of interest not only to managers, but to park partners and the public. Status and trends in water quality will be summarized in a way that is both meaningful and easy to interpret. Example graphics that may be appropriate for resource briefs are presented in Table SOP 11-3 and Figure SOP 11-3. An example resource brief is provided in Appendix B.

Table SOP 11-1. Example report table showing summary statistics for January–June, 2012, for Obed River at Adams Bridge. Similar summary tables for all months of the reporting year for each of the five monitoring sites will be attached as appendices to annual data series reports. Raw and corrected data will be available upon request (in the table, “% valid n” is the proportion of possible data points for each month that were checked and approved). [$\mu\text{S}/\text{cm}$ —microsiemens per centimeter; C—Celsius; mg/L —milligrams per liter; NTU—nephelometric turbidity units].

Month	Statistic	Specific Conductance ($\mu\text{S}/\text{cm}$)	Temp ($^{\circ}\text{C}$)	DO (mg/L)	pH	Turbidity (NTU)
January (n=1,488)	Mean	82.5	6.09	11.97	7.44	7.1
	StDev	11.7	1.98	0.68	0.09	10.7
	Maximum	125	10.1	13.6	7.8	65
	Minimum	64	1.8	10.6	7.3	0
	% valid n	89.99	90.12	90.12	90.18	90.12
February (n=1,392)	Mean	84.4	8.14	11.75	7.55	4.1
	StDev	10.6	2.03	0.74	0.16	4.21
	Maximum	136	10.9	13.8	8.2	34
	Minimum	70	1.4	10.2	7.3	1
	% valid n	100	100	100	100	85.56
March (n=1,488)	Mean	83.1	12.64	10.16	7.60	3.30
	StDev	8.4	2.87	0.96	0.20	3.39
	Maximum	127	16.6	13	8.4	31
	Minimum	67	6.3	8	7.2	1
	% valid n	100	100	100	100	44.79
April (n=1,400)	Mean	104.6	14.79	9.16	7.56	3.45
	StDev	25.5	2.03	0.78	0.16	4.8
	Maximum	172	19.7	11.2	8.1	83
	Minimum	65	10.2	7.3	7.2	1
	% valid n	99.86	99.86	99.86	99.86	56.72
May (n=1,488)	Mean	152.2	17.84	8.15	7.55	6.6
	StDev	34.1	1.91	0.90	0.18	14.0
	Maximum	254	22.3	9.8	8	143
	Minimum	90	14.6	5.9	7.1	0

Month	Statistic	Specific Conductance (µS /cm)	Temp (°C)	DO (mg/L)	pH	Turbidity (NTU)
	% valid n	99.87	100	100	100	99.4
June (n=1,440)	Mean	273.8	19.84	8.08	7.75	1.7
	StDev	55.2	1.73	0.80	0.18	1.6
	Maximum	347	25.2	10.6	8.4	26
	Minimum	153	15.8	6.2	7.3	0
	% valid n	99.86	99.86	99.86	99.86	90.10

Table SOP 11-2. Tennessee and Kentucky water-quality (WQ) criteria for fish and aquatic life, and typical water-quality values in headwater streams at BISO and OBRI (from Rikard et al. 1986). [µS/cm—microsiemens per centimeter; NTU—nephelometric turbidity units; C—Celsius; mg/L—milligrams per liter].

Parameter	Tenn. WQ Criteria (2013)	KY Surface Water Standards (2013)	Typical WQ Values in BISO, OBRI Headwater Streams
Conductivity (µS/cm)	n/a	shall not adversely affect the indigenous aquatic community	≤ 30 (sandstone); ≤ 60 (limestone)
pH	6.5–9.0; shall not change more than 1 unit over a 24-hour period	6.0–9.0; shall not change more than 1 unit over a 24-hour period	5.5–7.0 (sandstone); 6.0–7.5 (limestone)
Turbidity (NTUs)	shall not materially affect fish and aquatic life	shall not adversely affect the indigenous aquatic community	< 10
Temperature (°C)	≤ 30.5; shall not change more than 2°C per hour	≤31.7; the normal fluctuation of temp shall be maintained	0–25.0
Dissolved Oxygen (mg/L)	≥5.0	≥5.0 as a 24 hour average; ≥4.0 at any time	≥5.0

Table SOP 11-3. Example summary table showing water quality status and trends for two continuous monitoring sites for 2013. [$\mu\text{s}/\text{cm}$ —microsiemens per centimeter].

Priority Resource or Site	Specific Measure	Condition Status/ Trend	Reference Condition/Resource Condition Comments
Water quality— New River, at New River	pH, temperature, dissolved oxygen, conductivity, turbidity		Results show continued high conductivity during 2013—above 150 $\mu\text{s}/\text{cm}$ for 7 months, and above 300 $\mu\text{s}/\text{cm}$ for most of November, a level thought to be detrimental to mussels. Turbidity monitoring at New River also indicates that the New River turbidity routinely exceeds 250 NTUs in response to runoff events.
Water quality— Obed River, at Adams Bridge	pH, temperature, dissolved oxygen, conductivity, turbidity		Data indicate elevated conductivity during 2013, with values regularly exceeding 300 $\mu\text{s}/\text{cm}$ in the summer, during low flow, a level thought to be detrimental for mussels. Water quality is good further downstream, above Daddy's Creek and at Alley Ford.

Condition Status	Trend in Condition	Confidence in Assessment
 Warrants Significant Concern	 Condition is Improving	 High
 Warrants Moderate Concern	 Condition is Unchanging	 Medium
 Resource is in Good Condition	 Condition is Deteriorating	 Low

Figure SOP 11-2. Status and Trends key

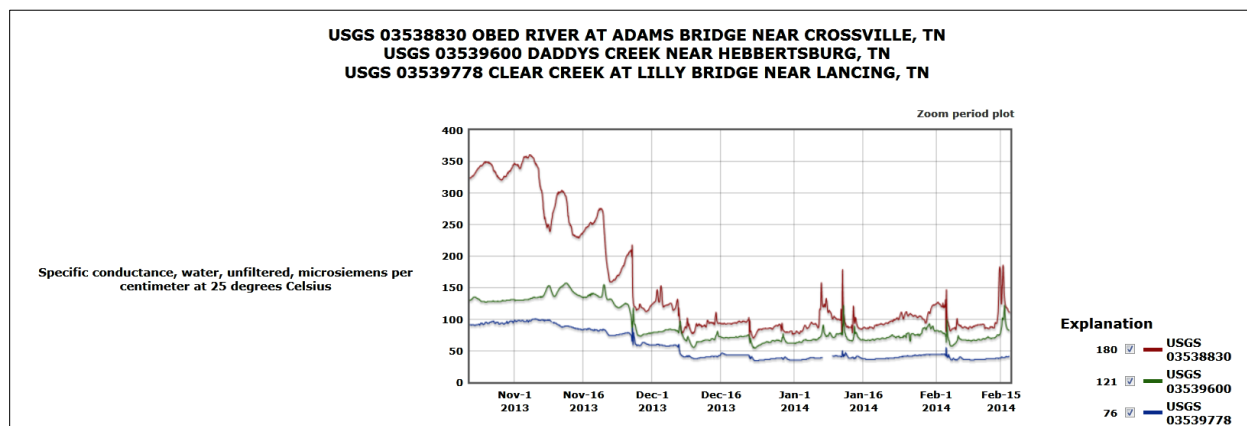


Figure SOP 11-3. Graph showing specific conductance in Obed River (red line), Daddy's Creek (green), and Clear Creek (blue), the three major tributaries which comprise Obed Wild and Scenic River, from mid-October 2013 to mid-February 2014. Perennially high specific conductance at Adams Bridge at the upstream boundary of the park is an indication of urbanization in the Obed watershed. The largest known population of the federally endangered purple bean mussel (*Villosa perpurpurea*) in the park has disappeared in recent years from a site downstream of this station.

Synthesis and Trend Reports

Synthesis and /trend reports will be prepared every five years, unless network and park staff agree more frequent intervals would be beneficial. These reports often have multiple objectives, and attempt to place monitoring results in a broader regional and historical context. Analyses may include data sets from related projects, including other network monitoring, academic research, and studies of federal and state agencies working within the region. Management recommendations are often provided in these reports. As long-term data are accumulated, the potential for significant in-depth analyses within parks, and across the region, will continue to improve.

As an example for this protocol, the network tested for trends and power using four years of data from the site with the longest history of monitoring—Obed River, Adams Bridge. Trends were analyzed with the seasonal Kendall test. This commonly used non-parametric test is performed on median values, rather than means, and works well with data that are not normally distributed and that commonly contain outliers, both of which are characteristic of APHN data, and of water quality-monitoring data in general (Helsel and Hirsch 2002). The code for running the trend test in R software was developed by Irvine et al. (2012) and adjusted to accommodate this data set (Appendix A). The seasonal Kendall test determines if there is a trend common to all seasons across years. “Seasons” can be defined as any period of time we want to test for, for example, trends may be examined across all Januarys, or all Februarys, to see if there is a trend common to all months. The test removes variability due to season, improving overall trend estimates for each water-quality parameter. If there is a linear relationship between streamflow and a particular parameter, the water-quality data can be adjusted to account for variability due to flow, improving the overall estimates of trends in the water-quality parameters. A flow adjustment procedure is included in the R code mentioned earlier in this section.

The seasonal Kendall test for trends generally produces valid results if the product of the number of years and the number of seasons tested for is greater than 25 (Helsel and Hirsch 2002). This example included four years of data with 12 monthly medians per year, likely adequate for running the test. Results showed a small but statistically significant declining trend in median monthly temperature, and no trends in the remaining four parameters (conductivity, pH, DO, turbidity). P-values from the trend test were:

Table SOP 11-4. Summary table showing seasonal Kendall water quality trends for a continuous monitoring station (Obed River at Adams Bridge) for 2009 through 2013.

	Conductance	Dissolved oxygen	pH	Temperature	Turbidity
P-value	0.176	0.205	0.268	0.040	0.128

In this example, a “p-value” of less than 0.05 signified a statistically significant trend. In this case the p-value is lower than the default alpha value of 0.05. Alpha is the probability of a 'Type I' error, or the chance of detecting a trend when one does not exist. A p-value lower than alpha indicates an

acceptable level of confidence that the detected trend is a true trend. If alpha is set higher, the ability to detect trends improves, but the likelihood of a Type I error also increases. A higher alpha (e.g., 0.10) is sometimes used in long-term monitoring, to ensure potential trends are brought to the attention of managers, even if there is a higher chance that the trend is not truly present.

Because temperature exhibited a linear correlation with flow (Figure SOP 11-4), the flow adjustment procedure was run on temperature data (removing the variability in temperature due to flow) and the trend test was repeated. With the influence of flow removed, the trend in temperature was no longer statistically significant ($p = 0.0899$).

Power to detect trends (i.e., ability to detect trends when they actually exist) will also be provided in APHN trend reports. An example power analysis was performed for this protocol, using the Obed River, Adams Bridge data. Again, the procedure and the R code for running the test were developed by Irvine et al. (2012) and adjusted to accommodate this data set (Appendix A). The program uses the variability in monthly medians in the four years of existing data to simulate data for user-specified periods of time (5, 10, 15 and 20 years, in this example), and calculates the power to detect a user-specified uniform annual rate of change. In this example, power to detect year-to-year changes of 1% and 2.5% was tested for each of the five water-quality parameters. When conducting this analysis, consider the following: (1) the variability observed in the actual data used to generate simulated data for estimating power should be representative of the expected variability over the period of interest in the power calculations; (2) the measures to be used and the levels of change to be tested should be meaningful and realistic. For instance, it may be more ecologically meaningful to test for trends in maximum conductivity and maximum temperature, rather than median values (as used in this example). Additionally, because temperature and pH have arbitrary zero points, the percentage changes being tested must be reviewed to ensure that the results are meaningful. An analysis looking at a 20% change in temperature will provide very different results when the mean temperature is 2 degrees ($20\% = 0.4$ degrees) than it will when the mean temperature is 20 degrees ($20\% = 4.0$ degrees). Continuing investigation is needed to ensure the measures used are appropriate for APHN purposes.

The results of the power analysis are shown in Figure SOP 11-5. Power to detect a 2.5% per year change reaches nearly 100% after 10 years for the four parameters analyzed (the test was not run for turbidity, because the data proved to be too variable). Detection of a 1% per year change at 80% power takes less than 5, 8, 13 and 16 years for pH, dissolved oxygen, temperature, and conductivity, respectively. This result is very conservative for conductivity, which has a strong non-linear relationship with flow, as shown in Figure SOP 11-4. Adjusting for variability in conductivity due to flow should improve power considerably (the adjustment was not made in this example).

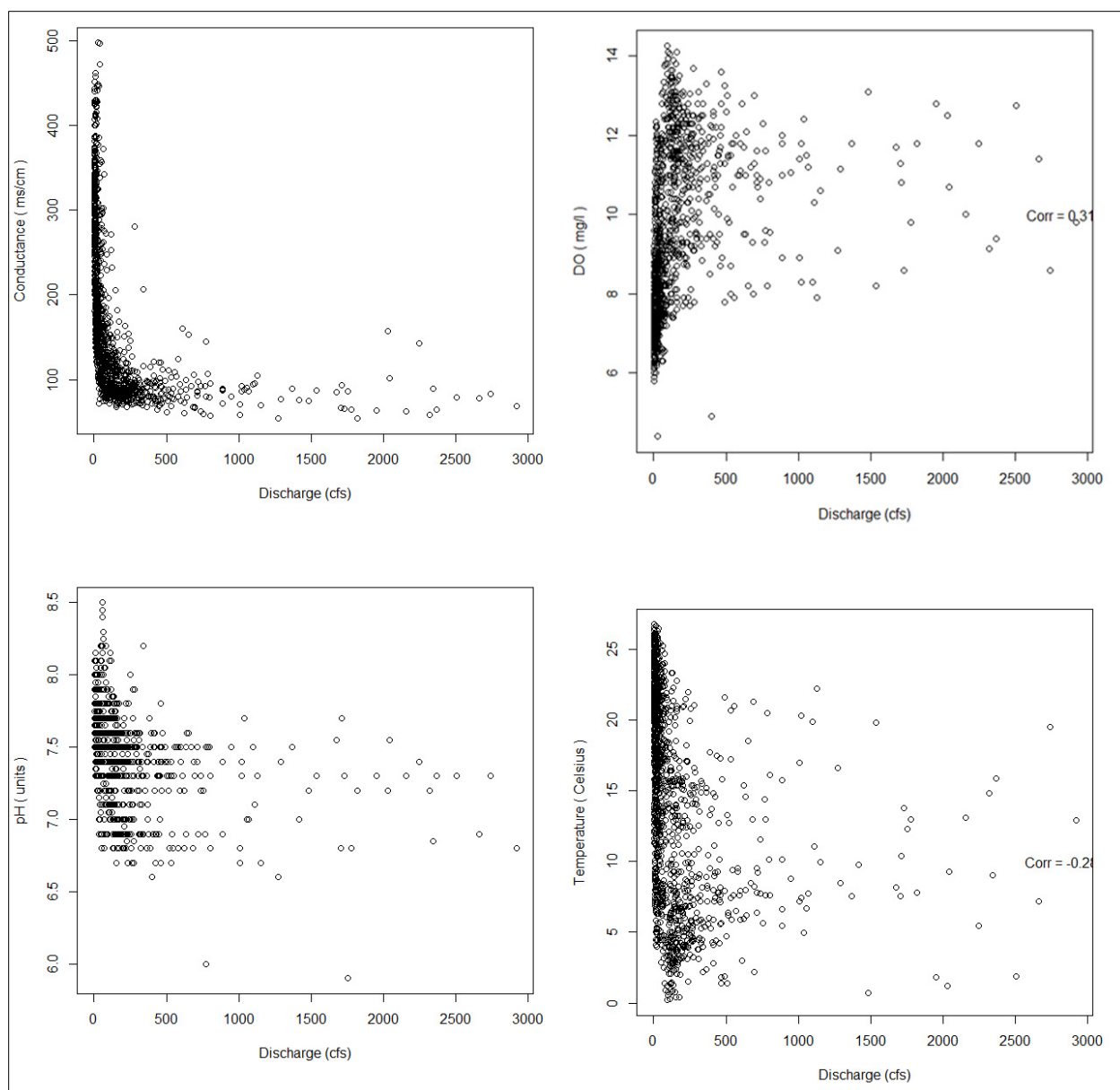


Figure SOP 11-4. Scatterplots of discharge (flow) versus daily medians of four water quality parameters. Conductivity exhibits a strong non-linear relationship with flow, which can, in principle, be used to improve estimates of trend and power for this parameter.

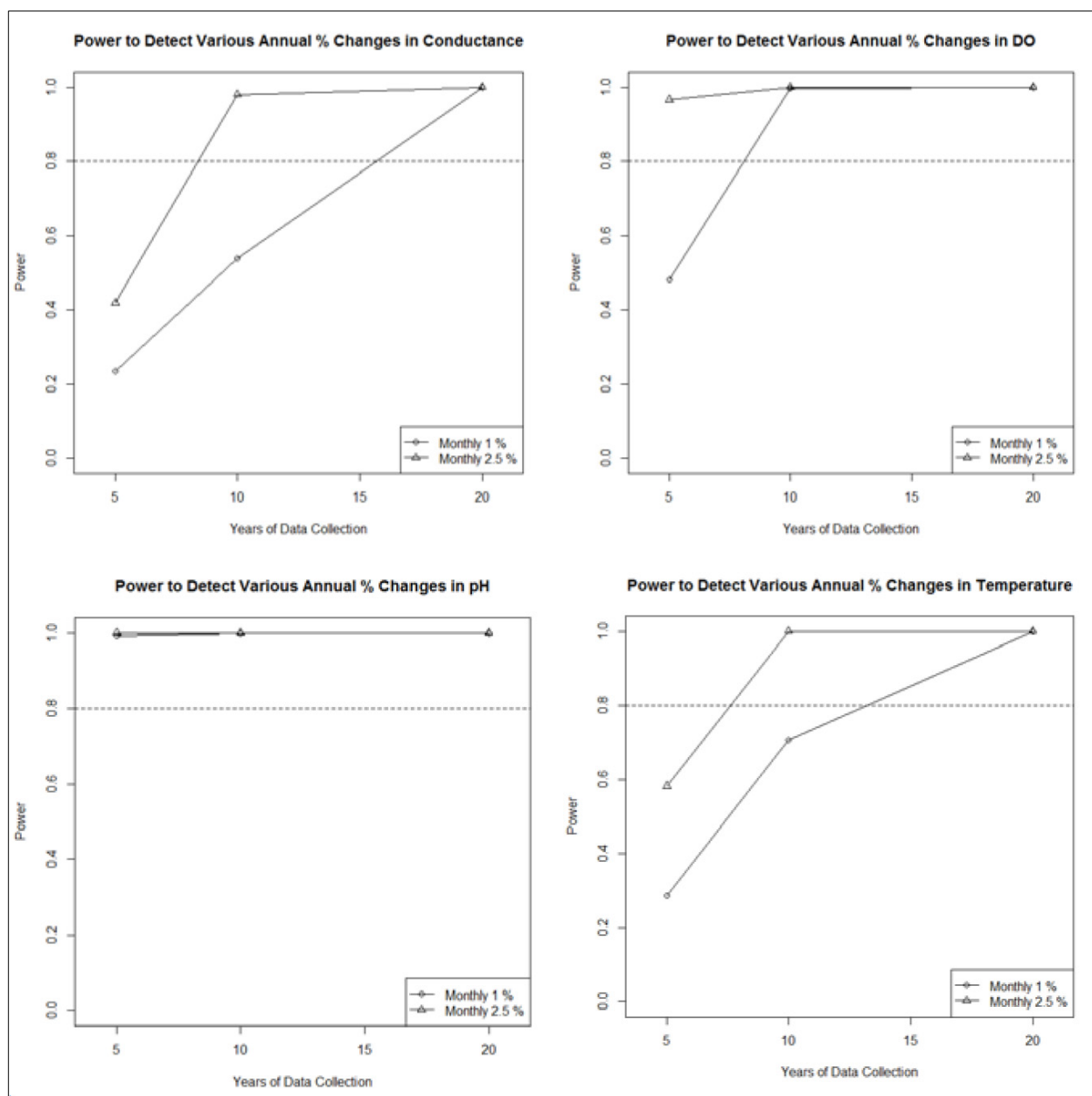


Figure SOP 11-5. Estimated power of the seasonal Kendall test to detect 1% and 2.5% per year changes in monthly medians in conductance, dissolved oxygen, temperature and pH (reading clockwise from the graph in the upper left) at Obed River, Adams Bridge, over 5, 10, 15 and 20 year sampling periods.

Journal Articles and Conference Presentations

When the opportunity arises, the publication of monitoring results in scientific journals will allow the Appalachian Highlands Network to reach the scientific community in a way that publication of internal NPS reports cannot. Peer-reviewed publications may promote investigation by members of the scientific community, either independently or in cooperation with the Appalachian Highlands Network. Ultimately, publication in peer-reviewed journals and the collaboration that ensues should foster a greater understanding of ecosystem components and processes. Similarly, presentation of

findings at conferences allow the network to reach broader audiences. All journal articles and presentations developed by the network will be discussed with and made available to parks prior to publication or presentation of their data.

Literature Cited

- Helsel, D. R., and Hirsch, R. M. 2002. Statistical methods in water resources: U.S. Geological Survey techniques of water-resources investigations, book 4, chap. A3. Available at: <http://water.usgs.gov/pubs/twri/twri4a3/> (last accessed March 2018).
- Irvine, K. M., K. Manlove and C. Hollimon. 2012. Power analysis and trend detection for water quality monitoring data: an application for the Greater Yellowstone Inventory and Monitoring Network. Natural Resource Report NPS/GRYN/NRR – 2012/556. National Park Service, Fort Collins, Colorado.
- Rikard, M., S. Kunkle, and J. Wilson. 1986. Big South Fork National River and Recreation Area water quality report – 1982-1984. Water Resources Report No. 86-7. National Park Service, Water Resources Division. Denver, Colorado.

Appendix A

Obed Power Analysis

Dr. Tim Robison

In this report, we discuss a framework for investigating the statistical power of detecting a trend in water-quality parameters. As pointed out by Irvine et al. (2012), water-quality parameters typically characterized by skewed, non-normal probability distributions and hence modeling is often best accomplished via nonparametric techniques. One of the most commonly used tests for trend in water resources is the seasonal Kendall test, a non-parametric approach designed to detect trends while simultaneously accounting for inherent seasonal variation (Helsel and Hirsch 2002). Irvine et al. (2012) developed an empirical bootstrap approach to estimate the power for trend detection using the seasonal Kendall test. This approach avoids any distributional assumptions, making it appealing for trend detection in water-quality parameters. The approach allows for conducting a power analysis for detecting monotonic trends of varying magnitude over different lengths of sampling and different collection frequencies for a particular sampling location. The approach is illustrated using data collected from Adams Bridge. The power analysis will be presented for detection of 1% and 2.5% per annum changes based on the assumption of available monthly median data over a four year time period (2010–2014). The water-quality parameters of interest are conductance, dissolved oxygen, pH, temperature and turbidity.

To utilize the adapted R code from Irvine et al. (2012; adapted for data involved five digit Julian dates vs. the four digit Julian dates utilized by Irvine et al. 2012) requires a specific format for data preparation. Data preparation should follow that prescribed by Irvine et al. (2012) in Appendix A. The adapted R-code to run the procedure with five digit Julian date data is provided in Appendix B. The details associated with the power analysis algorithm are provided in pp. 15-21 in Irvine et al. (2012).

Before illustrating the power calculations using the Adams Bridge site, it is important to highlight points made by Irvine et al. (2012) on the appropriate use of their procedure:

1. The user should thoughtfully consider the validity and quantity of the existing data utilized for the bootstrap re-sampling. The approach of Irvine et al. (2012) assumes the presence of an adequate amount of existing valid data. Here, there are four years of monthly medians available for the Adams Bridge site. Upon using the Irvine et al. (2012) approach, we are inherently assuming that the existing four years of monthly medians accurately reflects the year to year variation in monthly medians that one would expect in these parameters for the period of interest in the power computations. As an example, we have four values for the January median pH in our existing data (one value for each year 2010–2013). We are assuming the variation in these four medians is representative of what we would expect to see in pH over a 10-year period if we are examining power for a 10-year period. If we expect to see greater variation over a 10 year-period than we currently have in our four medians, then a parametric bootstrap could be implemented instead of the existing nonparametric bootstrap but this would have to be programmed apart from the program of Irvine et al. (2012).

2. The user should consider what a biologically meaningful rate of per annum change is to detect. We have arbitrarily assumed per annum rates of 1% and 2.5% are of interest but these values are easily changed by the user of the program.
3. The R-code of Irvine et al. (2012) assumes there are no ‘non-detections’ or missing values in the pilot data. If non-detects or missing values are present, they should be removed before running the R-code.
4. Flow weighting or flow adjustment should improve the ability to detect trend and hence elevate the reported power values. If the parameter of interest is highly correlated to flow, the approach of Irvine et al. (2012) will yield conservative estimates of power and a proper adjustment for flow will likely yield higher power values. In the Adams Bridge data, we will see that conductance and temperature have a strong relationship with flow and discharge.

Trend Analysis

Before reporting the power analysis on the water-quality parameters of interest, we will illustrate trend analyses of water-quality parameters using the code of Irvine et al. (2012), which follows the work of Alley (1988) and Hirsch et al. (1982). The analyses uses the data in the .csv file “AdamsBridge_trend.csv” as the input data file. A reference tutorial on the use of the Irvine et al. (2012) R code is provided in Appendix E of Irvine et al. (2012). Future analyses should format data as described on p. 25 of Irvine et al. (2012).

Seasonal Kendall (no flow adjustment)

The Seasonal Kendall test is a non-parametric test that assesses whether or not all seasons show the same trend over time. In the analyses presented here, “season” = “month.” Since the seasonal Kendall test statistic is one that tests for concordant trends across seasons (i.e. parallel trends across time in the monthly medians over years), it is possible to conclude there is no trend over time when, in fact, some months may be exhibiting an increasing trend over time while other months are exhibiting a decline over time. The net result in such a case is there is no significant trend over time since the positive and negative months would, in effect, cancel each other out. It is imperative to plot the data in order to properly interpret the p-value from the season Kendall test.

While the seasonal Kendall is a non-parametric test and is robust to the presence of outliers, an index plot of the water-quality parameter over time is useful to check for data entry errors or other anomalies in the data collection process. Figure SOP 11A-1 shows these index plots for conductance, dissolved oxygen, pH, temperature and turbidity, respectively.

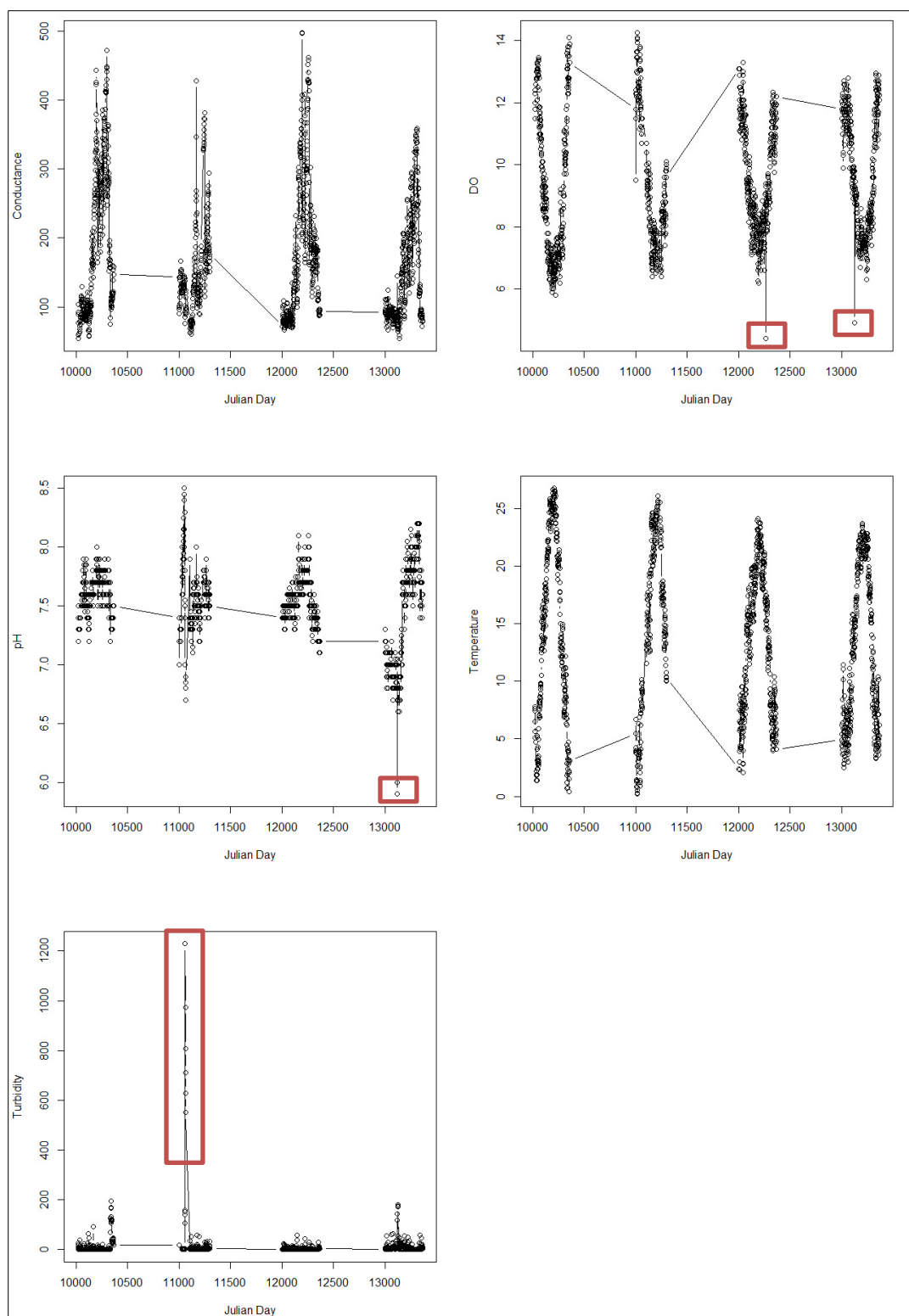


Figure SOP 11A-1. Index plots of conductance (a), dissolved oxygen (b), pH (c), temperature (d), and turbidity (e) vs. Julian Day. The plots exhibit the time series in these parameters and can be used to identify data entry errors or other anomalies in data collection. Red boxes indicate potential anomalies.

Once data entry errors and data anomalies are resolved, consider whether the parameter of interest is correlated to discharge. Figure SOP 11A-2 shows scatterplots of conductance, dissolved oxygen, pH, temperature and turbidity versus flow, respectively. Other than conductance, all parameters seem to suggest little, if any correlation with discharge. Consequently, no adjustment for discharge would appear to be helpful in the power analysis. In terms of conductance, however, an adjustment for discharge might be beneficial in terms of removing variation.

As mentioned earlier, the seasonal Kendall test is a test for concordant trends across months. For non-significant p-values (i.e. p-values > 0.05) it may be that months are exhibiting opposite patterns (increasing monthly medians for some months and decreasing monthly medians for others). As such, plots such as those provided in Figure SOP 11A-3 are an important component of the analysis. For all parameters the same general trend seems to exist across time for each of the 12 months, suggesting concordant trends across time.

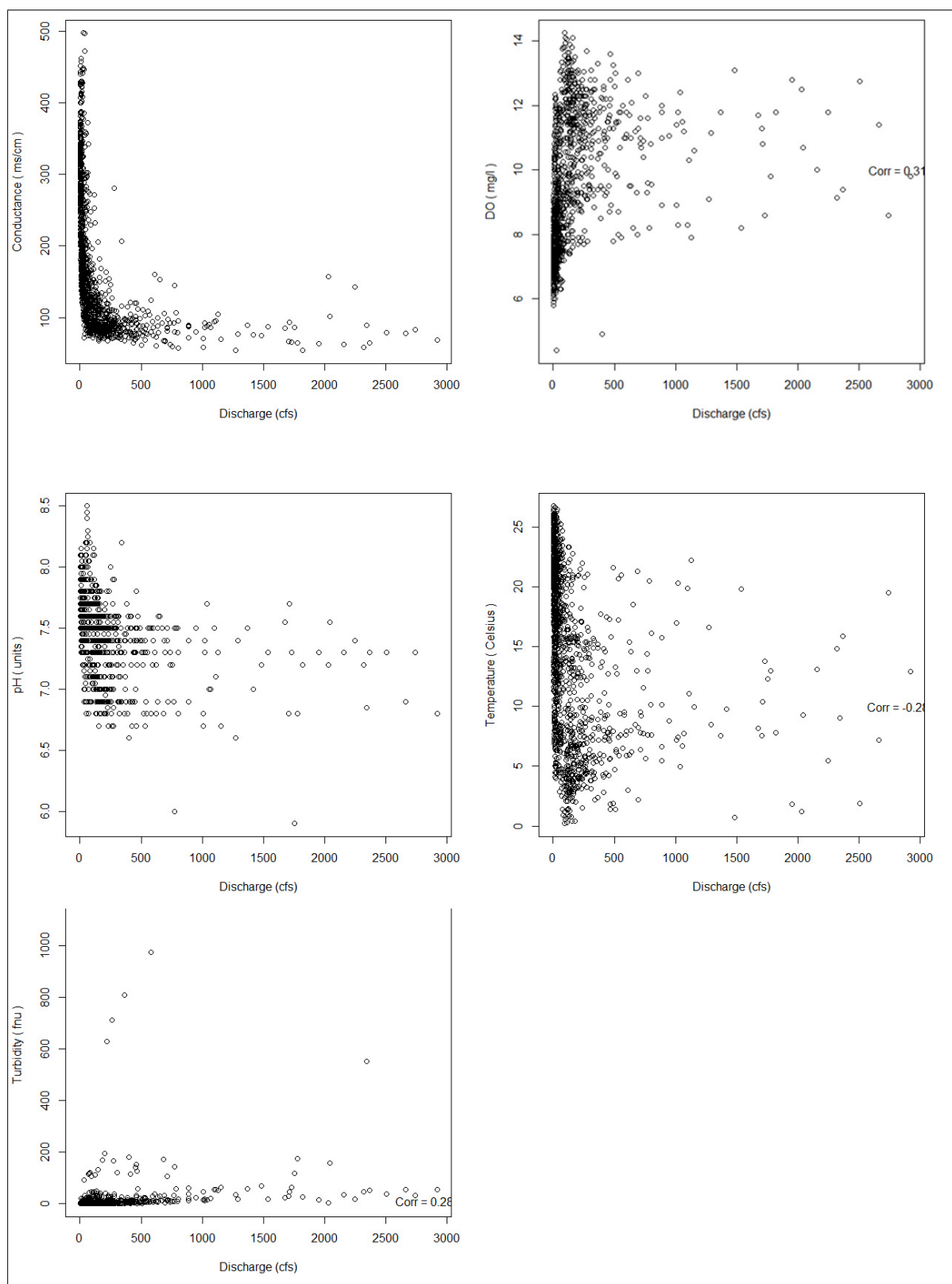


Figure SOP 11A-2. Scatterplots of conductance (a), dissolved oxygen (b), pH (c), temperature (d), and turbidity (e) vs. discharge.

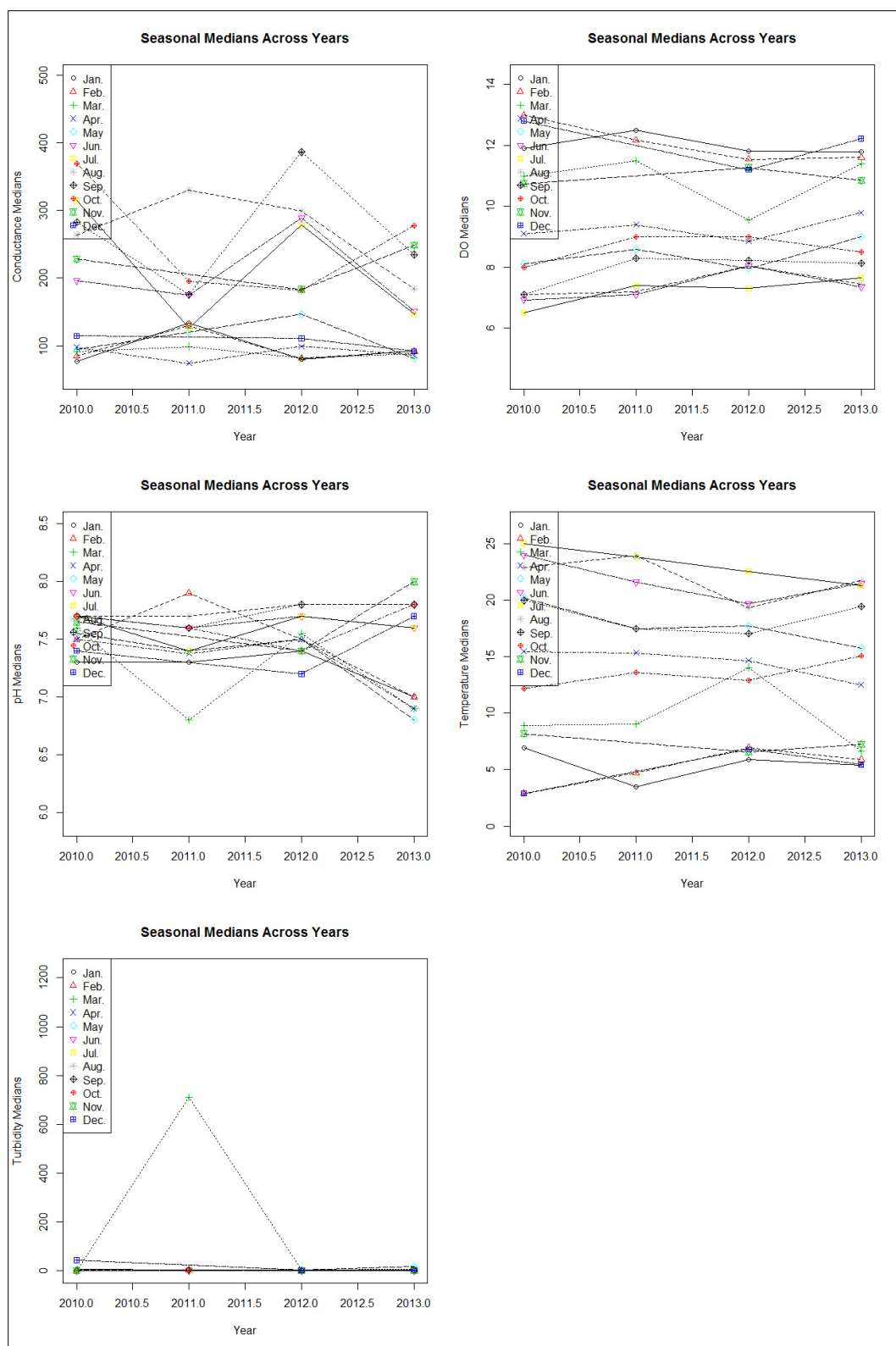


Figure SOP 11A-3. Monthly medians of conductance (a), dissolved oxygen (b), pH (c), temperature (d), and turbidity (e) and discharge over time. These median values are the data used in the seasonal Kendall test without flow adjustment.

Power

In Figure SOP 11A-4 we provide plots which show the estimated power for detecting 1% and 2.5% per annum changes in conductance (a), dissolved oxygen (b), pH (c), and temperature (d) for the Adam's Bridge site, assuming monthly sampling for periods of 5, 10, and 15 years. A power analysis of the turbidity data was not conducted due to the anomalies present with turbidity. As an example of the interpretation, Figure SOP 11A-4 suggests we achieve a little over 40% power to detect a 2.5% per annum change in the median conductance when we sample for five years and this increases to just over 95% power when we sample for 10 years. The power to detect changes in dissolved oxygen and pH is substantially higher than it is to detect the same magnitude changes in conductance and temperature.

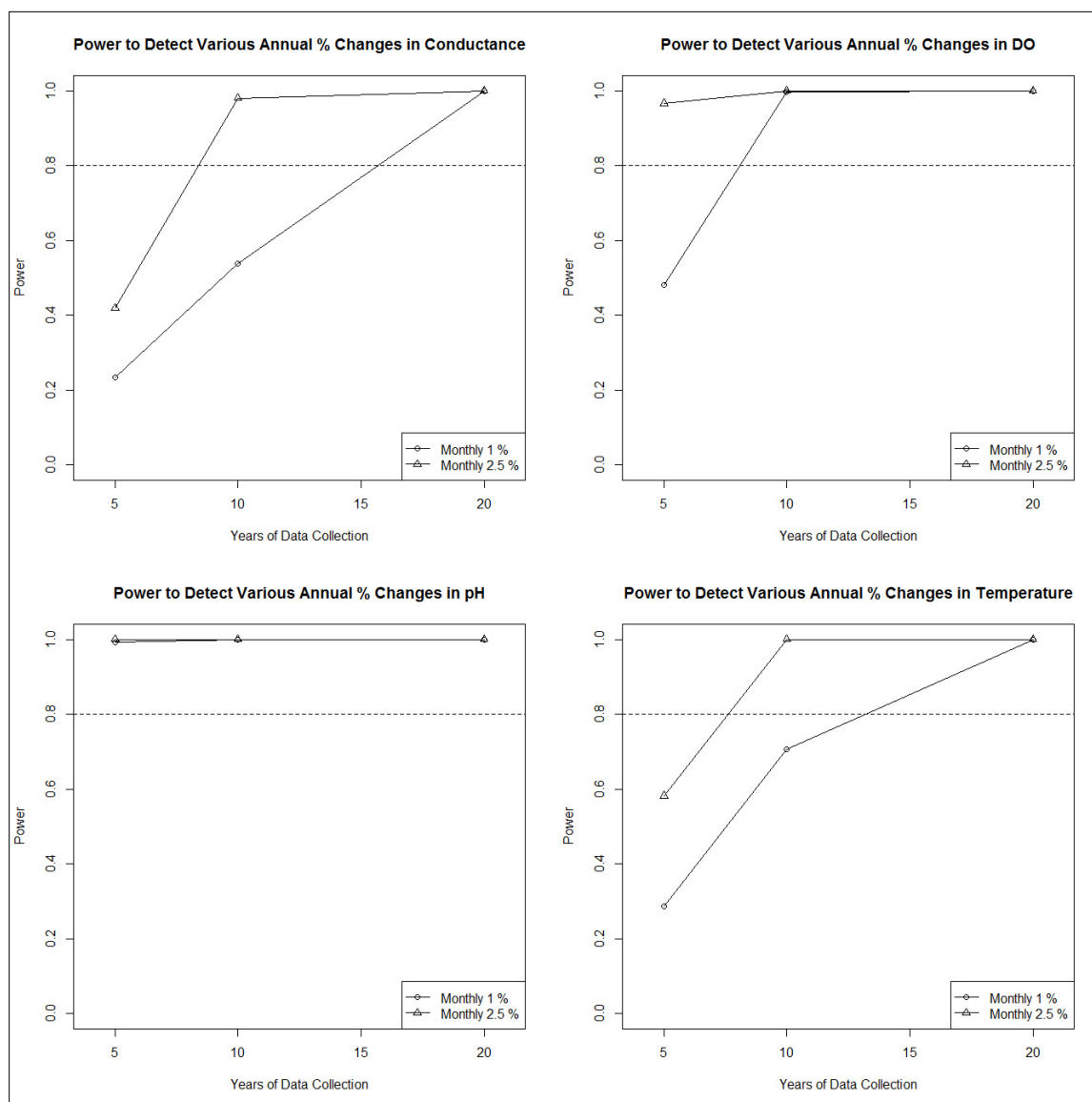


Figure SOP 11A-4. Estimated power of seasonal Kendall test to detect 1% and 2.5% per annum changes in conductance (a), dissolved oxygen (b), pH (c), and temperature (d) at Adam's Bridge for 5, 10, and 20 years of sampling using monthly medians

R Code

```
# Power Code for GRYN Water Quality Power Analysis

# Author: Kathi Irvine and Cynthia Hollimon

# Date: March 2012


# The following power code can be used to determine the power of
the Seasonal Mann Kendall test for detecting a given

# magnitude of trend.

# The procedure requires historic data to re-sample from in order
to estimate power.

# Also, the definition of season needs to be input by the user,
typically based on the hydrograph.

# We assume that one observation per season is available.


# SUBMIT THE FOLLOWING LINES OF CODE FROM

# HERE TO


library(Kendall)


## Kendall Functions

power.kendall<-function (x, y) {

  tau <- 0

  ptau <- 0

  sltau <- 0

  score <- 0

  varscore <- 0
```

```

denom <- 0

i <- !(is.na(x) | is.na(y))

x <- x[i]

y <- y[i]

iws <- numeric(length(x))

ifault <- 0

outF <- .Fortran("tauk2", as.single(x), as.single(y),
as.integer(length(x)),

    as.single(tau), as.single(ptau), as.single(sltau),
as.single(score),

    as.single(varscore), as.single(denom), as.integer(iws),
    as.integer(ifault), PACKAGE = "Kendall")

tau <- outF[[4]]

sl <- outF[[6]]

sc <- outF[[7]]

var.sc <- outF[[8]]

denom <- outF[[9]]

ier <- outF[[11]]

ans <- list(tau = tau, sl = sl, S = sc, D = denom, varS =
var.sc)

oldClass(ans) <- "Kendall"

ans
}

power.MannKendall<-function (x) {
    power.kendall(1:length(x), x)
}

```

```

Power.fun<-
function(data.in,alpha.level,nboot,change.of.interest,no.years,param.assigned,season.location,seasons,month.compare){

# INPUTS FOR POWER FUNCTION

#   data.in=
#   alpha.level
#   nboot
#   change.of.interest
#   no.years
#   param.assigned
#   season.location
#   seasons
#   month.compare


# definitions of hydrologic seasons

#BICA: Aug 10-April 14, April 15 - June 19, June 20- Aug. 9
#YELL: Nov 1 - April 15, April 16-June 15, June 16- Aug 15, Aug 16-Oct 31
#GRTE: Aug 15-April 14, April 15-June 9, June 10-Aug. 14


# translating to day of the year

```

```

seasons.GRTE<-c(228,105,106,161,162,227)

seasons.YELL<-c(306, 106,107,167,168,228,229,305)

seasons.BICA<-c(223,105,106,171,172,222)


# defining months instead of seasons


months <-
c(1,31,32,60,61,91,92,121,122,152,153,182,183,213,214,244,245,274,2
75,305,306,335,336,366)


###  subsetting to the parameter of interest


      param1<-
subset(data.in,data.in$ParamGroup==param.assigned)


      # creating a season variable


      day.of.year<-as.numeric(substr(param1$JulianDate,3,6))


# may need to be altered for different season definitions


if(missing(season.location)) season.intervals <- months else

      if(season.location=="GRTE") season.intervals<-seasons.GRTE
else

      if(season.location=="YELL") season.intervals<-
seasons.YELL  else

```

```

season.intervals<-seasons.BICA

if(length(season.intervals)/(2*seasons)!=1) print("Error Number of
Seasons and Season Location do not match")

if(month.compare == T | missing(season.location)) {month.var <-
numeric() #setting up month vars for comparison

  for(i in 1:length(day.of.year)) {

    {

      if(day.of.year[i] >=months[1]&day.of.year[i]<=months[2])
month.var[i] <- 1 else

      if(day.of.year[i] >=months[3]&day.of.year[i]<=months[4])
month.var[i] <- 2 else

      if(day.of.year[i] >=months[5]&day.of.year[i]<=months[6])
month.var[i] <- 3 else

      if(day.of.year[i] >=months[7]&day.of.year[i]<=months[8])
month.var[i] <- 4 else

      if(day.of.year[i] >=months[9]&day.of.year[i]<=months[10])
month.var[i] <- 5 else

      if(day.of.year[i] >=months[11]&day.of.year[i]<=months[12])
month.var[i] <- 6 else

      if(day.of.year[i] >=months[13]&day.of.year[i]<=months[14])
month.var[i] <- 7 else

      if(day.of.year[i] >=months[15]&day.of.year[i]<=months[16])
month.var[i] <- 8 else

      if(day.of.year[i] >=months[17]&day.of.year[i]<=months[18])
month.var[i] <- 9 else

      if(day.of.year[i] >=months[19]&day.of.year[i]<=months[20])
month.var[i] <- 10 else

      if(day.of.year[i] >=months[21]&day.of.year[i]<=months[22])
month.var[i] <- 11 else

```

```

        if(day.of.year[i] >=months[23]&day.of.year[i]<=months[24])
month.var[i] <- 12}}}
```

```

if(missing(season.location)) {season.var <- month.var} else  #if
running only a monthly analysis
```

```

if(season.location=="GRTE"|season.location=="BICA") {season.var<-
numeric()
```

```

    for(i in 1:length(day.of.year))
```

```

    {if(day.of.year[i]<=season.intervals[2]|day.of.year[i]>=season.inte
rvals[1]) season.var[i]<-1 else
```

```

    if(day.of.year[i]>=season.intervals[3]&day.of.year[i]<=season.inter
vals[4]) season.var[i]<-2 else
```

```

    if(day.of.year[i]>=season.intervals[5]&day.of.year[i]<=season.inter
vals[6]) season.var[i]<-3}} else
```

```

if(season.location=="YELL") {season.var<-numeric()
```

```

    for(i in 1:length(day.of.year))
```

```

    {
```

```

    if(day.of.year[i]<=season.intervals[2]|day.of.year[i]>=season.inter
vals[1]) season.var[i]<-1 else
```

```

    if(day.of.year[i]>=season.intervals[3]&day.of.year[i]<=season.inter
vals[4]) season.var[i]<-2 else
```

```
if(day.of.year[i]>=season.intervals[5]&day.of.year[i]<=season.intervals[6]) season.var[i]<-3 else
```

```
if(day.of.year[i]>=season.intervals[7]&day.of.year[i]<=season.intervals[8]) season.var[i]<-4
```

```
}}
```

```
Power.out<-
```

```
function(data.in,alpha.level,nboot,change.of.interest,no.years,param.assigned,season.location,seasons,season.var){ #new function loop
```

```
## Determine median values for the different seasons
```

```
medians<-tapply(param1$Result,season.var,median)
```

```
## Find a set of epsilon stars based on medians. keep residuals within Seasons!
```

```
epsilons<-rep(NA,dim(param1)[1])
```

```
epsilons<- param1$Result-  
medians[as.character(season.var)]
```

```
# de-trended by seasonal medians
```

```
# Build a bunch of storage objects
```

```

        tau<-
array(NA,dim=c(length(unique(season.var)),nboot,(length(no.years)))
)

        sktau<-matrix(NA,nrow=nboot,ncol=(length(no.years)))

        ts.out<-
matrix(NA,nrow=nboot,ncol=(length(no.years)))

        sim.out<-
matrix(NA,nrow=nboot,ncol=(length(no.years)))

        S<-
array(NA,dim=c(length(unique(season.var)),nboot,(length(no.years)))
)

        power<-rep(NA,(length(no.years)))

        power.mat<-
matrix(NA,(length(change.of.interest)),(length(no.years)))


        # Calculate denominator of Z-statistic for each timecut
(since it's based on sample size alone, we can do it at this point)

        # this is a normal approximation to the distribution of
the test-statistic as stated in equation 8


        denom.mat<-rep(NA,(length(no.years)))

        for(j in 1:length(no.years)){

                denom.mat[j]<-no.years[j]*(no.years[j]-
1)*(2*no.years[j]+5)/18

        }


        denom.vec<-denom.mat*length(unique(season.var))


        # For each change.of.interest

```

```

for(h in 1:length(change.of.interest)){

# Begin bootstrapping
    for(i in 1:nboot){

        # TIME LOOP
            for(j in 1:length(no.years)){

                years<-0:(no.years[j]-1)  #years in this
run

                # Simulating realistic data with monotonic non-linear
trend
                # using T2 as defined in Eq 5b of Yue and Pilon 2004
                # requires B2= baseline median each season,
a2=multiplicative change for each one year increase in time

                fixed.trend<-exp(change.of.interest[h]*years)

                #bootstrap the residuals within a season to add onto
the fixed.trend vector
                boot.eps<-
tapply(epsilons,season.var,sample,length(years),replace=TRUE)

                # create one realization of a time series for
each season

```

```

        for(k in 1:length(unique(season.var))){
            boot.by.seas<-
medians[k]*fixed.trend+boot.eps[[k]]

            # Calculate tau and S within each season and
each timecut using the MannKendall function from package Kendall
(see comment below)

            out<-power.MannKendall(boot.by.seas)

            tau[k,i,j]<-out$tau
                S[k,i,j]<-out$S
            }

            # Calculate test statistic by
summing over seasons and dividing by appropriate sqrt(denominator)

            # See Hirsch et al. 1982 Water
Resources Research Eqn. 8 and 9

            sktau[i,j]<-sum(S[,i,j])

            ts.out[i,j]<-
ifelse(sktau[i,j]>=0,(sktau[i,j]-
1)/sqrt(denom.vec[j]),(sktau[i,j]+1)/sqrt(denom.vec[j]))

            # Collect a 1 if null (no trend) is
rejected; a 0 otherwise for both methods.

            sim.out[i,j]<-
ifelse(abs(ts.out[i,j])>=qnorm(1-alpha.level),1,0)

        } #end of j loop

```

```

    }      # end of i loop

## Section 4: Calculate Power

    # Sum up number of times null was rejected within
    each timecut and divide by the number of bootstraps to get power
    under each method.

    for(r in 1:(length(no.years))) {

        power[r]<-sum(sim.out[,r])/nboot

    }

    power.mat[h,] <- power

} #end of h loop

if(month.compare == F | length(unique(season.var)) <= 4) {

    plot(1,ylim=c(0,1),xlim=c(min(no.years)-
1,max(no.years)+1),type="l",xlab="Years of Data
Collection",ylab="Power",main=paste("Power to Detect Various Annual
% Changes in", param.assigned,sep=" "))

    abline(h=.8,lty=2)

    for(i in 1:length(change.of.interest)){

        points(no.years,power.mat[i,],pch=i)

        lines(no.years,power.mat[i,],lty=1)

        if(month.compare==F & length(unique(season.var)) <=
4) {leg.text = c(paste("Seasonal",change.of.interest*100,"%",sep="
"))}

points=(1:length(change.of.interest))

        lines=1} else

        if(month.compare==F &
length(unique(season.var)) > 4) {leg.text =
c(paste("Monthly",change.of.interest*100,"%",sep=" "))}

```

```

points=(1:length(change.of.interest))

                                lines=1} else

                                leg.text =
c(paste("Seasonal",change.of.interest*100,"%",sep="
"),paste("Monthly",change.of.interest*100,"%",sep=" "))

points=rep(1:length(change.of.interest),2)

                                lines=rep(1:2,
each=length(change.of.interest))

                                }

                                legend("bottomright",legend=leg.text,pch=c(points),lty=c(lines
))

                                }                                else

                                for(i in 1:length(change.of.interest)){
                                points(no.years,power.mat[i,],pch=i)
                                lines(no.years,power.mat[i,],lty=2)
                                }

# output the number of observations available for the bootstrap
within season

no.obs<-table(season.var)

                                list.out<-list(param.assigned, seasons, no.years,
alpha.level, nboot, change.of.interest, power.mat,no.obs)

```

```

        names(list.out)<-c("Parameter","Number of
Seasons","Years of Data Collection","Alpha","Iterations","Annual
Rate of Change ","Power","No. Obs. Available")

```

```

        return(list.out)

```

```

}

```

```

season.out <-
Power.out(data.in,alpha.level,nboot,change.of.interest,no.years,par
am.assigned,season.location,seasons,season.var)

```

```

        if(month.compare == T) {month.out <-
Power.out(data.in,alpha.level,nboot,change.of.interest,no.years,par
am.assigned,season.location,seasons=12,season.var=month.var)

```

```

}

```

```

        if(month.compare == T) {list.out.all <-
c(season.out,month.out)} else

```

```

        list.out.all <- season.out

```

```

        return(list.out.all)

```

```

}

```

```

## END POWER FUNCTIONS

```

```

## HERE

```

```
data.in <- read.csv("Conduct_update_power.csv",header=T)
```

```
attach(data.in)
```

```
names(data.in)
```

```
data.in2 <- read.csv("DO_update_power.csv",header=T)
```

```
attach(data.in2)
```

```
names(data.in2)
```

```
data.in3 <- read.csv("pH_update_power.csv",header=T)
```

```
attach(data.in3)
```

```
names(data.in3)
```

```
data.in4 <- read.csv("Temperature_update_power.csv",header=T)
```

```
attach(data.in4)
```

```
names(data.in4)
```

```
Power.fun(data.in,alpha.level=0.1,nboot=1000,change.of.interest=c(0.01,0.025),no.years=c(5,10,20),
```

```
param.assigned=as.character("Conductance"),seasons=12,month.compare=F)
```

```
Power.fun(data.in2,alpha.level=0.1,nboot=1000,change.of.interest=c(0.01,0.025),no.years=c(5,10,20),
```

```
param.assigned=as.character("DO"),seasons=12,month.compare=F)
```

```
Power.fun(data.in3,alpha.level=0.1,nboot=1000,change.of.interest=c(  
0.01,0.025),no.years=c(5,10,20),
```

```
param.assigned=as.character("pH"),seasons=12,month.compare=F)
```

```
Power.fun(data.in4,alpha.level=0.1,nboot=1000,change.of.interest=c(  
0.01,0.025),no.years=c(5,10,20),
```

```
param.assigned=as.character("Temperature"),seasons=12,month.compare  
=F)
```

Literature Cited

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- Irvine, K. M., K. Manlove and C. Hollimon. 2012. Power analysis and trend detection for water quality monitoring data: an application for the Greater Yellowstone Inventory and Monitoring Network. Natural Resource Report NPS/GRYN/NRR – 2012/556. National Park Service, Fort Collins, Colorado.

Appendix B: Example Water Quality Resource Brief

Appalachian Highlands Network
Inventory & Monitoring Program

Inventory and Monitoring Division
National Park Service
U.S. Department of the Interior



Continuous Water-Quality Monitoring, 2017

Obed Wild and Scenic River and Big South Fork National River and Recreation Area

Importance

Significant Resources and Serious Threats

As the park names imply, aquatic and riparian resources are key resources at Big South Fork National River and Recreation Area and Obed Wild and Scenic River. Both park units contain nationally significant aquatic resources, and portions of both rivers include designated Outstanding National Resource Waters. Big South Fork NRRRA (Figure 1) protects 11 endangered mussel species and the only existing population of the endangered tuxedo darter (*Etheostoma lemniscatum*) (Figure 2). Among its aquatic resources, Obed WSR protects one of only two remaining populations of the endangered Alabama lampshell mussel (*Lampsilis virescens*), as well as a significant population of the threatened spotfin chub (*Erimonax monachus*).

These two park units also support the largest concentration and most pristine examples remaining of the globally imperiled Cumberlandian cobble bar or riverside scour prairie, which is habitat for 27 rare plant species, including two threatened species—Cumberland rosemary (*Conradina verticillata*) and Virginia spirea (*Spiraea virginiana*). Big South Fork NRRRA and Obed WSR encompass 89% of the Cumberland rosemary populations left in existence. These cobble bar prairies and their rare species depend on natural flood regimes and unpolluted water, as do the fish and mussels that inhabit the rivers.

Water resources within these parks are influenced by a variety of natural conditions and anthropogenic factors that occur upstream of park boundaries. Most of the threats to water resource integrity at Big South Fork and Obed originate upstream of park boundaries, including coal mining, oil and gas extraction, logging, agriculture, municipal development, and associated municipal and industrial water demand and wastewater discharge. The New River, the largest tributary to the Big South Fork, drains a basin that supplied more than half of Tennessee's coal during the 1970's.

Objectives

Determine trends in core parameters:

- pH
- Dissolved oxygen
- Conductivity
- Temperature
- Turbidity

Using continuous data loggers at five fixed integrator sites to determine compliance with state water-quality standards and to detect long-term physical and chemical water quality trends.



Figure 1. The Big South Fork of the Cumberland River is the largest free-flowing river that lies entirely within the Cumberland Plateau of Kentucky, Tennessee, Alabama, and Georgia.



Figure 2. Clockwise from top: freshwater mussels at BISO (11 endangered species); endangered tuxedo darter at BISO (only existing population); threatened spotfin chub at OBRI; measuring water quality.

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September 2018

Figure SOP 11B-1. Example water-quality resource brief, page 1 of 5.

Methods

The National Park Service (NPS) Appalachian Highlands Inventory and Monitoring Network (APHN) has developed a network of discrete water-quality monitoring stations within and adjacent to Big South Fork and Obed park waters. That network will be sampled on a fixed schedule to analyze key field and laboratory physical and chemical water quality analytes that are indicative of water resource integrity. To complement the discrete monitoring network, the Appalachian

Highlands Network has deployed continuous water-quality monitoring infrastructure in tandem with United States Geological Survey (USGS) streamflow monitoring stations within and adjacent to each park. The NPS/USGS partnership allows internet broadcast of near real-time water-quality data collected at 30-minute intervals from strategic monitoring locations for each park.

Water Quality Reference Conditions

As Indicated by Continuous Water Quality Stations
Under undisturbed conditions, water chemistry of Cumberland Plateau streams ranges from extremely dilute, low ionic strength waters in headwater drainages to moderately soft water in the larger streams where APHN continuous monitors are deployed. Continuous water-quality monitoring by the network indicates that only the contiguous drainages of Clear Creek at Lilly Bridge (USGS # 03539778) in the Obed

system (Tennessee River drainage) and Clear Fork near Robbins (USGS # 03409500) in the Big South Fork system (Cumberland River drainage) consistently exhibit water chemistry approaching reference conditions. At these locations, specific conductance is consistently below 50 µs/cm during seasons of higher streamflow and rarely exceeds 100 µs/cm during extreme low flows typical of late summer and fall months. The key for water-quality conditions is detailed in Figure 1.

Table 1. Symbol key for water quality status and trends at continuous water quality monitoring stations in Appalachian Highlands Network parks.

Condition Status Symbol	Condition Status Description	Trend in Condition Symbol	Trend in Condition Description	Confidence in Assessment Symbol	Confidence in Assessment Description
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Obed Wild and Scenic River

Water Quality Trends

The Appalachian Highlands Network has deployed continuous water-quality monitors at three locations within the Obed River drainage: Data collected at these stations indicate distinct water quality fingerprints of water at each of the individual stations. As previously discussed, Clear Creek (Figure 3) water quality is generally indicative of near reference conditions for Cumberland Plateau streams, with the exception of infrequent dissolved oxygen depletion.

Water quality at the Daddys Creek near Hebbertsburg station (USGS #03539600) typically remains well within regulatory standards for pH and dissolved oxygen and target (non-regulatory) conditions for specific conductance (< 200 µs/cm).

In contrast, the Obed River at Adams Bridge station (USGS #03538830) often exhibited 24 hour diurnal pH fluctuation in excess of the maximum one pH unit mandated by Tennessee Department of Conservation (TDEC) and exceeded the maximum recommended specific conductance (< 200 µs/cm) routinely during summer and early fall months during the low flow season.



Figure 3. Clear Creek at Obed Wild and Scenic River, just above the Lilly Bridge sampling station.

Figure SOP 11B-2. Example water-quality resource brief, page 2 of 5.

During the summer and fall of a 2016 drought, specific conductance at Adams Bridge exceeded 400 $\mu\text{S}/\text{cm}$ for more than two months, peaking in excess of 600 $\mu\text{S}/\text{cm}$ (Figure 4) during late October and early November of 2016. The Adams Bridge Station also exhibited routine violation of minimum dissolved oxygen standards (≥ 5.0 mg/L) during summer months.

Diurnal dissolved oxygen (DO) and pH fluctuations occur naturally in most surface waters, including the waters of the Obed and Big South Fork River systems. During daytime hours, algae and other aquatic plants generate dissolved oxygen (an alkaline gas) through photosynthetic activity, and pH is driven upward as a consequence of this increase in alkaline gas.

During nighttime hours, photosynthesis is reduced and respiration (decay) occurs, generating carbon dioxide (an acidic gas) with a concomitant reduction in pH. Nutrient enrichment of surface waters significantly influences the amplitude of the diurnal DO/pH curve, and continuous monitoring stations at Obed River exhibit distinct DO/pH fingerprints in response to variable nutrient concentrations at the respective monitoring locations.

Water-quality monitoring under the APHN Discrete Water-Quality Monitoring protocol has identified elevated concentrations of both nitrogen and phosphorous species at individual monitoring stations, with concentrations of both species significantly elevated at the Obed River at Adams Bridge station.

As a consequence of nutrient enrichment, standing crop of aquatic algae and plants is greater at Adams Bridge than at other monitoring stations, generating an oxygen demand during evening hours that

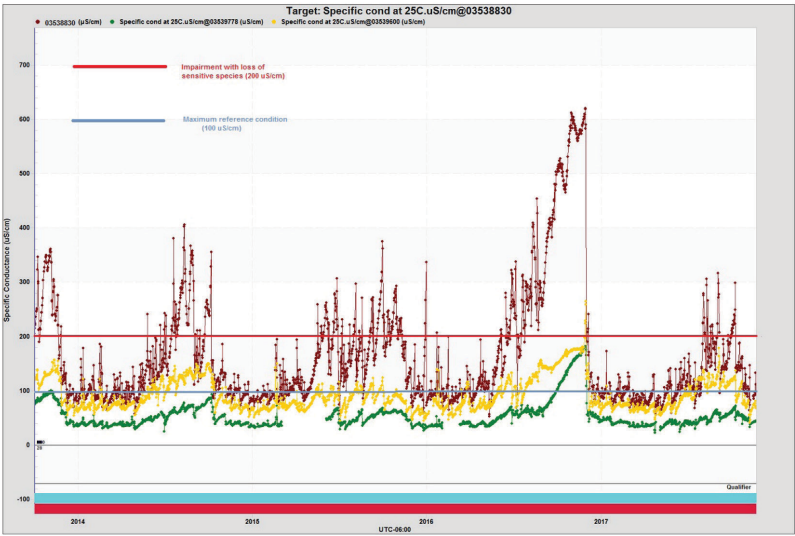


Figure 4. Specific conductance at continuous monitoring stations in the Obed Wild and Scenic River (2014–2017). Obed River, Daddys Creek and Clear Creek.

contributes to a routine violation of minimum DO criteria (red curve in Figure 6) during summer and fall months.

Less frequent dissolved oxygen sags have also occurred at the Clear Creek at Lilly Bridge station during the most recent two-year period. The oxygen sags at Lilly Bridge are less pervasive in occurrence than those at Adams Bridge, and appear to be related to runoff events rather than chronic seasonal conditions. Although less pervasive than at Obed River at Adams Bridge, oxygen demand and DO reductions at Clear Creek are of concern. Water-quality conditions at Obed WSR are summarized in Table 2.

Table 2. Water-quality status and trends at continuous water-quality monitoring stations in Obed Wild and Scenic River.

Location	Specific Measures	Condition	Explanation
Obed River at Adams Bridge (USGS # 03538830)	pH; temperature; dissolved oxygen; conductivity ; turbidity		TDEC 303D listed for nutrient loading. Routinely exceeds recommended specific conductance associated with healthy aquatic systems. Diurnal pH fluctuation exceeds 1.0 unit per day frequently during low flow seasons. Diurnal dissolve oxygen fluctuation frequently falls below 5.0 mg/l during low flow seasons in summer and fall.
Daddys Creek near Hebbertsburg (USGS # 03539600)	pH; temperature; dissolved oxygen; conductivity ; turbidity		Continuous water-quality monitoring indicates generally good water quality. Data do indicate that Daddys Creek is affected to some extent by urban and suburban development in the Fairfield Glades community and surrounding areas.
Clear Creek at Lilly Bridge (USGS # 03539778)	pH; temperature; dissolved oxygen; conductivity ; turbidity		Continuous water-quality monitoring indicates a high-quality resource. Although not pristine, Clear Creek water quality approaches reference conditions for undisturbed watersheds on the Cumberland Plateau. Infrequent dissolved oxygen sags may indicate either watershed wide or localized source of nutrient enrichment. Dissolved oxygen sags range from single night duration to nightly for a one-week period.

Figure SOP 11B-3. Example water-quality resource brief, page 3 of 5.

Big South Fork National River and Recreation Area

Water Quality Trends

The Appalachian Highlands Network has deployed continuous water-quality monitors at two locations within the Big South Fork River drainage. Data collected at these stations indicate distinct physical and chemical water quality variability between these stations. As previously discussed, at Clear Fork near Robbins (USGS # 03409500), physical and chemical water quality is generally indicative of near-reference conditions for Cumberland Plateau streams. Diurnal pH and dissolved oxygen fluctuations rarely violate TDEC in-stream water-quality criteria in the absence of severe drought (Figure 6).

Water quality at the New River at New River station (USGS # 03408500) routinely exhibits relatively high specific conductance, and the New River watershed is a source of very high sediment load (reflected by turbidity) during runoff events (Figure 5). The New River watershed has been heavily mined for coal in the past and has historically been associated with large-scale timber extraction. Recent investigations do suggest that conditions in the New River watershed and downstream reaches of the Big South Fork drainage may be improving (Figure 7). Water-quality conditions at Big South Fork NRRA are summarized in Table 3.



Figure 5. Variation in turbidity during the same runoff event at New River (left) and Clear Fork (right).

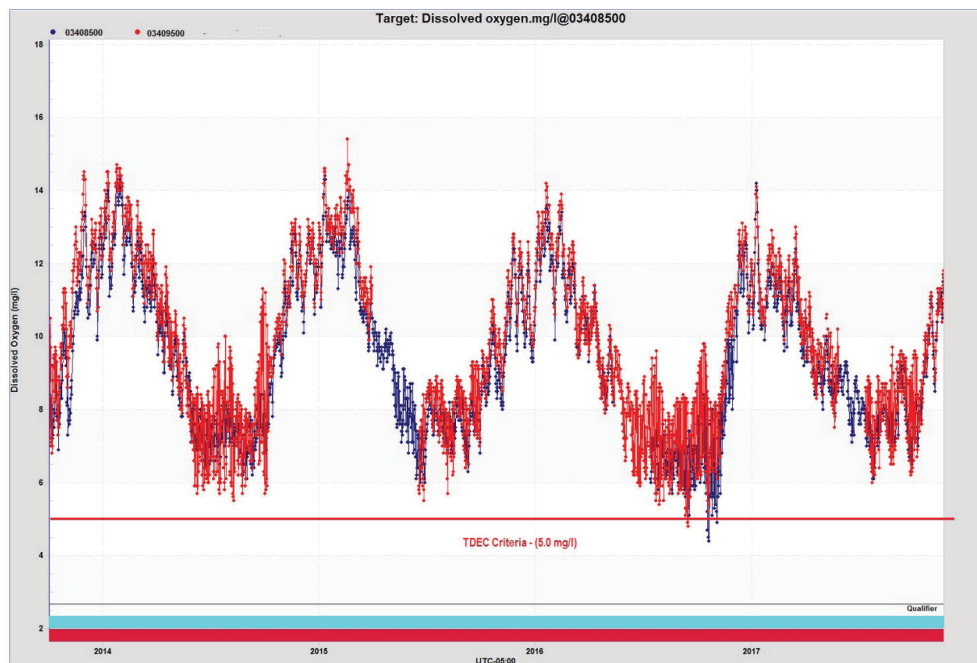


Figure 6. Diurnal dissolved oxygen fluctuation at Big South Fork continuous monitoring stations (2014–2017).

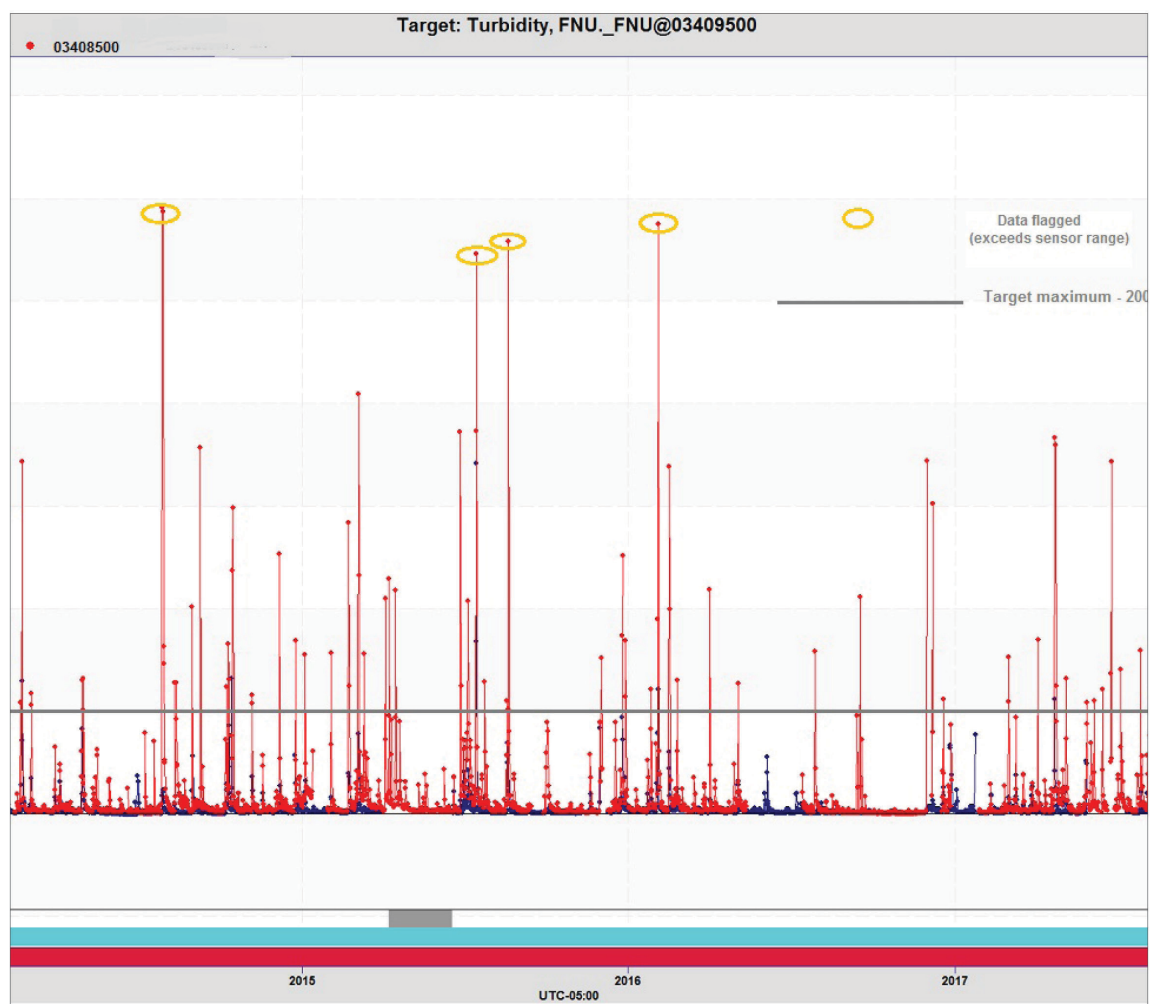


Figure 7. BISO turbidity at New River (red) and Clear Fork (blue) continuous monitoring stations.

Table 3. Water-quality status and trends at continuous water-quality monitoring stations in Big South Fork National River and Recreation Area.

Location	Specific Measures	Condition	Explanation
New River at New River (USGS # 03408500)	pH; temperature; dissolved oxygen; conductivity ; turbidity		Heavy sediment loading from upstream mineral extraction and logging. Routinely exceeds recommended specific conductance associated with healthy aquatic systems.
Clear Fork near Robbins at Burnt Mill (USGS # 03409500)	pH; temperature; dissolved oxygen; conductivity ; turbidity		Continuous water-quality monitoring indicates a high-quality resource. Although not pristine, Clear Fork water quality approaches reference conditions for streams of the Cumberland Plateau.

For More Information

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Figure SOP 11B-5. Example water-quality resource brief, page 5 of 5

Appalachian Highlands Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure CWQ12

Continuous Water Quality Protocol Revision—Version 1.4

Please cite this as:

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Appalachian Highlands Network Standard Operating Procedure NPS/APHN/SOP—CWQ12.
National Park Service, Asheville, North Carolina.

Summary

This standard operating procedure (SOP) is a guide for protocol revision for Appalachian Highlands Network (APHN) continuous water quality monitoring protocol.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
2/28/2016	UGA	Formatting and scientific editing.	Format to NPS standards	1.1
6/10/2016	APHN	Addressing UGA comments.	Address UGA comments.	1.2
11/20/2016	APHN	Addressing Regional comments.	Addressing Regional comments.	1.3
10/26/2017	APHN	Addressing peer review comments	Addressing peer review comments	1.4

Overview

This SOP explains how to make and track changes to the narrative and SOPs for monitoring protocols implemented by the Appalachian Highlands Network. Individuals editing the protocol narrative or any one of the SOPs need to follow these procedures to eliminate confusion on how data are collected and analyzed. All observers conducting the monitoring should be familiar with this SOP in order to identify and use the most current methods.

Although approved protocols have been developed using current standardized methods, all long-term monitoring programs need to be flexible to adapt to changes. As new technologies, methods, and equipment become available, protocols will need to be updated as appropriate.

A Revision History Log accompanies each protocol narrative and SOP. Whenever revisions are made, this log should be filled out and inserted into the new version.

Appalachian Highlands Network protocols typically consist of four sections: narrative, SOPs, QAP, and supplementary materials.

Protocol Narrative: This is the main body of the protocol, explaining the “who,” “what,” “when,” and “why” and an overview of “how” a protocol is to be implemented at each intended park. The protocol narrative follows a standard outline as detailed in Oakley et al. (2003), and, along with appendices and associated standard operating procedures, is subject to external peer review and approval by the regional or national inventory and monitoring program coordinator prior to implementation. In almost all cases, APHN protocols reference or include externally-published documents critical to their implementation. These documents include reference manuals, user guides, field identification guides, or monitoring protocols developed by partnering agencies (e.g., USGS, EPA, NOAA).

Standard Operating Procedures: Each protocol is accompanied by standard operating procedures that detail “how” each protocol is to be implemented. Each protocol’s SOPs cover aspects of field implementation, data management, analysis, reporting, safety, and equipment maintenance to ensure consistent implementation of methods over time. SOPs are intended to be “living documents” that are updated as necessary; in general, all changes related to a protocol should be made at the SOP level rather than to the protocol narrative or supporting appendices.

Quality Assurance Plan: A quality-assurance plan has been created for use by the Appalachian Highlands Network to guide the implementation of the Long-Term Water-Quality Monitoring Protocol for Continuous Sampling (Hughes et al. 2016). This quality-assurance plan documents the standards, policies, and procedures used by the network for activities related to the collection, processing, storage, analysis, and publication of monitoring data. The policies and procedures documented in this quality-assurance plan complement the quality-assurance plans for other monitoring activities conducted by the network and supplement the National Inventory and Monitoring Division Quality Management Plan in development.

Supplementary Material: Supplementary materials include any documents, maps, charts, or other materials that are referenced in the body of the protocol narrative or in the standard operating procedures necessary for implementation of the protocol. These may include, but are not limited to operations manuals, software documentation, or other appropriate materials. Supplementary materials may be included in appendices containing in-depth explanatory information related to each protocol narrative that is not expected to change over time. Depending on the content, appendices might require independent peer review or approval prior to review and approval of the overall protocol.

Revision of network protocols will be the responsibility of the network program manager, in consultation with the network's ecologist, hydrologist and data manager, as well as cooperating statisticians. All changes will be made in a timely manner with the appropriate level of review.

Procedures

The following procedures ensure both minor and major revisions to this protocol remain consistent with the objectives and methodologies of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area (BISO) and Obed Wild and Scenic River (OBRI): Protocol Narrative* (Hughes et al. 2018).

General Procedures

1. Prior to making changes, proposed edits must be discussed with the network program manager and network data manager. It is imperative to consult with the data manager prior to making changes because certain types of changes may jeopardize data set integrity unless they are planned and executed to avoid this. Also, because certain changes may require altering the database structure or functionality, advance notice of changes is important to minimize disruptions to project operations.
2. Attempt to incorporate the changes by first modifying the SOP(s), without making changes to the protocol narrative. If it is clear changes will also be needed for the narrative, then revise it as well.
3. Make all revisions using the track changes feature of Microsoft Word. For minor changes, at least one other person must review the revision. If the change is more extensive, a discussion of the changes with APHN staff is warranted before acceptance of the revision. All proposed changes need to be sent to the regional program manager for review in a tracked-changes version, even if the changes are deemed minor. The network should make a recommendation regarding whether changes are minor or major, but the regional program manager is responsible for ensuring that protocol changes do not affect data quality or integrity. For major changes, the regional program manager will determine if outside review is warranted. Examples of major changes include modifications of the sampling design, significantly altered field methods, and revised analysis techniques.

4. Record the changes in the revision history log of the SOP or in the narrative, as appropriate. Include the previous version number, the date of revision, name(s) and affiliation(s) of author(s), description of and reasons for the changes, and section of SOP or narrative where changes were made.
5. Record all changes to a protocol document (narrative or SOP) in the document's revision history log, with the exception of typographical corrections or formatting changes. For protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance and timing of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...).
6. Each revision of the protocol narrative must be sent through the NPS inventory and monitoring publications manager to obtain a unique NRR number. Standard operating procedures are no longer published as NRR reports and do not need a new number.
7. Notify the data manager of the change or changes so the metadata for the protocol can be updated.
8. Distribute the revised version to all appropriate parties, including the members of the field crew and appropriate APHN staff. The revised version must also be posted on the network's website, the national protocol database must be updated, and the NPS Integrated Resource Management Applications portal (IRMA) reference must be updated.
9. Previous versions should be archived in accordance with standard APHN data management policies. Such historical information may be crucial for understanding, interpreting, and analyzing data.
10. All edits require review for clarity and technical soundness. Small changes to existing documents (e.g., formatting, simple clarification of existing content, small changes in the task schedule or project budget, or general updates to information management handling SOPs) may be reviewed in-house by project cooperators and APHN staff. Major changes to data collection, analysis techniques, sampling design, or response design must be reviewed by the regional program manager in a tracked-changes version. The regional program manager will determine if an external peer review is necessary.
11. Narrative and SOP updates may occur independently. A change in one SOP will not necessarily invoke changes in other SOPs or a narrative update may not require SOP modifications.

Additional Guidance for Updating Protocol Narratives and Appendices

1. In general, substantive changes should not be made to the protocol narrative. The following are acceptable (and expected) reasons for updating the protocol narrative.

- a. Changes to the sampling design following:
 - i. Revisions based on a formal protocol review at the network, regional, or national level.
 - ii. Addition or subtraction of monitoring objectives.
 - b. Significant changes in field methods, as a result of changes to the sampling design or changing monitoring objectives.
 - c. Major revisions in analysis techniques.
2. Protocol narratives are published to IRMA as “Protocol” document types.
 3. All changes to protocol narratives require approval by the regional or national inventory and monitoring program coordinator prior to implementation.
 4. Expansion of the study area where a protocol is to be implemented (such as newly-acquired lands) does not typically warrant a major revision number change provided that the protocol is implemented in the new areas as prescribed in the protocol and associated SOPs. However, the sampling design section must be updated as a minor revision number.

Additional Guidance for Updating Standard Operating Procedures

1. All SOPs should be reviewed and revised as necessary prior to annual protocol implementation.
2. Standard operating procedures should not be updated or altered midway through a field season except where required for safety purposes, or unless expanded to include relevance to other APHN protocols. This will ensure that within-park and within-year data are collected consistently.
3. Alterations to field procedures should only occur with consultation and approval by the appropriate ecologist or hydrologist.
4. All changes to SOPs require approval by the network program manager and responsible ecologist or hydrologist, and the regional program manager prior to implementation.

[This SOP was adapted from the Southeast Coast I&M Network Protocol Revision SOP (Wright and Curry 2016)]

Literature Cited

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