Protocol for Monitoring Springs at Ozark National Scenic Riverways, Missouri.
Heartland I&M Network

SOP 4: Documenting CORE 5 Water Quality Variables

Version 2.00 (5/17/2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	5/17/2018	J.A. Hinsey, H. R. Dodd and D. E. Bowles	Includes changes to data logger deployment, calibration, QA-QC, and reporting. Form for recording static readings is included.	Embraces the water quality guidance issued by NPS Water Resources Division	2.0

This SOP addresses the equipment and methods required to measure the Core water quality variables in association with aquatic invertebrate monitoring in network parks. The basic Core water quality variables or parameters are temperature, dissolved oxygen, specific conductance, pH, and turbidity and are known as CORE 5. This SOP was prepared using guidance and language from the National Park Services Water Resources Division (WRD 2003) and Wagner et al. (2006).

I. CORE 5 Water Quality Parameters

The CORE 5 water quality variables are defined as follows:

Temperature

Accurate temperature measurement is an essential component of water quality monitoring. Dissolved oxygen, pH, and specific conductance are all temperature-dependent parameters. Most modern instruments for measuring these parameters are automatically temperature compensated, meaning they remove the effects of temperature variability on data output by adjusting the measurements to a standard temperature, usually 20 or 25ºC (Radtke et al. 2004). Dissolved oxygen, pH, and specific conductance are measured as temperature compensated (WRD 2003). These meters generally have internal temperature sensors and they display temperature values as well as the parameter being measured.

Dissolved oxygen

Sources of dissolved oxygen (DO) in surface waters are primarily atmospheric reaeration and photosynthetic activity of aquatic plants. DO is a crucial factor in chemical reactions in water and in the survival of aquatic organisms. In surface waters, DO concentrations typically range from 2 to 10 milligrams per liter (mg/L). DO saturation decreases as water temperature increases, and DO saturation increases with increased atmospheric pressure. Super saturation (greater than 100% DO saturation) related to excess photosynthetic production of oxygen by aquatic plants as a result of nutrient (nitrogen and phosphorus) enrichment, sunlight, and warm water temperatures can occur in streams during low-flow conditions. Occasions of saturated oxygen commonly are related to cascading flow conditions. DO may be depleted by inorganic oxidation reactions or by biological and chemical processes that consume dissolved, suspended, or precipitated organic matter.

DO sensors must be temperature compensated for proper operation because the permeability of the membrane and solubility of oxygen in water changes as a function of temperature. The membranes of DO sensors are prone to fouling, the membrane may lose its elasticity, and the cathode-anode measuring electrodes are susceptible to chemical alteration. Fouling of the membrane includes coating from oily or other organic substances, silt, attachment of aquatic organisms, growth of algae, or deposition of other materials. Chemical alteration of the DO electrodes can be caused by a strong oxidizing or reducing chemical agent, such as a chemical spill, by metal-rich drainage water, or by organic-rich waters.

pH

pH is a measure of the hydrogen (H^+) ion concentration in water. At 25ºC, pure water is neutral at pH 7. A solution is considered acidic with a pH of less than 7 and basic with a pH greater than 7, if the solution is at 25ºC. Temperature has a strong effect on H^+ ion activity and must be taken into account when measuring pH. For example, pure water at 30ºC is neutral at a pH of 6.92; water at 0ºC is neutral at a pH of 7.48 (Radtke et al. 2003). Most natural waters exhibit slightly basic pH values, around pH 8 (WRD 2003).

Specific conductance

Conductivity is a measure of the capacity of water (or other media) to conduct and is related to the concentration and types of dissolved ions in water. As dissolved ions increase so will conductivity, making it a good indication of total dissolved solids (TDS) in water. It serves as an early indicator in baseline monitoring for more specific measurements of individual ions (WRD, 2003). Groundwater generally has higher conductivity because it is in contact with bedrock for long periods of time, increasing the concentrations of dissolved bicarbonates and magnesium. Springs and seeps will generally show higher conductivity than the river or streams, and increases in conductivity in the river/stream often indicate large inputs of groundwater or pollution into the system.

Specific conductivity is the conductance of water normalized to unit length and unit cross section at a specified temperature. Conductivity is highly dependent on temperature and may change as much as 3% for each 1°C change (Radtke et al., 1998a). What appears to be a significant change in conductivity of a water body may be just a consequence of seasonal changes in temperature. Raw conductivity is not temperature compensated, making it difficult to compare measurements between sites. For this reason, temperature compensated specific conductivity at 25ºC should be reported for water quality assessment. Raw conductivity may need to be recorded for other purposes such as determining the correct voltage and amperage settings for electrofishing.

Turbidity

Turbidity, reported in nephelometric turbidity units (NTU), is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms. During periods of low flow (base flow), many streams have low turbidities, usually less than 10 NTU. Higher turbidity can be achieved as a result of a rainstorm or other upstream disturbance when particles from the surrounding land are washed into the river/stream making the water a muddy brown color. During high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the streambed, causing higher turbidities. High concentrations of particulate matter affect light penetration and productivity, diminish recreational values, and degrade habitat quality. Increased sedimentation and siltation can also occur, which may harm habitat and aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For these reasons, turbidity readings can be used as an indicator of potential pollution and other human disturbance in the watershed.

II. Water Quality Measurements

Water quality measurements are taken in the field by one or both of the following methods depending on site specific requirements listed in Table 1.

Table 1. Specific requirements for water quality measurements.

Spring Name	Type Measurement	Instrument Type	UTM Easting, UTM Northing
Alley	Unattended	Calibrated Data logger	638380, 4113105
Big	Unattended	Calibrated Data logger	678598, 4091458
Blue	Unattended	Calibrated Data logger	663169.435 4114855.5

Phillips	Unattended	Calibrated Data logger	683240.473 4078617.422
Pulltite	Unattended	Calibrated Data logger	633792.168 4133070.266
Round	Unattended	Calibrated Data logger	641174.916 4127375.826
Welch	Discrete	Calibrated Data logger	N/A

Discrete (in situ) CORE 5 measurements

Discrete (*in situ*) CORE 5 measurements are taken during sampling based on site specific requirements using a pre-calibrated datalogger. These measurements serve to represent the natural condition of the surface water system and are a general measure of water quality condition at the time of sampling.They do not reflect changes in water quality (e.g., diurnal fluctuations or those associated with a hydrologic event) that are likely to have occurred in the stream. Site specific measurement requirements are listed in Table 1.

Unattended CORE 5 measurements

Unattended CORE 5 measurements are taken repeatedly at a preset interval over the time period that sampling is conducted based on site specific requirements using a pre-calibrated data logger (sonde). CORE 5 water quality parameters measured with small intervals (i.e., minutes to hours) between repeated measurements are considered continuous because few if any significant water quality changes are likely to go unrecorded. When the goal is to characterize events of short duration, but such events are difficult to capture manually using discrete measurements (see above), unattended monitoring is appropriate. Unattended monitoring of core parameters helps address questions concerning daily or seasonal variability, or short-term changes (e.g., precipitation related events) that might not be apparent or that might prevent accurate understanding of long-term data. Unattended monitoring also provides the most comprehensive data set upon which to establish temporal variability around the period of biotic sampling. Such information is necessary to document correlations, possible cause and effect relationships, and differentiate natural variability from anthropogenic-induced change to an aquatic system. Site specific measurement requirements are listed in Table 1.

III. Training, Calibration, Storage, and Maintenance in Lab

Training

1. All personnel using the water quality equipment are required to read the manufacturer’s operations manual and HTLN lab guide prior to using the equipment for the first time.
2. The manufacturer’s operations manual and HTLN lab guide will contain equipment-specific instructions used and will be kept in a designated area in the Heartland Network Aquatic Program laboratory for access by all personnel.

3. The Project Leader is responsible for ensuring that all team members using these instruments fully understand how they are calibrated and deployed and that they have read this protocol, operations manual, and the HTLN lab guide.

Equipment Inspection

1. Prior to using the water quality equipment for calibration or taking measurements, all equipment and accessories associated with equipment usage will be inspected for obvious defects or damage (e.g., meter, cable, transport cup, sensor guard, storage sleeve, sponge, and probes).
2. Batteries are to be installed at this time and show no signs of corrosion. It is very important to follow manufacturer guidelines regarding battery installation as the meter will not function and could be damaged if batteries are installed incorrectly.

Calibration

1. ALL equipment must be calibrated prior to each field use and upon return from the field according to instructions in the manufacturer's operations manual and HTLN lab guide. Calibration procedures should not vary from manufacturer recommendations.
2. Equipment will be calibrated no more than 2-3 days prior to deploying the instrument due to potential for drift. To the extent possible, equipment should be calibrated 24 hours or less before deployment.
3. Calibration standard solutions will be those approved for each specific type of equipment. Parameter measurements are only as accurate as the standards used for calibration. Use only standards that have been certified traceable to the National Institute of Standards and Technology (NIST) Standard Reference Manual. Label standards with the date they were received and opened, and expiration date if necessary. Discard standards on their expiration date. Always be careful not to contaminate the standard solutions by inserting an electrode or other material into the stock solution or by pouring used solution back into the stock solution bottle. Do not dilute the buffer with water dripping from the electrodes.
4. Take note of manufacturer's recommended battery power requirements to maintain calibration in the equipment.
5. The manufacturer's operations manual and HTLN lab guide are to be consulted for guidance on troubleshooting specific equipment during calibration.
6. A log book of calibration values for each parameter will be maintained and kept with the equipment at all times. These calibration values will be used in determining drift corrections during data analysis.
7. The logbook should include date calibrated, measured values, initials of the person who calibrated the instrument, and purpose for the calibration including whether calibration is "pre" or "post" deployment.
8. Any problems encountered during calibration are to be noted in the logbook and other information that might be important for troubleshooting.

Maintenance and Storage

The manufacturer's operations manual and HTLN lab guide are to be consulted for maintaining equipment and for short-term and long-term storage of all equipment to prevent costly damage or poor performance.

IV. Field Operations

Pre-field Operations

1. After calibration and before proceeding to the field, inspect the meter, cable, transport cup, sensor guard, storage sleeve, sponge, and sensors for obvious defects or damage. Make sure fully charged batteries are installed properly.
2. As items are placed in the container, they are checked against a field checklist to ensure all items are included. At a minimum, the following should be included:
    a. Equipment with cables, fully charged batteries, calibrated sensors, and transport cup installed
    b. Sensor guard or deployment cage
    c. PVC Chains and locks as needed for data loggers (sondes)
    d. Field storage sleeve with sponge
    e. Graduated cylinder for measuring calibration standard solutions
    f. Deionized water at room temperature
    g. Manufacturer recommended calibration solutions that are not expired
    h. Manufacturer's operations manual and HTLN lab guide for field operations
    i. Log book for recording calibration, maintenance, and repairs
    j. Data sheets copied on waterproof paper
    k. Maintenance kit that replacement parts
    l. Extra fully charged batteries
3. When transporting equipment ensure it is protected from moisture and extreme heat/cold.

Field Measurements

Discrete (in situ) CORE 5 measurements using a calibrated data sonde.

1. Prior to taking field measurements, field calibrate parameters on the instrument that is described in the manufacturer's operations manual and HTLN lab guide for field operations. Some parameters may need calibrated daily while others may only need calibrated weekly or monthly.
2. Calibration values are to be recorded in the equipment logbook. The logbook should include date calibrated, measured values, initials of the person who calibrated the instrument, and purpose for the calibration. Any problems encountered during calibration are to be noted in the logbook and other information that might be important for troubleshooting.
3. At the field site, ensure sensors are protected from potential damage by placing them in a protective cage (if supplied by manufacturer) or deployed in a location where the potential for damage is minimal. Measurements should be taken at three places (n=3, top, middle, bottom) in the spring run that are representative of those sections. Water should not be too turbulent.
4. Measurements should not be taken at the following locations unless required by study objectives or unless they are representative of the entire sample reach:
    a. Directly below sections with turbulent flow
    b. In still water

    c. From or immediately adjacent to the bank
5. Take care to avoid stirring up sediments and debris in the stream channel and take the sample upstream of any disturbances; only one person needs to be in the water taking the measurement. Another person can be on the bank recording the data.
6. Immerse all sensors completely in the water.
7. Record readings for all parameters displayed on the waterproof data sheet for discrete measurements (Figure 1).
8. Accurate field notes and calibration logs are essential in processing the data
9. When measurement is completed, install probes in the field storage container provided by the manufacturer until need for the next measurement or for transport back to the lab.
10. Prior to leaving the site, the lead biologist in the field should review the recorded data for accuracy and resolve any questions, if possible, while data recorder is still available to respond. If data is considered in error, it will be noted on the data sheet.

Unattended CORE 5 measurements using data logger (sonde)

1. At the field site, ensure sensor guard (if provided by manufacturer) is installed to protect sensors during deployment.
2. The logging interval for data loggers (sondes) will be set to record data at 1-hour intervals in accordance with manufacturer's operations manual and the HTLN lab guide. There is no pre-determined time for logging duration, but that period should be, at minimum, 24 hours and should bracket the time during sampling of aquatic biota. Data should be downloaded after two weeks or less of logging, and the unit recalibrated prior to redeployment.
3. File names for logged data will uniquely identify the site and the year the data is collected.
4. Logging should not exceed 30 days on a single set of batteries.
5. The data sonde should be placed in an area of the stream that is representative of the entire reach or habitat being sampled. Water at this location should not be turbulent.
6. Deployed data sondes must always be secured in protective cages (example: pvc tubes with holes for good water flow), chained to a permanent, non-movable object, and locked. Every effort should be made to hide the unit so that is not readily visible to the casual observer.
7. Locations of data loggers will be recorded using a GPS unit at first deployment at those sites (Table 1). Once site locations of the data loggers are determined, loggers will be repeatedly deployed at these locations each time the park is sampled. A GPS reading for return visits and redeployment at the same site is not required. However, if a water quality monitoring location must be moved, then a GPS location will be collected at the new site. GPS locations of sonde deployments are managed by the HTLN GIS Specialist and stored in a geodatabase on the HTLN server.
8. After data logging is complete, then install the transport cup with a small amount of water to protect sensors as recommended by manufacturer.
9. Stop logging data and download data to a separate storage device according to manufacturer's operations manual and HTLN lab guide for field operations then store in a protective container/case for transport back to lab.

10. Prior to leaving the site, the lead biologist will review the logged data for accuracy and resolve any questions, if possible. If there are data in question, it will be resolved back in the lab.

V. *Post-field Operations in Lab*

Once equipment is returned to the lab, it is removed from the protective container/case and placed in an area where it is protected from dust as well as excessive heat and cold. All cables and connectors are kept dry and free of dirt. The containers are also left open to dry. Maintenance and storage functions are instrument specific so it is important to consult the manufacturer's operations manual and HTLN lab guide for guidance for both short and long term storage.

The following outlines post-field operations after returning to the lab and based on the type of equipment used:

Discrete and Unattended CORE 5 data logger (sonde)

Post-calibration

1. ALL data loggers must be post-calibrated within 2-3 days for all parameters upon return from the field according to instructions in the manufacturer's operations manual and HTLN lab manuals. To the extent possible, post-calibration should be conducted within 24 hours or less upon return. Calibration procedures should not vary from manufacturer recommendations.
2. The manufacturer's operations manual and HTLN lab guide are to be consulted for guidance on troubleshooting specific equipment during post-calibration.
3. For additional information on calibrating data loggers, see the calibration section above.
4. Any problems encountered during post-calibration are to be noted in the logbook and other information that might be important for troubleshooting.

Quality Control/Quality Assurance

1. Verifying the data through the QA/QC process is critical for ensuring that sound and accurate data are recorded. Accurate field notes and calibration logs are essential in processing the data
2. The following QA/QC procedures will be followed:
   a. Data sondes will not be calibrated more than 2-3 days prior to deploying or after retrieving the instrument. Ideally, the sonde should be calibrated immediately prior to deployment or after retrieval for post-calibration when possible.
   b. Data loggers are removed from the field for downloading, cleaning and calibration every two weeks or less and post calibrated prior to redeployment.
3. Wagner et al. (2006) recommend the use of standards/buffers, water baths, or calibrations under saturated conditions (dissolved oxygen/DO) both before and after sonde deployment (pre- and post-calibrations) to verify operation of the equipment and QA/QC.
4. Potential problems associated with potential data logger errors include:
   a. Sensors have a maximum reporting level that is limited by the type of sensor and the signal-processing electronics. For example, during periods of runoff when sediment

    concentrations are high, it is not uncommon for sensors to record values at its maximum reporting limit, or to become fouled with sediment.
    b. When a sensor has reached its maximum signal output, the same maximum data value may be recorded repeatedly over time. This period can be for a few hours or days depending on stream conditions.
    c. Additionally, not all sensors have the same maximum reporting level. The maximum sensor response may differ from the reported maximum limit.
5. Initial data evaluation should begin immediately upon completion of the field trip to ensure all necessary information is available and to check for possible instrument malfunctions that may not have been observed in the field. Record any required QC computations (% drift in pre- and post-calibrations) and final record review to ensure the data are accurate and ready for publication.

Data Management

1. Unattended CORE 5 data stored on a separate storage device in the field is uploaded to a personal computer according to the manufacturer's operations manual and HTLN lab guide for data management
2. The downloaded data is stored in an Excel spreadsheet and then checked against acceptable ranges to support aquatic life and acceptable ranges for the instrument/probe.
3. Regardless of how data are recorded and downloaded, the data should be evaluated by the Project Leader immediately after it is downloaded to confirm the accurate transfer of data and to detect possible instrument or sensor error.
4. Because of poor calibration or instrument malfunction, data values may sometimes be recorded that are outside these ranges. Faulty or fouled sensors and recorders, or unforeseen events, can produce erroneous data. In addition, because the water and substrate is disturbed during sonde deployment, erroneous data may occur when the sonde collects a measurement(s) soon after deployment. These erroneous data points should be deleted. Therefore, all data should be reviewed to remove obvious erroneous data from the data set.
5. The initial data evaluation is conducted to verify the accurate transfer of raw field data (instrument readings) to the spreadsheet and to evaluate and identify potentially erroneous data. Accurate field notes and calibration logs are essential in processing the data.
6. Once data pass the initial QA/QC process and erroneous data removed (delete data containing data out of range, adjust negative turbidity values), if necessary, the following steps are taken to correct and analyze the data according to the HTLN lab guide for data management:
    a. Calculate the drift percent correction value using the pre- and post- calibration values recorded in the log book in accordance with the HTLN lab guide.
    b. Determine the need for drift correction based the value of the calibration drift % correction as follows:
        i. <= 10% - no correction
        ii. >10% and <30% – possible correction needed, left up to Project Leader
        iii. >= 30% - do not use data

c. The corrected and adjusted data will be analyzed using summary statistics (mean, range, standard deviation) for each site and date. This information will be presented in summary and synthesis reports to support collected data.
d. All corrections, adjustments, and summary statistics will undergo a 100% QA/QC to check calculations and transfer of data is accurate.
e. This data is secondarily reviewed by the Laboratory QA officer (or Project Leader). If no errors or discrepancies are identified, the Project Leader approves the data and it is now considered valid and reportable.
f. The unattended CORE 5 summary data is then provided to the Environmental Protection Agency using the NPStoret database in accordance with the National Park Service Water Resources Division and the HTLN lab guide for data management.

7. A PDF is saved of the final dataset and summary statistics and stored on the Heartland Network Server.

Storage

1. Once data analysis is complete, remove batteries from all data loggers and other battery operated equipment.
2. Store sensors and equipment according to manufacturer's operations manual and HTLN Lab Guide ensuring its protection and taking into consideration whether storage requirements are short term (2 weeks or less) or long term (>2 weeks).

VI. References:

Radtke, D.B., J. V. Davis, F. D. Wilde. 1998a. Specific electrical conductance: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chapter A6, section 6.4, accessed June, 2004 from http://pubs.water.usgs.gov/twri9A6/

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Water Resources Division (WRD). 2003. Vital signs long term monitoring projects: Part C draft guidance on WRD required and other field parameter measurements, general monitoring methods and some design considerations in preparation of a detailed study plan, accessed March, 2007 http://www.nature.nps.gov/water/vitalsigns/assets/docs/wqPartC.pdf

SPRINGS CORE 5 DISCRETE SAMPLE FORM

Park: ____________________

Spring Name: ____________________

Recorded by: ____________________

Date: ____________________

Time: ____________________

Equipment: _______ YSI 6920 - HTLN#____
_______ YSI ProPlus
_______ Other ________________________

CORE 5 WQ DATA

Transect/Location			
Temperature (C^{o})			
Specific conductance (µS)			
pH			
DO (mg/liter)			
Turbidity (ntu)			

Enter -999 if no data collected

Welch Spring: take readings at <u>Transects 1, 2, and 3</u> of spring-run along river-left.

All other springs, take readings <u>near the source</u> at left, middle, and right side of channel.

NOTES:

	Initials	Date
Entered:		
QAQC:		
Updated:		
10% QAQC:		
Scanned		
Filed:		

Figure 1. Form for recording discrete water quality readings in springs.