National Park Service
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Natural Resource Stewardship and Science

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

Quality Assurance Plan

Natural Resource Report NPS/APHN/NRR—2018/1720

ON THE COVER
Clear Creek at Lilly Bridge in the Obed Wild and Scenic River system during low seasonal streamflow (October, 2009). NPS has established a continuous water quality monitoring station that is co-located with USGS streamflow gage number 03539778 at this location.

Photograph by James Hughes, Appalachian Highlands Inventory & Monitoring Network, National Park Service.

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Executive Summary

In accordance with guidelines set forth by the National Park Service Inventory and Monitoring Division, the Appalachian Highlands Inventory and Monitoring Network (APHN) created a quality-assurance plan in the implementation 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). 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 for activities complement the quality-assurance plans for other monitoring activities conducted by the Appalachian Highlands Network and supplement the National Inventory and Monitoring Division Quality Management Plan (in prep).

List of Terms[1]

Accepted Data. Data that have undergone all Quality Assurance and Quality Control (QA/QC) procedures as defined in a published protocol and associated standard operating procedures.

Accuracy. A measure of the degree of conformance of the values generated by a specific method or procedure with the true value. The concept of accuracy includes both bias (systematic error) and precision (random error). The EPA recommends this term not be used and instead, precision and bias be used to convey the information usually associated with accuracy. See Precision and Bias.

Bias. Systematic error manifested as a consistent positive or negative deviation from the known or true value. It differs from random error which shows no such deviation.

Calibration. Determination, by measurement or comparison with a standard, the correct value of each measure on a meter or other device, or the correct value for each setting of a control knob. The levels of the calibration standards should bracket the range of planned measurements.

Certified Data. Certified data have: (a) been through QA/QC procedures as outlined in the quality assurance plan; (b) meet expected quality standards, or are appropriately identified and annotated at the record level where they do not meet those standards; (c) have documented procedures for data collection, processing, and transformation in appropriate metadata formats; and (d) are suitable for use. In Aquarius and NWIS, data certified in accordance with this QAP are defined as Approved.

Comparability. The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator.

Data Qualification. A code or annotation that signals data do not meet specified data-quality standards. These qualifications include data-quality ratings, approvals, or other data qualifiers applied using Aquarius software.

Data Quality Objectives (DQOs). Qualitative and quantitative statements that clarify the objectives of observations, define the appropriate type of data, and specify levels of uncertainty acceptable to managers when using data. DQOs provide the statistical framework for planning data collection and management as the basis for establishing the quality and quantity of data needed to support decisions. Includes Qualitative Data Quality Values (DQVs), and informs development of Measurement Standards (or Measurement Quality Objectives; MQOs), Performance Standards, Accreditation Standards, and Policy Standards.

Data Quality Values (DQVs). Desired qualitative characteristics of data and data sets related to intrinsic data quality (reasonability, accuracy, objectivity, credibility), contextual data quality (relevance, timeliness, completeness, comparability), representational data quality (interpretability, understandability, consistency), and data accessibility (security, discoverability, utility).

[1] Definitions are based on a combination of USGS (1995) and EPA (1997).

Data Validation: Quality Control tools or processes designed to evaluate legitimacy of data through the data management lifecycle. Data that do not pass validation procedures are either corrected using prescribed methods or flagged and graded to inform data users as to their appropriate use.

Data Verification: Quality Assurance tools or processes where data are checked for accuracy and inconsistencies through the data management lifecycle. Data Verification helps to ensure data are complete, properly formatted so they can be processed, and accurately translated when transferred from one source to another.

Minimum Detection Limit (MDL): The minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, qualitatively or quantitatively measured, and reported to be greater than zero.

Minimum Quantification Limit (MQL): The concentration of analyte in a specific matrix for which the probability of producing analytical values above the method detection limit is 99 percent.

Precision: The degree of similarity among independent measurements of the same quantity, without reference to the known or true value.

Provisional Data: Provisional data have undergone incomplete QA/QC procedures as defined in the QAP and are not suitable for general use. Provisional data may be used in some cases, however, depending on the amount of QA/QC completed, and the intended use.

Quality Assurance (QA): The set of activities designed to ensure data, products, or services meet defined standards of quality with a stated level of confidence. Quality Assurance focuses on ensuring data are collected to and managed to the highest practicable quality, at or above stated data-quality standards.

Quality Assurance Plan (QAP): Documentation of Quality Assurance and Quality Control procedures for a protocol, program (inventory, and overall inventory and monitoring), and national database application (i.e., NPS Data Store).

Quality Control (QC): Operational techniques and activities used to ensure data or products meet designated requirements for quality. Quality Control procedures focus on testing data for quality and can include both an evaluation of whether data quality meet data-quality objectives and procedures to correct data.

Raw Data: Data in their state of original collection, either in the form of paper or electronic field forms, electronic sensor files, or digital media (photo, video, or audio). These data generally have been collected following some QA procedures, but have not undergone any QC procedures.

Sensitivity: The ability of a method or instrument to discriminate between minimally different levels of a variable of interest by producing a noticeably different measurement response.

Standards, Measurement (also Measurement Quality Objectives): Data-quality requirements specifying the level of precision, bias, sensitivity, and resolution data must meet to be accepted for use in analysis.

Standards, Performance: Data-quality requirements specifying the detection ability, sensitivity, and variability of equipment, sensors, or observers to reliably measure characteristics within target populations.

Standards, Accreditation: Data-quality requirements related to individuals or organizations involved with data collection, analysis or processing to ensure desired data credibility and defensibility. Examples include professional accreditation/certificates, required training, chain-of-custody requirements and others.

Standards, Policy: Data-quality requirements related to ensuring appropriate management, use, dissemination, qualification, and documentation of data.

Introduction

The National Park Service (NPS) Inventory and Monitoring Program was established by an act of Congress in 1999 to provide more than 270 national park system units a core suite of baseline minimum scientific information (inventories) and to identify and implement long-term monitoring of high-priority indicators of resource condition in those units (Fancy et al. 2009). The overarching purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and determine how well current management practices are sustaining those ecosystems.

This quality assurance plan (QAP) documents the standards, policies, and procedures of the Appalachian Highlands Inventory and Monitoring Network (APHN) for the collection, processing, storage, analysis, and publication of monitoring data described in the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018). The policies and procedures documented or referenced in this quality assurance plan complement the quality assurance plans for other monitoring activities conducted by the Appalachian Highlands Inventory and Monitoring Network and supplement the quality management plan for the NPS Inventory and Monitoring Program (in prep). The QAP also serves as a guide for all APHN personnel involved in protocol or program activities, and as a resource for identifying memoranda, publications, and other literature that describes associated techniques and requirements in more detail.

Protocol Overview

The *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) describes the background, rationale, and sampling design for monitoring water quality using continuous sampling at two APHN parks. The parks are Big South Fork National River and Recreation Area (BISO), and Obed Wild and Scenic River (OBRI). The main goals of the protocol are: (1) to outline an overall strategy for time-series water-quality monitoring that is credible and scientifically rigorous, and (2) to provide a specific set of instructions in the form of standard operating procedures (SOPs) sufficiently detailed to ensure consistent and comparable data collection for current and future practitioners.

The structure of the protocol follows the recommended framework and suggestions of Oakley et al. (2003). *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) also describes important aquatic resources within the affected parks and briefly summarizes characteristics of geology, soils, climate and hydrology considered when monitoring water quality at the two parks. Identifying known water-quality issues in the parks, as well as describing some of the important linkages between water quality and park resources may help provide early warning of changing conditions or issues of concern in the future.

The objective of the protocol is to determine annual status and long-term trends for five core water-quality parameters (dissolved oxygen, conductivity, temperature, pH and turbidity) at selected index

sites using fixed station continuous monitoring data loggers at Big South Fork NRRA and Obed WSR. Continuous water-quality monitors (datasondes) are deployed year-round at five U.S. Geological Survey (USGS) streamflow gages located on the major rivers and larger tributaries of each park, generally upstream of their most sensitive aquatic resources. Water-quality parameters are measured at 30-minute intervals, allowing for eventual determination of trends at daily, monthly, seasonal and annual time scales. Water-quality data are broadcast to the USGS National Water Information System (NWIS) and made available on the Internet in near real-time; providing park managers, partners and the public with early warning of upstream disturbances, and enabling APHN staff to conduct repairs efficiently so disruptions in the data record can be minimized.

Time-series data collected using this protocol will be stored in NWIS and analyzed using Aquatic Informatics Aquarius software. Two primary emphases of the National Park Service (NPS) Inventory and Monitoring Program are to ensure results and knowledge obtained from monitoring are communicated in a timely manner, and to maximize understanding in order to best meet park needs. Where appropriate, monitoring results will be shared as broadly as possible with park partners, NPS staff, and the public. Water-quality status will be summarized in annual reports and resource briefs at the end of each calendar year. Longer-term trends and synthesis reports will be written every five years, unless network and park staff agree a shorter interval is needed. The synthesis reports will include information from a regional perspective in order to look at landscape-scale changes. Water-quality data collected using this protocol will provide a scientific foundation for evaluating water quality in major streams of the Big South Fork NRRA and Obed WSR.

Protocol Activities and Modules

Data are collected or derived as a part of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) in 12 different activities or modules (Table 1).

The primary objective of the protocol is to determine daily, monthly, seasonal and annual water-quality trends for five parameters (dissolved oxygen, conductivity, temperature, pH and turbidity) at selected index sites using fixed-station continuous-data loggers at Big South Fork NRRA and Obed WSR. The Appalachian Highlands Network's continuous monitoring stations are co-located with USGS streamflow gages, affording the opportunity to relate water-quality data to daily, seasonal, and annual trends in streamflow and to the frequency, magnitude, and duration of extreme runoff events.

Table 1. Protocol activity matrix for the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Activity Type	Activity Number	Activity	Description
Site Recon, Establishment, and Maintenance	1	Site recon and establishment	A site must not be selected without first determining if data collected at that site is representative of up/downstream conditions. Cross-section surveys of field parameters must be made to determine the most representative location for monitor placement. A site must not be selected without first determining that the data quality value for representativeness (Table 3 and Table 4) will be met.
Field Observations	2	Cross-section surveys	Cross-section survey data (activity 1 and annual repeat checks) must be recorded on USGS Continuous Monitoring Field Forms and input into electronic format using USGS SiteVisitAq software (King et al. 2009).
	3	Monthly O&M site visit	Sensor fouling and calibration drift data collected as part of monthly operation and maintenance (O&M) site visits. During a site visit pH, temperature, dissolved oxygen, conductivity, and turbidity are collected using a reference meter and datasonde. This information must be recorded on USGS Continuous Monitoring Field Forms and input into electronic format using USGS Continuous Hydrologic Instrumentation Monitoring Program (CHIMP) software. CHIMP files are subsequently converted by USGS SiteVisitAq software into Aquarius readable format for drag and drop entry into Aquarius. Follow procedures described in SOP CWQ07 *Operation and Maintenance Site Visit—Version 1.4* (Hughes et al. 2018c) of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) and USGS procedures described in Wagner et al. (2006).
Sensor Data	4	pH	pH data are collected every thirty minutes, year-round.
	5	Temperature	Temperature data are collected every thirty minutes, year-round.
	6	Dissolved Oxygen (DO)	Dissolved oxygen (DO) data are collected every thirty minutes, year-round.
	7	Conductivity	Conductivity data are collected every thirty minutes, year-round.
	8	Turbidity	Turbidity data are collected every thirty minutes, year-round.

Table 1 (continued). Protocol activity matrix for the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018).

Activity Type	Activity Number	Activity	Description
External Data	9	Stage	Water level (stage) data are collected and available from USGS.
	10	Streamflow Discharge	Discharge data based on stage/discharge curves developed by and available from USGS.
Quality Control Data	11	Datasonde Calibration	Calibration data are collected and used to assess drift of deployed monitors. Data are used to shift and/or rate data according to procedures described in Wagner et al. 2016.
	12	Data Correction, Qualification & Grading	Data outliers and uncorrectable fouling conditions are manually flagged using USGS NWIS-based Aquarius software consistent with the methods described in Wagner et al. (2006).

Sampling Design

Information regarding the sampling design is provided in Table 2.

Table 2. Activity-level sample design matrix for the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018). Numbers (left column) match those in the Protocol Activity Matrix (Table 1).

Activity Type	Activity Number	Description	Sampling Design	Revisit Design
Field Observations	2	Cross-section surveys	Targeted; five USGS "integrator sites with existing stream gages selected to represent physical and chemical water quality conditions "delivered" to park waters from upstream areas within their respective watersheds.	Revisit annually
Field Observations (continued)	3	Monthly O&M site visit	Targeted; five USGS "integrator sites with existing stream gages selected to represent physical and chemical water quality conditions "delivered" to park waters from upstream areas within their respective watersheds.	Revisit monthly (or as needed if data indicate a sensor problem)
Sensor Data	4	pH	Targeted[1]	Continuous, recorded at 30-minute intervals.
	5	Temperature	Targeted[1]	Continuous, recorded at 30-minute intervals
	6	Dissolved Oxygen	Targeted[1]	Continuous, recorded at 30-minute intervals
	7	Conductivity	Targeted[1]	Continuous, recorded at 30-minute intervals
	8	Turbidity	Targeted[1]	Continuous, recorded at 30-minute intervals

[1] Five USGS "integrator" sites with existing stream gages, selected to represent physical and chemical water quality conditions "delivered" to park waters from upstream areas within their respective watersheds.

Data Quality Objectives

Tables 3–5 provide data-quality values and standards for implementation.

Table 3. Data Quality Values (DQVs) for the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Data Quality Category	Data Quality Value	Definition	Protocol Considerations
Intrinsic Data Quality	Accuracy	Measurements reflect the true value of the parameter being observed. This applies to measures (length, width, position) or classes (species, types, or categories). Includes components of precision and bias.	Pre-deployment calibration of datasonde sensors are conducted in a laboratory environment in accordance with methods described in SOP CWQ05 *Equipment and Calibration—Version 1.4* (Hughes et al. 2018a). Continuous monitor operation and maintenance site visits are conducted in accordance with schedule and methodologies described in Hughes et al. (2018) and in accordance with methodologies described in Wagner et al. (2006).
	Representativeness	Measurements represent conditions at the time of sampling. Combined with accuracy, leads to repeatable data collection.	Representativeness of monitor deployment location evaluated by comparison of field data with cross-section profile to ensure that station location is at well-mixed section of the river and can be considered representative of the water body at the time of data collection. Sensor fouling and calibration drift evaluated as part of monthly continuous monitoring site visits. Data adjusted as necessary in accordance with accepted operating procedures described in Wagner et al. (2006).
Contextual Data Quality	Comparability	The degree to which data can be compared among sample locations, data sources, or periods of time.	Instrumentation, standard operating procedures, calibration procedures, and routine maintenance schedule is identical for all continuous monitoring stations. Data management and editing is conducted in accordance with standard operating procedures (SOP 10) that are consistent between stations.

Table 3 (continued). Data Quality Values (DQVs) for the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018).

Data Quality Category	Data Quality Value	Definition	Protocol Considerations
Contextual Data Quality (continued)	Timeliness / Currency	How recent the data need to be to be considered valid for their intended use. Data represents conditions and/or is available and in a format for use at the appropriate time in the decision-making process.	Data at each station are collected on 30 minute/24 hours per day/365 days per year schedule. Data are available in near real time on internet via partnership with USGS and are stored in USGS NWIS system for long-term accessibility. Real time availability of data allows for timely identification of water resource conditions of concern. Data management and editing in accordance with standardized procedures described in SOPs 9 and 10 assure that long-term data trends and comparisons between stations are verifiable. Data spikes and fouling data removed from record on a weekly basis. Data shifts processed on a monthly basis within two weeks of continuous monitoring station O&M site visit. Complete processing of data for individual water year completed on an annual basis at all stations. Certification of data completed on an annual basis with individual station reports. Where certified data cannot be provided for resource management decisions in a timely manner, provisional data may be made available for use.
	Completeness	All data/ measures required to evaluate accuracy representativeness are present; incomplete data sets (either at a location, across sampling locations, or over time) lose utility or relevance. Data records contain values as planned across the period of record.	Methods, sampling plans, and analyses are designed and implemented such that they result in a complete data set across space and the planned period of record. However, instrument failure, logistical issues, and other concerns occasionally result in an incomplete record. To be used for analyses, data for each season must be 90% complete, and data for each year must be 90% complete.

Table 3 (continued). Data Quality Values (DQVs) for the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018).

Data Quality Category	Data Quality Value	Definition	Protocol Considerations
Representational Data Quality	Consistent Representation	Use of standard definitions when describing data quality or resource quality based on data	Standard definitions of data quality are provided. Provisional data indicate data that have been reviewed but not certified. Provided data is defined (by USGS) as data provided by cooperating agency (i.e., NPS). Certified data are defined as those data that have been reviewed, QA/QC checked, and edited in accordance with procedures described in SOP CWQ08 *Quality Assurance/Quality Control—Version 1.4* (Hughes et al. 2018d) and in Wagner et al. (2016). Data are reported and flagged in comparison to established management, ecological, or regulatory thresholds in accordance with procedures described in Hughes et al. (2018).
Data Accessibility	Secure	Access to data, products, and systems limited to appropriate audiences.	Continuous water quality monitoring data are stored and managed in the USGS NWIS system. No protected data will be generated as part of the APHN Long-Term Water-Quality Monitoring Protocol for Continuous Sampling.

For activities that involve quantitative measurements taken by field personnel, requisite Measurement Quality Objectives (MQOs) are defined in Table 4. Standards for data protection are included in Table 5.

Table 4. Measurement Quality Objectives for the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018). Activities match those in the Protocol Activity Matrix (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Activity	Measure / Quality Indicator	Quality Objective
Site Recon and Establishment	Location Accuracy	Continuous monitoring stations are located at established USGS streamflow gages. Geographic coordinates, period of record, drainage area, and other information are available online for individual USGS gages. Deployment proximity varies by station depending upon site-specific conditions, but do not vary by more than 30 meters from coordinates of USGS gages.
	Location Description Detail	Maps, narrative directions, and site access descriptions are included in field folders for each continuous sampling location.
pH (including pH component of cross-section surveys)	Units	standard pH units
	Accuracy	± 0.2 units
	Resolution	0.01 units
	Range	0 to 14 units
	Reporting	Report to one decimal place.
	Calibration/Data Correction Criteria	± 0.2
	Maximum allowable discrepancy from field meter[1]	± 2.0
Temperature (including temperature component of cross-section surveys)	Units	degrees Celsius (°C)
	Accuracy	± 0.15°C
	Resolution	0.01°C
	Range	- 5 to 50˚C

[1] USGS guidance states that the maximum allowable limits shown in Table 4 are considered minimum standards in the consideration of whether data are correctable or should be deleted. USGS Water Science Centers are encouraged to establish stricter requirements. Even with the establishment of maximum allowable limits, professional judgment by the protocol lead is still needed in record processing.

Table 4 (continued). Measurement Quality Objectives for the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018). Activities match those in the Protocol Activity Matrix (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Activity	Measure / Quality Indicator	Quality Objective
Temperature (including temperature component of cross-section surveys) (continued)	Reporting	Report to one decimal place
	Calibration/Data Correction Criteria	± 0.2
	Maximum allowable discrepancy from field meter[1]	± 2.0
Dissolved Oxygen (including dissolved oxygen component of cross-sectional surveys)	Units	milligrams per liter (mg/L)
	Accuracy	± 1%
	Resolution	± 1%
	Range	0 to 50 mg/L
	Reporting	Report to one decimal place
	Calibration/Data Correction Criteria	± 0.3
	Maximum allowable discrepancy from field meter[1]	± 2.0 or 20%, whichever is greater
Specific Conductance (including specific conductance component of cross-sectional surveys)	Units	microsiemens per centimeter [µS/cm])
	Accuracy	0.5% within calibrated range
	Resolution	1 µS/cm
	Range	0 to 100,000 µS/cm
	Reporting	Report to whole number

[1] USGS guidance states that the maximum allowable limits shown in Table 4 are considered minimum standards in the consideration of whether data are correctable or should be deleted. USGS Water Science Centers are encouraged to establish stricter requirements. Even with the establishment of maximum allowable limits, professional judgment by the protocol lead is still needed in record processing.

Table 4 (continued). Measurement Quality Objectives for the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018). Activities match those in the Protocol Activity Matrix (Table 1). Accuracy, range, and resolution standards from YSI, Inc. (2009).

Activity	Measure / Quality Indicator	Quality Objective
Specific Conductance (including specific conductance component of cross-sectional surveys) (continued)	Calibration/Data Correction Criteria	± 5 or ± 3% of the measured value, which-ever is greater
	Maximum allowable discrepancy from field meter[1]	± 30%
Turbidity (including turbidity component of cross-sectional surveys)	Units	nephelometric turbidity units [NTU]
	Accuracy	± 2% of reading or 0.3 NTU (whichever is greater)
	Resolution	0.1 NTU
	Range	0 to 1000 NTU
	Reporting	Report to whole number
	Calibration/Data Correction Criteria	± 0.5 or ± 5% of the measured value, whichever is greater
	Maximum allowable discrepancy from field meter[1]	± 3.0 or ± 30%, whichever is greater

[1] USGS guidance states that the maximum allowable limits shown in Table 4 are considered minimum standards in the consideration of whether data are correctable or should be deleted. USGS Water Science Centers are encouraged to establish stricter requirements. Even with the establishment of maximum allowable limits, professional judgment by the protocol lead is still needed in record processing.

Table 5. Data Protection standards for the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018). With the exceptions noted, all data collected should be made publicly available in a timely fashion.

Data Type	Type of Data	Level of Protection	Rules for Dissemination
Continuous Water-Quality Data and Information	Water-Quality Data	Unprotected	Data available on-line as public information.
Location Data and Information	Permanent Sampling Locations	Operationally protected	Provided upon request only. Shown in reports
Personally Identifiable Information	Non-NPS Staff Information	Legally Protected	All but first name and last initial redacted from public release

Quality Assurance Procedures

The following Quality Assurance procedures are designed to ensure that collected or generated data meet specified requirements (Table 6).

Table 6. Quality Assurance procedures to be conducted in the implementation of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Activity Type	Activity Number	Activity	QA Procedure	Description	Citation / Link
Site Recon and Establishment	1	Site recon and establishment	Integrator site that is equipped with USGS gage and associated telemetry.	Deploy water quality datasondes in a consistent manner. Calibrate sensors in accordance with established methods. Utilize datasondes that are mutually compatible (ideally same manufacturer) at all continuous monitoring stations.	SOP CWQ05: *Equipment and calibration—Version 1.4* (Hughes et al. 2018a). SOP CWQ06: *Linking YSI 6920 Datasondes to USGS Gages—Version 1.4* (Hughes et al. 2018b).
Field Observations	2	Cross-section surveys	Cross-section water quality survey	Conduct field measurements to verify acceptable mixing of water body to ensure that continuous monitor is deployed at location that is representative of water quality of the entire width of stream.	SOP CWQ07: *Operation and Maintenance Site Visit—Version 1.4* (Hughes et al. 2018c). Wagner et al. (2006)
	3	Monthly O&M site visit	Monthly O&M site visit	Evaluate sensor fouling and calibration drift.	SOP CWQ07
Sensor Data	4	pH	Lab calibration prior to deployment.	Calibration log books maintained for individual datasondes.	SOP CWQ05
	5	Temperature	Quarterly two point checks conducted.	Calibration log books maintained for individual datasondes.	SOP CWQ05

Table 6 (continued). Quality Assurance procedures to be conducted in the implementation of the Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative (Hughes et al. 2018).

Activity Type	Activity Number	Activity	QA Procedure	Description	Citation / Link
Sensor Data (continued)	6	Dissolved Oxygen (DO)	Lab calibration prior to deployment.	Calibration log books maintained for individual datasondes.	SOP CWQ05
	7	Conductivity	Lab calibration prior to deployment	Calibration log books maintained for individual datasondes.	SOP CWQ05
	8	Turbidity	Lab calibration prior to deployment	Calibration log books maintained for individual datasondes.	SOP CWQ05
External Data	9	Stage data from USGS	Stage data review	Measured by USGS infrastructure (constant bubbler system) equipped with purge system to prevent fouling.	Stage data reviewed and subjected to QA/QC by USGS in accordance with established USGS procedures.
	10	Discharge data from USGS	Stage/discharge curve development and maintenance	USGS conducts 6 to 10 measurements annually to develop and adjust stage/discharge curve.	Stage/discharge curve developed by USGS and subjected to QA/QC in accordance with USGS criteria.

General or Shared QA Procedures

The following quality assurance (QA) procedures are either shared among activities or consistently required as data migrate through the workflow.

Data Entry & Verification (All Activities)—Data are verified during data entry in a process which involves checking the accuracy of computerized records against the original source, mainly paper field records for operation and maintenance site visits entered into USGS CHIMP software. Data entry personnel will check 100% of the records to the original field forms. The primary goal of data entry verification is to determine where errors are being introduced into the data entry forms. Data entry errors are minimized through the use of automated methods within the forms (e.g., CHIMP range limits, pick lists, and calendars). After the computerized data are verified to accurately reflect the original field data, the paper forms are archived and the electronic version is used for all subsequent data activities.

Training Requirements

Although protocol-specific quality assurance procedures are documented in Table 6, Table 7 summarizes Division- or NPS-wide training requirements.

Table 7. Training and professional certification requirements for IMD scientific staff involved with the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Specialized Training – Title or Description of Course	Personnel/Groups Requiring Training	Purpose	Training Provider	Recurrence Requirements	Location of Training Records / Certificates1
Water Quality Field Methods	Protocol Lead	Increase consistency among networks, WRD, and parks on methods	USGS QW 1028	Once	Personal certificate record scanned to electronic format.
	Protocol Lead	Increase consistency among networks, WRD, and parks on methods	NPS	Once with 3-year refresher	DOILearn
Standard Procedures for Continuous Water Quality Monitors	Protocol lead and permanent hydrologic technicians	Ensure consistency with USGS methods for continuous water quality monitors.	USGS SW 2298	Once	Personal certificate record scanned to electronic format.
DOI Scientific Integrity Training	All IMD scientific employees	Ensure understanding of roles and responsibilities	DOI / DOILearn	Once	DOILearn
Hydrologic Data Collection & Certification	NPS or contract personnel collecting water quantity data expected to be used in regulatory or legal proceedings	Ensure requisite credibility of data collectors and data	USGS	Once with 3-year refresher	DOILearn certifications retained on file in program headquarters as per records management plans

[1] If training records and/or certificates are on file elsewhere, document their location in this column. If training records and/or certificates do not exist or are not available then this should be noted.

Quality Control Procedures

The following Quality Control (QC) procedures are designed to ensure collected or generated data meet specified requirements and are appropriately annotated or corrected. The procedures are shared among activities required as data migrate through the workflow.

Identification of Protected Data: Within the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River* (Hughes et al. 2018) the sampling locations are operationally protected. Sampling locations are only given out upon request.

Geospatial Data Verification: The USGS surveys the station location for USGS streamflow gages associated with the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018). The USGS also surveys levels of monuments, markers, and gage elevation data on a five-year frequency to verify accuracy of stage/discharge record.

Identification of Suspect Data: Time-series water-quality data collected as part of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) are processed in accordance with SOP CWQ10 *Continuous Water Quality Records Processing: Version 1.4* (Hughes et al. 2016f). Data spikes, sensor fouling data, and sensor failure data are identified and graded in the data record in accordance with SOP CWQ10.

Data Correction Procedures: Time series water quality data collected as part of the APHN Long-Term Water Quality Monitoring Protocol for Continuous Sampling are processed in accordance with SOP CWQ10. Calibration criteria and data correction criteria are identified in Table 4. When data fail to meet data correction criteria data shifts, corrections are made in strict accordance with the procedures described in SOP CWQ10 utilizing data obtained during continuous monitoring station operation and maintenance site visits. Null values are neither displayed nor interpolated.

Data Grading: Data are graded using pre- and post-deployment calibration data.

Data Annotations and Qualifications

An assessment of the accuracy of the continuous water-quality data record is a required component of the data certification process. The initial assessment of accuracy is made as part of operation and maintenance site visits and is based upon combined fouling and calibration drift values recorded before any data corrections are applied. If field comparison of a deployed monitor and field meter do not meet the measurement quality objectives for accuracy described in Table 4 (which correspond with “excellent” criteria in Table 8), apply corrections to the data record.

Data corrections will be made in accordance with procedures described in Wagner et al. (2006), using USGS Aquarius software. All data corrections have a starting date and time, and an ending date and time that delineate the data correction interval. 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. Sensor fouling commonly begins as soon as the sonde is deployed in the aquatic environment. If certain environmental or hydrologic events, such as a rise in gage height (affecting turbidity, for example); or increase in temperature (affecting DO, for example); can be identified as significant fouling events; the event may be used as the start or end date for a fouling correction. Thus, a zero correction is applied at the start of the correction interval, the full correction is applied at the end of the correction interval, and corrections to the data between the start and end dates are linearly interpolated (Bartholoma 2005).

Final data evaluation consists of reviewing the data record, checking data corrections, and making any needed final corrections. When review is completed, the data are verified for publication and rated for quality. Data that cannot be verified or are rated as unacceptable are retained for record checking and review purposes but are not published. After corrections are applied, final data are annotated based upon quality control criteria described in Table 8.

Table 8. Quality Control (QC) annotation codes to be recorded for data records that are collected under the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Parameter	Annotation Code	Description
Temperature, in ºC	Excellent	≤ ± 0.2
	Good	> ± 0.2 – 0.5
	Fair	> ± 0.5 – 0.8
	Poor	> ± 0.8
Specific conductance, in µS/cm	Excellent	≤ ± 3%
	Good	> ± 3 – 10%
	Fair	> ± 10 – 15%
	Poor	> ± 15%
Dissolved oxygen, in mg/L	Excellent	≤ ± 0.3 or ≤ ± 5%, whichever is greater
	Good	> ± 0.3 – 0.5 or > ± 5 – 10%, whichever is greater
	Fair	> ± 0.5 – 0.8 or > ± 10 – 15%, whichever is greater
	Poor	> ± 0.8 or > ± 15%, whichever is greater
pH, in pH unit	Excellent	≤ ± 0.2
	Good	> ± 0.2 – 0.5
	Fair	> ± 0.5 – 0.8
	Poor	> ± 0.8
Turbidity, in turbidity units	Excellent	≤ ± 0.5 or ≤ ± 5%, whichever is greater
	Good	> ± 0.5 – 1.0 or > ± 5 – 10%, whichever is greater
	Fair	> ± 1.0 – 1.5 or > ± 10 –15%, whichever is greater
	Poor	> ± 1.5 or > ± 15%, whichever is greater

Roles and Responsibilities

Table 9 identifies organizations and individuals involved in the implementation of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) including all contractors and subcontractors.

Table 9. Roles, responsibilities and contact information for persons or organizations affiliated with implementation of the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Name	Affiliation / Position	Role	Contact Info
Brian Mitchell	Regional Program Manager	QAP approval, protocol approval and ensuring data meet quality objectives	Brian_Mitchell@nps.gov
Brian Witcher	Network Program Manager	Program coordination	Brian_Witcher@nps.gov
Jim Hughes	Protocol Lead	Protocol implementation/data certification/reporting	James_D_Hughes@nps.gov
Varies	Protocol Technician	Data collection/data entry	–
Jerry Garrett	USGS	Gage establishment and maintenance/NWIS	jwgarret@usgs.gov

Project Quality Assessment

Routine Data Quality Evaluations

Periodic data audits and quality control inspections are conducted to maintain and improve data quality procedures (Table 10). Data audits verify that staff is operating in conformance with the data quality procedures specified in this plan and referenced standard operating procedures. In addition, audits should track and facilitate the correction of any deficiencies. Quality checks promote a cyclic process of continuous feedback and improvement of both the data and the quality-planning process. The results of quality assessments will be documented and reported to the network program manager as an internal report instead of being published in one of the NRSS report series. The monitoring protocol lead is responsible for ensuring nonconformities in data management practices are corrected.

Data quality (i.e., percent valid observations graded fair or higher) will be included in resource briefs and annual reports. Data quality is reviewed on an ongoing basis to evaluate overall efficacy of methods and QA/QC procedures in collecting, processing, and reporting data that meet specified quality standards. Protocol leads and program managers will evaluate QA/QC data to identify procedures that need to be refined, or to identify additional procedures to be developed.

Table 10. Routine data quality evaluation reports to be produced as a part of implementing the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Report	Purpose and Description	Frequency
Monthly data assess	Internal document describing data editing to remove outliers and fouling data points and to implement shifts to adjust data based upon information obtained as part of routine O&M site visits.	Conducted cumulatively for the period of record and in logical subgroups (parks, field season, etc.) as data are certified.
Data Quality Objective Review	Ensure that data quality objectives are appropriate to meet stated monitoring objectives.	Data quality review conducted annually as part of the annual operational review. Data quality objectives reviewed every fifth year during the annual protocol operational review.
Site fidelity/up-time	For continuous monitoring stations, the length of time stations are operational as compared to planned operation time. May be parameter specific.	Annually and concurrent with synthesis reporting.
Annual WQ station report	Conducted consistent with USGS standards for annual reporting of continuous water quality monitoring stations.	Annually.
Training / Certification Compliance	Ensure resources/ time available to maintain certification requirements.	Annually prior to work plan development.

Communicating Data Quality

The Appalachian Highlands Network will document data quality sufficient to notify end-users, program ecologists and other network staff about the QA/QC procedures used in the management of data quality as well as the data quality goals and objectives. To meet this requirement, the quality assurance plan will be included or referenced when disseminating any data collected under this protocol, in addition to providing all data quality annotations with data.

Documentation

Records

NPS Director's Order 11D: Records and Electronic Records Management (NPS 2012) and its appendix (NPS Records Schedule) describe NPS activities and standards in maintaining and providing access to records at all levels of the Service. Director's Order 11D states all records of natural and cultural resources and their management are considered mission-critical records, that is, necessary for fulfillment of the NPS mission. The NPS Records Schedule, which provides guidelines on natural resource-related records including the results of inventory and monitoring programs, indicates that all natural resource records are considered "permanent" and need to be retained either in an appropriate park museum facility or at the National Archives and Records Administration. Records maintained in the implementing the APHN Long Term Water Quality Monitoring Protocol for Continuous Sampling (Hughes et al. 2016) are presented in Table 11.

Table 11. Required records to be maintained as a part of implementing the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018).

Sample Collection Documents and Records	On-site Analysis Documents and Records	Off-site Analysis Documents and Records	Data Assessment Documents and Records	Other
Data collection notes, including: • USGS continuous monitor field forms, and • water quality meter calibration and maintenance log	–	USGS CHIMP automated correction loaders/Aquarius	Data QA/QC Snapshots for published reports	Manuscript submittal forms for published reports
Site establishment / documentation notes: USGS continuous monitor field forms	–	Personnel training certifications / documentation maintained at office.	Data snapshots for published reports (or links to automatically generate)	Peer review memos and author responses for published reports
Photos	–	–	–	–
Raw sensor data maintained in USGS data loggers	USGS gage folders	Raw and edited sensor data in NWIS	–	–
USGS Memorandum of Understanding	–	–	–	–

Metadata

Metadata for all published data products must be Federal Geographic Data Committee (FDGC) compliant. The abstract for all metadata must include the following link https://irma.nps.gov/DataStore/Reference/Profile/2236686 to ensure data can be traced to all methods used for data collection, processing, the latest version of the protocol, this QAP, and all associated standard operating procedures.

Data Certification

Data certification is the process confirming that:

- Data have been through all QA/QC procedures as outlined above
- Data either meet specified quality standards or, data that do not meet those standards, are appropriately identified and communicated at the record level.
- Procedures for data collection, processing, and transformation have been documented in appropriate metadata formats
- Data are suitable for use.

Per Inventory and Monitoring Division Data Certification Guidelines, in the absence of an approved QAP, data that have been through all QA/QC procedures as outlined in the approved protocol narrative and standard operating procedures are deemed "acceptable." After review and approval of this QAP, data certification will occur not less than one year after data processing is complete. The protocol lead (APHN hydrologist) is responsible for certifying that all processes have occurred in accordance with SOP CWQ8 *Quality Assurance/Quality Control—Version 1.4* (Hughes et al. 2018d), SOP 9 *Data Management—Version 1.3* (Hughes et al. 2018e), and SOP CWQ10 *Continuous Water Quality Records Processing—Version 1.4* (Hughes et al. 2018f).

Information Dissemination

All data reports disseminated for public use are based on NPS certified data. Data for general dissemination underwent QC procedures and received a grade of good or excellent as described in Table 9. Data will be NPS certified prior to internal use for supporting park-, regional-, or national-level resource management decisions. In some cases the use of provisional data (data that have not undergone complete QA/QC as defined in this QAP) may be warranted to base decisions on best-available science.

Use of Provisional Data. Raw water-quality data collected in accordance with the *Long-Term Continuous Water-Quality Monitoring at Big South Fork National River and Recreation Area and Obed Wild and Scenic River: Protocol Narrative* (Hughes et al. 2018) is available in near real-time via USGS telemetry. Although real-time data are not validated, have not undergone rigorous QA/QC review, and are not considered provisional data, these data are useful to identify water-quality conditions of concern that may require a rapid response from resource management staff. Water-quality conditions of concern will be identified by the protocol lead as part of daily review of data on the Internet and relayed to appropriate park staff through verbal or email communication.

Provisional data are time-series water-quality data identified as provisional data by the USGS and have not been certified by NPS. These data may be utilized in informal written or verbal briefings to park management staff. These data may be utilized to alert appropriate staff of daily or seasonal trends and variability between monitoring stations that indicate water-quality conditions that merit attention. Provisional data may also be utilized to document conditions that are indicative of regulatory non-compliance or other conditions with management implications. Prior to utilization of provisional data, the protocol lead must verify that water-quality data obtained by continuous water-quality monitoring are not reflective of fouling or other sensor failure. In many situations, this may necessitate an unscheduled operation and maintenance site visit.

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

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