

QUALITY ASSURANCE PROJECT PLAN

for

Waccamaw Watershed Academy's Volunteer Water Quality Monitoring Program

June 2021



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Section A: Project Management

A1 TITLE AND APPROVAL SHEET


Waccamaw Watershed Academy's
Volunteer Water Quality Monitoring Program QAPP
April 2021

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Coastal Carolina University


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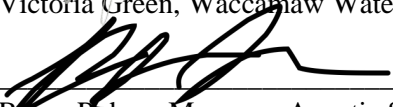
APPROVALS:



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Date 2021-07-09
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Date 7/9/2021
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Table of Acronyms

CCU	Coastal Carolina University
DQO	Data Quality Objectives
EQL	Environmental Quality Laboratory
IDOC	Initial Demonstration of Capability
LCS	Laboratory Control Sample
MS4	Municipal Separate Storm Sewer Systems
OEM	Original Equipment Manufacturer
NPDES	National Pollutant Discharge Elimination System
SCDHEC	South Carolina Department of Health and Environmental Control
QC	Quality Control
VOLT	Volunteer Operations and Logistics Team
WWA	Waccamaw Watershed Academy

A3 DISTRIBUTION LIST

These individuals and organizations will receive a copy of the approved Quality Assurance Project Plan (QAPP) and any subsequent revisions:

- Waccamaw Watershed Academy at Coastal Carolina University
 - Director
 - Program Manager
 - Volunteer Monitoring Coordinator
- Winyah Rivers Alliance
 - Waccamaw Riverkeeper
- Horry County Stormwater Department
 - Stormwater Manager
 - Watershed Planner
- Georgetown County Stormwater
 - Division Manager
- Town of Surfside Beach
 - Director of Public Works
- Town of Briarcliffe Acres
 - Town Clerk
- City of Conway
 - Head of Public Works
- Murrells Inlet 2020
 - Executive Director
- South Carolina Department of Health and Environmental Control
 - Director, Water Quality Division
 - Director, Monitoring, Protection, and Assessment Division
 - Manager, Surface Water Monitoring

The Waccamaw Watershed Academy's Volunteer Water Quality Monitoring QAPP is available for download at www.coastal.edu/wwa/vm/.

A4 PROJECT/TASK ORGANIZATION

Coastal Carolina University's Waccamaw Watershed Academy (WWA) is partnering with small municipal separate storm sewer system (MS4) communities in the Myrtle Beach Urbanized Area to monitor water bodies of interest within the Waccamaw River Basin (hydrologic unit 03040206) and the Coastal Drainage Basin (hydrologic unit 03040208). This QAPP covers monitoring performed by volunteers that is organized into two programs, one within the Waccamaw River Basin (aka "Waccamaw Program") and the other within the Coastal Drainage Basin (aka "Coastal Program"). The latter includes sampling sites located within the towns of Surfside Beach and Briarcliffe Acres and within Murrells Inlet (an unincorporated area that lies within Horry and Georgetown County).

The WWA's Volunteer Operations and Logistics Team (VOLT) provides technical support for the volunteer monitoring programs that includes:

- Development, distribution and revision of all documentary materials including: internal standard operating procedures, a handbook for volunteer monitors, forms and this QAPP.
- Training of all personnel including volunteers.
- Acquisition and quarterly maintenance of monitoring equipment and supply kits.
- On call support to volunteers to resolve technical issues.
- Development and implementation of a quality control/quality assurance program followed by an internal data validation review.
- Development, implementation and maintenance of a password-protected online data entry system and long-term data archiving of electronic and paper records.
- Development, implementation and maintenance of a publicly accessible database that provides online interactive data delivery and data download.
- Organization, and delivery of data conferences for the general public and appreciation events for the volunteer monitors.
- Presentations to local stormwater advisory boards, committees, and commissions
- Provision of rapid response reports to the local stormwater managers to facilitate illicit discharge detection.

The VOLT operates under the guidance of the Waccamaw Watershed Academy Director who performs data validation services. The Waccamaw Watershed Academy is an operational group within the Burroughs and Chapin Center for Marine and Wetland Studies at Coastal Carolina University. The VOLT includes a project manager, a volunteer monitoring coordinator, a field coordinator, volunteer field leaders, volunteer teams and CCU students as shown in the following organizational chart.

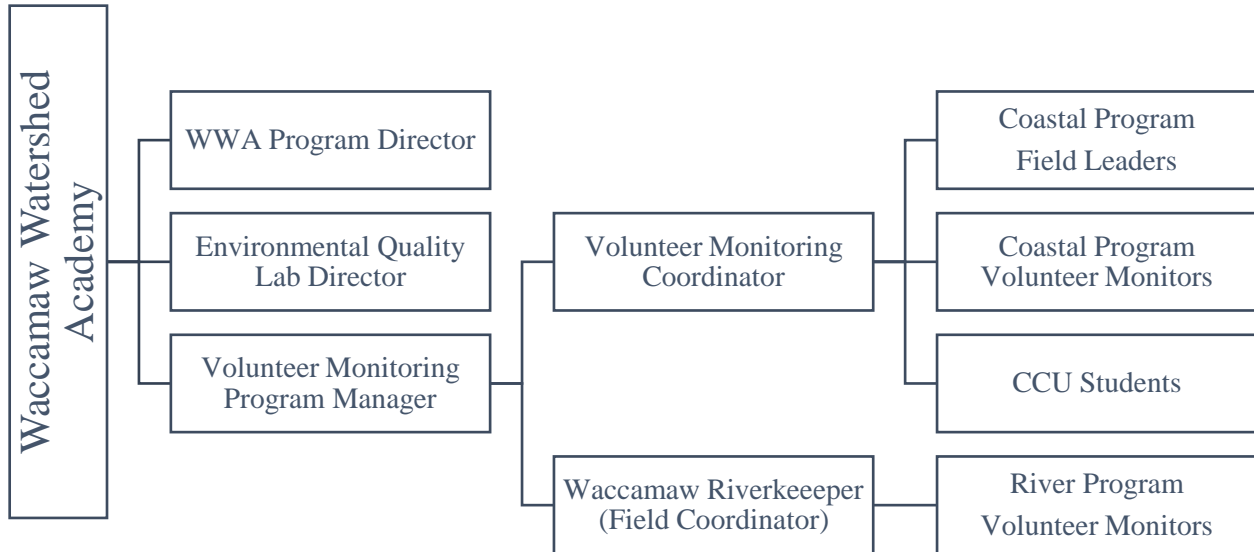


Figure 1: Organization Chart

A5 PROBLEM DEFINITION/BACKGROUND

Starting in 2006, the federal Clean Water Act expanded its National Pollution Discharge Elimination System (NPDES) to require that even relatively small municipalities reduce polluted stormwater runoff by developing and implementing local stormwater management plans. In South Carolina, compliance activities are implemented by local municipalities referred to as small Municipal Separate Storm Sewer Systems (MS4s). Horry and Georgetown counties collectively contain eight regulated MS4s – each with a stormwater program approved by the SC Department of Health and Environmental Control (SCDHEC).

The WWA’s volunteer water quality monitoring programs are designed to detect the impacts of polluted stormwater runoff in the Waccamaw River and selected areas within the Coastal Drainage Basin. The primary use of the monitoring data is to support compliance with the requirements under SCDHEC NPDES Phase II stormwater permit # SCR030000 by the regulated MS4 communities. The pollutants of concern (and related indicators) are: pathogens (*E. coli*), sediment (turbidity), eutrophication and hypoxia (nutrients, pH and oxygen).

From a regulatory perspective, the primary goal of the volunteer monitoring programs is to provide tangible evidence of public engagement and public outreach as required in the NPDES stormwater permit. This evidence is provided to SCDHEC via the reporting activities of the Coastal Waccamaw Stormwater Education Consortium. The program activities and resultant data are also used by nongovernmental

organizations, such as Murrells Inlet 2020 and the Waccamaw RIVERKEEPER®, to meet their organizational goals.

The volunteer monitoring data address other permit requirements including the effectiveness of construction nonpoint pollution controls and illicit discharge detection. The sampling sites have been selected to provide the “watershed approach” formally recommended in 1997 by the EPA as a best management practice for identifying and controlling sources of waterborne pollution. This strategy provides data that assists local municipalities by:

- Increasing geographic and temporal coverage of water quality monitoring in the region beyond what is covered by other entities, including regulatory work conducted by SCDHEC and CCU’s Environmental Quality Lab (#26001002).
- Identifying pollution "hot spots"
- Detecting illicit discharges through rapid reporting to the small MS4s to facilitate quick follow-up field investigations
- Detecting trends over time, including improvements from implementation of stormwater management activities.

Other goals related to compliance with NPDES Minimum Control Measures 1 and 2 include:

- Creation and support of citizen scientists who are as environmental stewards and mentors for their local communities.
- Environmental outreach to local communities and K-12 in the form of data presentations, web pages and appearances in mass media (TV, newspapers, etc.)
- Provision of data to support student projects (K-12 and university) and other entities (consultants, researchers, etc.)

A6 PROJECT/TASK DESCRIPTION

The volunteer monitoring activities covered by this QAPP are organized into two programs: the Waccamaw River Program and the Coastal Program. The latter includes sampling sites located within the towns of Surfside Beach and Briarcliffe Acres and within Murrells Inlet (an unincorporated area that lies within Horry and Georgetown County).

Sampling is typically conducted twice a month year-round by trained volunteers at fixed sites in the watersheds as listed in Table 1. Site selection and site accessibility considerations are detailed in Section B1. Because WWA is an entity of Coastal Carolina University, sampling is conducted once in December to accommodate the university’s winter break.

During each sampling event, measurements of temperature, conductivity, total dissolved solids, salinity, dissolved oxygen and pH are made in situ, using hand held meters. Grab samples are collected for analysis of nitrate, nitrite and ammonia using test strips in the field. Samples are collected for turbidity and fecal bacteria and returned to the volunteer’s home laboratories for measurement of turbidity via a benchtop meter, *E. coli* and total coliforms by plating and incubating. Full sampling protocol and analysis methods can be found in the Volunteer Water Quality Monitoring Handbook (Appendix A).

Volunteers enter data into a password-protected online database and mail field and lab datasheets to the VOLT. Validated results, regulatory compliance issues and other notable trends are conveyed to the small MS4’s stormwater managers within two weeks of data collection. The data are archived into a database

that is publicly accessible via an online data portal. The data are also uploaded semiannually to the EPA’s Water Quality Portal, which also feeds into a variety of data access tools.

Table 1: Sampling Site Locations

Program Area	Site Name	Latitude	Longitude
Waccamaw River	Highway 9	33.91126	-78.7148
	Reaves Ferry	33.85049	-78.8976
	Conway Waterfront	33.83276	-79.0442
	Pitch Landing	33.80066	-79.055
	Bucksport Landing	33.65195	-79.095
	Wachesaw Landing	33.56191	-79.086
	Hagley Plantation	33.43645	-79.1825
	Sampit River	33.35675	-79.2805
	Enterprise Landing	33.69417	-78.992
	Sterritt Swamp	33.8215	-78.9654
	Peachtree Landing	33.69461	-79.0478
Murrells Inlet	Woodland Drive Pond	33.58947	-78.9909
	Point Drive Canal	33.58048	-79.0101
	Rum Gully Creek	33.5697	-79.0167
	Marina Colony Pond	33.5628	-79.0297
	HS	33.55233	-79.0401
	BHR	33.54383	-79.0479
	Bike Bridge	33.52922	-79.0611
	Oyster Landing Beach	33.52402	-79.062
Surfside Beach	4th Ave. N.	33.60937	-78.9704
	11th Ave. N.	33.61412	-78.9654
Briarcliffe Acres	Cabana Road	33.78733	-78.7427
	North Lake	33.78873	-78.7421
	South Lake	33.78668	-78.7484

A7 OBJECTIVES & CRITERIA FOR MEASUREMENT DATA

Visual Site Assessment

Volunteers report physical observations of their sites at the time of each sampling. The results are recorded on field datasheets in a standardized format, such as direction of water flow, weather conditions, presence of odors, litter, etc.

Precision, Accuracy, and Measurement Range for Chemical and Bacterial Monitoring

The table below illustrates the required precision, accuracy and measurement ranges for the parameters measured by the volunteer water quality monitors. The table also describes the method, its sensitivity and calibration requirements. In this table, “meter” refers to the Thermo Scientific Orion Star A329 Portable pH/ISE/Conductivity/RDO/DO Meter. Sensitivity is the concentration of the lowest calibration mark, reading or standard. Values provided by the Original Equipment Manufacturer are noted with (OEM).

Table 2: Data Quality Objectives (DQO)

Parameter	Method (Range & Units)	Duplicate Precision	Accuracy (Allowable range comparing monitor value to QA value)	Sensitivity (Resolution)	Sensitivity (Reporting Limit)	Calibration
pH	Meter (0 to 14 standard pH units) (OEM)	≤ 0.10*	±0.10 pH for 6.00 buffer	±0.01 pH (OEM)	4.00	Two-point calibration with 4.00 and 7.00 buffers
Temperature	Meter (0 to 50°C) (OEM)	≤ 0.1*	±0.3 (quarterly NIST thermometer check)	±0.1 °C (OEM)	<0.0 °C (OEM)	NA
Specific Conductivity	Meter (1 µS/cm to 200 mS/cm) (OEM)	≤ 1% µS/cm or ≤ 0.1 mS/cm*	± 5%	±0.01 µS/cm	<0.01 µS/cm (OEM)	One-point calibration (100 µS/cm, 1413 µS/cm, or 12.9 mS/cm)
Total Dissolved Solids (TDS)	Meter (0 ppm to 200 ppt)	NA		±0.01 ppm or ppt	Calculated by the meter from specific conductivity	NA
Salinity	Meter (0.01 to 42 psu)	NA	± 0.5 psu	±0.001	<0.2 psu	NA
Dissolved Oxygen (DO)	Meter (0 to 20 mg/L or 0 to 200%) (OEM)	≤ 0.20 mg/L ≤ 5%DO	± 10% DO	±0.01 mg/L (OEM)	<0.01 mg/L or 0.0 % (OEM)	Water saturated air calibration
Nitrite +Nitrate	Hach Test Strip (0 to 50 ppm)	NA	± one half of a color block	± one half of a color block	<0.5 ppm	NA
Nitrite	Hach Test Strip (0 to 3.0 ppm)	NA	± one half of a color block	± one half of a color block	<0.075 ppm	NA
Ammonia	Hach Test Strip (0 to 6.0 ppm)	NA	± one half of a color block	± one half of a color block	<0.125 ppm	NA
Total Coliforms and <i>E. coli</i>	Micrology EasyGel (0 to 30,000 CFU/ 100 mL)	NA	NA	±33 or 100 CFU/100 mL	<33 or <100 CFU/100 mL (3 mL or 1 mL sample)	NA

Turbidity	Hach Turbidimeter (0 to 1000 NTU)	≤1 NTU for values ≤ 10 NTU, ≤1% for values >10 NTU*	±10% of assigned Gelex Check value	±0.01 NTU on lowest range	<0.01 NTU on lowest range (lowest Gelex secondary standard is approximately 4.0 NTU)	StablCal Formazin Turbidity Standards (quarterly)
NA = not applicable *Required agreement between last two of three replicates that are averaged to generate sample result.						

Compliance with duplicate precision criteria for temperature, DO, pH and specific conductivity is determined from the last two of three field replicates. If out of control, another replicate is measured. Accuracy is assessed from calibration checks performed on sampling day prior to sampling. Compliance with duplicate precision criteria for turbidity is determined from the last two of three lab replicates. If out of control, another replicate is measured. Accuracy is assessed using two Gelex secondary standards (low and high) immediately prior to sample determinations. For nutrients and *E. coli* accuracy is checked only during performance of initial and ongoing demonstrations of capability. Due to financial constraints, precision is not monitored for these parameters and hence these DQO's are labelled as NA.

Certified Field Samplers and Master Calibrators must demonstrate proficiency for each parameter listed in Table 2 by successfully completing an Initial Demonstration of Capability. Ongoing demonstration of capability is demonstrated via successful completion of a re-certification course at a minimum frequency of once every two years. As part of these demonstrations of capability, volunteers must meet DQO's in Table 2 for accuracy and precision. The meter proficiency is demonstrated in the field through comparison to results obtained by a certified analyst. The nutrient, turbidity and bacteria proficiencies are demonstrated in the lab with blind performance test samples.

A8 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

Volunteer monitors can choose to engage in water monitoring at various levels. These include: (1) Field Sampler; (2) Bacteria Analyst; (4) Turbidity Analyst; (5) Master Sampler; (6) Data entry; and (7) Team Leader. Training requirements are summarized in Table 1 of Appendix A.

All volunteers are normally required to undergo the Field Sampler training. This is done in two steps: (1) a hands-on session conducted in Coastal Carolina University's Environmental Quality Lab (EQL) that is set up and directed by the VOLT, followed shortly thereafter by (2) a field-based training in which volunteers are shown how to collect water at their sampling sites.

Training and certification through Initial Demonstrations of Capability (IDOC) for measurement of turbidity and fecal bacteria is provided as needed within each program as well as to address the interests of the volunteers. Ideally, at least one team member is certified to calibrate the Orion multimeter through Master Sampler training.

Retraining (Continuing Demonstrations of Capability) is performed using two strategies: (1) Annual site visits to observe team activities and (2) retraining sessions. Additional visits are conducted if volunteers are having difficulty meeting the acceptance criteria in Table 2. These visits are conducted by a member of the VOLT who verifies through close observation that sampling protocols are being followed. The

VOLT staff also verify that site conditions are sufficiently safe. Volunteers will be issued a retraining certification that is valid for two years, with a six-month grace period.

A9 DOCUMENTS AND RECORDS

Volunteers will calibrate the Orion multimeter at their homes using solutions provided by the VOLT and documented on the calibration datasheet. Field data will be recorded on datasheets. Bacteria and turbidity analyses will be performed at the volunteer's homes and will be recorded on the corresponding datasheets (Appendix A).

Volunteers enter their data, along with brief observational comments, into a password-protected online database. To minimize transcription errors, the online database rejects entries that are outside of acceptable ranges. Self-addressed stamped envelopes are provided so that the volunteers can mail all the original datasheets to the VOLT. Upon receipt, the VOLT review the datasheets checking for transcription errors and compliance with required QC. If necessary, the VOLT fixes transcription errors and rejects or qualifies data. Valid measurements that exceed the preprogrammed ranges can be manually entered. The volunteers may also type comments along with their data entry into the online database describing any observations during that sampling.

Electronic backups of all databases are automatically generated once a month and saved on an external hard drive. All records including datasheets, calibration logs, preparation logs and chain of custodies are stored in program specific binders until the end of the calendar year. Datasheets are then bound and stored at CCU indefinitely.

Copies of the Volunteer Water Quality Monitoring Handbook and this QAPP are distributed by the VOLT who also is responsible for all updates. Electronic copies are accessible through the WWA's website: <https://www.coastal.edu/wva/vm/qualityassurance/>

Section B: Measurement/Data Acquisition

B1 SAMPLING PROCESS DESIGN

As described in Section A5, volunteer monitoring activities are organized into two programs: the Waccamaw River Program and the Coastal Program. The latter includes sampling sites located within the towns of Surfside Beach and Briarcliffe Acres and within Murrells Inlet (an unincorporated area that lies within Horry and Georgetown County). Sampling is conducted twice a month year-round (once in December) at fixed sites in the watersheds as listed in Table 1. Sampling and analyses procedures are detailed in Appendix A.

The goal of all the programs is to provide a long-term characterization of water quality with sufficient geographic density to enable detection of unusual conditions that could be caused by an illicit discharge. The long-term record is also intended to detect trends in improving or degrading water quality as a consequence of stormwater runoff. These activities help meet the goals of program's funding partners' stormwater management programs, i.e. (1) to provide a venue for public engagement and outreach education, (2) illicit discharge detection and (3) an assessment of the effectiveness of post-construction stormwater treatment practices. The pollution problems of concern turbidity, fecal bacteria contamination, eutrophication and hypoxia. The parameters measured to track these problems include: dissolved oxygen, specific conductivity, pH, temperature, nitrate, nitrite, ammonia, turbidity and *E. coli*.

A sufficiently long time series is required to establish site-specific normal values that permit detect of trends and outliers (potential illicit discharges). This reflects environmental variability arising from stormwater runoff, flooding, drought, extreme temperatures (hot and cold), high tides (king tides and storm surges) and construction activities.

Each program has additional goals that influenced the selection of sampling sites. These are:

Waccamaw River: To characterize the river, most sites are located in the main stem at public boat landings. One site is located in a tributary (Sterritt Swamp) immediately downstream of the county landfill and several large planned unit developments. A second is located in the Atlantic Intracoastal Water (Enterprise Landing) just upstream of its merger with the Waccamaw River. A third site is located in the Sampit River just upstream of its merger with Winyah Bay which is also the terminus of the Waccamaw River. The pollutant of concern is oxygen demand since the Waccamaw River has an approved TMDL for dissolved oxygen.

Murrells Inlet: A primary goal is to characterize land-based inputs of stormwater via small freshwater streams that discharge into the Inlet. To this end, six representative freshwater streams are sampled near their terminus to the Inlet. Two sites are located in the saline waters of the Inlet. The pollutant of concern is fecal bacteria since Murrells Inlet has an approved TMDL for fecal coliforms. Since most of the samples are freshwater, *E. coli* is used as the indicator fecal bacteria.

Surfside Beach: A primary goal is to characterize land-based inputs of stormwater via swashes into the recreational coastal waters of the town of Surfside Beach. Several sites in the surf zone are on the federal 303(d) list for recreational impairments due to contraventions of *Enterococcus* water quality criteria. So, the pollutant of concern is fecal bacteria. Since the samples are comprised of freshwater, *E. coli* is used as the indicator fecal bacteria.

Briarcliffe Acres: This program has two primary goals. The first is to determine if fecal bacteria contamination is still present in Briarcliffe Acres Swash. The ocean front homes were connected to a municipal sewer line in 2017 while the remaining homes in the uplands remain on septic

tanks. The volunteers sample at a mid-point site in the swash. The EQL also performs *Enterococcus* measurements on samples collected at the Head of the Swash, the midpoint and the Mouth of the Swash. The EQL also makes weekly *Enterococcus* measurements in the surf zone for the City of Myrtle Beach at a site (WAC-09A) that is on the federal 303(d) list for recreational impairments. The second goal is to evaluate the success of professional water quality management in two community ponds, particularly in regard to eutrophication (algal blooms).

Site selection for each program was determined by identifying areas which were deemed accessible and safe for the volunteers as well as areas of interests for the storm water managers. All sites are publicly accessible, or landowner permission was acquired for sampling use.

If sites become inaccessible due to excessive rainfall, flooding, road construction or changes in property ownership, efforts will be made to conduct sampling at a different time or nearby alternate location. These deviations are approved in consultation with the VOLT and documented on the field datasheets. Data are qualified as needed through comments in the online database. In some cases, sampling is not possible. If less than 50% of the sites in a specific program can be sampled, the sampling event is delayed or cancelled according to the discretion of the VOLT.

In the event of equipment failure or sampling error, the volunteer monitoring coordinator in partnership with the Field Leader will attempt to resample within an appropriate time frame. The volunteers are encouraged to contact the VOLT as soon as possible to evaluate these options.

B2 SAMPLING METHODS REQUIREMENTS

Detailed sample collection methods and measurement procedures are provided in the Volunteer Water Quality Monitoring Handbook (Appendix A). These are briefly summarized in the following table.

Table 3: Sampling Method Requirements for ambient water matrix.

Parameter	Sampling Equipment	Sample Holding Container	Sample Preservation Method	Maximum Hold Time
Temperature	Thermo Scientific Orion Star A329 Portable pH/ISE/Conductivity/RDO/DO Meter	2 L thermos	None	Measured immediately
Dissolved Oxygen	Thermo Scientific Orion Star A329 Portable pH/ISE/Conductivity/RDO/DO Meter	2 L thermos	None	Measured immediately

Conductivity/TDS /Salinity	Thermo Scientific Orion Star A329 Portable pH/ISE/Conductivity/RDO/DO Meter	2 L thermos	None	Measured immediately
pH	Thermo Scientific Orion Star A329 Portable pH/ISE/Conductivity/RDO/DO Meter	2 L thermos	None	Measured immediately
Nitrate and Nitrite	Hach AquaChek strip	2 L thermos	None	Measured immediately
Ammonia	Hach AquaChek strip	4 mL plastic vial	None	Measured immediately
Turbidity	Hach 2100Q Turbidimeter	500 mL plastic bottle	On ice	48 hours
<i>E. coli</i> / Total Coliform	Micrology Coliscan Easygel	30 mL sterile bottle	On ice	8 hours
*Unless analyses are conducted within two hours of sampling.				

In-situ measurements are performed with Orion multimeters outfitted with sensors for pH, specific conductivity, and dissolved oxygen. The sensors are rinsed with DI water and dried with a lint free cloth before and after calibration and sampling. Calibration of pH and conductivity is performed within 24 hours of sampling. Calibration is confirmed with a laboratory control sample (LCS) analyzed the morning of sampling. The LCS is preferably analyzed in the field and hence is commonly referred to as a “field check”. The DO calibration is similarly confirmed by checking water-saturated air (Appendix A). Calibration sheets are submitted by the volunteers to the VOLT for review and archiving.

The turbidity samples are not preserved if analysis is conducted within two hours of sampling to eliminate delays bringing samples to room temperature immediately prior to analysis (Appendix A). After analysis, turbidity samples can be disposed of down the drain. Quarterly, used turbidity bottles are returned to the EQL where they are washed according to the EQL’s labware cleaning procedures.

Bacteria samples collected for analysis are kept on ice for the duration of their maximum eight-hour hold time (Appendix A). After counting, plated bacteria samples are sterilized using bleach and disposed of in household trash following Appendix A.

Volunteer monitors return their equipment kits to the VOLT for quarterly maintenance. This maintenance work includes: (1) checking batteries in all the equipment; (2) for the turbidity meter, recalibrating and reassigning true values to the secondary Gelex standards; and (3) for the Orion multimeter, checking meter performance through calibration and measurement of the field checks. Expendables are also replenished during quarterly kit maintenance including: calibrating standards, pH buffers, conductivity and pH field checks, bacteria supplies, nutrient strips, purified water, etc.

CCU's EQL provides support lab facilities for equipment maintenance, this includes refrigerators, freezers, incubators and water purification (deionizers). Bacteria and turbidity analysts perform their work in their homes using equipment maintained by the VOLT as described above.

Any problems encountered during sampling are reported to the field leader and VOLT via phone or text. Typical corrective actions are shown in the following table. Protocols for handling corrective actions for problems arising during analysis and data review are described in Section C1.

Table 4: Corrective Actions to Address Sampling Problems

Problem	Corrective Action	Notes
Site not accessible due to safety issues such as flooding	Relocate site	This is done in collaboration with the VOLT. In some cases, the VOLT may perform sampling. All details of nonroutine sampling are noted in Comment section of the Field Datasheet.
Conductivity sensor not working	Call VOLT to troubleshoot. If equipment is still not working, save leftover water from turbidity sample on ice.	VOLT coordinates sample pick up for measurement of conductivity at the EQL within 28-day hold time. Conductivity temperature is not reported.
pH sensor not working	Call VOLT to troubleshoot. If equipment is still not working, save leftover water from turbidity sample on ice.	VOLT coordinates sample pick up for measurement of pH at the EQL. pH temperature is not reported. Data are qualified since measurement is made beyond regulatory hold time (15 minutes).
Oxygen sensor not working	Call VOLT to troubleshoot. If equipment is still not working, no result is reported unless VOLT is able to make a measurement close in time to collection of other data.	
Turbidimeter meter not working	Call VOLT to troubleshoot. If equipment is still not working, save turbidity sample at on ice.	VOLT coordinates sample pick up for measurement of turbidity at the EQL within 48 hour hold time.
Bacteria supplies missing, incubator not working	Call VOLT to troubleshoot. If equipment is still not working or supplies are missing, no result is reported unless VOLT can retrieve sample for analysis in lab within 8-hr hold time.	Problems discovered after samples have been plated cannot be remedied, so no result is reported.
Nutrient strips missing	Call VOLT to troubleshoot. If missing supplies cannot be easily addressed, save leftover water from turbidity sample at on ice.	VOLT coordinates sample pick up for measurement of nitrogen in the EQL within 48 hours.

B3 SAMPLING HANDLING AND CUSTODY REQUIREMENTS

Hold times are shown in Section B2. Only turbidity and bacteria samples are transported from the field. They are either transported to the home of the analyst or to the EQL. The samples are transported on ice in a cooler except for turbidity samples that are analyzed within two hours of sample collection.

At time of data entry into the online database, a unique lab sample ID is automatically generated with the following format: VM_XX_YY_####. The letters VM denote the volunteer monitoring program. XX denotes the monitoring location (WR for Waccamaw River, MI for Murrells Inlet, SB for Surfside Beach, and BA for Briarcliffe Acres). YY indicates the two-digit year. #### is a four-digit number that is automatically generated by the database.

B4 ANALYTICAL METHODS REQUIREMENTS

Full analytical methods are detailed in the Volunteer Water Quality Monitoring Handbook (Appendix A). To perform the tasks described in this QAPP, the WWA volunteers use five field (nutrients, pH, dissolved oxygen, temperature, and conductivity) analysis procedures and two laboratory analysis techniques (turbidity and bacteria):

- Temperature by thermometer or thermistor, based on Method 2550 B. of Standard Methods
- Conductivity by electrical conductivity, based on Method 2510 B. of Standard Methods
- Dissolved oxygen by optical fluorescence, based on Method 4500-O G. of Standard Methods
- pH (hydrogen ion concentration) by electrometric method, based on Method 4500-H+ B. of Standard Methods
- Turbidity by nephelometry, based on Method 2130 B. of Standard Methods
- *E. coli* and Total coliform using Micrology's EasyGel media followed by a visual plate count after an 18-hr incubation at 35C.

B5 QUALITY CONTROL REQUIREMENTS

Quality Control activities include ones performed by the volunteers as described in the Volunteer Water Quality Monitoring Handbook and others performed by the VOLT. The former are summarized in Section A7 which includes relevant acceptance criteria.

The QC activities performed by the volunteers include:

- Calibration of the Orion Multimeter for pH, Specific conductivity and pH. Verification of the calibration of the Turbidimeter with Gelex secondary standards. Verification of bacteria incubator temperature with a NIST thermometer permanently kept inside the incubator.
- Calibration check with a field check (LCS) for specific conductivity and pH.
- Check for drift in meter measurements while sampling. Additional readings are required if drift criteria are not met.
- Check that datasheets are complete and correct. Volunteer who performs this check signs off on the datasheet.

These QC activities are document on datasheets that include acceptance criteria and a requirement to identify whether each QC activity was in or out of control. Volunteers are taught how to perform their QC duties as part of their training.

The training requirements are:

- Bacteria analysis
 - Must achieve 75% to 125% recovery of true value on plates they have prepared.
- Turbidity
 - Must achieve accuracy within 10% of the established true value and precision as measured by percent relative standard deviation of less than 10%
- Chemical monitoring
 - For all Orion multimeter parameters, must achieve accuracy within 10% of the established true value and as measured by percent relative standard deviation of less than 10%. The IDOC is performed in the field with the true value determined by an independent meter calibrated by the VOLT.
 - For master samplers, the IDOC involves them using a meter they have calibrated.
 - Nutrient measurements are performed with Hach test strips that are semi-quantitative and hence used as a screening tool. The IDOC is performed in the lab with blind standards to ensure the analyte is present within the working range of the strips.

Continuing demonstration of capability (retraining) is required biannually.

The following QC activities are performed by the VOLT:

- Check of temperature consistency between temperature measurements reported by the conductivity, pH and dissolved oxygen sensors. Agreement should be within 0.5C.
- Check of temperature sensor accuracy. This is performed as part of quarterly kit maintenance using a NIST thermometer maintained by CCU's EQL
- The accuracy of the NIST thermometer kept in the bacteria incubator is checked annually.
- Check for noise in meter measurements. This is performed by code that automatically generates control charts from data in the database (replicate meter measurements).
- QC review of all datasheets (including calculations) and logs (chain of custody, standard preparation, thermometer calibration, chemical and equipment receipt, primary standard receipt, consumables receipt). This is documented by reviewer's sign off on the sheets.
- Check for receipt of all datasheets.
- QC review of all received datasheets.
- Check that all sensors are operating within OEM specifications.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, MAINTENANCE REQUIREMENTS

All equipment is provided by the WWA and thoroughly inspected. All consumables are replaced quarterly during kit maintenance and prior to their expiration dates. While stored at the volunteer's home, equipment is kept in a cool (but not freezing), dark, and dry place. EasyGel bacteria media is stored in the volunteer's home freezer in a plastic bag. Prior to use, all probes are calibrated and quality control criteria met.

Table 5: Major equipment maintenance intervals. Replacement parts are stored at CCU.

Instrument	Type of Maintenance	Frequency
Orion A329	Batteries changed	As needed
Orion A329 DO Probe	DO Cap changed	Annually
Orion A329 pH probe	pH probe changed	As needed. Usually within 18 months.
Orion A329 DO probe	DO probe changed	As needed. Warranty period is 2 years since purchase.
Orion A329 Conductivity probe	Conductivity probe changed	As needed Warranty period is 2 years since purchase.
Orion A329 Meter	Meter replacement	As needed. Warranty period is 3 years since purchase.
Hach Turbidimeter	Meter replacement	As needed. Warranty period is 1 year since purchase.
Hach Turbidimeter	Batteries changed	As needed

B7 INSTRUMENT CALIBRATION AND FREQUENCY

Routine calibration activities for the Orion Multimeter and Hach Turbidimeter are listed in the following table.

Table 6: Routine Calibration activities and frequency.

Parameter	Frequency	Notes
Conductivity probe	Each Use	Calibrated by Master Sampler at their home with day prior to sampling.
	Quarterly	Calibrated at CCU's EQL by VOLT. Probe replaced if necessary.
Dissolved Oxygen probe	Each Use	Calibrated by Master Sampler at their home with day prior to sampling.
	Quarterly	Calibrated at CCU's EQL by VOLT. Probe replaced if necessary.
Temperature	Quarterly	Checked versus certified NIST at CCU's EQL by VOLT.
pH probe	Each Use	Calibrated by Master Sampler at their home with day prior to sampling.

	Quarterly	Sensor cleaned and calibrated at CCU's EQL by VOLT. Probe replaced if necessary.
Turbidimeter	Each Use	Calibration checked by Turbidity Analyst using two secondary Gelex standards.
	Quarterly	Meter calibrated at CCU's EQL by VOLT using primary standards purchased from OEM.

Details of the calibration activities and acceptance criteria are provided in the following table.

Table 7: Equipment calibration procedures and acceptance criteria.

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)
Orion A329 pH probe	Two-point calibration with 4.00 and 7.00 Standards	With a day prior to sampling	Standards within 0.10. Calibration slope (92 to 102%). Standard mV within 30 mV. LCS performed in field (aka field check) within ± 0.10 pH.	If fails, rinse probe, refill solutions, and recalibrate. Contact VOLT for replacement probe
Orion A329 Conductivity Probe	Calibration with standard	With a day prior to sampling	Standard within acceptance range (10%) and LCS within 10%`	Rinse probe, refill solutions, & recalibrate. Contact VOLT for replacement probe
Orion A329 Dissolved Oxygen Probe	Water Saturated Air	With a day prior to sampling	Post calibration 90-110%	Rewet sponge, let acclimatize, recalibrate. Contact VOLT for replacement probe
Hach 2100Q Turbidimeter	Quarterly Calibration with StablCal	Quarterly	Verification standard within $\pm 10\%$ of established value	Recalibrate

B8 INSPECTION/ACCEPTANCE REQUIREMENTS FOR SUPPLIES AND CONSUMABLES

The supplies needed for sampling are described in Appendix A. WWA will supply all materials needed for sampling. Quarterly, consumables are replenished during kit maintenance conducted by the VOLT at CCU's EQL.

B9 DATA ACQUISITION REQUIREMENTS (NON-DIRECT MEASUREMENTS)

Weather, water quality, and tidal data are combined with volunteer data in order to produce holistic sampling reports. A brief overview of data from other sources is listed in the table below.

Table 8: Data from other sources

Existing Data	Data Source	How Data Will Be Used	Acceptance Criteria	Limitations on Data Use
River Daily Discharge	USGS WaterWatch	Context for WR provisional reports	As produced by USGS	None
Precipitation	USGS tipping bucket rain gage	Ingested into VM online database.	As produced by USGS. These data are generally in provisional status at the time of acquisition by the VM program	None
DO, pH, Cond, T and Turbidity	From USGS in-situ sensors at Hwy 9, Reaves Ferry, Conway, Bucksport and Hagley Landings	Comparison for volunteer collected data for provisional reports	As produced by USGS. These data are generally in provisional status at the time of acquisition by the VM program	None
Tide Chart	NOAA	Context for provisional reports	As produced by USGS. These data are generally in provisional status at the time of acquisition by the VM program	None
Rainfall	CoCoRaHS	Ingested into VM online database.	As produced by CoCoRaHS	None
Murrells Landing water quality data	Waccamaw Watershed Academy	Increased spatial coverage	Same as Table 2. In-situ measurements performed with YSI Pro DSS datasonde calibrated per EQL (Lab # 26001002).	None
Waccamaw River Volunteer Monitoring Program (North Carolina)	Waccamaw Riverkeeper	Increased spatial coverage	Same as Table 2.	None

B10 DATA MANAGEMENT

The volunteer monitoring program collates its sampling results and relevant rain data in a MySQL database that feeds data to webapps available to the public at www.coastal.edu/wwa/. This database also feeds data to control charting code. A separate database is used to track volunteer training and contract information. Additional scripts are used to automatically send out reminder emails of upcoming sampling dates and to perform monthly backups to an external hard drive in CCU's EQL.

Volunteers are assigned a unique login ID and password for data entry into online database and submit data as described in Appendix A. The data entry code checks for errors and rejects data not within the expected range.

The Burroughs & Chapin Center for Marine and Wetlands Studies server hosts the volunteer monitoring program's MySQL database. The RedHat Enterprise Linux server is a virtual machine hosting a MariaDB 5.5.64 database server running PHP 5.4.16. The machine is updated, maintained, and scanned regularly by CCU's Information Technology Services. A snapshot of the virtual machine image is captured nightly. The database and machine data are also redundantly stored on an enterprise storage environment.

All datasheets and paperwork are bound annually using a uniform format. The binders are maintained in an archive room in the EQL that requires users to sign out the binders. Hard copies of the volunteer training records are kept in individual personnel folders. Records are reviewed quarterly to ensure that retraining is performed annually for each activity that a volunteer is qualified to conduct.

Section C: Assessment and Oversight

C1 ASSESSMENTS AND RESPONSE ACTIONS

Assessments are tools used to determine if quality assurance needs of the project are being met by current policies. These tools are summarized in the following table. The VOLT meets periodically (as needed) as a quality improvement team to continually assess project work processes and laboratory operations, identify needed improvements, assign responsibilities for making improvements, and monitor progress on improvement actions. This may result in corrective changes in the SOPs, the Volunteer Water Quality Monitoring Program Handbook and this QAPP that are tracked as revisions to these documents.

Table 9: Assessment type, frequency, and description

Assessment	Frequency	Description	Notes
Initial demonstration of capability (IDOC)	Initially, prior to reporting data independently	Depending on the parameter, the analyst makes repetitive measurements to demonstrate the ability to achieve necessary accuracy and precision.	IDOC packets are assembled by the VOLT. They are reviewed and approved by the VM Program Manager.
Data generator review	Every time data is generated	Conduct real-time review and verification of 100% of the data resulting from their activities.	This is done by the Master Samplers who calibrate the Orion multimeters and by the bacteria and turbidity analysts
Peer review	Every time data is generated	Field data sheets are checked for correctness and completeness.	This job is performed by one of the team members.
VOLT review of all datasheets	After each sampling event	Receipt of datasheets is documented and missing datasheets tracked. Datasheets are reviewed for technical correctness for, proper units/significant digits, calculation verifications, variations documented, transcription errors, QC measurements within limits or qualified, and hold times were met or exceptions documented.	Review is performed by VOLT. Status of all datasheets is signed off by the data validator.
Nonconformance reviews.	After each sampling event.	Nonconformance reports are generated as needed based on reviews of datasheets, meter precision and data validation steps.	Reports are generated by the VOLT. Resolution is supervised and approved by the VM Program Coordinator in collaboration with the data validator.
Review of meter precision	Monthly	Orion multimeter measurement precision for each sensor is evaluated with an automated control charting protocol. Problematic trends are addressed through nonconformance reporting	Output from the control charting software is generated by the VOLT who performs an initial review. The control charts are then reviewed by the data validator.

		documented on the Control Chart Review Checklists.	
Data validation	Biweekly after each sampling event	Data are assembled into provisional reports that include comparison to site-specific percentiles for each parameter. Also included are field conditions such as antecedent rainfall, tide stage and discharge. On the Waccamaw River, data are compared to in-situ USGS measurements using control charts. All variances from the VM Monitoring Handbook and QC acceptance criteria are noted.	This report is assembled by the VOLT following review of all the datasheets. Report is reviewed and a narrative summary generated by a data validator. Provisional reports are sent to field leaders and stormwater managers.
Review of logs and other internal lab records	Upon completion of log pages	Logs are checked for correctness and completeness. Checks are also performed for internal consistency with other records such as chain of custody records.	This review is performed by the VM Program manager.

C2 REPORTS TO MANAGEMENT

After each sampling event, a provisional report is generated for each volunteer water quality monitoring program and sent electronically to MS4s and funding partners. The provisional report summarizes the volunteer data, compares findings to relevant data collected by other sources, and places the data in the context of site trends over time.

Annually, a water quality report is generated for the Coastal Waccamaw Stormwater Education Consortium (CWSEC) as part of their annual report. The CWSEC Annual Report can be found online at <http://cwsec-sc.org/>.

Volunteers, the stormwater managers and the public can access the complete set of data for each program and all sites using the online webapp that includes tools to generate graphs and summary statistics. The webapp includes information on relevant water quality standards. The VM and related rain data can also be downloaded into .csv files.

Section D: Data Validation and Usability

D1 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

All processes in the volunteer monitoring program (sampling, sample receiving and handling, sample analysis, data reduction, data reporting, data review, etc.) are subject to examination to evaluate adherence to project specifications. This examination consists of several layers of review, verification and validation as summarized in Section C1. These reviews ensure that all data released by the volunteer monitoring program were scrutinized by qualified independent reviewers and are scientifically sound, appropriate to the method and completely documented.

In brief, volunteers sampling accuracy and precision will be assessed during retraining. During field sampling and lab analysis, volunteers conduct field checks for each parameter and verify that values are within the acceptance range. Volunteers are provided percentile ranges for each parameter to help them quickly identify unusual data. Back at their homes, the online data entry form checks for obvious errors and data outside of acceptable ranges. Following each sampling, all datasheets are reviewed by the VOLT and compiled for the provisional report. The provisional report compares volunteer collected data with data from other sources to identify suspicious data. After the provisional report is generated, the data is uploaded to the online database. Monthly, control charts are conducted and replicates not within the acceptance criteria are removed. As the entire sampling process has multiple QC steps, data is very rarely removed by control charting.

D2 VALIDATION AND VERIFICATION METHODS

Data verification is performed by the VOLT, who review all datasheets and logbooks. The Volunteer Program Manager resolves any issues prior to data validation. After determining that the data have met chain of custody and QC requirement, the VOLT assembles the project data and supporting indirect data into a Provisional Report. The data validator performs the final review step, aka data validation that involves a relational technical review. All of the project data must receive this review before being uploaded the project database. This level of review must ensure that:

- Spatial and temporal relationships within and between related parameters are scientifically reasonable and are supported by the indirect data. Anomalies in the data will be investigated.
- Contravention of water quality criteria are noted.

If the some or all of the data are deemed unusable, the data validator will reject specific results or the entire sampling event depending on the nature of the usability issue.

D3 RECONCILIATION WITH USER REQUIREMENTS

Data that does not meet DQO as outlined in Section A7 will be reviewed by the VOLT and reported to the Volunteer Monitoring Program Manager. If equipment error is suspected, the VOLT will discuss remedies with the volunteer monitor and determine if equipment needs to be will be returned to the VOLT for maintenance. If volunteer error is suspected, volunteers will be corrected and retrained until the error is resolved.

REFERENCES

Standard Methods, 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, American Water Works Association, Water Environment Federation.

APPENDIX A

WWA's Volunteer Water Quality Monitoring Handbook