BENTHIC MACROINVERTEBRATE COMMUNITY ASSESSMENT PROGRAM (BMCAP)

QUALITY ASSURANCE PROJECT PLAN

Program Administered and Plan Prepared by:
North Carolina Department of Environmental Quality
Division of Water Resources
Water Sciences Section
Biological Assessment Branch

EPA Approved
December 27, 2017
Version 1.3

Abbreviations

BAB	Biological Assessment Branch
BI	Biotic Index
BMCAP	Benthic Macroinvertebrate Community Assessment Program
CWA	Clean Water Act
DO	Dissolved Oxygen
DWR	Division of Water Resources
EBIII	Lead Environmental Biologist
EEP	Ecosystem Enhancement Program Report
EPA	Environmental Protection Agency
EPT	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies)
EPTBI	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Biotic Index
EPT N	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Abundance
EPTs	**E**phemeroptera (Mayflies)+**P**lecoptera (Stoneflies)+**T**richoptera (Caddisflies) Taxa Richness
WSS	Water Sciences Section
HQW/ORW	High Quality Waters/Outstanding Resource Waters
ISB	Intensive Survey Branch
MIS	Division of Mitigation Services
NCBI	North Carolina Biotic Index
NCDEQ	North Carolina Department of the Environment Quality
NCDOT	North Carolina Department of Transportation
NFQA	National Field Quality Assurance
NGO	Nongovernmental Organizations
NPDES	National Pollutant Discharge Elimination System
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
S	Total Taxa Richness
SOP	Standard Operating Procedures
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

REVISION LOG

BENTHIC MACROINVERTEBRATEQAPP

Note: Actions older than 5 years may be removed from this record

Date Edited	Editor	Version Edited	Section Edited	Changes/updates
11/13/2017	David Huffman	Ver 1.3	A5. Project/Task Description and Schedule	Updated Figure A5.1 Map
11/08/2017	David Huffman	Ver 1.3	A5. Project/Task Description and Schedule	Updated Sampling Schedule
10/13/2017	David Huffman	Ver 1.3	A8. Documentation and Records	Updated Data Report Package
10/04/2017	David Huffman	Ver 1.3	Entire Document	Updated personnel and organizational names.
12/16/2013	Michael Walters	Ver. 1.1	Entire Document	Division of Water Quality (DWQ) changed to Division of Water Resources (DWR). Biological Assessment Unit (BAU) changed to Biological Assessment Branch (BAB). Updated all headers, footers, and hyperlinks. Deleted all references to the Watershed Assessment Team (WAT).
12/16/2013	Michael Walters	Ver. 1.1	Title Page	Updated document date & version to December 2013 & Version 1.2
12/16/2013	Michael Walters	Ver. 1.1	Abbreviations	Updated list of acronyms
12/16/2013	Michael Walters	Ver. 1.1	A1. Signature and Approval Sheet	Updated personnel and organizational names.
			A2. Distribution List	Updated personnel and organizational names.
12/16/2013	Michael Walters	Ver. 1.1	A3. Project Organization	**Project Management and Oversight:** Updated staff duties **Table A3.1:** Updated Organizational Chart
12/16/2013	Michael Walters	Ver. 1.1	A5. Project/Task Description and Schedule	**Overview:** Changed number of benthic sites sampled from 6000 to 3100. **Sampling Schedule:** Updated years sampled for Yadkin River Basin and the next year to be sampled as part of the basinwide assessment program. **Data Management:** Changed "Fourth Dimension (4-D)" to "Microsoft Access". Inserted words "of data entry" for clarification.
12/16/2013	Michael Walters	Ver. 1.1	A6. Quality Objectives and Criteria	Replaced Text: "a written study plan that is reviewed by the BAU supervisor (and often the ESS Chief) before actual sampling is conducted" with "the procedures documented in the Benthic Macroinvertebrates SOP". **Comparability:** Removed Text: "or from the written study plan". Updated the text regarding taxonomic QA to reflect current methods. Replaced "log book" with "database" to refer to the storage medium for taxonomic QA results. **Field & Laboratory Measurements:** Changed the words "approximately six" to "one set of" to describe the number of overlap samples collected. Updated the text regarding taxonomic QA to reflect current methods.
12/16/2013	Michael Walters	Ver. 1.1	A7. Special Training/ Certification	**Laboratory Staff:** Replaced bulleted "Annual internal taxonomic updates" with "Continuous internal taxonomic updates".

REVISION LOG

Date Edited	Editor	Version Edited	Section Edited	Changes/updates
12/16/2013	Michael Walters	Ver. 1.1	A8. Documentation and Records	**Project Records:** Changed physical location of database files from on-site in ESS to the Western Data Center **Data Report Package - Basinwide Assessment Reports:** Replaced "Fourth Dimension" with "Microsoft Access".
12/16/2013	Michael Walters	Ver. 1.1	B1. Sampling Process Design	**Site Locations:** Replaced "three" with "four" to accurately describe the number of basinwide assessments conducted to date in the Broad River Basin. **Sampling & Measurements – Qual 4 Method:** Changed "<3.0" to "≤3.0" with respect to the conditions under which small stream sampling is conducted.
12/16/2013	Michael Walters	Ver. 1.1	B2. Sampling Methods	**Benthic Macroinvertebrate Collection Techniques – Sand Collections:** Updated the equipment and method used for sand collections
12/16/2013	Michael Walters	Ver. 1.1	B3. Sample Handling and Custody	**Sample Identification:** Changed “Station Number” to “Station Location”. Changed “Name of Collectors” to “Initials of Collectors”. **Collection Card Number:** Updated details on collection cards.
12/16/2013	Michael Walters	Ver. 1.1	B4. Analytical Methods	No longer sending mollusks and crayfish to the museum – removed 1st sentence in 2nd paragraph). **Bioclassifications:** Added small-stream samples to list of those receiving a regular bioclassifications. Removed boat samples from the list.
12/16/2013	Michael Walters	Ver. 1.1	B5. Quality Control	**Laboratory Activities and Training:** Updated the text regarding taxonomic QA to reflect current methods. Replaced "log book" with "database" to refer to the storage medium for taxonomic QA results.
12/16/2013	Michael Walters	Ver. 1.1	B6. Equipment Testing, Inspection, and Maintenance	**Table B6.1** Removed maintenance requirements for YSI 85 & Accumet meters. Added maintenance requirements for YSI Professional Plus meters.
12/16/2013	Joanna Gmyr	Ver. 1.1	B7. Instrument Calibration and Frequency	Replaced text in this section and added more detailed description of meter calibration.
12/16/2013	Michael Walters	Ver. 1.1	B9. Acquired Data (Non-Direct Measurements)	Added GIS as another source for geo-referenced data.
12/16/2013	Michael Walters	Ver. 1.1	B10. Data Management	Updated records for sampling events from 6,000 to 7,000.
12/16/2013	Michael Walters	Ver. 1.1	C2. Reports to Management	Changed "Lead Biologist" to "BAB Supervisor".
12/16/2013	Michael Walters	Ver. 1.1	D2. Validation and Verification Methods	Deleted text: “Lead Environmental Biologist and the".
12/16/2013	Joanna Gmyr	Ver. 1.1	Appendices	Changed reference format to Appendices A, B, & C (previous format – Appendices 1 & 2)
12/16/2013	Michael Walters	Ver. 1.1	Appendix 1	Changed to Appendix A - Inserted current Benthic SOP (Revised Dec. 2013, Version 4.0)
12/16/2013	Joanna Gmyr	Ver. 1.1	Appendix 2	Changed to Appendix B - Updated Meter Calibration Sheet (version 6/5/2012)
12/16/2013	Joanna Gmyr	Ver. 1.1	Appendix C	Added Appendix C – Guidance Tables for YSI Pro Plus Field Meter.
12/20/2011	Joanna Gmyr	7/3/2007	A1, A2, A3	Updated signature list, distribution list, & project organization.
12/20/2011	Joanna Gmyr	7/3/2007	Acronyms	Updated list of acronyms
12/20/2011	Joanna Gmyr	7/3/2007	A3	Updated Figure A3.1
12/20/2011	Joanna Gmyr	7/3/2007	A5	Updated Figures A5.1 and A5.2
12/20/2011	Joanna Gmyr	7/3/2007	Appendix 1	Inserted newly revised Benthic SOP (Revised Dec. 2011)

REVISION LOG

Date Edited	Editor	Version Edited	Section Edited	Changes/updates
12/20/2011	Joanna Gmyr	7/3/2007	Appendix 2	Inserted current Field Meter Calibration Sheet (Revised 04/18/2010)
12/01/2011	Eric Fleek	7/3/2007	References	Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, DWQ. May 29, 2009.
11/30/2011	Eric Fleek	7/3/2007	Cover Page	Updated submittal date and added version identification (version 1.1)
11/30/2011	Eric Fleek	7/3/2007		Added a revision log to QAPP
11/30/2011	Eric Fleek	7/3/2007	Analytical Methods	Referenced the completion of the small streams biocriteria and changes in sampling methodologies. Added the following reference: NCDWQ 2009, Biocriteria for the Small Streams of the North Carolina Mountains and Piedmont: Memorandum. NC Dept. of Environment and Natural Resources, Division of Water Quality. May 29, 2009.

Table of Contents

SECTION A:

PROJECT MANAGEMENT

A1. Signature and Approval Sheet

Approved by:

Victor Holland
Benthic Macroinvertebrate Program Coordinator
Environmental Sciences Section, NC DWR

4/4/18
Date

Eric D. Fleek
Biological Assessment Branch Supervisor
Environmental Sciences Section, NC DWR

4/3/18
Date

David Huffman
Quality Assurance Coordinator
Environmental Sciences Section, NC DWR

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Date

Cyndi Karoly
Section Chief
Environmental Sciences Section, NC DWR

4/9/18
Date

Christopher J. McArthur
Environmental Protection Agency Region IV

4/13/18
Date

2. Distribution List

Primary Distribution:

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Geryl Ricks, NC Monitoring, Grant Technical Officer
Johnnie Purify, Monitoring and Information Analysis Section Chief
Chris McArthur, NC Monitoring Coord. & Marine Monitoring Program Coord.
Joanne Benante, Water Quality Planning Branch Chief

NC Department of Environmental Quality, Division of Water Resources

Environmental Sciences Section

Cyndi Karoly, Water Sciences Section (WSS) Chief
Eric Fleek, Biological Assessment Branch Supervisor
Brian Wrenn, Ecosystems Branch Supervisor
Jason Green, Intensive Survey Branch Supervisor
Cindy Moore, Aquatic Toxicology Branch Supervisor
Jill Paxson, Estuarine Monitoring Team Leader
Jeff DeBerardinis, Stream Fish Community Assessment Program Coordinator
David Huffman, Quality Assurance Coordinator
Debra Owen, Lakes Monitoring Program Coordinator
Brian Pointer, Ambient Monitoring System Coordinator
Michael Walters, Benthic Macroinvertebrate Community Assessment Program Coordinator

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Victor Holland, Benthic Biologist
Mike Turner, Benthic Biologist
Matt Stillwell, Biological Technician
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Sherri Knight, Winston-Salem (WSRO)
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Jim Gregson, Wilmington (WiRO)
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Water Planning Section
Tom Fransen, Water Planning Section Chief

Courtesy Distribution:
Jay Zimmerman, NC Division of Water Resources Director
Linda Culpepper, NC Division of Water Resources Deputy Director
Jon Risgaard, Water Quality Regional Operations Section Chief
Jeffrey Poupart, Water Quality Permitting Section Chief
Ian McMillan, Basin Planning Branch Chief
Pam Behm, Modeling and Assessment Branch Supervisor

A3. Project Organization

The Benthic Macroinvertebrate Community Assessment Program (BMCAP) is housed within the Water Sciences Section of the Division of Water Resources (DWR), within the North Carolina Department of Environment Quality (DEQ). Activities associated with the BMCAP (fieldwork, project management, QA, data management, analysis, and reporting) are performed by Biological Assessment Branch (BAB) staff members, with additional assistance provided by other staff in the Water Sciences Section.

An abbreviated draft organizational chart for the Division of Water Resources is provided in Figure A3.1. Information on specific individuals' roles and responsibilities follows. Phone numbers and addresses for the offices listed can be found at http://www.ncwater.org/.

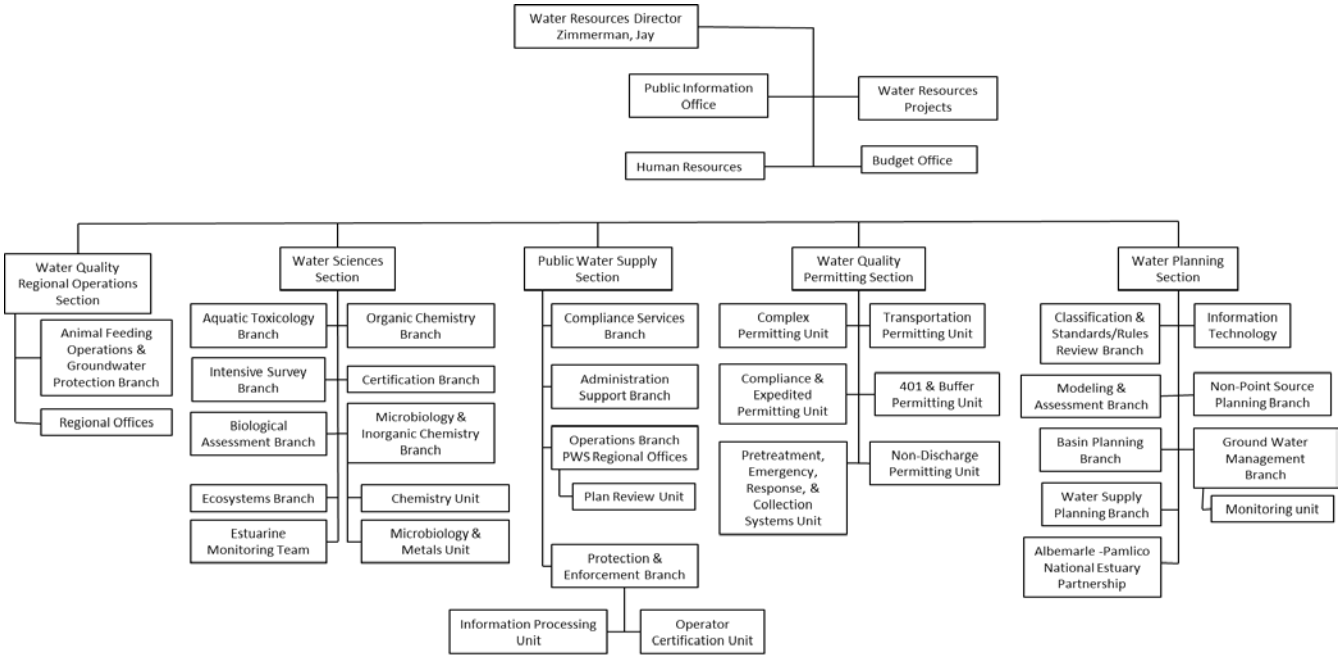

Figure A3.1 DWR Organizational Chart

Project Management and Oversight

Biological Assessment Branch (BAB) Supervisor
Eric D. Fleek

Supervises benthic macroinvertebrate and fisheries programs. Serves as liaison between BAB and other internal NC DWR consumers of BAB data. Acts as a liaison with other divisions within NCDEQ, NCDOT, EPA, USGS, and various NGO's as well as with individual citizens. Approves all final reports and policy/method revisions. Responsible for QA/QC of macroinvertebrate database and participates in QA/QC of some macroinvertebrate samples. Participates in field sampling, laboratory identification, data entry, and report generation. Ensures the BMCAP is conducted in accordance with all pertinent QAPP's and SOP's. Recommends new employee hires and approves changes to the BMCAP. Acts as the primary macroinvertebrate QA/QC for BAB staff. Maintains the macroinvertebrate QA/QC database. Curates the virtual macroinvertebrate collection. Responsible for macroinvertebrate programmatic development, study designs, field sampling, stream reclassifications (e.g., ORW/HQW), and laboratory identification. Leads field and laboratory training of BMCAP staff.

Lead Environmental Biologist BAB
Michael D. Walters
Program Coordinator

Maintains BAB's Macroinvertebrate bench sheet, collection card, and habitat records collection. Assists in the maintenance of the BAB Microsoft Word Access database structure and design. Works to ensure correct data entry and report generation. Maintains and updates the BAB macroinvertebrate SOP. Maintains sampling equipment.

Environmental Biologist BAB
Steven R. Beaty

Conducts continuous taxonomic reviews and updates. Maintains and updates the BAB macroinvertebrate taxonomy documents. Primary curator of the physical macroinvertebrate reference collection. Provides primary assistance to other staff with problematic invertebrate taxonomy and acquires new and/or revised regional invertebrate taxonomic keys. Also, maintains contact with regional macroinvertebrate taxonomic experts.

Field Staff
Consists primarily of staff from the Biological Assessment Branch. Additional assistance and support from other units in the WSS Sciences Section as needed.

Field staff members assist with sample collection and processing.

Program QA Coordinator
David Huffman
QA Coordinator, Ecosystems Branch, WSS

Documents QA practices of BMCAP. Maintains BMCAP QAPP. Develops and recommends QA/QC improvements. Ensures that the BMCAP is conducted in accordance with the BMCAP QAPP.

Primary Data End-Users

Water Planning Section
Tom Fransen, Section Chief

Supervises the Basin Planning Branch and the Modeling and Assessment Branch.
These units include numerous staff acting as primary end-users of data produced by the BMCAP.

Staff from the Water Planning Section should:

- Provide input to the Lead Environmental Biologist and BAB Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report any data anomalies to the Lead Environmental Biologist and BAB Supervisor.
- Report any waterbodies in need of assessment.

Regional Office Surface Water Protection

Regional Supervisors:

Jim Gregson, Wilmington Regional Office
Landon Davidson, Asheville Regional Office
Corey Basinger, Mooresville Regional Office
Trent Allen, Fayetteville Regional Office
David May, Washington Regional Office
Danny Smith, Raleigh Regional Office
Sherri Knight, Winston-Salem Regional Office

There are seven regional offices within the NCDEQ. The regional offices perform the Department's duties on a local level and are responsible for compliance and enforcement actions.

Staff from the regional offices should:

- Provide input to the Lead Environmental Biologist and BAB Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report data anomalies to the Lead Environmental Biologist and BAB Supervisor.
- Report waterbodies in need of assessment.

Water Quality Permitting Section
Jeffrey Poupart, Section Chief

The Water Quality Permitting Section includes the Complex Permitting Branch and the 401 & Buffer Permitting Branch. The Complex Permitting Branch is responsible for administering the State's National Pollutant Discharge Elimination System (NPDES) program that was established to control point-source discharges of water pollution. The Branch functions to protect, maintain, and enhance the State's waters by fostering compliance with North Carolina's environmental statutes, regulations, and permits. When compliance is not met, this Section may take enforcement actions.

Staff from the Section should:

- Provide input to the Lead Environmental Biologist and BAB Supervisor on changes needed to the BMCAP as part of a continuous program assessment process.
- Report data anomalies to the Lead Environmental Biologist and BAB Supervisor.
- Report waterbodies or impacts from permitted facilities in need of assessment.

U. S. EPA
EPA Region 4

- Reviews, provides comments, and approves QAPP and subsequent revisions on behalf of EPA Region 4.
- Performs mid-year and end-of-year assessments of all DWR monitoring programs, including the BMCAP, to determine progress on tasks listed in the annual §106 grant workplan.

A4. Problem Definition and Background

Introduction

As part of funding agreements between North Carolina and the U. S. Environmental Protection Agency (EPA), DWR agrees to monitor the waters of the State and report findings to the EPA to support the goals of the Clean Water Act (CWA). The CWA defines as its objective: ". . . *to restore and maintain the chemical, physical, and biological integrity of the Nation's waters, and, where attainable, to achieve a level of water quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water*."

Benthic Macroinvertebrate Community Assessment Objectives

The DWR utilizes several programs and tools to assess the quality of the State's waters. One of the most tested and peer-reviewed programs is the BMCAP. The primary objective of this program is to provide benthic macroinvertebrate community ratings for wadeable and non-wadeable streams to the Water Planning Section for use support determinations and for the Basin Planning Branch's Basin Water Resource Plans. Secondary objectives of the Benthic Macroinvertebrate Community Assessment Program are to provide data suitable for supporting the following DWR activities:

- Water Planning Section
  - Biennial 303(d) and 305(b) reporting to EPA, including identification of areas of impairment or degradation,
  - TMDL development,
  - Stream reclassifications (e.g., ORW, HQW),
  - Prioritization of restoration activities, and
  - Background information for Use Attainability studies.
- Water Quality Permitting Section
  - Identification of background levels of constituents for determination of NPDES permit limits, and
  - Identification of dischargers causing unacceptable impacts.
- Regional Offices
  - Background information to assist with water quality management activities in each region.
  - Benthic macroinvertebrate data used as supporting evidence for use in enforcement actions initiated by DWR for violations of the Clean Water Act.

A5. Project/Task Description and Schedule

Overview

The BMCAP is an additional water quality assessment tool that has been in existence since the late 1970's, but with a consistent sampling methodology since 1983. Its core mission is to sample a set of fixed sites located on lower Strahler order, wadeable and non-wadeable creeks, streams, swamps, and rivers on a five-year rotating basis to support the DWR's Basinwide Management Plan Program. More than 3,100 sites (located throughout the Coastal Plain, Piedmont, and Mountains) have been assessed by the BMCAP (Figure A5.1). Most of the stations are located at bridge crossings or other public accesses and are accessible by land.

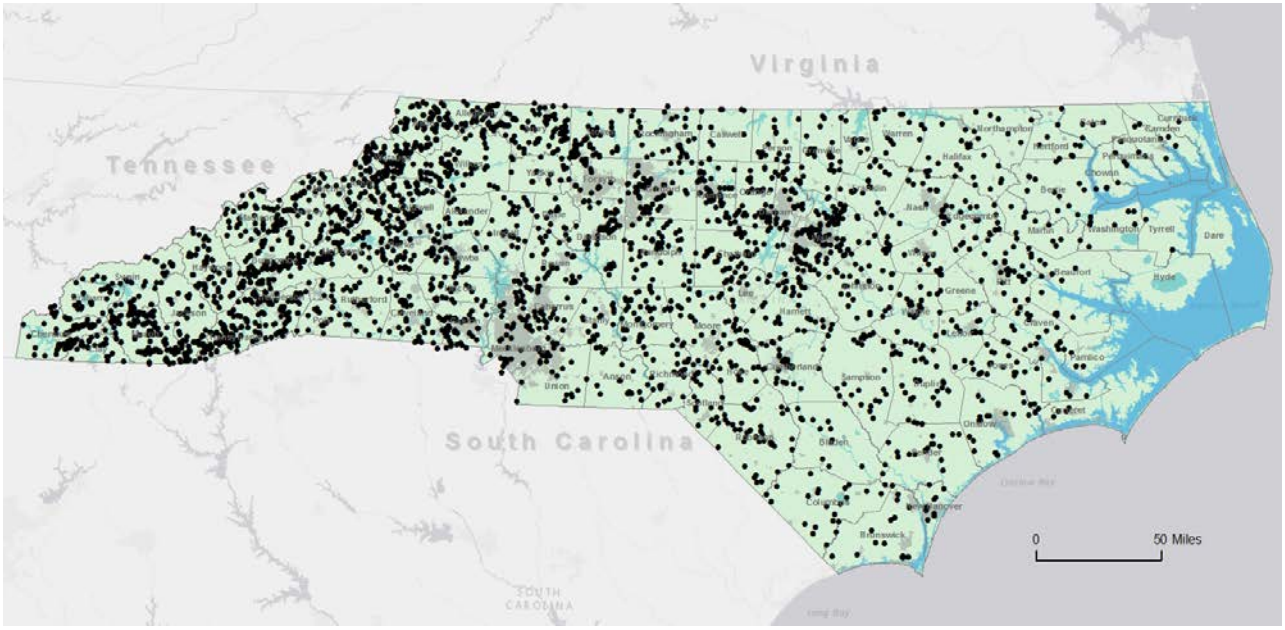

Figure A5.1 Benthic Macroinvertebrate Community Assessment Sites

Benthic Macroinvertebrate Community Indicators

The Biological Assessment Branch uses aquatic macroinvertebrates as one type of indicator of biological integrity in streams and rivers. A large number of sites are sampled each year during basinwide sampling and special studies; resulting information is used to document both spatial and temporal changes in water quality and to complement water chemistry analyses. Although bioassessments are useful for identifying biological impairments, they do not identify the causes of impairment. Linking biological effects with their causes is particularly complex when multiple stressors impact a waterbody (USEPA, 2000).

There are several reasons for using biological surveys to monitor water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may be missed. The biota, especially benthic macroinvertebrates, reflects both long and short-term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are less mobile than many other groups of organisms, and are of a size that makes them easy to collect. Moreover, chemical and physical analyses for a complex mixture of pollutants are generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat, 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions and allows for comparison of sites that are in close proximity (Engel and Voshell, 2002).

Analysis of faunal assemblages is one way to detect water quality problems (Rosenberg et al, 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the taxa associated with organic loading (and low dissolved oxygen) are well documented. Recent studies have begun to identify the biological impacts of sedimentation and toxic stress (Burton, 1991; Waters, 1995; Bode and Simpson, 1982; Clements, 1994).

The core indicators used by the BMCAP to calculate bioclassifications are EPT Taxa Richness (EPTs) and the Biotic Index (BI). In addition, some samples also use Total Taxa Richness (S), EPT Biotic Index (EPTBI), and EPT Abundance (EPT N) to calculate bioclassifications. Standard Qualitative samples, EPT samples, and Boat samples are rated *Excellent*, *Good*, *Good-Fair*, *Fair*, or *Poor*. The bioclassifications or stress categories for swamp stream samples are *Natural*, *Moderate*, and *Severe*; a habitat evaluation score is also included as a metric for swamp samples. Further discussion on these indicators can be found in Section B4 of this document and in the Benthic Macroinvertebrates SOP (Appendix A).

Other Water Quality Indicators

Although benthic macroinvertebrate communities are the primary tools used in the BMCAP, other water quality measurements (e.g., water temperature, dissolved oxygen, pH, specific conductance, and water clarity) are also monitored at every site in accordance with the Intensive Survey Branch's SOP (ISB Home Page). In addition, a non-quantitative stream and riparian habitat assessment is also performed at each site.

Sampling Schedule

Sites that are part of the DWR's Basinwide Monitoring Program are sampled once every five years, usually between June and September. For example, basinwide sites in the New, Watauga, and Cape Fear River Basins were sampled in 1998, 2003, 2008, 2013 and will be sampled again in 2018. However, Cape Fear swamp streams (i.e., seasonally flowing low gradient coastal plain system, generally east of the I-95 corridor) are sampled in February and March. Special study sites that are designed to address a specific, short term question (e.g., Use Attainability, impacts from a permitted discharger, watershed modifications, *etc*.) are usually sampled only once and may be sampled at any time of the year; however, all effort is made to sample during the summer when practicable.

Additional details on sampling methodology can be found in Sections B1 and B2 of this document and in the Benthic Macroinvertebrates SOP (Appendix A).

Data Management

All results are warehoused in the BMCAP's Microsoft Access database. The database is updated whenever samples are completed or when errors in previously entered data are identified during the annual audit. The annual audit randomly selects 10% of the total number of samples entered into the database that year; those samples are checked for accuracy of data entry as detailed in the Benthic Macroinvertebrates SOP (Appendix A). Audits are conducted by either the Lead Environmental Biologist and or the BAB Supervisor.

Reporting

There are five primary forms of reporting generated by the BMCAP:

- Basinwide Assessment Reports
- HQW/ORW Stream Reclassification reports
- TMDL reports
- Division Mitigation Services (MIS) Ecosystem Enhancement Program Report (EEP)
- Other site-specific special study memoranda (e.g., regional office requests)

All documents are provided to DWR management, Water Planning Section and Regional Office staff, and other interested parties. The information may be incorporated into Basin Water Resources Plans and required biennial reports to EPA for inventory and impairment (combined 303(d) and 305(b) reporting).

Basinwide Assessment Reports

All monitoring programs managed by the WSS are reported in the Basinwide Assessment Reports. These documents are made publicly available at Reports, Publications and Data Home Page. This is the

primary reporting method for the Benthic Macroinvertebrate Community Assessment Program. Results are reported the following year for each of the seventeen major river basins in the state on a five-year rotating schedule that is based on the DWR Basinwide Planning Schedule (Figure A5.2). The cycle began in 1990, and as of 2005, the Year 1 basins are in their fourth monitoring and reporting cycle. All historic data are reviewed when the assessment reports are prepared. However, only data from the most recent five-year assessment period will be analyzed for Use Support determinations by the DWR's Basin Planning Branch.

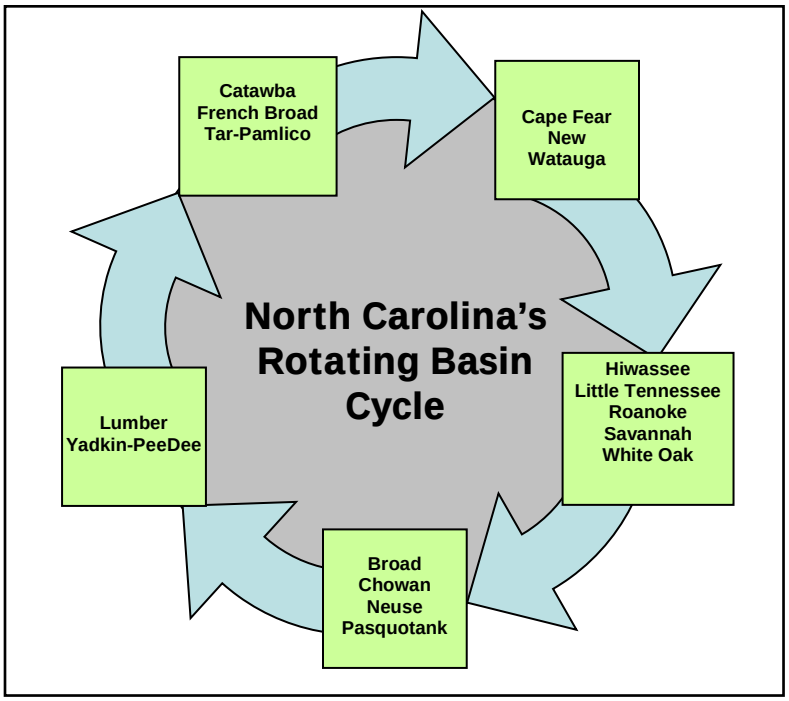

Figure A5.2: Rotating Basin Assessment Cycle

For each report, results are presented by sub-basin as narrative summaries and graphical representations. Description of known issues or sources of bias (e.g., sampling conditions, significant climatic events such as droughts or hurricanes, *etc*.) should be sufficient to give the reader adequate context for appropriate interpretation of the results.

The main audience for the information reported in the Basinwide Assessment Report is staff from DWR's Basin Planning Branch. For each monitoring site, if the benthic macroinvertebrate community is rated *Fair* or *Poor*, that particular stream reach may be subject to official impairment and subsequent 303(d) listing. Enough information should be provided in the Basinwide Assessment Report to allow the Basin Planning Branch staff to make informed decisions when determining if impairment is warranted for each monitored waterbody. Impairment can lead to further actions by other DWR programs, such as intensive studies, development of TMDLs or other strategies, and implementation of additional pollutant controls, all of which can have costly impacts for NCDEQ as well as NPDES dischargers, municipalities, industries, and animal operations. To prevent inaccurate judgments of impairment from being made, the Basin Planning Branch has developed basic data quality and quantity criteria, described in individual Water Resource Plans (available at https://deq.nc.gov/about/divisions/water-resources/planning/basin-planning/water-resource-plans) to determine data sources appropriate for the Branch's uses. Information contained in the Basinwide Assessment Report for each monitoring site allows Basin Planning Branch staff to easily identify whether the dataset for a particular site meets these criteria.

High Quality Waters/Outstanding Resource Waters (HQW/ORW) Reclassification Reports
HQW/ORW reports evaluate reclassification requests based on existing or new data and determine whether the waterbodies requested meet the criteria for HQW/ORW.

TMDL Reports
TMDL reports detail watershed conditions for streams on the 303(d) list and attempt to identify stressors to the biological community.

Division Mitigation Services EEP Reports
The BAB samples selected watersheds for MIS studies, and the biological findings are summarized in EEP reports.

Special Study Memoranda
Results of special studies are summarized in formal reports and internal memoranda. These reports are approved by the BAB Supervisor and the WSS Section Chief and forwarded to the appropriate party or regional office staff.

A6. Quality Objectives and Criteria

Specific components of a quality assurance and quality control plan are described in the Benthic Macroinvertebrates SOP (Appendix A). All investigations conducted by the BMCAP follow the procedures documented in the Benthic Macroinvertebrates SOP.

Bias
The BMCAP is based on judgmental sampling design. As a result, bias will exist due to site locations (i.e., sites that can be safely waded or accessed by the sampling crew). However, this is acceptable given that monitoring sites are generally established for targeted long-term monitoring of known or suspected areas of concern; identification of temporal patterns at these static locations are a major objective of the program.

Other sources of bias:

- Sampling is performed under existing flow and water clarity conditions. Ideally, monitoring is conducted under low to normal flow conditions with clear or slightly turbid water clarity. Sampling is not conducted if the water is so turbid that instream habitat, which lies below the surface of the water, cannot be seen. In addition, if the water level is so high or swift that sampling would jeopardize the safety of the staff, collection operations are suspended.
- Almost all sites are located at bridge crossings for ease of access and to avoid trespassing on private property. Field staff is instructed to sample on the upstream side of the bridge, if possible, and beyond the artificially created bridge pool and bridge substrate habitats.

Using consistent sampling techniques, laboratory methods, and data analyses as described in the Benthic Macroinvertebrates SOP (Appendix A) minimizes bias from other sources.

Comparability
Fixed station locations, generally consistent seasonal sampling, and adherence to the BMCAP's SOP for sampling ensure that comparable samples are taken at each site visit. Deviations from the SOP due to unusual sampling situations are documented in the appropriate report or memorandum. To ensure that sampling effort and accuracy are comparable between disparate personnel, annual "overlap" samples of the same site are taken by different field crewmembers (if possible), and results are compared.

Random samples are re-identified for taxonomic consistency. When each biologist completes a block of ten samples, one of the ten is randomly selected for reidentification by a second, randomly selected biologist (the "QA biologist"). Random selection of samples and QA biologists is performed by a computer program at the beginning of each month for all BAB invertebrate biologists. The randomly selected sample (the "QA sample") is given to the QA biologist for reidentification, which should be completed within four weeks. After QA discussions (which will involve other biologists) the BAB Supervisor scores the original identification for accuracy and logs the information into a QA database.

If a sample fails a QA, three additional samples are randomly selected from the nine remaining samples in the QA block. If all three samples pass, no further action is taken. If any one of the three samples fail QA, the remaining six samples from the block are also reviewed.

Scoring the original identifications of QA samples involves taxonomic identification, abundance categories, and data entry. Error points are assigned as described in the Benthic Macroinvertebrates SOP (Appendix A, Table 17). The final score is the sum of error points divided by the number of taxa in the sample (as determined by the QA biologist) then multiplied by 100. A score of less than 90 is a fail.

Completeness
It is expected that some sites will not be sampled due to problems such as inclement weather, poor water clarity, extremes in flows, equipment malfunctions, vacant positions, and staffing during the field season. As many sites as possible are sampled during the field season, given existing staffing resources. Invariably, some Basinwide Assessment Program "fixed" sites will not be sampled and may not be re-sampled until the next monitoring cycle. However, if a basinwide site is unable to be sampled during the

normal basinwide schedule (June through August) it is normal practice to attempt a re-sample within that calendar year, preferably as close to June, July, or August as possible. For example, in July and August of 2005, basinwide sampling of the Broad River was hampered by high flow. However, base flows returned to normal in September 2005, and those sites that could not be sampled in July 2005 were assessed in early September 2005. Typically, this is not an issue; between 2000 and 2005, only seven out of 400 basinwide sites were not sampled during normal basinwide sampling.

Field and Laboratory Measurements

Quality control practices in place for the BMCAP are described in the Quality Assurance section of the Benthic Macroinvertebrates SOP (Appendix A). All full-time permanent BAB staff are responsible for participating in and helping to oversee the collection of benthic macroinvertebrate community samples. Each year, the BMCAP conducts one set of "overlap" samples and one annual habitat assessment training session. "Overlap" samples are taken with different field crewmembers, and results are compared. In addition, if new staff are hired before the annual training, these staff members are added as a fourth crew member and accompany the typical three-person crew for purposes of learning BAB's field sampling procedures. Field water quality instruments are calibrated for each sampling trip prior to that day's work.

Full-time permanent BAB staff, under the general supervision of the BAB Supervisor and the Environmental Biologist III, performs all laboratory identifications of samples. To ensure consistency between taxonomists, all staff members have access to the following resources:

- Regional keys and checklists,
- Internal keys,
- Internal taxonomy document,
- Internal reference collection (consisting of specimens verified by outside taxonomic experts), and
- Internal virtual reference collection available via the BAB server.

In addition, each BAB staff member is required to submit one randomly selected sample out of every ten for QA/QC evaluation. If a score of less than 90 is attained another three samples in the block of ten samples are re-examined by other benthic taxonomists. If any of those three samples score less than 90, the remaining six samples in the block of ten are re-examined. The taxonomist is instructed as to the taxonomic problems discovered during re-examination efforts. Additional information regarding the QA/QC procedure can be found in the Benthic Macroinvertebrates SOP (Appendix A).

A7. Special Training/Certification

Field Staff
Components of the field sampling methods, habitat assessments, and water chemistry measurements are described in the Benthic Macroinvertebrates SOP (Appendix A). A staff of three full-time, permanent BAB biologists conducts fieldwork for the BMCAP. An experienced benthic biologist, trained and skilled in field benthic sampling methods and organism identification, must be present for all sample collections.

One biologist of the three-person field crew is the lead investigator (i.e., Trip Leader) and is primarily responsible for meter use, pre- and post-calibration, safety, required documentation, sampling methods, sample handling, safety, and other field activities. Components of the safety program are described in the Benthic Macroinvertebrates SOP (Appendix A).

Formal documentation of training activities currently consists of annual "overlap" sampling and annual habitat assessment training, as described in the Benthic Macroinvertebrates SOP (Appendix A). In addition, if new staff are hired before the annual "overlap" sampling, these individuals are added as a fourth crew member and accompany the typical three-person crew for purposes of learning BAB's field sampling procedures.

Laboratory Staff
Each Environmental Biologist working in the benthos program is responsible for identifying varying numbers of benthos samples per year. Rigorous and redundant measures are in place to ensure that macroinvertebrate identifications are consistent between taxonomists. This is accomplished through use of the following resources:

- Current regional taxonomic keys,
- Internal taxonomy documents,
- Internal reference collection,
- Communication with external taxonomic experts,
- Continuous internal taxonomic updates,
- Attendance at regional and national benthological meetings, and
- BAB's virtual reference collection, which is accessible from each biologist's desktop computer.

For additional information on the specifics of the BMCAP's QA/QC program, please refer to the Benthic Macroinvertebrates SOP (Appendix A).

Endangered Species Permit
Each year, the BAB collects samples where Federally Listed Endangered Species are present. While these taxa are not taken during BAB sampling, an Endangered Species Permit is acquired annually for the entire BAB staff. As a result, BAB staff is able to gain entry into habitat where these organisms are known to occur.

A8. Documentation and Records

Quality Assurance Information, SOP, QAPP, and Other Support Documentation
Once all approval signatures have been obtained, the QA Coordinator will electronically distribute copies of the approved QAPP to persons on the distribution list in Section A2 of this document. Copies must be disseminated within 30 days of final approval. The original hardcopy with approval signatures will be kept on file in the QA Coordinator's office at WSS.

The QA Coordinator is to be notified of changes made to the SOP or any other documentation referenced by this QAPP. The QA Coordinator will then be responsible for distributing the information, as described above. The QA Coordinator will also be responsible for keeping current copies of all these documents on file at WSS.

Because the BMCAP is ongoing, this QAPP will be reviewed on at least an annual basis and, if appropriate, any changes or updates made at that time. However, critical revisions can be made at any time. The QA Coordinator is responsible for completing revisions, obtaining signatures of approval, and disseminating the revised document to those on the distribution list (section A2) within 30 days of final approval. The version or revision number and date shall be easily identifiable by the document control information on each page. A complete list of all revisions/updates will be provided with each annual update.

Project Records
All hard copies of benthic macroinvertebrate reports, written study plans, field meter calibration sheets (Appendix B), macroinvertebrate taxonomic bench sheets, collection cards, and habitat forms are kept in perpetuity in file cabinets located in a common lab space in the WSS building. Data are also entered into a Microsoft Access database, which is backed up daily. Electronic files on the BAB network data drive are maintained indefinitely at the Western Data Center in Forest City NC.

Electronic Data Storage
All field and laboratory measurements and site visit comments are ultimately warehoused in the BMCAP's Microsoft Access database. Copies of this data warehouse reside on the BMCAP's shared drive on the state's server. Backups are run daily on the servers. The database is updated on an as-needed basis whenever samples are completed or whenever errors in previously entered data are identified. In addition, corrections to data are also completed during annual database auditing. Details of electronic data management and warehousing methods are further described in Section B10 of this document.

Data Report Package
Data are analyzed for sampling locations within each of the seventeen major basins in the state on a rotating five-year schedule. All available historic and current data, station visit comments/observations, and station information (including but not limited to stream index numbers) are stored electronically in the BMCAP's Microsoft Access database. These data are used in part to develop the Divisions Basinwide Management Plans. BMCAP's bioassessment data are made publicly available through this interactive, GIS-based mapping platform:
https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=8b1c7bf2303740e88fc2d870b054e1bd
The Lead Environmental Biologist and BAB Supervisor also provide raw and analyzed data to staff from other state and federal agencies, private consultants, academia, municipalities and private citizens.

SECTION B:

DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

The BMCAP is an additional water quality assessment tool that has been in existence since the late 1970's, but with a consistent sampling methodology since 1983. Sites are either assessed every five years as part of the DWR's Basinwide Monitoring Program to monitor overall basin conditions or only evaluated once if part of a watershed-specific special study. Sites are sampled by designated BAB staff and other WSS or DWR Branches if needed due to staffing constraints. Each year, approximately 140 benthic macroinvertebrate basinwide sites are sampled, with special studies increasing the number of sites up to 300.

Site Locations

Sites are established at publicly accessible, fixed locations (i.e., specific latitude and longitude), generally at bridge crossings. Locations and their geo-references were originally identified using USGS 7.5 minute topographic maps or Maptech Terrain Navigator ® software. Stations are strategically located to monitor a specific area of concern:

- Overall water quality in a larger watershed,
- Effect of point source discharges (e.g., municipal WWTP),
- Effect of non-point sources of pollution (e.g., urban areas, animal operations, agriculture),
- Effect of land use changes,
- Waters of significant ecological, recreational, political, or municipal use, or
- Waters that show impairment due to unknown causes.

Several river basins have undergone four basinwide assessments (e.g., Broad River Basin), and several large waterbodies (e.g., Cape Fear River, Tar River, Neuse River, Yadkin River, French Broad River, Broad River) have data preceding the start of basinwide sampling (i.e., late 1980's). As a result, maintenance of these sites on a long-term basis is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within the benthic macroinvertebrate community. Consequently, requests from DWR staff for station establishment and/or discontinuation are assessed on the value gained from a long-term perspective. Requests for additional sampling of sites (usually a one-time sampling event within a watershed) are handled through special studies. Adjustments to site locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff,
- Changes to location accessibility,
- Reason for sampling is no longer valid (i.e., a discontinued discharge),
- Emergence of new water quality concerns, or
- Resource constraints, particularly staff vacancies.

If any of these concerns arise, the Environmental Biologist III will meet with the BAB Supervisor to determine if it is appropriate for the site to be discontinued.

Sampling Frequency

A large number of sites are sampled each year during basinwide sampling and special studies. Resulting information is used to document both spatial and temporal changes in water quality and to complement water chemistry analyses. The BMCAP conducts macroinvertebrate sampling in all of North Carolina's physiographic provinces (Figure B1.1) in both wadeable and non-wadeable waters. Non-swamp sites that are part of the Basinwide Monitoring Program are sampled once every five years and usually between June and September. Swamp sites that are part of basinwide sampling are sampled once every five years between February and March. Watershed-specific special study sites are usually sampled only once and may be sampled at anytime of the year.

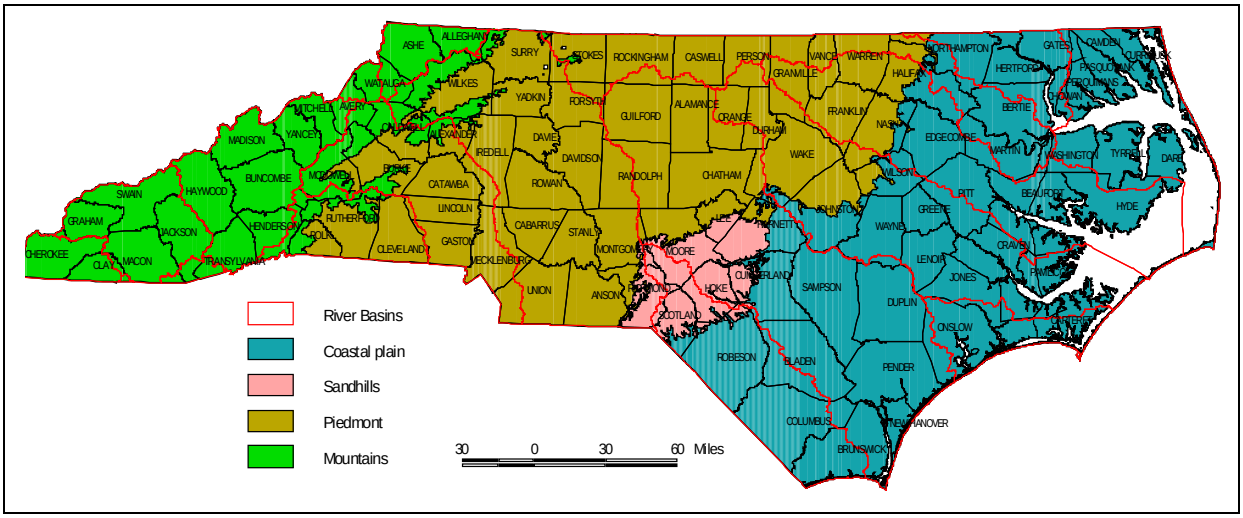

Figure B1.1 Physiographic Regions and River Basins in North Carolina

Sampling and Measurements

The Biological Assessment Branch utilizes the following five methods to collect benthic macroinvertebrates:

1. The **Standard Qualitative Method** is used to assign water quality ratings to most wadeable flowing streams and rivers in North Carolina. This methodology is applicable for most site and/or date comparisons and should be used for all evaluations of impaired streams large enough to be rated.

   Standard Qualitative collections include one leaf pack sample, three sweep net samples, two kick-net samples, one sand sample, two rock/log samples, and three visual collections with all aquatic invertebrates retained for analysis.

2. The **EPT Method**, an abbreviated version of the regular qualitative technique, is used to quickly determine differences in water quality between sites. This method is particularly useful for watershed or basin assessment studies with large numbers of sites and/or emergency sampling where it is desirable to rapidly assess the effect of spills or unusual discharges. Although the EPT method is a more rapid sampling technique, there are situations where the EPT method may provide too little information for an adequate assessment of water quality. Such situations include areas with naturally low EPT richness and areas where the abundance of more tolerant groups must be assessed. If a biotic index must be calculated, then an EPT sample is inappropriate.

   EPT collections include one kick net sample, one leaf pack sample, one sweep sample, and three visual collections with only EPT taxa retained for analysis.

3. The **Qual-4 Method** is used for small streams with drainage areas $\leq$ 3.0mi^2 (NCDWQ 2009) that will likely have few EPT taxa but where data are needed to assess differences in the benthic community.

   Qual-4 collections include one kick net sample, one leaf pack sample, one sweep sample, and three visual collections with all aquatic invertebrates retained for analysis.

4. **Swamp Sampling** is used for swamp streams that cease to flow in the summer months but have visible flow during late winter.

   Swamp samples are comprised of three sweep net samples, three rock/log samples, and three visual collections with all aquatic invertebrates retained for analysis.

5. **Boat Sampling** is used for nonwadeable freshwater rivers.

   Boat collections include nine ponar samples, one stick/leaf pack sample, three sweeps, three visual collections with all aquatic invertebrates retained for analysis.

In order to decide which is the most appropriate sampling technique, an investigator must consider the number of sites to be sampled, what kind of existing data might be used for comparisons, how soon a report will be required, and what kind of differences must be detected between sites.

Once collected, invertebrates are separated or “picked” from the rest of the sample in the field using forceps and white plastic trays. Organisms are picked in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera, and all Hemiptera (except Naucoridae, Belostomatidae, Corixidae, and Nepidae). These are not picked because either abundance is difficult to quantify, or they are not truly benthic organisms.

The picked organisms are preserved in glass or plastic vials containing 95% ethanol and transported to the BMCAP laboratory for analysis.

Field measurements and the collection of benthic macroinvertebrates are taken in accordance with the Benthic Macroinvertebrates SOP (Appendix A). All field data (e.g., water chemistry, habitat data, etc.) are recorded on the Benthos Collection Card and Habitat Field Data Sheet. Specific collection and location data (e.g., Stream Name, County, Date, Road Crossing, Collection Type, Collection Card Number, and Collectors) are all recorded in the following three locations to ensure sample integrity: 1) Benthos Collection Card, 2) Habitat Assessment Filed Data Sheet, and 3) Label Sample, which is placed in the sample container.

B2. Sampling Methods

Benthic Macroinvertebrate Collection Techniques

Kick Net Collections

A kick net consists of a double layer of flexible nylon door or window screening held in place between two halves of a wooden pole using wood screws. The screening is reinforced with denim along all edges and has lead weights sewn into the bottom edge.

To collect samples, the kick net is positioned upright on the streambed, while the area upstream is physically disrupted using feet and/or hands. The debris and organisms in the kick net are then washed down into a sieve bucket with a US Standard No. 30 mesh (0.600 mm opening) bottom and larger leaves and debris are removed.

Two kicks are taken from riffle areas for Full-Scale samples and one riffle kick for EPT and Qual-4 samples. No kick net samples are taken for Boat and Swamp Samples. The two samples should be collected from areas of differing current speed. In very small streams or sandy areas lacking riffles, kicks should be taken from root masses, snags, or bank areas. This sampling device collects all types of benthic macroinvertebrates, but emphasis is placed on Ephemeroptera, Plecoptera, and Trichoptera.

Sweep Net Collections

A long-handled triangular sweep net is another versatile sampling device. Three samples are collected by vigorously sweeping through the appropriate habitats. Sweeps are usually taken from bank areas, including undercut banks, root mats, and macrophyte beds. A sweep net can also be used to sample small diameter gravel riffles and bedrock as a supplement to the kick net sample.

Fine-Mesh Collections

Since the kick and sweep nets utilize a relatively coarse mesh size, an alternative sampling technique was developed to sample the smaller invertebrates (especially the Chironomidae). Fine nitex mesh (300 microns) is placed between four-inch PVC pipefittings designed to screw together. This device can be used in a variety of ways; however, the simplest technique is to wash down rocks or logs into a large plastic tub partially filled with water. A single composite sample can be made from several (usually 10-15) rocks and/or logs. The material remaining in the tub is poured through the fine mesh sampler, and the water is allowed to drain completely. The fine mesh sampler and remaining residue are placed in a plastic container filled with 95% ethanol. The sample is allowed to sit for several minutes, pulled out of the alcohol, and then backwashed into a picking tray. Field preservation makes small chironomids and oligochaetes more visible and easier to pick up with forceps. This technique is also an effective method for collecting small or very firmly attached EPT taxa (e.g., *Hydroptila*, *Leucotrichia*, and *Neotrichia).*

Sand Collections

Sandy habitats often contain a distinct fauna; however, extraction of this fauna by means of dredge-type sampling can be tedious. Sandy substrates (in areas with definite flow, if possible) are sampled with a long-handled net constructed of fine mesh (300 microns) nitex netting. The lower edge of the net frame is set on the substrate while the sand is vigorously disturbed by the collector's foot. The material collected is emptied into a large plastic container half-filled with water. A "stir and pour" elutriation technique is used in conjunction with the fine mesh sampler. After field preservation, the specimens are picked for collection.

Leaf-Pack Collections

Leaf-packs, sticks, and small logs are washed down into a sieve bucket with a U.S. Standard No. 30 sieve bottom (0.600 mm openings). Generally, three to four leaf packs are collected from rocks or snags in areas with fast currents.

Visual Collections
Visual inspection of large rocks and logs often yields additional specimens, as this habitat cannot be adequately sampled by either kicks or sweeps. In addition, substrate in extremely fast or slow currents is crucial in attaining a representative sample; most collection techniques used in the Standard Qualitative and EPT samples do not systematically assess these areas.

The tops of rocks are a specialized microhabitat with a number of characteristic taxa. Specimens are often more visible after lightly washing off any silt that has accumulated on the top of the rock. Decaying logs should be picked apart to look for chironomids, and many taxa can be found under loose bark.

Certain species inhabit crevices in rocks or logs and cover the openings over with silk strands. Over time, the silk becomes covered with silt and periphyton and is hard to see. There is usually a faint opening on each end of this retreat. If the tip of forceps is inserted into one opening, the larvae will usually come out the other opening.

Polycentropodid caddisflies build funnel-shaped silken retreats (up to six inches in length) in areas of relatively slow current. Out of water, the case collapses and resembles a gelatinous brown glob. The larvae will often crawl out if left out of the water for several minutes or can be more efficiently removed by probing with forceps.

In sandy coastal plain rivers, samples should be collected from a log in an area of faster current with some portion raised above the substrate. The net may be the only visible evidence of these organisms, and they must be dug out of their retreats with forceps.

If dead shells are observed along the shore, a mussel search should be conducted. If possible, mussels should be identified in the field and returned (alive) to the stream. If sampling in an area with known populations of endangered or threatened mussels, any live mussels should be photographed or sketched and returned to the stream.

Ponar Collections
Ponar grabs are collected at three locations between midstream and the bank, with three replicates at each location (a total of 9 samples). If possible, the three locations should include a variety of depths, with at least one location in the 2-3 meter range. Sandy samples should be elutriated and processed through a fine-mesh sampler. Ponars collections should not be utilized in areas normally sampled during shore work (i.e., <2 meters deep). The petite ponar should be lowered slowly to avoid disturbance of surface sediments.

Field Water Quality Measurements
Measurements made in the field include water temperature, pH, specific conductance, stream flow (low, normal, high), qualitative estimates of water clarity (clear, slightly turbid, turbid, tannin-stained, or blackwater), and dissolved oxygen. Field measurements are discrete and are made *in situ* by field staff at the time of the station visit. All field activities are to be performed in accordance with the Intensive Survey SOP (ISB Home Page).

Physical measurements are to be taken in accordance with the Intensive Survey SOP (ISB Home Page). Any irregularities or problems encountered by field staff are communicated to the Environmental Biologist III and the BAB Supervisor who will assess the situation, consult with other project personnel, and recommend a course of action for resolution. Deviations from these procedures for unusual sampling situations shall be documented in the appropriate report or memorandum.

B3. Sample Handling and Custody

All samples are handled by full-time permanent BAB staff in accordance with the Benthic Macroinvertebrates SOP (Appendix A). While in the field, all biological samples and all data sheets are under the custody of the BAB staff and are kept locked in the field vehicle at all times. Upon arrival at the laboratory, samples and all applicable paperwork are locked in BAB staff offices and archived onsite. There are no minimum temperature requirements for invertebrate samples, and there are no maximum holding times. All applicable field data are recorded on the BMCAP's Habitat Assessment Field Data Sheets, Benthos Collection Card, and Sample Labels.

Sample Identification

While in the field, all biological samples are stored in 95% ethyl alcohol in plastic sealable containers with a pencil-written sample label placed inside. This label includes the following information:

- Name of Waterbody,
- Collection Date,
- Station Location,
- Sample Type,
- Collection Card Number, and
- Initials of Collectors.

Upon arrival at the laboratory, the sample label and the contents of the plastic storage container are transferred to a glass sample jar. Once taxonomic processing commences, a Benthic Macroinvertebrate Lab Sheet is filled-out and site location information is transcribed from the Sample Label to this form.

Collection Card Number

Each sample collected as part of the BMCAP is assigned a unique identification number by the Lead Environmental BAB Biologist in batch form as needed during the year. This five-digit Collection Card Number is recorded in the following four locations to ensure sample integrity: The Benthos Collection Card, Habitat Assessment Field Data Sheet, Sample Label, and Benthic Macroinvertebrate Lab Sheet.

B4. Analytical Methods

When a sample is returned to the laboratory for analysis, the person responsible for processing the sample will combine all vials collected from a site into one sample dish. All organisms in the sample are identified to the lowest possible taxonomic level, recorded on a Benthic Macroinvertebrate Lab Sheet, and designated as *Rare* (1-2 specimens observed), *Common* (3-9 specimens observed), or *Abundant* ($\geq$10 specimens observed).

All samples are labeled and stored in the BMCAP laboratory for an indefinite period. Taxonomic data are entered into the benthos database (Microsoft Access) by the analyst who processed the sample. After the data are entered, the database is checked for coding or relative abundance errors. When the data are saved, the following values are automatically calculated by the software:

- EPT Taxa Richness,
- Biotic Index Value for the sample,
- Total Taxa Richness,
- EPT Biotic Index Value for the sample,
- EPT Abundance, and
- Bioclassification.

Typically, bioclassifications are automatically calculated by the Microsoft Access software. However, if a sample is collected outside the summer period, from a small stream, or from a swamp stream, the bioclassification must be manually calculated using the scoring tables in the Benthos Macroinvertebrate SOP (Appendix A). After all taxa in a sample are entered into the database, any necessary seasonal corrections are performed manually. The bioclassification is entered manually based on the corrected values, and notes about corrections are made in the comment section for each sample.

Several data summaries (also referred to as indicators or metrics) can be produced from benthos samples to detect water quality problems. Research shows that unstressed streams and rivers contain many invertebrate taxa and have a relatively high proportion of intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

Bioclassifications

The core indicators used by the BMCAP to calculate bioclassifications are EPT Taxa Richness (EPTs) and the Biotic Index (BI). In addition, some samples also use Total Taxa Richness (S), EPT Biotic Index (EPTBI), and EPT Abundance (EPT N) to calculate bioclassifications. Standard Qualitative samples, EPT samples, and Small Stream samples are rated *Excellent*, *Good*, *Good-Fair*, *Fair*, or *Poor*. The bioclassifications or stress categories for swamp stream samples are *Natural*, *Moderate*, and *Severe*; a habitat evaluation score is also included as a metric for swamp samples. Boat samples do not receive bioclassifications.

EPT Taxa Richness (EPTs)

Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are the most intolerant of the aquatic insect orders. The association of good water quality with high species (or taxa) richness has been thoroughly documented. EPT Taxa Richness is a metric that indicates good water quality when EPT richness is high and degraded water quality when richness is low. Bioclassification criteria for EPT Taxa Richness values have been developed for each of the three major ecoregions (mountains, piedmont, and coastal plain) and can be used to evaluate water quality for EPT and Standard Qualitative samples.

Biotic Index (BI)

Bioclassifications are also based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI). Both tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions. The NCBI is calculated by summing the tolerance value of individual taxa

multiplied by their abundance value, to give an average tolerance value. The EPT Biotic Index (EPTBI) is a similar summary measure where only EPT taxa are used in the calculation.

Total Taxa Richness (S)
Total Taxa Richness (S) is a metric used for Swamp samples and measures how many different kinds of taxa are found in the sample. Higher values generally indicate better water quality.

EPT Abundance (EPT N)
EPT Abundance (EPT N) is a metric that is also used for swamp samples and is used in Standard Qualitative samples when EPT taxa richness and the NCBI suggest different bioclassifications. In these situations, the abundance value is used in that instance to give more weight to one metric over the other.

Stream width or drainage area of a small watershed plays a role in determining which type of sample to collect and whether the standard bioclassifications can be assigned. It was previously determined that streams less than four meters wide should not be rated using the standard criteria because fewer taxa are expected in very small watersheds. As a result, biocritiera were developed for small streams and are defined as streams with drainage areas $\leq$3.0mi^2.

Small streams are sampled using the Qual-4 sample method and a set of biocritiera for the Piedmont and Mountain ecoregions are now established (NCDWQ 2009). As a result, these small streams can now be assigned one of the five bioclassifications (i.e., Excellent, Good, Good-Fair, Fair, Poor) to North Carolina's non-swamp waterbodies.

Field Measurements
In addition to the ISB SOP sections cited in Table B4.1, the instruction manual for the appropriate meter should also be consulted.

Table B4.1 Field Measurement Method References and Reporting Levels
Adopted from Intensive Survey Branch SOP (**ISB Home Page**).

Parameter	NC DWR's Intensive Survey Branch's SOP & section	EPA method	Reported to nearest
Dissolved oxygen	III.3	360.1	0.1 mg/L
pH	III.4	150.1	0.1 s. u.
Water temperature	III.1	170.1	0.1 ºC
Specific conductance	III.5.2	120.1	1 µmhos/cm

Laboratory Analyses
All samples are taxonomically processed in the WSS laboratory in accordance with the Benthic Macroinvertebrates SOP (Appendix A).

B5. Quality Control

Field Activities and Training

Quality assurance and control practices in place for the BMCAP are described in the "Quality Assurance" section of the Benthic Macroinvertebrates SOP (Appendix A). All full-time permanent BAB staff are responsible for participating in and helping to oversee the collection of benthic macroinvertebrate community samples. Each year the BMCAP conducts "overlap" sampling and annual habitat rating training. "Overlap" samples are taken with different field crewmembers (if possible), and results are compared. In addition, if new staff are hired before the annual training, these individuals are added as a fourth crew member and accompany the typical three-person crew for purposes of learning BAB's field sampling procedures.

Field water quality instruments are calibrated for each sampling trip prior to that day's work. Meter calibrations for dissolved oxygen (DO), pH, and specific conductance are checked after each sampling event to confirm that significant drift has not occurred and that the data collected is accurate and representative. If final calibration readings are beyond acceptable limits (DO = $\pm$0.5; pH = $\pm$0.2; conductance = $\pm$10%), the data are discounted and are not entered in the database.

Laboratory Activities and Training

Full-time permanent BAB staff members, under the general supervision of the BAB Supervisor and the Lead Environmental Biologist, perform all laboratory identifications of samples. To ensure consistency between taxonomists, all staff have access to current regional keys, current regional checklists, in-house keys, the in-house taxonomy document, an in-house reference collection consisting of specimens verified by outside taxonomic experts, and an in-house virtual reference collection comprised of thousands of specimen photos available via the BAB server.

Reference specimens (most verified by taxonomic experts) are maintained in a reference cabinet in the WSS laboratory. A reference specimen list is also maintained and updated periodically.

Random samples are re-identified for taxonomic consistency. When each biologist completes a block of ten samples, one of the ten is randomly selected for reidentification by a second, randomly selected biologist (the "QA biologist"). Random selection of samples and QA biologists is performed by a computer program at the beginning of each month for all BAB invertebrate biologists. The randomly selected sample (the "QA sample") is given to the QA biologist for reidentification, which should be completed within four weeks. After QA discussions (which will involve other biologists) the BAB Supervisor scores the original identification for accuracy and logs the information into a QA database.

If a sample fails a QA, three additional samples are randomly selected from the nine remaining samples in the QA block. If all three samples pass, no further action is taken. If any one of the three samples fail QA, the remaining six samples from the block are also reviewed.

Scoring the original identifications of QA samples involves taxonomic identification, abundance categories, and data entry. Error points are assigned as described in the Benthic Macroinvertebrates SOP (Appendix A, Table 17). The final score is the sum of error points divided by the number of taxa in the sample (as determined by the QA biologist) then multiplied by 100. A score of less than 90 is a fail.

In addition, each year a random subset (10%) of data entered into the database that calendar year is audited by either the BAB Supervisor or the Environmental Biologist III for accuracy.

B6. Equipment Testing, Inspection, and Maintenance

A routine preventative maintenance program minimizes the occurrence of instrument and equipment failures. Preventative maintenance is limited because most of the sampling and measuring equipment is electronic (i.e., no movable parts to repair). As a result, most repairs occur when the equipment no longer functions.

Each member of the BMCAP is responsible for regular inspection and maintenance of their assigned field sampling equipment. All sampling equipment should be visually inspected for damage at the start of each sampling day and repaired if needed before further use. Moreover, at least one extra kick and sweep net sampler should be taken for each field trip. In addition to benthic macroinvertebrate equipment, the BMCAP also uses several electronic devices for measuring water chemistry *in situ* at each site; the required maintenance for this equipment is shown in Table B6.1. Refer to instruction manuals for manufacturer's recommendations for inspection, maintenance, and repair.

Table B6.1. Water Quality Field Instrumentation Maintenance.

Equipment	Task	Frequency
YSI Professional Plus meter	Check battery level	Daily
	Check GLP files to confirm correct calibration	Daily
	Inspect membrane for holes, tears, bubbles, fouling or other damage	Daily
	Inspect glass bulb for scratches, fouling or other damage	Daily
	Replace membrane and KCl solution	As needed if damaged, DO not calibrating or calibrations do not hold, responding slowly, showing excessive drift, or providing erratic readings
	Inspect gold cathode	As needed, when replacing membrane
	Clean cathode	As needed, if tarnished or plated
	Replace pH probe	As needed if damaged, pH not calibrating or calibrations do not hold, responding slowly, showing excessive drift, or providing erratic readings

B7. Instrument Calibration and Frequency

Water Quality Field Instrumentation

All field meters are to be inspected and calibrated at a minimum at the beginning and end of each day used. Field staff should record calibration information on the Water Quality Monitoring Field Meter Calibration Sheet form (Appendix B) including staff name, date/time of initial calibration and post-sampling check, and meter number. The specific calibration procedures are documented in meter-specific guidance tables (Appendix C) and in the manufacturers' instruction manuals. Dissolved oxygen meters should be calibrated using the air calibration method.

Standards should be selected so that they bracket the range of measurements expected that day. Traceable pH buffers (standards) and specific conductance standards are purchased by the BAB. Specific conductance is typically calibrated with a 1,000 µS/cm standard first, then calibration is verified with a 500 µS/cm standard. Meters currently in use require pH standards of 4.0, 7.0, and/or 10.0 S.U.

Meters should also be checked against standards periodically throughout the day and recalibrated if needed if any of the following occur:

- physical shock to meter;
- DO membrane is touched, fouled, or dries out;
- unusual (high or low for the particular site) or erratic readings, or excessive drift;
- extreme readings (e.g., extremely acidic or basic pH; D.O. saturation >120%);
- measurements are outside of the range for which the meter was calibrated.

A post-sampling check is completed at the end of each sampling day to confirm significant drift has not occurred and that readings are accurate and representative. If post-sampling check readings are not within the acceptable QC ranges (DO= ±0.5, Specific conductance= 10%, pH=±0.2) or a post-sampling check is not completed, data are determined questionable and are removed from the dataset.

B8. Inspection/Acceptance for Supplies and Consumables

Most of the equipment (sieve buckets, nets, picking trays, sample tubs, sample containers, forceps, fine mesh samplers, label paper, ethyl alcohol, *etc*.) used in the BMCAP is not required to meet strict technical standards for manufactured quality. Typically, the Lead Environmental Biologist and at least one other Environmental Biologist II are responsible for the selection, procurement, and maintenance of all equipment and consumables associated with the BMCAP.

B9. Acquired Data (Non-Direct Measurements)

All data are directly generated through the BMCAP field activities and subsequent laboratory analyses, with two exceptions:

- Geo-referenced data (latitude and longitude) are obtained from Maptech Terrain Navigator® software, DWR's geographical information system software/data layers, or from a Garmin GPS meter.
- Watershed drainage areas for each site are obtained from the U. S. Geological Survey or from DWR's geographical information system software/data layers.

Both of these resources are used for planning and site characterization before site visits.

In addition to this data, regional checklists that detail the invertebrate taxa known or thought to occur in North Carolina are updated annually and added to the Taxonomy Document, which is included within the Benthic Macroinvertebrates SOP (Appendix A).

B10. Data Management

Approximately 140 sites are sampled annually as part of the BMCAP, resulting in over 7,000 records since the program's inception. Collection cards and habitat forms are completed in the field and are locked in the field vehicle, along with the corresponding invertebrate sample, throughout the duration of the sampling trip. Upon return to the lab, the paperwork and invertebrate sample are transferred to and stored in the office of the biologist responsible for processing. After processing, the sample and all associated paperwork are stored permanently onsite. The BAB staff member who executed the taxonomic analysis enters the results into the BMCAP's Microsoft Access database. The biologist reviews the data for completeness, data entry errors, and unlikely or impossible values. Random audits of a subset (10%) of data entered into the database that year are performed by the BAB Supervisor and/or the Lead Environmental Biologist. Copies of this database reside on BAB's network drive. Backups are run daily on the network drive. The database is updated on an as needed basis whenever new samples are completed or whenever errors in previously entered data are identified.

SECTION C:

ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

The Lead Environmental Biologist (in conjunction with the BAB Supervisor) is responsible for the BMCAP and serves as the coordinator and the liaison between the program, the BAB, the WSS, the Basin Planning Branch, and other data users. Issues with any aspect of the program noted by these entities should be reported as soon as possible to the Lead Environmental Biologist or the BAB Supervisor to determine the course of action (if any) to be taken. Any collection, data management, or taxonomic problems noted by the Lead Environmental Biologist are reported to the BAB Supervisor for corrective measures.

Annually, all field staff participate in USGS' National Field Quality Assurance (NFQA) program. The NFQA is a yearly proficiency test for pH and specific conductance. Staff who do not receive satisfactory results are provided additional field meter training and retested. The QA coordinator oversees the NFQA Program for WSS.

C2. Reports to Management

The BAB Supervisor reports quarterly BMCAP sample statistics to DWR management, which in turn reports these data to EPA Region 4. These statistics include the number of basinwide samples conducted, the number of special study samples collected, and the number of special studies conducted per quarter.

SECTION D:

DATA VALIDATION AND USABILITY

D1. Data Review, Verification, and Validation

Data verification and validation occurs at every step of data generation and handling. Each full-time permanent BAB staff member of the BMCAP is responsible for verifying that all records and results produced or handled are completely and correctly recorded, transcribed, and transmitted. The Lead Environmental Biologist and the BAB Supervisor are also responsible for ensuring that all activities performed (sampling, analyses, data entry, etc.) comply with all requirements outlined in the BMCAP QAPP and SOP. These responsibilities include, but are not limited to: taxonomic QA/QC, annual overlap field sampling, annual database audits, and meter calibration.

Data that are entered into the BMCAP's database are constantly being checked for errors, and a random subset (10%) of all data entered that year is audited for accuracy. Some of the data entry checks include:

- County - Only North Carolina counties allowed; confirmation that the county in the database matches the site location;
- Ecoregion - Only four physiographic regions can be entered for non-swamps (Mountains, Piedmont, Sand Hills, or Coastal Plain); For swamps, there are five physiographic regions (Region A, B, C, P, and S);
- Latitude and Longitude - Only coordinates located in North Carolina can be entered;
- Road Crossing - Confirmation that the crossing in the database matches the site on the map;
- Water Quality Variables (temperature, specific conductance, dissolved oxygen, and pH) – "Flag" values outside ranges normally encountered and do not allow the data to be saved;
- Validate seasonal taxa corrections;
- Validate the river basin and subbasin; does it match the site location, etc.

In terms of data acceptance, there are certain instances in which a sample collected through the BMCAP may be abandoned. Typically, these occasions are generally restricted to special studies requested by DWR regional offices and include (but are not limited to) brackish/estuarine waters, perennially non-flowing waters, or samples taken directly below impoundments. On these occasions, the samples are collected, processed, and analyzed for inclusion in a report, but the data are not entered into the Microsoft Access database, and no bioclassification is generated.

D2. Validation and Verification Methods

Each member of the BMCAP is responsible for ensuring that each site's Habitat Assessment Field Data Sheet, Benthos Collection Card, and Sample Identification Label are filled out accurately and that the Sample Identification Label is placed in the sample container at the time of collection. These data are checked at the time of collection and at the time of data entry. Additionally, 10% of these data are re-checked during the annual database audit.

Sample data are also considered invalid if post-sampling meter calibrations for dissolved oxygen (DO), pH, and specific conductance are beyond acceptable limits (DO = $\pm$0.5; pH = $\pm$0.2; conductivity = $\pm$10%). If meter calibrations are not within the acceptable limits, the data are discounted and are not entered in the database.

The BAB Supervisor also review all reports and memoranda for completeness and accuracy. Any issues will be resolved by the BAB Supervisor.

Any issues observed with the data (data not plausible or not representative of the stream or watershed as a whole; conflicts with results from other DWR monitoring programs; etc) should be communicated to the Lead Environmental Biologist and the BAB Supervisor. The recipient of the data may request that the site be re-sampled by the BMCAP the following year or may choose to not use the data in Use Support ratings, Use Attainability studies, or as background information.

D3. Reconciliation with User Requirements

After the data have been analyzed and summarized, results from the program are communicated *via* WSS Chief-approved Basinwide Assessment Reports and internal site-specific memoranda. Statistical validation methods are not used to determine possible anomalies or outliers of the data. Any issues encountered in meeting the performance criteria as stated in Section A6 of this document (or limitations in the use of data) are documented in the final report.

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Web Links

NC Division of Water Resources ..... https://deq.nc.gov/about/divisions/water-resources

NC Basin Planning ..... https://deq.nc.gov/about/divisions/water-resources/planning/basin-planning

NC 303b and 303d Reports ..... https://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/water-quality-data-assessment

NC Water Resources Standards..... https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards

NC Biological Assessment Branch ..... https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/biological-assessment-branch

NC Intensive Survey Branch Homepage ... https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/intensive-survey-branch

Intensive Survey Branch SOP ..... https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/intensive-survey-branch

NC Basinwide Assessment Reports ..... https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/reports-publications-data