Environmental Quality

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

January 18, 2017

Forrest R. Westall, Sr.
Executive Director
Upper Neuse River Basin Association
P.O. Box 270
Butner, NC, 27509

Re: UNRBA QAPP, Version 1.1 for the Falls Lake Watershed Monitoring Program

Dear Mr. Westall:

The Division of Water Resources hereby approves the Upper Neuse River Basin Association's (UNRBA) revised Quality Assurance Project Plan, Version 1.1 (QAPP) for the Falls Lake Watershed Monitoring Program. This will allow for the continued collection of water quality data and information acceptable for use in developing a reexamination of the Falls Lake Nutrient Management Strategy.

Our mutual records concur that the Division previously approved the UNRBA's QAPP (UNRBA Approved QAPP, Version 1.0, 2014), Monitoring Plan (Approved UNRBA Monitoring Plan, 2014), and Description of the Modeling Framework (UNRBA Approved Description of a Modeling Framework, 2014) for the adaptive management provision outlined in the Falls Lake Rules, often referred to as the Reexamination. This approval applies to the minor revisions in the QAPP, and the previous approvals to the Monitoring Plan and Description of the Modeling Framework remain in effect.

Thank you to all members of the UNRBA for your continuing efforts to improve water quality in Falls Lake. If you have further questions, please contact Rich Gannon in the NonPoint Source Planning Branch at 919-807-6440 or Cyndi Karoly in the Water Sciences Section at 919-743-8416.

Sincerely,

S. Jay Zimmerman
Director

Cc: Tom Fransen
Rich Gannon
John Huisman
Pam Behm
Brian Wrenn
Jason Green

QUALITY ASSURANCE PROJECT PLAN

for

The Upper Neuse River Basin Association
Water Quality Monitoring Program

Prepared for:
The Upper Neuse River Basin Association
P.O. Box 270
Butner, NC 27509

Program Administered and Plan Prepared by:
Cardno
5400 Glenwood Avenue
Raleigh, NC 27612

Previous version approved by the
North Carolina
Department of Environmental Quality
Division of Water Resources on
July 30, 2014 (Version 1.0)

Version 1.1
July 20, 2016

ABBREVIATIONS

BOD_5: biochemical oxygen demand, 5-day
c.u.: color units
CAAE: Center for Applied Aquatic Ecology, NCSU
CASTNET: Clean Air Status and Trends Network
$CBOD_5$: carbonaceous biochemical oxygen demand, 5-day
Chl *a*: chlorophyll *a*
DO: dissolved oxygen
DOC: dissolved organic carbon
DWR: Division of Water Resources, NCDEQ
EFDC: environmental fluid dynamics code
EPA: U.S. Environmental Protection Agency
ISB: Intensive Survey Branch, NCDEQ
LCS: laboratory control sample
MDL: method detection limit
NADP: National Atmospheric Deposition Program
NC: North Carolina
NCAC: North Carolina Administrative Code
NCDENR: North Carolina Department of Environment and Natural Resources
NCDEQ: North Carolina Department of Environmental Quality, formerly NCDENR
NCSU: North Carolina State University
NH_3: ammonia
$NO_2 + NO_3$: nitrite plus nitrate
NOAA NCDC: National Oceanic and Atmospheric Administration National Climatic Data Center
NTU: nephelometric turbidity units
PO_4: phosphate
PQL: practical quantitation limit
Pt-Co: platinum-cobalt
QA: quality assurance
QAM: Quality Assurance Manual
QAPP: Quality Assurance Project Plan
QC: quality control
RPD: relative percent difference
SLPH: State Laboratory of Public Health, NC Department of Health and Human Services
SM: Standard Methods for the Examination of Water and Wastewater
SOP: standard operating procedure
SRP: soluble reactive phosphorus (sample filtered, but not digested)
SUVA: specific ultraviolet absorbance
TKN: total Kjeldahl nitrogen
TOC: total organic carbon
TP: total phosphorus (sample digested, but not filtered)
TRP: total reactive phosphorus (sample not digested and not filtered)
TSP: total soluble phosphorus (sample filtered and digested)
TSS: total suspended solids
UNRBA: Upper Neuse River Basin Association
USGS: United States Geological Survey
UV: ultraviolet

REVISION LOG

UNRBA Monitoring Program
Quality Assurance Project Plan

Date	Version Edited	Section	Changes/Updates	Editor
30 July 2014	1.0	All	Initial Approved QAPP	N/A
27 June 2016	1.0	All	NCDENR has been updated to NCDEQ throughout, except where referring to specific citations of reports generated when the agency was still referred to as NCDENR.	M. Van de Bogert
27 June 2016	1.0	A-Project Management	Project staff and roles have been updated to reflect changes made at DEQ, UNRBA, and Cardno.	M. Van de Bogert
27 June 2016	1.0	A.6 – Overview	Added a paragraph describing how QA procedures will be defined for non-routine and short-term Special Studies conducted by the UNRBA (e.g., sediment sampling, bathymetric mapping, etc.)	M. Van de Bogert
27 June 2016	1.0	Table A.6.1	Added Volatile Suspended Solids to the table of parameters which may be measured at monitoring locations.	M. Van de Bogert
27 June 2016	1.0	A.6 and throughout.	References to "Environment 1, Inc." have been updated to more generally specify "DWR-certified laboratories".	M. Van de Bogert
27 June 2016	1.0	A.7 and Table A.7.1	Acceptance criteria for field blanks has been revised to specify the criteria as less than the reporting limit.	M. Van de Bogert
27 June 2016	1.0	A.7	Matrix spike frequency has been clarified to be *at least* 1 per 20 samples, but may be more frequent when specific methods require (e.g., EPA's nitrogen methods).	M. Van de Bogert
27 June 2016	1.0	A.7	The actions associated with matrix spike results outside of specified control limits has been corrected to match the procedures specified in Section B.5. This makes the QAPP consistent with EPA guidelines for matrix spike evaluations.	M. Van de Bogert
27 June 2016	1.0	A.7	Under the Required Practical Quantitation Limit section, the QAPP has been updated to specify that each data value will be stored with the laboratory's reporting limit and method detection limit at the time of analysis.	M. Van de Bogert

Date	Version Edited	Section	Changes/Updates	Editor
27 June 2016	1.0	A.7	A statement was added noting that bias can result when samples are collected under targeted flow conditions if samples are assumed to be collected independent of flow. The QAPP specifies that samples collected as part of a targeted flow effort will be identified as such in the database.	M. Van de Bogert
27 June 2016	1.0	A.7	QAPP was updated to correct that samples may be collected even under stagnant conditions, though flow conditions will be noted in the metadata associated with the samples.	M. Van de Bogert
27 June 2016	1.0	A.8	Sentence about field staff routinely collecting samples for the State's Monitoring Coalition was removed; while this is currently true, we cannot know that this will always be true and it need not be included in this QAPP. The requirement that field staff be from a DWR-certified field laboratory remains.	M. Van de Bogert
27 June 2016	1.0	A.9	Removed specific details of reporting that are more appropriate for a contract document than a QAPP. Basic reporting requirements remain.	M. Van de Bogert
27 June 2016	1.0	B.1	Noted that revised Monitoring Plan documents specifying the details of what samples are collected and from where and when are periodically posted to the UNRBA website.	M. Van de Bogert
27 June 2016	1.0	Tables B.1.3 and B.2.1	Volatile Suspended Solids have been added to the tables of water quality parameters which may be measured under this program.	M. Van de Bogert
27 June 2016	1.0	B.3	Sample labeling requirements have been simplified while maintaining all necessary information.	M. Van de Bogert
27 June 2016	1.0	B.3	Sample storage temperature was changed from "at 4 degrees Celsius" to "below 6 degrees Celsius" to better align with State requirements.	M. Van de Bogert

SECTION A — PROJECT MANAGEMENT

A.1 Signature and Approval Sheet

Upper Neuse River Basin Association, Water Quality Monitoring Program
Quality Assurance Project Plan, Version 1.1

Approved by:

Paul Leonard, Cardno Principal in Charge	Date
Matthew Van de Bogert, Cardno Project Manager	Date
Mark Oliveira, Environment 1, Inc. President & Quality Assurance Manager	Date
Forrest Westall, UNRBA Executive Director	Date
Pam Hemminger, UNRBA Chair, Board of Directors	Date
Tom Fransen, NC Division of Water Resources Water Planning Section Chief	Date
Cyndi Karoly, NC Division of Water Resources Water Sciences Section Chief	Date

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A.3 Distribution List

Primary Distribution:

Upper Neuse River Basin Association
Forrest Westall, Executive Director
Haywood Phthisic, Assistant to Executive Director

NC Department of Environmental Quality, Division of Water Resources
Cyndi Karoly, Water Sciences Section Chief
Tom Fransen, Water Planning Section Chief
Pam Behm, Modeling and Assessment Branch Chief
Steve Kroeger, Ecosystems Branch Chief
John Huisman, Non Point Source Branch, Nutrient Strategy Coordinator
Cam McNutt, Modeling and Assessment Branch

Cardno
Paul Leonard, Principal in Charge
Matthew Van de Bogert, Project Manager
Alix Matos, Senior Project Engineer
Chris Mickle, Database Administrator
Lauren Handsel, Water Resources Specialist

Environment 1, Inc.
Mark Oliveira, President, Project QA/QC Manager, Field Supervisor
Steve Jones, Laboratory Supervisor
Chad Davis, Field Staff
Ashley Vanderburg, Field Staff

A.4 Project Organization

Introduction

The UNRBA Water Quality Monitoring Program is conducted under the direction of the Upper Neuse River Basin Association (UNRBA). The UNRBA water quality monitoring program is aimed at fulfilling the association's mission to collect and analyze data for the development and evaluation of strategies to reduce, control, and manage pollutant discharge (Box A.4.1). The purpose of this QAPP is to provide users of any data collected as part of this program with documentation that clearly describes the quality systems used to obtain the data. This QAPP will assist data users to avoid any conflicts in data use that do not meet the demands of their specific data quality objectives.

Box A.4.1. The mission of the UNRBA

The mission of the UNRBA is to preserve the water quality of the Upper Neuse River Basin through innovative and cost-effective pollution reduction strategies, and to constitute a forum to cooperate on water supply issues within the Upper Neuse River Basin by:

- *Forming a coalition of units of local government, public and private agencies, and other interested and affected communities, organizations, businesses and individuals to secure and pool financial resources and expertise;*
- *Collecting and analyzing information and data and developing, evaluating and implementing strategies to reduce, control and manage pollutant discharge; and*
- *Providing accurate technical, management, regulatory and legal recommendations regarding the implementation of strategies and appropriate effluent limitations on discharges into the Upper Neuse River Basin.*

The day-to-day operations of data collection and quality assurance procedures which occur under the guidance of this QAPP will be directed by Cardno. The Monitoring Program will be overseen by the UNRBA. The UNRBA Executive Director, Forrest Westall, serves as the primary point of contact with Cardno and its subcontractors (hereafter referred to as the Cardno Project Team). The UNRBA Executive Director along with the UNRBA Path Forward Committee will provide general project guidance.

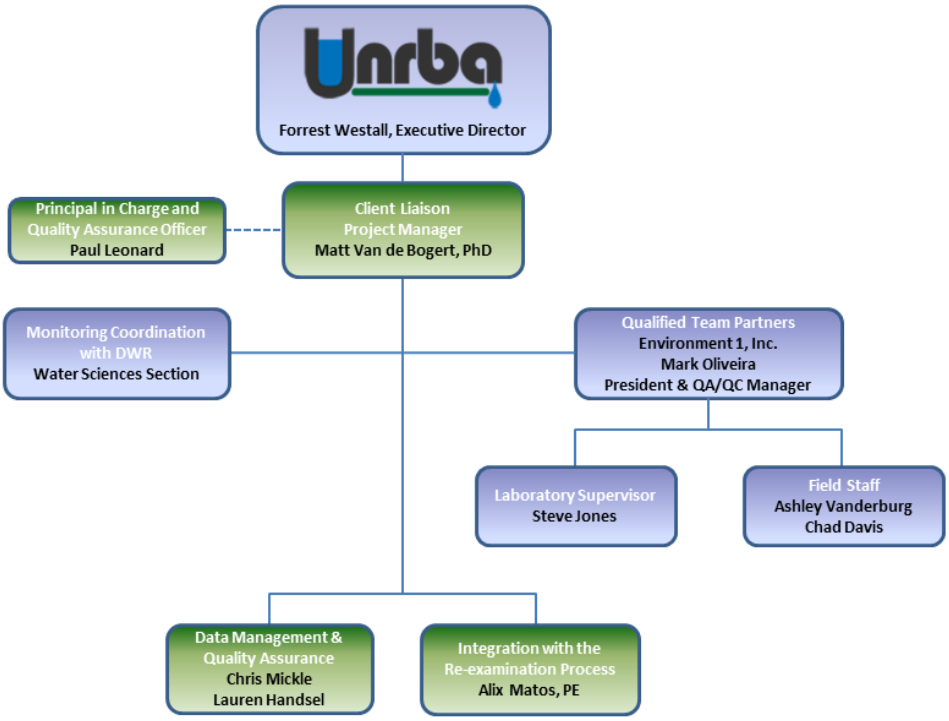

Figure A.4.1. UNRBA Monitoring Program Organizational Chart

Project Management and Oversight

Principal-in-charge
Paul Leonard, Cardno

- Responsible for oversight of the project including ensuring that the overall performance, direction, and quality of the monitoring program are aligned with project goals.

Project Manager
Matthew Van de Bogert, Cardno

- Responsible for ensuring that the monitoring program is conducted in accordance with all relevant QAPPs and standard operating procedures (SOPs)
- Reviews and approves all reports, work plans, corrective actions, QAPPs, and any other major work products and their revisions
- In consultation with UNRBA Executive Director, approves changes to program and ensures changes comply with UNRBA goals and North Carolina Department of Environmental Quality Division of Water Resources (henceforth, DWR) requirements
- Reports to UNRBA Executive Director and keeps Executive Director apprised of monitoring program status and progress
- Oversees special study field work conducted by Cardno staff

Quality Assurance Manager
Lauren Handsel, Cardno

- Performs data management tasks including tracking samples and results, reviewing data, identifying and correcting errors, uploading data to final database upon verification of adherence to all aspects of this QAPP
- Communicates needed or suggested changes to the Project Manager for approval
- Performs field and lab audits to assure compliance with this QAPP and associated SOPs and communicates needed corrective actions to Project Manager and field staff supervisors when needed
- Documents QA practices of the UNRBA monitoring program
- Maintains the UNRBA monitoring QAPP

Database and Web Interface Administrator
Chris Mickle, Cardno

- Designs and maintains database structure, web interface, data archives and backups
- Works with Project Manager and Project Coordinator to respond to issues raised by program participants with respect to database, data entry, and online data access

Data Generation (Measurements and Analyses)

QA/QC Manager, Field Supervisor
Mark Oliveira, President, Environment 1, Inc.

- Primary contact between Cardno and Environment 1, Inc.
- Schedules monitoring program according to QAPP guidelines
- Responsible for QAPP compliance
- Notifies Project Manager of any issues encountered
- Responsible for enforcing response or corrective actions of supervised field staff as necessary.
- Responsible for all data submissions/uploads
- Reviews field calibration sheets and results of all quality control checks after each monitoring event to assess the adequacy of the control checks and to identify any problems
- Notifies Project QA Manager in writing of any quality control check issues
- Proposes corrective actions for QA/QC issues.
- Serves as the point of contact for questions relating to quality control of reported data

Laboratory Supervisor
Steve Jones, Environment 1, Inc.

- Manages laboratory which performs all analyses on samples taken as part of the UNRBA monitoring program
- Responsible for oversight of all analytical activities and for ensuring that all analyses are performed in accordance with the standard operating procedures for this project
- Maintains laboratory certification from DWR for all analyses performed for the UNRBA

Field Staff
Ashley Vanderburg and Chad Davis, Environment 1, Inc.
Lauren Handsel, Cardno

- Performs all field activities including field measurements, observations, and sampling in accordance with QAPP and SOPs
- Notifies Environment 1, Inc. Field Supervisor or Cardno Project Manager of any issues encountered

Primary data end-users

UNRBA
Forrest Westall, Executive Director

- Liaison between the UNRBA (primary data end-user) and Cardno staff
- Receives semi-annual reports from Cardno on monitoring program
- Facilitates interactions between UNRBA Board of Directors, the Path Forward Committee, and Cardno for annual review of and updates to the monitoring program prior to the start of each fiscal year
- Provides input to the Project Manager on changes needed to the monitoring program as part of a continuous program assessment process

NCDEQ
Division of Water Resources (DWR)

- Reviews, provides comments, and approves QAPP and subsequent revisions.

A.5 Problem Definition and Background

The Upper Neuse River Basin Association (UNRBA) has contracted with Cardno to develop and administer a monitoring program to collect data necessary to assess water quality in Falls Lake and its watershed. This data will be used to support a re-examination of Stage II of the Falls Lake Nutrient Management Strategy (NCAC 15A 02B.0275(5)). This Quality Assurance Project Plan (QAPP) is intended to cover data collected under the administration of the UNRBA by Cardno and does not supplant any existing QAPPs of member organizations. The procedures outlined in this QAPP are intended to follow those in existing Division of Water Resources (DWR) QAPPs as closely as possible so that the data collected under this monitoring program meet the same Quality Assurance/Quality Control standards as data collected by DWR.

To meet requirements outlined in the Falls Lake Rules, DWR must review and approve any monitoring study plan to assure that data collected under this program are acceptable for potential regulatory use. One objective of this QAPP, in conjunction with the standard operating procedures (SOPs) in the

Appendices, is to provide the documentation necessary to demonstrate compliance with DWR Quality Assurance standards.

Specific goals of the monitoring program include

- facilitating estimates of nutrient, carbon, sediment, and chlorophyll loading to Falls Lake
- aiding in parameterization of water quality models, and
- providing water quality data at jurisdictional boundaries within the Falls Lake watershed.

The monitoring plan is designed to be an adaptive program. The results of early monitoring activities and initial analyses may be used to refine the monitoring program on an annual or semi-annual basis. Most monitoring changes are expected to relate to the specific locations being sampled or the frequency with which samples are taken. These changes will not result in revisions of this QAPP. If parameters not included in this QAPP are proposed for later inclusion in the routine monitoring program to support efforts requiring DWR approval per the Falls Lake Rules, they will be documented in revised versions of this QAPP, cataloged in the Revision Log at the beginning of the document, and provided to DWR for review.

To facilitate UNRBA's data management needs, Cardno will create and maintain a database that includes data generated under sections B.1 through B.8 of this QAPP as well as data collected by federal, state, and/or local agencies as described in section B.9. All database entries will be tracked according to the data-generating organization. Data included in the database will be limited to data collected within Falls Lake and at sites defined as lake loading sites or jurisdictional boundary sites in the Monitoring Plan (Appendix A). It will also include any special studies conducted under the Monitoring Plan. The database will not include data collected by UNRBA member jurisdictions at sites other than those specified in the Monitoring Plan.

Data produced by the UNRBA monitoring program will be provided to the UNRBA members to support the goals and efforts of that organization. UNRBA anticipates using this data to facilitate updates to the Falls Lake Nutrient Response model built using the Environmental Fluid Dynamics Code (EFDC). The model structure and equations are described in the Falls Lake Nutrient Response Model Final Report (NCDENR 2009). Data will be used to refine loading estimates as well as concentrations of key water quality parameters within Falls Lake. Data collected will also be used to refine the sampling program. Sampling locations or sampling frequencies which produce redundant or uninformative data with respect to the modeling framework may be discontinued, suspended, or reduced, while additional locations may be added or sampling frequencies increased.

A.6 Project Description and Schedule

Overview

The overall goal of the field sampling program is to provide an accurate and representative picture of the current water quality conditions at specific sampling stations throughout the watershed. The environmental data collected under this task may be used as input to or calibration data for water quality and hydrologic models developed or refined under subsequent UNRBA tasks. The UNRBA monitoring program will take place over four years with the possibility of one additional year if needed and approved by the UNRBA. Routine monitoring under this program may consist of efforts categorized

into three different categories each with its own set of locations, schedule, and parameters to be monitored.

A. Routine monitoring of tributaries near the point where they enter Falls Lake to improve estimates of nutrient, carbon, chlorophyll, and sediment loading from the tributaries.
B. Routine monitoring of water quality at jurisdictional boundaries to provide information on water quality at multiple locations for individual jurisdictions.
C. Routine monitoring of water quality at locations within Falls Lake itself. (Initially there are no current UNRBA monitoring locations within Falls Lake itself but modifications may be considered by the UNRBA in the future.)

In addition to the Routine Monitoring described above, the UNRBA may conduct targeted Special Studies which are limited in their temporal and spatial scope and are aimed at answering specific questions relative to the anticipated model needs for the reexamination process (for example discharge through lake constriction points, bathymetric mapping, and lake sediment characterization). These Special Studies are short term projects with their own Study Plans which are summarized in the UNRBA Monitoring Plan and are posted on the UNRBA web site at https:\www.unrba.org\monitoring-program.

A. Lake Loading Locations

Locations monitored for quantifying lake loading include one station on each of the 17 Falls Lake tributaries which are modeled as part of the Falls Lake Nutrient Response Model. In addition, the Little River will be monitored before its confluence with the Eno River. A current map and table of sites, coordinates, and sampling frequencies can be found in Appendix 1. Parameters that may be monitored at the lake loading sites can be found in Appendix 1, but parameters may be added or removed based on data analysis or tributary-specific concerns. Table A.6.1 lists the parameters which may be measured under this QAPP, though not all of these will be measured at every location or during every monitoring year. The project manager will maintain a current list and historical record of monitoring stations, parameters measured, and sampling frequency. Any new parameters added to the routine monitoring program which are not included in the most current version of the QAPP will be addressed in a revised QAPP which will be re-submitted for DWR review. The frequency of sampling at lake loading sites may vary from site-to-site. The UNRBA will determine and review sampling frequency annually prior to the start of each fiscal year with input from reports and recommendations from Cardno.

Table A.6.1. Parameters which may be measured as part of this monitoring program

Field Measurements	Laboratory Analyses
Water temperature	Total Kjeldahl nitrogen
Specific conductance	Soluble[1] Kjeldahl nitrogen
Dissolved Oxygen	Nitrate + nitrite
pH	Ammonia
Air temperature	Total phosphorus (TP)
Turbidity	Total soluble[1] phosphorus (TSP)
Instantaneous discharge	Total reactive P (TRP[2]) ("total orthophosphate")
	Soluble reactive P (SRP[1,2]) ("soluble orthophosphate")
	Total organic carbon (TOC)
	Dissolved organic carbon (DOC)
	Chlorophyll *a*
	Total suspended solids (TSS)
	Volatile suspended solids (VSS)
	Turbidity
	Color (Pt-Co color units and absorbance at 440nm)
	Tannins and Lignin
	UV absorbance (at 254nm) (for SUVA calculation)
	Carbonaceous biochemical oxygen demand ($CBOD_5$)
	Biochemical oxygen demand (BOD_5)

[1] For the purposes of this QAPP, the term "soluble" is interchangeable with "dissolved" or "filterable".

[2] Reactive phosphorus is often called orthophosphate, however the method used for measuring this quantity is not 100% specific to orthophosphate and thus "reactive phosphorus" is the preferred term because it specifies the inclusion of all forms of phosphorus which react to the reagents used in this method.

B. Jurisdictional Boundary Locations

Jurisdictional boundary sites include tributary locations at municipal and county boundaries which have been identified by the UNRBA for routine monitoring. The specific locations monitored, the frequency of monitoring, and the specific parameters to be measured may vary in time; the monitoring plan will be reviewed annually by the UNRBA. A map and table of locations, coordinates, and sampling frequencies for the initial set of jurisdictional boundary sites are included in Appendix 1. The project manager will maintain a current list and historical record of monitoring stations, parameters measured, and sampling frequency.

Parameters that may be measured at jurisdictional boundary sites are a subset of those listed in Table A.6.1. Any new parameters added to the routine monitoring program which are not included in the most current version of the QAPP will be addressed in a revised QAPP which will be re-submitted for review.

C. In-lake Monitoring

UNRBA may choose to temporally or spatially supplement the monitoring already conducted by DWR, the City of Raleigh, the City of Durham, or the Center for Applied Aquatic Ecology in Falls Lake or to add sampling for parameters not collected by those organizations now or in the future. Initially, there are no in-lake sites included for routine sampling in the monitoring plan, however, this QAPP will cover sampling and analytical methods and quality assurance/quality control protocols for lake sampling for the parameters listed in Table A.6.1.

Measurement Methods Overview

Tributary and Lake Field Measurements

Measurements made in the field are temporally discrete and made *in situ* whenever possible by field staff at the time of the station visit. If *in situ* measurements cannot be made (e.g., probe cords may be too short to cover the distance between a bridge sampling location and the water body), parameters may be measured from a sample as long as the SOPs specified for each parameter are followed and measurements are made immediately after the sample is taken. All field measurements are performed in accordance with laboratory SOPs (Appendix 6), DWR Wastewater/Groundwater Laboratory Certification Approved Procedures for Field Analysis (Revised April 2013) (Appendix 2) and/or the DWR Intensive Survey Branch (ISB) SOP version 2.1 (Revised December 2013) (Appendix 3), as appropriate. Turbidity may be measured in the field using equipment which meets the specifications of EPA Method 180.1 Revision 2.

Specific field measurements and sampling methods are documented in section *B.2: Sampling Methods*.

Analytical Samples

Lab analyses will be conducted by DWR certified laboratories with experience working with samples collected under ambient conditions. Each laboratory's analytical methodologies are not managed under this QAPP, except to specify that each laboratory has, and must maintain, certification from the DWR Laboratory Certification Program or the State Laboratory of Public Health for the parameters currently certified by these agencies and as specified in Table B.1.3. The laboratories will meet the criteria for reporting levels, analytical methods, accuracy, and precision which are specified in this QAPP and are appropriate for ambient monitoring conditions.

The specific analytical methods to be used are listed in section *B.4: Analytical Methods* of this document. Precision and accuracy targets are described in section *A.7: Quality Objectives and Criteria*.

Data Management

To facilitate the organized collection of data along with systematic review for quality assurance, the UNRBA will use a web-based environmental data and document management systems. The data management system will facilitate the upload, review and validation of monitoring data prior to inclusion in the project database. The document management system will be used to archive field data sheets, calibration sheets, photographs, laboratory and quality control reports for each monitoring event. Data will be uploaded by field and laboratory staff into a "holding area" of the data management system prior to review and validation of the data into the official database. Field and laboratory staff will be responsible for reviewing data submittals prior to uploading to the data management system for typographical errors and omissions. The Quality Assurance Manager will validate all uploads per the quality assurance protocols of this QAPP prior to appending data to the project database. Details of the quality assurance procedures associated with data management can be found in section B.10: Data Management.

A.7 Quality Objectives and Criteria

The data collected in support of the UNRBA monitoring program will meet the quality objectives detailed in this section.

Accuracy

Accuracy is a measure of agreement between an observed value and an accepted reference or true value. The measurement of accuracy may include components of random error or systematic error and bias. Laboratory accuracy can be assessed through laboratory control samples (LCS, analysis of a known value), method blanks (MB, analysis of sample with no analyte present), and matrix spike samples (MS, analysis of a known quantity of analyte added to a field sample). Biases due to field procedures will be assessed via equipment blanks and field filter blanks.

Field Accuracy Objectives

Field accuracy is assessed through equipment blanks and field filter blanks (for analyses requiring immediate filtration in the field). Equipment blanks will be collected at a rate of 1 per 20 samples when an intermediary device is used to collect samples (e.g., pole sampler, lab line, van Dorn bottle, or similar devices).

Sampling equipment may become contaminated through the normal course of monitoring. If the equipment is not properly cleaned and rinsed, subsequent samples may become contaminated from residue left from previous locations. Equipment blanks will be used to assess cross-contamination of samples by equipment or sampling techniques. Equipment blanks are obtained by running reagent grade deionized water through the sampling equipment which is then submitted to the analytical laboratory for analysis. Blank samples should be collected from a final deionized water rinse of the specified equipment after the equipment has been cleaned in accordance with appropriate cleaning procedures per standard operating procedures (Appendix 3). Blanks must be treated in the same manner as field samples, including handling, preservation, and hold times.

Additionally, equipment blanks for filtration equipment used for collecting samples of soluble nutrients (Total soluble phosphorus (TSP), soluble reactive phosphorus (SRP), and soluble TKN) will be collected at the start and end of each sampling day when field filtration occurs. Field filtration blanks are obtained by filtering reagent grade deionized water through filtration equipment (including filter) and pouring into separate containers for laboratory analyses. Field filtration blanks should be collected after the filtering apparatus has been cleaned with deionized water according to the appropriate cleaning procedures. Sample preservation, handling, and hold times must be consistent for blanks and field samples.

Equipment blanks should have reported values less than ½ of the reporting limit. Equipment blanks with values higher than the reporting limit must be reported to the project manager for resolution. A summary of QC objectives for field methods with frequency, acceptance criteria, and necessary corrective actions is provided in Table A.7.1.

Table A.7.1. Quality Control Objectives for Field Methods

QC Sample	Data Quality Indicator	Frequency	Acceptance Criteria	Corrective Action
Equipment Blank	Accuracy/ Bias as contamination	1/20 field samples	Concentration < RL	Contact Project Manager
Field Blank - Filtration Equipment	Accuracy/ Bias as contamination	Beginning and end of each sampling day.	Concentration < RL	Contact Project Manger
Field Duplicate	Precision	1/10 field samples	Parameter-specific. See Table A.7.3	Qualify associated field data and/or resample

Laboratory Accuracy Objectives

Laboratory accuracy will be assessed through the analysis of method blanks, laboratory control samples (LCS), and matrix spike samples (MS). Blanks should have concentrations less than ½ of the reporting level. The percent recovery (%R) for LCS and MS samples should meet the objectives identified in the appropriate columns of Table A.7.2. Laboratory Control Samples (LCS) will be analyzed at the rate of 1 LCS per batch of up to 20 samples. In the event that the %R of a LCS falls outside of the range specified in Table A.7.2., all associated samples should be re-prepared and reanalyzed. Matrix Spike (MS) samples will be analyzed for those parameters whose methods require it at the rate of at least 1 per batch of up to 20 samples or more frequently when specified by designated methods (e.g., NH4, NOx, and TKN all require MS samples for every 10 routine samples). If the %R for MS samples falls outside of the range specified in Table A.7.2. but the method is otherwise in control, the recovery problem is judged to be matrix related rather than system related, per EPA method documents (e.g., EPA Method 353.2 for Nitrate-Nitrite). All MS recoveries outside of the specified criteria should be addressed in the data report. Samples associated with MS recoveries outside of control limits in conjunction with LCS values outside of control limits should be re-prepared and re-analyzed. Any remaining samples associated with MS and LSC values which do not meet criteria will be qualified in the database with the qualifier code J2.

Precision

Precision is a measure of the degree of reproducibility of repetitive measurements under a given set of analytical conditions (exclusive of field sampling variability). It is the degree of mutual agreement among independent measurements as the result of repeated application of the same process under similar conditions. Precision is documented on the basis of replicate analysis, including field replicates, laboratory duplicate samples, or matrix spike duplicate samples. Precision may also be assessed by comparing results of split samples analyzed by independent laboratories as described in section B.5.

Parameter-specific precision objectives for field and laboratory measurements are provided in Table A.7.3. Matrix spike/matrix spike duplicate (MS/MSD) samples will be used where indicated in Table A.7.3 to evaluate analytical precision and will be used as a basis for qualifying data where necessary. Lab duplicates will be used to document precision at ambient concentrations, but RPD values for lab duplicates which are outside the specified criteria will not necessarily lead to qualified or discarded data if LCS and MS/MSD samples otherwise show the method and batch to be in control. Following the suggested guidelines of Mitchell (2006), the criteria for precision will only be applied to samples with measured concentrations which are at least five times greater than the method detection limit. Duplicate samples which have low concentrations of analyte may have a higher RPD because the same absolute

value of analytical error applied to a lower sample concentration will be associated with a larger percent error.

Field Precision Objectives

Field precision for samples analyzed in the laboratory is assessed through duplicate sample analyses. Field duplicate samples will be collected at a frequency of approximately 10% as detailed in section B.5. Duplicates are produced by splitting a single sample into two or more aliquots immediately after the sample is collected. Each aliquot is placed into a separate container and analyzed separately. Field duplicate samples will not be collected for soluble nutrients (e.g., total soluble phosphorus, soluble reactive phosphorus (SRP, or dissolved orthophosphate), or soluble TKN). Precision for these parameters will be determined from the associated total (non-filtered) nutrient analysis. Field filter blanks will be used to assess bias from contamination from filters or the filter apparatus for these parameters.

The metric used for precision is the relative percent difference (RPD) between the results of the duplicate samples calculated as

$$RPD = \frac{|C_A - C_B|}{0.5(C_A + C_B)} \times 100$$

where C_A = measured concentration of duplicate sample A
C_B = measured concentration of duplicate sample B

When the precision of field duplicates exceeds the acceptance criteria listed in table A.7.3, the associated data will be evaluated by the Laboratory QA/QC Manager and the Project QA Manager and will be qualified if appropriate. If the exceedance is due to low concentrations of analyte (e.g., if absolute error is not large and the RPD is within the laboratory's calculated concentration-specific range for analytical precision given in Table A.7.3) and the method is otherwise in control, the data will not be qualified. The project manager will be notified when field duplicates exceed the precision acceptance criteria to assess the issue and to determine if changes to field procedures are necessary.

The precision of physical parameter readings (e.g., dissolved oxygen, pH, and conductivity) is assessed by comparing the instrument calibration readings with the post-check readings. Meters will be calibrated at the beginning of each field day and calibrations will be checked after approximately four hours and again after the last sample of the day. Specific conductance must read +/- 10% of the true value of the standard used. The pH readings must be +/- 0.2 s.u. of the check buffers. The dissolved oxygen reading must be +/- 0.5 mg/l of the saturation value. If the calibration check criteria are exceeded, the instrument will be recalibrated and the associated field data will be qualified, resampled, or deleted.

Laboratory Precision Objectives

The precision of laboratory analyses are assessed by comparing laboratory replicate analyses or by comparing matrix spikes (MS) with matrix spike duplicates (MSD) as prescribed by the specified analytical method for each parameter. Laboratory duplicates or matrix spike duplicates are conducted at a frequency of 1 per batch of up to 20 samples. If the relative percent difference (RPD) exceeds the acceptable criteria for any parameter (Table A.7.3), results will be reviewed with the lab supervisor.

Samples in the affected batch will be reanalyzed or results will be justified in the data report. Generally, no corrective action is taken for matrix spike results exceeding the control limits as long as the LCS recoveries are acceptable.

Ideally, samples split between laboratories ("split samples") would meet the same precision criteria as field duplicates (Table A.7.3). However, split samples analyzed by separate laboratories using different equipment with different noise levels cannot be expected to meet the same rigor as duplicate samples analyzed by a single laboratory using one piece of equipment. Furthermore, analyte concentrations in split samples may be near the reporting limit and achieving these precision targets (expressed as percent difference) on very low concentrations may not be possible. Therefore, split sample precision values outside of this range will not automatically result in qualification of data, but will be reviewed by the Project Manager in consultation with the Laboratory QA/QC manager. An action plan will be developed only if necessary based on professional judgment and discussion with DWR. The results of all split sampling efforts and any associated action plans will be documented in the reports to UNRBA described in section A.9. These reports will also provide written documentation of any data which are rejected as a result of the split sampling effort along with the reasons for these rejections.

Required Practical Quantitation Limits

The practical quantitation limits (PQLs) required for the UNRBA's monitoring objectives are reported in table A.7.2. In addition to meeting the PQLs specified, laboratories will maintain up-to-date method detection limits (MDLs) for the analytical methods used in the project. These MDLs must support the specified reporting limits and will be recorded in the project database. MDLs may be updated by results of new studies using the method specified in the Federal Register, 40 CFR Part 136 Appendix B. Specifically, MDLs will be calculated as the product of the standard deviation of at least 7 replicate analyses times the student's t value appropriate for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom.

Measured values which are above the laboratory's method detection limit but below the specified reporting level will be reported as measured but qualified with the data qualifier code N3. These data may be used to indicate if improvements in reporting levels would significantly reduce the frequency of censored values in the data set. Measured values below the method detection limit will be reported as the reporting limit along with the qualifier code U. Each sample generated under this QAPP will be stored in the database with the laboratory's reporting limit and method detection limit to facilitate clarity in future data analyses.

Table A.7.2. Accuracy Objectives for Laboratory Analyses and Required Reporting Limits for the UNRBA Monitoring Program

Parameter	Data Accuracy Objectives (% recovery)		Required Reporting Limits	
	LCS[1]	Matrix Spike	Analysis Method(s)	PQL[2]
Total suspended solids, TSS (LCS analyzed quarterly)	mfg.[3]	NA	SM 2540 D - 1997	2.5 mg/L
Turbidity	90-110%	NA	SM 2130 B - 2001 EPA 180.1 Rev 2.0	1 NTU
Chlorophyll *a*	NA[4]	NA	EPA 445.0 Rev 1.2	1 µg/L
5-day carbonaceous biochemical oxygen demand, CBOD5	80-120%	NA	SM 5210 B - 2001	2.0 mg/L
UV absorbance at 254nm	85-115%	NA	EPA 415.3 Rev 1.2 SM 5910 B-2001[5]	0.001 cm^{-1}
Color, (Pt-Co units)	NA	NA	SM 2120 B[6]	5 c.u.
Visible Absorbance at 440nm	90-110%[7]	NA	Cuthbert and del Giorgio (1992)[8]	0.001 cm^{-1}
Total organic carbon, TOC	90-110%	75-125%	SM 5310 C - 2000	1 mg/L
Dissolved organic carbon, DOC	90-110%	75-125%	SM 5310 C - 2000	1 mg/L
Tannins and Lignin	mfg	80-120%	SM 5550	0.2 mg/L
Total phosphorus, TP	85-115%	80-120%	EPA 365.4 (1974)	0.02 mg/L
Total soluble phosphorus , TSP	85-115%	80-120%	EPA 365.4 (1974)	0.02 mg/L
Total reactive phosphorus, TRP ("total orthophosphate")	85-115%	80-120%	SM 4500 P E - 1999	0.01 mg/L
Soluble reactive phosphorus, SRP ("dissolved orthophosphate")	85-115%	80-120%	SM 4500 P E - 1999	0.01 mg/L
Ammonia, total, NH_3	85-115%	80-120%	EPA 350.1 Rev. 2.0 (1993)	0.01 mg/L
Nitrite + Nitrate, $NO_2 + NO_3$,	85-115%	80-120%	EPA 353.2 Rev 2.0 (1993)	0.01 mg/L
Total Kjeldahl Nitrogen, TKN	85-115%	80-120%	EPA 351.2, Rev 2.0 (1993)	0.2 mg/L
Soluble Kjeldahl Nitrogen	85-115%	80-120%	EPA 351.2, Rev 2.0 (1993)	0.2 mg/L

[1] LCS: laboratory control sample
[2] PQL: practical quantitation limit
[3] mfg: outside quality control standards are purchased and the manufacturer's published limits are used.
[4] Accuracy of chlorophyll *a* analyses will be assessed through annual participation in DWR's Chlorophyll *a* round robin.
[5] Certification through NC SLPH
[6] Per section 8.3.6 of the DWR Laboratory section's QAM (2003), EPA Region 4 has approved the use of a spectrophotometer operating at a single wavelength (460nm) in place of visual comparison for this analysis.
[7] Under evaluation
[8] Cuthbert, I.D. and P. del Giorgio. 1992. Toward a standard method of measuring color in freshwater. Limnology and Oceanography. 37: 1319-1326.

Table A.7.3. Precision Objectives and Criteria

Parameter	Field Precision – RPD		Analytical Precision - RPD	
	Estimated By	Objective	Estimated By	Objective
Total suspended solids, TSS	Field duplicates	≤ 30%	Lab duplicate	≤ 30%
Turbidity	Field duplicates	≤ 40%	Lab duplicate	≤ 30%
Chlorophyll *a*	Field duplicates	≤ 30%	Lab duplicate	≤ 20%
5-day carbonaceous biochemical oxygen demand, CBOD5	Field duplicates	≤ 40%	Lab duplicate	≤ 30%
UV absorbance at 254nm	Field duplicates	≤ 30%	Lab duplicate	≤ 20%
Color, (Pt-Co units)	Field duplicates	≤ 10 units	Lab duplicate	≤ 5 units
Color, Absorbance at 440nm	Field duplicates	≤ 30%	Lab duplicate	≤ 20%
Total organic carbon, TOC	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Dissolved organic carbon, DOC	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Tannins and Lignin	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Total phosphorus, TP	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Total Soluble Phosphorus, TSP	Not estimated	NA	MS/MSD or Lab duplicate	≤ 20%
Soluble Reactive Phosphorus, SRP ("Orthophosphate, dissolved")	Not estimated	NA	MS/MSD or Lab duplicate	≤ 20%
Total Reactive Phosphorus, TRP, ("Orthophosphate, total")	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Ammonia, total, NH_3	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Nitrite + Nitrate, $NO_2 + NO_3$,	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Total Kjeldahl Nitrogen, TKN	Field duplicates	≤ 30%	MS/MSD or Lab duplicate	≤ 20%
Soluble Kjeldahl Nitrogen	Not estimated	NA	MS/MSD or Lab duplicate	≤ 20%

Bias in monitoring design

Sample locations are selected based on existing monitoring locations and specific monitoring goals. As such, the data collected are meant to be representative of the locations identified and the cumulative effect of upstream processes. Use of the data to infer average conditions along the length of the tributaries or to any other end may result in biased interpretations.

Other sources of bias include the following:

- Sampling only in daylight and at different times of the day from one sampling event to the next may affect some parameters which fluctuate on a daily time scale (notably temperature and dissolved oxygen, but possibly others as well).

- Extreme or unusual conditions, such as storm events, may not be sufficiently sampled due to field staff safety concerns, station inaccessibility, and the infrequent nature of such events.
- Likewise, samples which are collected to *target* specific flow conditions may introduce a bias in the dataset if they are assumed to be collected from a random sample. Samples collected under targeted flow conditions will be identified as such in the database.
- Sampling locations are often located at bridge crossings due to ease of access. Sampling occurs on the upstream side of the bridge whenever possible to minimize impacts, but the actual effect of bridges on ambient water quality is unknown. Sampling may occur on the downstream side of a bridge if there are concerns about traffic safety, debris accumulating on bridge supports or high flow situations (safety of sampling equipment or probe immersion).

Applying consistent sampling methods, SOPs, and analytical methods will minimize bias from other sources.

Representativeness

Tributary sampling locations have been selected, where possible, such that they have sufficient flow year-round to allow for sampling of well-mixed areas of the waterbody. This allows the samples to represent the average condition of the waterbody at that point in time. In the event that a sampling location does not have sufficient water on a given sampling date to obtain a representative sample, field staff will advise the Project Manager. Samples will not typically be collected from disconnected pools with no connection to downstream waters. Samples may be collected from streams even when water appears to be slow moving or not moving at all. In all cases, flow conditions will be noted in the metadata associated with each sample.

Comparability

The objective for comparability is to have data which are comparable between sampling locations as well as comparable over time. Comparability is promoted by

- Fixed station locations
- The use of standard U.S. EPA approved methods where possible
- Consistent application of SOPs detailed in the QAPP and its appendices
- Consistent application of analytical methods specified in the QAPP
- Achieving the required practical quantitation limits detailed in the QAPP
- Use of data reporting qualifiers for samples not achieving the QA/QC criteria specified

Completeness

It is expected that some site visits or samples will be missed due to problems such as inclement weather, temporary station inaccessibility, equipment problems, and staffing issues such as illness. Many of these impediments are unavoidable. In the event of a missed sample, the Field Supervisor should contact the Project Manager to discuss options for obtaining the sample and to discuss whether long-term changes to the sampling program are necessary.

A.8 Special Training/Certification

Field staff

Field staff will be contracted from Division of Water Resources (DWR) certified field laboratories and each lab must maintain their certification for the duration of their monitoring contract. Inherent in the annual recertification process are acceptable results for proficiency testing for all applicable parameters. Field staff will be provided copies of the SOPs and this QAPP and these will be available to field staff at all times.

Laboratory (analytical) staff

Analyses will be conducted at laboratories that are certified by the DWR wastewater/groundwater laboratory certification program, and staff training will be performed in accordance with the requirements inherent in this certification. All laboratory personnel receive training and have proven proficiency in their designated analytical procedures. Laboratory personnel will be provided copies of the appropriate SOPs and this QAPP and these will be made available in the laboratory at all times. The laboratory must maintain certification for parameters being sampled under this program, where available. Certification may come from either DWR or the NC State Laboratory of Public Health (NC Department of Health and Human Services, Division of Public Health). Parameters requiring certification and the certifying authority are listed in Table B.1.3. In the event that the laboratory loses certification for nay parameters, it will be the laboratory's responsibility to find an alternate certified laboratory and to contract that lab to conduct those analyses under the QA/QC requirements of this QAPP.

A.9 Documents and Records

Quality assurance information, SOPs, and other support documentation

Once all approval signatures have been obtained, the QA Manager will electronically distribute copies of the approved QAPP to persons on the distribution list in Section A3 of this document. Copies will be disseminated within 30 days of notification of final approval. The original hard copy with approval signatures will be kept on file in the QA Manager's office at Cardno.

The QA Manager is to be notified of changes made to SOPs, analytical methods, or any other documentation referenced by this QAPP by the field and laboratory staff. The QA Manager will then be responsible for distributing the information, as described above. The QA Manager will also be responsible for keeping current copies of these documents on file at Cardno. The QA Manager will periodically (at least annually) check with appropriate staff at DWR to determine if DWR has made any changes to the SOPs referenced in the Appendices to this QAPP. The QA Manager will then assess whether those changes are material to this QAPP and will recommend a course of action to the Project Manager.

For the duration of the UNRBA data collection project, this QAPP will be reviewed on at least an annual basis and, if appropriate, changes or updates will be made at that time. However, critical revisions can be made at any time. The QA Manager is responsible for completing revisions, obtaining signatures of approval, and disseminating the revised document to those on the distribution list within 30 days of final approval. Changes to the Appendices of this QAPP do not constitute changes to this QAPP and will not necessitate resubmission to and re-approval by DWR. Changes to the Monitoring Plan which do not

affect the suite of SOPs, methods, and quality assurance criteria documented in this QAPP will not necessitate re-approval of this QAPP by DWR. Addition of parameters to the Monitoring Plan which are being collected to support modeling under the Falls Lake Rules will require revisions to this QAPP which will then be resubmitted to DWR for approval. The addition of parameters to the monitoring plan which fall outside the scope of the Falls Lake Rules will not necessitate the resubmission and re-approval of this QAPP.

Revisions to this QAPP will be tracked by version numbers and approval date which shall be easily identifiable by the document control information on each page. A complete list of all revisions/updates will be maintained at the beginning of the document, beginning with the first DWR-approved version.

Project Records

The records produced during this project, their location, retention time, format, and disposition at the end of the required retention time are summarized in Table A.9.1

Field data collection forms.

Field log sheets serve as a daily record of events, observations, and measurements during all field activities. Field staff will record all relevant information relating to sampling activities on the field log sheets. Field data will be transcribed and reviewed by field staff and uploaded to the UNRBA data management system as described in sections A.6, B.10, and D of this QAPP.

Entries on the field log sheet will include:

- Names of the field crew
- Date
- Sampling start time
- Location of sampling activity
- Sampling method
- Sampling equipment used
- Type of samples collected
- Date and time of each sample collection
- Sample identification numbers
- Preservatives used
- Field measurements
- Field observations and details related to analysis or integrity of samples (e.g., weather conditions, noticeable odors, colors, etc.)
- Qualitative stream-flow description or rating

Field meter calibration sheets will be used to record daily meter calibrations, standard solutions and concentrations used, and all readings from post-calibration checks and any recalibrations of the instruments during the day.

Electronic copies (e.g., scanned pdf files) of the field data sheets and field calibration logs will be uploaded to the UNRBA's electronic document management system. Hard copies will be organized and archived by the laboratory and will remain available at the laboratory offices for review by members of the project team for a period of 5 years following the conclusion of the monitoring program.

Photographs

Photographs will be taken at the sampling locations for each routine site visit when samples are collected. These will serve to verify the site and conditions present during sampling. At a minimum, a photograph should be taken at the sampling location looking in the upstream direction. Additional photographs may be taken at each site to document conditions at the discretion of the field staff. For each photograph taken, the following information should be recorded on the field data log sheet:

- Time, date, location, direction of photograph, weather conditions
- Description of the subject photographed (e.g., upstream, downstream, note deer carcass, etc.)
- Name of person taking photograph
- Photograph identification numbers

Whenever possible, photos should be taken with a device capable of storing time, date, and location metadata with the photograph. This data can serve as a QA check that samples were collected at the correct location as well as providing a visual reference of the conditions at the site in the event that questionable results are obtained. Review of photographs and their metadata will not be a routine part of QA/QC procedures for each monitoring event, but will provide the ability to spot-check as necessary.

Photographs will be uploaded to the UNRBAs document management web site monthly.

Table A.9.1. Project Records, Format, and Retention Time[1]

Document	Minimum Retention Time (following conclusion of project)	Format	Disposition
Field Staff. Location: Staff office.			
Meter calibration sheets	5 years	hard copy	Discard
Field data sheets – hard copy	5 years	hard copy	Discard
Field data – electronic	5 years	comma delimited text files	Discard
Staff notes	5 years	hard copy	Discard
Photographs	5 years	electronic (e.g., jpg)	Discard
Courier logs (where applicable)	5 years	hard copy	Discard
Project Manager. Location: Cardno			
Data review notes	10 years	hard copy / electronic	Discard
Audit reports, field and lab	5 years	hard copy / electronic	Provide to UNRBA
Database Manager. Location Cardno			
Master database	10 years	PostgreSQL	Provide electronic archive to UNRBA
Field and laboratory data – electronic submissions from field and laboratory staff	10 years	comma delimited text files	Archive electronically, provide to UNRBA
Electronic copies of field notes, photographs, data reports, etc.	10 years	electronic files, e.g., *.pdf, *.jpg, etc.	Archive electronically, provide to UNRBA

[1]The countdown clock for all retention times begins at the conclusion of the monitoring program—not on the date each individual document is created.

Electronic data storage

All field measurements and observations, site visit comments, and analytical results (including data qualifiers) are ultimately warehoused in a PostgreSQL database. Copies of this warehouse reside on the Cardno server and backups will be made on a daily basis and stored for a period of 30 days. Copies of monthly backups will be archived for a minimum of 10 years. The database will be stored in a minimum of two physical locations: currently, one in the Cardno office in Raleigh, North Carolina and the other in Cardno's Austin, Texas, datacenter. Details of electronic data management and warehousing methods are further described in section *B.10: Data Management*.

Data Reporting

Annual reports will be submitted to the UNRBA which will include summaries of data collected at monitoring locations, analysis of deviations of samples from expected values, and recommendations for sampling in the following fiscal year. The report may include further analyses as agreed upon by Cardno and the UNRBA.

SECTION B — DATA GENERATION & ACQUISITION

B.1 Sampling Process Design

Overview

The UNRBA monitoring program is designed to monitor water quality in tributaries entering Falls Lake, at select jurisdictional boundaries throughout the watershed, and, if deemed necessary, at locations within Falls Lake to supplement data being collected by DWR. Sampling locations and sample frequency are selected based on existing data and the current understanding of loading from each tributary and its influence on Falls Lake water quality as predicted by the DWR Falls Lake Nutrient Response Model. These sites and sample frequencies are meant to be adaptive and are subject to change. The initial monitoring plan is provided as Appendix 1; periodic updates will be available via the UNRBA website. The Project Manager will keep a current list of all monitoring locations, frequencies, and parameters to be sampled, along with a historical record of any changes made to this plan.

Station Locations

Sample locations are located at fixed locations (i.e. specific latitude and longitude). Tributary locations are selected so that they are publically accessible, generally at bridge crossings, and so that they are representative of tributaries even under high water conditions (e.g., they do not transition between lotic and lentic conditions under the normal range of Falls Lake water levels). Tables of initial sample locations are included in Appendix 1 and may change in future years of the monitoring program. The Project Manager will maintain a current list of all sampling stations and will be responsible for assuring field staff are aware of any changes to monitoring locations.

Field monitoring staff should make all reasonable attempts to:

- Conduct sampling and monitoring as consistently as possible at the same location in order to reduce unknown sources of variation.
- Sample tributaries in the main stream channel in an area of well-mixed flow outside of any discharge mixing zones.
- Use best professional judgment to sample from a fixed location that will introduce the least amount of contamination to the sample.
- Follow the “Bank/Dock Sampling” guidelines of the DWR ISB SOP (Appendix 3) if site conditions require that sampling occur from these locations.
- Notify the Project Manager within 48 hours of any sites that are sampled from locations other than those specified.
- Document temporary changes to sampling locations caused by safety concerns, accessibility, and stream flow patterns, on the field sheet and in the comments section of the data submittal sheet.
- Inform the Project Manager within one week if future sampling is expected to be prevented or its location altered due to accessibility or safety concerns.

Site Verification

At least once per year, and during each individual’s first sampling event at each site, field staff should record GPS coordinates in decimal degrees to at least the fourth decimal place (DD.DDDD) and verify the GPS coordinates against the values listed in the Monitoring Plan (Appendix 1). The Project Manager should be notified of any inconsistencies. On their first site visits, new field staff are expected to confirm

the field coordinates at each sampling location with a GPS device. GPS coordinates are expected to match the values identifying sampling locations to at least the first three decimal places.

In addition, photographs will be taken for each site at each monitoring visit. These photographs may be used to verify sites at which samples are collected.

Trespassing

Sites have been selected to be publicly accessible. In no case is trespassing on private property permitted when accessing sampling sites. This includes parking in private driveways.

Parameters Measured

Parameters to be measured vary by the category of sampling site and the initial list of parameters to be measured for each site is provided in Appendix 1. Table B.1.3 is a list of all parameters that may be measured under this QAPP and identifies the sampling SOP to be followed for each.

Sampling and Measurements

Field measurements and samples are taken in accordance with Sections III and IV of the DWR ISB SOP Version 2.1 (December 2013) (Appendix 3) and the DWR Wastewater/Groundwater Laboratory Certification Approved Procedures for Field Analysis, revised April 2013 (Appendix 2). Samples related to specific UV absorbance (SUVA) are collected according to EPA Method 415.3 (Appendix 4).

Required sample volumes, containers, preservation, and sample handling requirements are summarized in Table B.2.1. After collection and chemical preservation, samples are stored immediately on ice in coolers. The coolers are delivered by field staff to the laboratory.

If samples arrive at the laboratory in unacceptable condition (e.g., temperature out of range, inadequate chemical preservation) they can be rejected by laboratory staff. Resampling for these discarded samples should be performed as soon as possible and within 2 days for sites sampled weekly, 5 days for sites sampled monthly, and 10 days for sites sampled quarterly.

Sample Spacing

Samples defined as twice monthly shall be collected with no less than 10 and no more than 21 days between sampling events. Monthly samples should be collected with 23 to 36 days between samples. Quarterly samples should be collected with 80 to 100 days between samples.

All monthly jurisdictional boundary and lake-loading stations should be monitored within a 10 business-day period. Data should be collected at all lake-loading sites within a single 5 day period. The 5 lake loading stations with the largest drainage areas (Ellerbe Creek, Eno River, Little River, Flat River, and Knap of Reeds Creek) should be sampled on the same day. The second sample for the lake-loading stations with twice per month sampling should be collected on the same day at all locations between 10 and 21 days after the first sample of the month. All sites that are sampled quarterly should be sampled within a single 10-day period.

Table B.1.3. Water Quality Parameters and Sampling SOPs for the UNRBA Monitoring Program[1]

Parameter	STORET Code	Sampling SOP	Certifying Authority
Field Parameters			
Water temperature (°C)	00010	DWR WW/GW, April 2013.[2]	DWR
Specific conductance (µS/cm at 25°C)	00094	DWR WW/GW, April 2013.	DWR
Dissolved oxygen (mg/L)	00300	DWR WW/GW, April 2013.	DWR
pH (standard units, SU)	00400	DWR WW/GW, April 2013.	DWR
Air temperature (°C)	00020	DWR WW/GW, April 2013.	N/A
Turbidity (NTU)	82078	EPA 180.1 Revision 2.0	N/A
Instantaneous Discharge (CFS)	00061	ISB SOP Version 2.1	N/A
Secchi depth (m, lake sites only)	00078	ISB SOP Version 2.1	N/A
Samples for Lab Analysis			
Total suspended solids, TSS (mg/L)	00530	ISB SOP Version 2.1	DWR
Volatile suspended solids, VSS (mg/L)	00535	ISB SOP Version 2.1	DWR
Turbidity (NTU)	82079	ISB SOP Version 2.1	DWR
Chlorophyll *a* (µg/L)	70953	ISB SOP Version 2.1	DWR
5-day carbonaceous biochemical oxygen demand, $CBOD_5$ (mg/L)	80082	ISB SOP Version 2.1	DWR
5-day biochemical oxygen demand, BOD_5 (mg/L)	00310	ISB SOP Version 2.1	DWR
Color (Pt-Co units)	00080	ISB SOP Version 2.1	DWR
UV absorbance at 254nm (cm^{-1}) (for SUVA)	NA	EPA 415.3 / SM 5910B	SLPH
Visible absorbance at 440 nm, (cm^{-1})	NA	Same sample as UV absorbance.	N/A
Carbon			
Total organic carbon, TOC (mg C /L)	00680	ISB SOP Version 2.1	DWR
Dissolved organic carbon, DOC (mg C /L)	00681	EPA 415.3	DWR
Nutrients			
Total phosphorus, TP (mg P /L)	00665	ISB SOP Version 2.1	DWR
Total Soluble Phosphorus, TSP (mg P /L)	00666	ISB SOP Version 2.1	same as TP
Total Reactive Phosphorus, TRP, Orthophosphate, total[3] (mg P /L)	00660	ISB SOP Version 2.1	DWR
Soluble Reactive Phosphorus, SRP, Orthophosphate, dissolved[4] (mg P / L)	00671	ISB SOP Version 2.1	same as TRP
Ammonia, total, NH_3 (mg N / L)	00610	ISB SOP Version 2.1	DWR
Nitrite + Nitrate, $NO_2 + NO_3$ (mg N / L)	00630	ISB SOP Version 2.1	DWR
Total Kjeldahl Nitrogen, TKN (mg N /L)	00625	ISB SOP Version 2.1	DWR
Dissolved Kjeldahl Nitrogen, (mg N / L)	00623	ISB SOP Version 2.1	same as TKN

[1]Actual measurements collected may include a subset of these parameters, per the Monitoring Plan in Appendix 1.
[2] DWR Wastewater/Groundwater Laboratory Certification Approved Procedures for Field Analysis, revised April 2013.
[3] unfiltered, also referred to as total reactive phosphorus (TRP)
[4] filtered, also referred to as soluble reactive phosphorus (SRP)

Missed Samples

Occasional extreme events may prevent sampling from occurring according to the schedule prescribed above. Under those circumstances, any missed samples should be collected when safe conditions return and the original monitoring schedule should be resumed for subsequent sampling events.

Every reasonable attempt is to be made by field staff to complete all scheduled site visits; some missed visits are to be expected due to situations including, but not limited to, extreme weather, station inaccessibility, extreme flow (either low flow which makes sampling impossible or inappropriate due to pooling/backwaters, or flooding preventing access of normal sampling point), and meter problems. In these cases, the Project Manager should be notified within 2 days. The first missed event at any site due to lack of flow or site inaccessibility will be treated as a missed sample and a second sampling attempt will not be made. In this case, conditions will be evaluated by the Project Manager and discussed with the field laboratory to assess whether changes to the Monitoring Plan are necessary. Missed samples due to factors such as illness or extreme weather should be discussed with the Project Manager and arrangements made to resample the location as soon as practicable. Longer-term inaccessibility, most notably due to bridge construction, should be assessed by the Project Manager for consideration of temporary suspension or relocation of the station. It is important that stations not be moved without sufficient reason, as an uninterrupted long-term record is one objective of this program.

B.2 Sampling Methods

Overview

Samples and measurements for most parameters are to be taken in accordance with the North Carolina Department of Environmental Quality Division of Water Resources' Intensive Survey Branch Standard Operating Procedures (ISB SOP) (Appendix 3) and the approved procedures for the analysis of field parameters from the wastewater/groundwater laboratory certification program (Appendix 2). In addition, samples and measurements of parameters not measured by DWR (e.g., specific UV absorbance, SUVA, and field turbidity measurements) will follow existing EPA methods (Appendix 4). Any irregularities or problems encountered by field staff should be communicated to the Project Manager, either verbally or via email. The Project Manager will assess the situation, consult with other project personnel if needed, and recommend a course of action for resolution.

Field Measurements - Tributaries

Field measurements at tributary locations are to be taken just below the water surface (depth between 0.10 and 0.15 m). Temperature and dissolved oxygen shall be measured *in situ* whenever possible according to the methods of DWR WW/GW Laboratory Certification Program's Approved Methods for the Analysis of Field Parameters (Appendix 2). In the event that safety concerns prevent *in situ* sampling (e.g., highway bridge crossings, etc.) grab samples may be collected and measurements made immediately in a safe location according to the same DWR guidance documents. Specific conductivity and pH measurements may be made using grab samples.

Sample Collection - Tributaries

At tributary locations, samples for the parameters listed in Table B.1.3 will be obtained as grab samples just below the water surface (depth between 0.10 and 0.15 m). Samples will be collected using a bridge sampler on the upstream side of the bridge where possible or an approved intermediary device when samples are collected from a bank. An intermediary device may be used from a bridge if the water depth is not deep enough to accommodate a bridge sampler. When used, an intermediary device must be rinsed three times using water from the sampling location prior to obtaining the sample. Sample sizes and bottle types for each analysis are provided in Table B.2.1.

Field Measurements – Falls Lake

Measurements of temperature, pH, dissolved oxygen, and conductivity for lake samples will be made at discrete depths (from the surface to 10 m at 1m increments and at least every 5 m thereafter).

Sample Collection – Falls Lake

At lake locations, samples will be collected as photic zone composites. These samples will be a composite sample over the entire depth of the photic zone, calculated in the field as twice the Secchi depth, and will be collected using a Labline® Poly-Pro water sampler or similar depth-integrating sampling device. If using a Labline sampler, corks are removed from the device and it is then slowly lowered to a depth of twice the Secchi depth and then drawn back up to just below the surface. Lowering and raising the sampler is done at a slow and continuous pace in order to fill the sampler with a representative sample of the photic zone water column. If the photic zone is less than 1 m, samples may be taken as grab samples just below the water surface (depth ≈ 0.15m). Secchi depth should be measured according to the DWR ISB standard operating procedures (Appendix 3).

Although not routinely collected, discrete depth samples may be collected as part of a special study. In these cases, samples will be collected using a Labline or Van Dorn type sampler which is lowered to a specified depth and triggered as appropriate to collect the water sample.

Sample sizes and bottle types for each analysis are provided in Table B.2.1.

Table B.2.1. Sample Sizes, Bottle Types, Holding Conditions, and Preservation for Samples Included in the Monitoring Program

Analyte (unit)	Volume (ml)	Bottle Type (P = plastic)	Filter in Field?	Holding Temp. (°C)	Maximum Holding Time (d)	Preservative	Target pH
Total suspended solids, TSS Volatile suspended solids, VSS	1000	P (disposable)	No	≤ 6	7	None	N/A
Turbidity	200	P (disposable)	N/A	≤ 6	2	None	N/A
Chlorophyll *a*	500	P (brown, wide mouth)	In lab within 24 hours	≤ 6 before filtering ≤ -20 after filtering	24 after filtering	None	N/A
Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	1000	P (disposable)	N/A	≤ 6	2	None	N/A
Biochemical Oxygen Demand (BOD_5).	1000	P (disposable)	N/A	≤ 6	2	None	N/A
Total organic carbon, TOC	200	P (disposable)	N/A	≤ 6	28	H_2SO_4	< 2
Dissolved organic carbon, DOC	200	P (disposable)	In lab within 48 hours	≤ 6	28	H_2SO_4, after filtration.	< 2
UVA-254 (absorbance at 254 nm)	200	G-amber	No	≤ 6	2	None	N/A
Color (Pt-Co units)	* same sample as UVA						
Abs-440 (absorbance at 440 nm)	* same sample as UVA						
Total phosphorus, TP	500	P (disposable)	N/A	≤ 6	28	H_2SO_4	< 2
Total soluble phosphorus, TSP	200	P (disposable)	Yes	≤ 6	28	H_2SO_4	< 2
Total reactive phosphorus, TRP, "Orthophosphate, total"	200	P (disposable)	N/A	≤ 6	2	None	N/A
Soluble reactive phosphorus, SRP, "Orthophosphate, dissolved"	200	P (disposable)	Yes	≤ 6	2	None	N/A
Ammonia, total, NH_3	* same sample as total phosphorus						
Nitrite + Nitrate, $NO_2 + NO_3$	* same sample as total phosphorus						
Total Kjeldahl Nitrogen,	* same sample as total phosphorus						
Soluble Kjeldahl Nitrogen	* same sample as total soluble phosphorus						

B.3 Sample Handling and Custody

Sample Preservation

Chemical preservation of samples should occur within 15 minutes of collection. Samples should then immediately be placed in coolers with enough ice to ensure that samples are maintained ≤6° C until arrival at the laboratory. The chemical preservatives required for each sample are listed in Table B.2.1. Samples for DOC and UV absorbance may be held on ice and filtered in the lab within 48 hours of collection (per EPA method 415.3). Immediately after filtration (within 15 minutes), the DOC samples should be acidified and may be stored ≤6° C for up to 28 days from the time of collection. Samples for UV absorbance and color should not be acidified and should be analyzed within 48 hours of collection. Maximum holding times for all samples are provided in table B.2.1.

Sample Handling and Transport

Most samples will be both collected and analyzed by the same state-certified laboratory. In some instances, samples may be collected by one organization but transferred to another state-certified laboratory for analyses. In other cases, samples may be collected by certified laboratories but provided to DWR for analysis (e.g., split samples). Assuring sample integrity from collection through analysis will be achieved through appropriate sample labeling and documentation and laboratory submission sheets. Communication between field staff and laboratory staff will be maintained so laboratories know when to expect samples and are prepared to receive and process them appropriately.

Each batch of samples will be accompanied by log sheets containing the following sampling information: unique identification number, sample date and time, sample description, sample preservation (if any), sample preservation time, and the analyses required.

Sample Labels

Labels will be attached to each sample bottle which include all the information necessary to uniquely and completely identify that sample. Typically this will include the following information: client name, station ID (e.g., “FLR-5.0”), preservative (if any), collection date, sample number or time for that date (if multiple samples are expected to be collected on a given date), collection depth (if other than surface grab), and test code.

Transport

Coolers with samples will be hand delivered by field staff to laboratories. In the case of samples being collected by an entity other than the analytical laboratory, arrangements will be made in advance for the timely transfer of samples from the collector to a representative of the laboratory.

Laboratory handling

Laboratory handling will be performed in accordance with the Laboratory's Quality Assurance Manual (Appendix 5) and will be consistent with the guidelines set forth in this section of the QAPP.

The laboratory must have written standard operating procedures (SOPs) for sample custody including:

- Sample receipt
- Sample storage
- Sample tracking

In addition, the laboratory shall have written SOPs for laboratory safety, cleaning of analytical glassware, and traceability of standards used in sample analysis QA/QC.

Sample Receipt

The laboratory SOP for receiving and logging in samples shall include documentation of the following:

- presence or absence of sample labels
- sample label identification numbers
- condition of the sample bottles
- verification of agreement or non-agreement of information on receiving documents
- temperature of samples upon receipt
- resolution of problems or discrepancies

Sample Storage

Samples are maintained below six degrees Celsius and stored in appropriate areas as to prevent sample contamination.

Sample Tracking

The laboratory shall have written SOPs for tracking the work performed on any particular sample. Documentation of sample receipt, storage, preparations, and analysis, along with instrument calibration and other QA/QC activities shall be maintained.

B.4 Analytical Methods

Field Measurements

In addition to the SOPs identified in Table B.1.3, the instruction manual for the appropriate meter should be consulted for all field measurements. Reporting levels for all field measurements are provided in table B.4.1 below.

Table B.4.1. Field Measurement Reporting Levels

Parameter	Reported to nearest
Dissolved oxygen (DO)	0.1 mg/L
pH	0.1 SU
Water temperature	0.1 ºC
Specific conductance	1 µS/cm
Air temperature	1°C
Secchi depth (lake samples only)	0.1 m

Lab Analyses

A summary of the methods and PQLs (the laboratory's minimum reporting limit) to be used are listed in table A.7.1. The laboratory's Quality Assurance Manual is provided as Appendix 5 and all relevant laboratory SOPs for the project are included in Appendix 6.

B.5 Quality Control

Field Activities

Current QC practices in place for field measurements include meter calibrations and standard checks, which are covered in Section B7: *Instrument Calibration & Frequency* of this QAPP.

Field-duplicate samples of lab-analyzed parameters will be collected at approximately 10% of the stations being sampled each month. Given the initial monitoring plan, two sites from the set of lake loading stations and two sites from the set of jurisdictional boundary locations will be selected for duplicate sampling each month. The duplicates for the lake loading sites will be collected as follows: each month 1 of the 5 largest tributaries will be selected for duplicate samples (Ellerbe, Eno, Little, Flat, and Knap of Reeds) and one of the remaining 13 sites will also be selected. In this way, each of the largest 5 tributaries will have duplicate samples collected at least twice per year, and each of the remaining tributaries will have duplicate samples collected approximately once per year. Two sites will be selected at random (without replacement) from the set of jurisdictional boundary sites for duplicate samples.

In addition to annual proficiency testing as required under the North Carolina Groundwater/Wastewater Laboratory Certification procedures, split samples may be conducted with DWR on a regular basis. Split sample scheduling will be determined in collaboration with DWR per DWR's Study Plan for the Ongoing

Assessment of Falls of the Neuse Reservoir, Version 2 (NCDENR 2011). Acceptance criteria for split samples are discussed in section A.7.

Proficiency for chlorophyll *a* analyses will be determined through DWR's annual chlorophyll *a* round robin. Laboratories conducting chlorophyll analyses for the URNBA must participate in the annual round robin and achieve results within the acceptable range calculated using the NELAC Proficiency Testing (PT) method, EPA/600/R-04/003 or alternative method specified in the annual round robin final report.

Equipment blanks will be collected at a frequency of 10% to evaluate whether contaminants have been introduced into the samples during the sample collection due to exposure from ambient conditions or from the sample containers themselves. Blank samples should be collected from a final deionized water rinse of the specified equipment after the equipment has been cleaned in accordance with appropriate cleaning procedures per standard operating procedures (Appendix 3). Blanks must be treated in the same manner as surface water samples, including handling, preservation, and hold times and will be submitted to the laboratory with a separate identification number.

Field filter blanks will be collected for each day of sampling when field filtering occurs (i.e. total soluble phosphorus, soluble reactive phosphorus, or soluble Kjeldahl nitrogen; DOC will be filtered in the lab within 48 hours, per EPA method 315.3). Additional blanks and QA/QC checks will be conducted on a variable basis as part of a field and lab audits, when problems with contamination are suspected, or to assess changes in methods, preservatives, or equipment that are being considered.

If target analytes are found in the equipment or filter blanks, sampling and handling procedures will be reevaluated and corrective actions taken. These may include obtaining sampling containers from new sources, training of personnel, discussions with the laboratory, invalidation or qualification of the results, or other procedures considered appropriate.

Field meters will be calibrated at the beginning of each field day according to manufacturer's instructions and calibrations will be checked after approximately four hours and again after the last sample of the day. Quality control criteria for field meters are provided in section A.7.

Laboratory Activities

Required quality control checks for analytical samples will be conducted according to the laboratory's Quality Assurance Manual (Appendix 5) and as specified in section A.7 of this QAPP. The following elements are part of the standard laboratory quality control practices:

- Analysis of method blanks
- Analysis of laboratory control samples (LCS)
- Instrument calibration (including initial calibration, calibration blanks, and calibration verification)
- Analysis of matrix spikes (MS)
- Analysis of duplicates and matrix spike duplicates (MSD)

Quality control objectives and criteria for acceptance for each analysis are presented in Tables A.7.2: *QA Targets for Accuracy* and A.7.3: *QA Targets for Precision*.

Method Blanks

A method blank is an analyte-free matrix, analyzed as a normal sample by the laboratory using normal sample preparation and analytical procedures. A method blank is used for monitoring and documenting background contamination in the analytical environment. Method blanks will be analyzed at a frequency of one per sample batch (or group of up to 20 samples analyzed in sequence using the same method). Corrective actions associated with exceeding acceptable method blank concentrations include isolating the source of contamination and re-digesting and/or re-analyzing the associated samples. Blank contamination will be noted in the laboratory reports, but sample results will not be corrected for blank contamination. Corrective actions will be documented in the laboratory report's narrative statement.

Laboratory Control Samples

Laboratory control samples (LCS) are laboratory-generated samples analyzed as a normal sample using normal sample preparation and analytical procedures. An LCS is used to monitor the day-to-day performance (accuracy) of routine analytical methods. An LCS is an aliquot of clean water spiked with analytes of known concentrations corresponding to the analytical method. The LCS is used to verify that the laboratory can perform the analysis on a clean matrix within QC acceptance limits. Results are expressed as percent recovery of the known amount of the spiked analytical parameter.

One LCS is analyzed per sample batch. Acceptance criteria (control limits) for the LCS are defined by the laboratory and summarized in Tables A.7.2 and A.7.3 for each parameter. In general, the LCS acceptance criteria recovery range is 80 to 120 percent of the known amount of the spiked analytical parameter. Corrective action, consisting of a rerunning of all samples in the affected batch, will be performed if LCS recoveries fall outside of control limits. Such problems will be documented in the laboratory report's narrative statement.

Matrix Spikes

Matrix spikes (MS) are prepared by adding a known amount of the analyte of interest to a sample. MS are used as a similar function as the LCS, except that the sample matrix is a real time sample rather than a clean matrix. Results are expressed as percent recovery of the known amount of the spiked analytical parameter. Matrix spikes are used to verify that the laboratory can determine if the matrix is causing either a positive or negative influence on sample results.

One matrix spike is analyzed per sample batch. Acceptance criteria for the MS are defined by the laboratory and summarized in Tables A.7.2 and A.7.3. In general, the MS acceptance criteria recovery range is 80 to 120 percent of the known amount of the spiked analytical parameter. Generally, no corrective action is taken for matrix spike results exceeding the control limits, as long as the LCS recoveries are acceptable.

Laboratory Duplicates

A laboratory duplicate is a laboratory-generated split sample used to document the precision of the analytical method. Results are expressed as relative percent difference between the laboratory duplicate pair.

One laboratory duplicate will be run for each laboratory batch or every 20 samples, whichever is more frequent. Acceptance criteria for laboratory duplicates are specified in the laboratory QA Manual and

SOPs and are summarized in Tables A.7.2 and A.7.3. If laboratory duplicates exceed criteria, the corrective action will be to repeat the analyses.

B.6 Instrument Testing, Inspection, and Maintenance

Field Equipment

Field staff are responsible for regular cleaning, inspection, and maintenance of assigned equipment. All equipment should be visually inspected prior to use for damage or dirt, and repaired or cleaned if needed. If meters are stored for long periods (> 1 week) without being used, it is recommended that they be calibrated and inspected at least weekly to keep them in good working order. Staff should refer to instruction manuals for manufacturer's recommendations for inspection, maintenance, storage, and repair. Maintenance logs shall be retained to document equipment upkeep and servicing. A log entry shall include:

- Name of person maintaining the equipment
- Date and description of the maintenance procedure
- Date and description of any equipment problems
- Date and description of action taken to correct the problems
- List of follow-up activities after the maintenance is complete
- Date the next maintenance or equipment check will be needed

Laboratory Analytical Equipment

Laboratory analytical equipment will be maintained, inspected, and tested according to manufacturer's recommendations and accepted standard operating procedures for the selected analytical methods and the laboratory's QAM and SOPs (Appendix 5). Logs of instrument maintenance activities shall be kept in the lab and remain available for review by project team members.

B.7 Instrument Calibration and Calibration Frequency

Field Meters

All field meters are to be inspected and calibrated at a minimum at the beginning and end of each day used. All field meter calibrations will be re-checked after every four hours of use and quality assurance criteria for these calibration checks are provided in section A.7. Field staff should record calibration information on a field meter calibration log sheet (e.g., Log Sheet for YSI 556MPS, Appendix 6) which includes staff name, date/time of initial calibration and post-sampling check, and meter number. The specific calibration procedures are documented in Appendices 1-4 of the Intensive Survey Branch's SOP and in the manufacturers' instruction manuals. For specific conductance a single point calibration will be used. A three-point calibration will be performed for pH. DO meters should be calibrated using the moist-air calibration method.

Standards should be selected so that they bracket the range of measurements expected; pH buffers (standards) and conductivity standards must be traceable and must not have exceeded their expiration dates. Meters currently in use require pH standards of 4.0, 7.0, and 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 mg/L, Specific conductance= ±10%, pH=±0.2) or a post-sampling check is not completed, data are determined questionable and are removed from the dataset. The Project Manager should be notified within 1 business day of any such occurrences to determine whether sampling needs to be repeated.

Laboratory Instrumentation Calibration

All laboratory instruments will be calibrated according to the recommendations of the manufacturer and accepted procedures associated with the selected analytical methods, SOPs, and the laboratory's QAM (Appendix 5).

B.8 Inspection/Acceptance of Supplies & Consumables

The laboratory performs quality assurance of sample bottles, reagents, and chemical preservatives that are provided to field staff. Containers that are purchased as pre-cleaned should be certified by the manufacturer or checked to ensure that the parameters tested are below the published reporting limits. Containers should be stored in a manner that does not leave them susceptible to contamination by dust or other particulates and should remain capped until use. Any containers that show evidence of contamination should be discarded. Certificates for containers certified by the manufacturer should be kept on file by the laboratory.

Additionally, field staff should inspect all bottles before use. Any bottles that are visibly dirty or whose lids have come off during storage should be discarded. It is recommended that field staff periodically check bottles for contamination attributed to storage conditions by filling representative containers with analyte-free water, adding the appropriate preservative(s), and submitting them to the laboratory for wet chemistry analyses. Any container lots showing analyte levels at or above the reporting limits should be discarded.

The chemical preservatives used are provided by the laboratory. Certificates of purity from the manufacturer should be provided when purchased, and these certificates should be kept on file by the laboratory. Any preservatives that show signs of contamination, such as discoloration or the presence of debris or other solids, should not be used and should be discarded. A summary of inspections to be performed by field staff is presented in Table B.8.1.

Table B.8.1. Consumable Inspections and Acceptance Criteria

Item	*Acceptance criteria*
Sample bottles	• Bottle blanks less than laboratory reporting limits • No visible dirt, debris, or other contaminants
pH standards (4.0, 7.0, 10.0 SU)	• No visible discoloration, debris, or other contaminants • The standards must not be expired.
Conductivity standards (100, 1,000, 50,000 µS/cm)	• No visible discoloration, debris, or other contaminants • The standards must not be expired.
Acid for preservation (sulfuric, phosphoric)	• No visible discoloration, debris, or other contaminants
Distilled or deionized water	• No visible discoloration, debris, or other contaminants
Filters (membrane and glass fiber)	• No visible discoloration, debris, or other contaminants • No rips, missing pieces, or torn margins

B.9 Data Acquisition Requirements for Non-Direct Measurements

The UNRBA may use data collected by DWR, the United States Geological Survey (USGS), the City of Raleigh, the City of Durham, and/or NC State University's Center for Applied Aquatic Ecology (CAAE) which is collected under the respective organizations' QAPPs.

Data collected by the City of Raleigh, City of Durham, or CAAE for the parameters covered in this QAPP will only be used by UNRBA if the lab(s) conducting the analyses are certified by the appropriate certifying agency as listed in Table B.1.3.

Proficiency for chlorophyll *a* analyses will be determined through DWR's annual chlorophyll *a* round robin. Labs producing chlorophyll *a* data which will be used by UNRBA must participate in the annual round robin with results within the acceptable range calculated using the NELAC Proficiency Testing (PT) method, EPA/600/R-04/003 or alternative method specified in the annual round robin final report.

In addition to the proficiency testing requirements associated with laboratory certification and the chlorophyll *a* round robin, split samples may be periodically analyzed with these organizations and DWR if requested by DWR. Split sample scheduling will be determined in collaboration with DWR per DWR's Study Plan for the Ongoing Assessment of Falls of the Neuse Reservoir, Version 2 (NCDENR 2011). Acceptance criteria for split samples are discussed in section A.7.

In the absence of a DWR-approved QAPP, data collected by the City of Raleigh, City of Durham, CAAE, or other sources will need to meet DWR data quality requirements and undergo DWR review to evaluate data accuracy, precision and representativeness prior to use for potential regulatory purposes per the DWR data guidelines.

UNRBA may use stream flow data collected by the USGS, atmospheric deposition data from the National Atmospheric Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNET), and climate data from the National Oceanic and Atmospheric Administration's National Climatic Data Center (NOAA NCDC) or USGS. UNRBA may use temperature, dissolved oxygen, conductivity, and pH data collected *in situ* from CAAE's Falls Lake platforms in future model

calibration or validation. The specific use of these data is not within the scope of this document and will be discussed, if relevant, in modeling quality assurance documents.

Data collected by the outside sources discussed above may be included in the UNRBA data management system, and, if included, will be coded according to the data generating organization so that they can be effectively and easily separated from the data generated under other sections of this QAPP. Additionally, data will be stored with details on the method(s) used along with method detection and reporting limits, where applicable.

B.10 Data Management

Overview

The monitoring program performed under the guidance of this QAPP will produce on the order of 10,000 individual results annually. These results are the combination of field measurements and laboratory analyses across nearly 40 different sampling locations in the Falls Lake watershed. Organized data management is critical to this project.

To facilitate the organized collection of data along with systematic review for quality assurance, the UNRBA will use an environmental data management system. Data will be uploaded by field and laboratory staff into a "holding area" of the data management system prior to review and acceptance of the data into the official database. Several data QA/QC controls will be built into this system to trap errors in data recording and entry and these are described below.

Central to the tracking of data and relating results from a single station visit, is the assignment of a unique visit identifier (VisitID). This VisitID is composed of a site identifier and a date/time identifier. The time identifier associated with this VisitID shall be the arrival time at the site. This VisitID will carry forward through all stages of the data flow process—from the site visit through final entry into the official database.

Field measurements and observations are documented at the time of measurement by field staff on field data sheets. Field staff will upload these results along with any anomalies and other comments and observations using standardized spreadsheets to the Data Management System. Hard copy field sheets will be archived at the field staff office and copies will be electronically uploaded to the UNRBA's document management system for review by the Project QA Manager and Project Manager.

Samples are submitted to the laboratory with the appropriate documentation as described in section B.3 of this document. Analytical results, including data qualifier codes, are uploaded to the Data Management System in standardized excel spreadsheets. The laboratory will keep all bench sheets on file and will make them available for review for a period of at least five years from the completion of the monitoring program. In addition, full laboratory analytical and quality control reports will be uploaded by laboratory staff to the UNRBA's Document Management System for each monitoring event. These reports will include the following, as appropriate:

- Case narrative, including a statement of the conditions in which samples were received, description of any deviation from standard procedures, explanation of any data qualifiers used, and identification of any problems encountered during analysis.

- Computer generated report form containing all sample results

The Quality Assurance Manager will review uploaded files for errors and omissions. In addition to visual checks of the data, built-in quality assurance checks will alert the Quality Assurance Manager to missing values, out-of-range values, and values which are theoretically possible but substantially different from prior values. After review and any necessary corrections, and a final verification following the procedures in Section D, the data will be appended to the current database which will contain all data collected under this monitoring program from its start in 2014 through the project's termination.

SECTION C — ASSESSMENT AND OVERSIGHT

C.1 Assessments and Response Actions

The Project Manager acts as the liaison between the team members involved in data collection and analysis and the UNRBA. Issues with any aspect of the program noted by any member of the project team or management should be reported as soon as possible to the Project Manager who will assess the issue, consult with other parties as needed, and determine the course of action to be taken.

Field and Laboratory Audits

The Project Manager or her designee will accompany field staff on the initial visit to field sites to verify coordinates and address any site access issues. In addition, within two months of hire, new field staff will be observed on a sampling run by the Project Manager or her designee. Experienced field staff will be observed on sampling runs at least once every year. In addition, the Quality Assurance Manager will review previous field records including data sheets, log books, calibration records, and other documents. The main purpose of these assessments is to ensure that field staff are performing activities in accordance with current SOPs and to determine if there are any other issues that need to be addressed. Concerns or irregularities noticed by the reviewer will be discussed with field staff. If significant issues arise, the reviewer will notify the Project Manager, field staff, and the appropriate field supervisor by written memorandum, describing the issue and providing recommendations for correcting the issue. As the direct supervisor of field staff, the field supervisor is responsible for ensuring that these significant issues are resolved.

The laboratory is certified by the DWR laboratory certification program. The laboratory must maintain that certification throughout the duration of their participation in the monitoring program including all required proficiency testing and participation in the DWR sponsored chlorophyll *a* round-robin. If the lab loses certification for any parameters while under contract for this project, the lab will submit samples for parameter(s) in question to a laboratory with current certification for analysis. The Project Manager or her designee will complete a lab audit of the contract laboratory at least annually for the duration of the monitoring program. This audit will be scheduled, if possible, during the analysis of project samples. The audits will include an assessment of all quality system documents as well as the laboratory QAM (Appendix 5) and SOPs (Appendix 6). The audit will include a laboratory site visit and discussions with the Laboratory Director and QA/QC Manager. Also, spot checks will be performed to interview individual analysts with regard to methods used, knowledge of quality systems, training, and competency.

Field Measurements

Prior to each use of monitored equipment (e.g., dissolved oxygen or pH meters), the Field Staff will review previous calibration sheets and address any problems with the sensors prior to their use. The result of each review should be noted on the instrument's calibration sheet. At the conclusion of each monitored event, all calibration sheets will be reviewed by the laboratory QA/QC Manager to assess the adequacy of the quality control checks (e.g., post-use calibration checks) and to review the instrument's performance to identify any problems or necessary maintenance.

Field quality control checks consisting of field duplicates, equipment blanks, and filter blanks are analyzed for each sampling event as described in sections B.5 and A.7 of this QAPP. The laboratory

QA/QC Manager will review all field QA/QC data after each monitored event (e.g., monthly sampling event) and will assess the adequacy of the quality control checks and identify any problems. The laboratory QA/QC Manager will notify the Project QA Manager in writing of any quality control check issues and to discuss corrective actions.

Laboratory Measurements

The laboratory will perform quality control checks for each analysis as documented in sections A.7 and B.5 of this QAPP. Laboratory staff will provide a monthly summary of all QA/QC results noting any quality control issues and potential problems in the case narrative.

C.2 Reports to Management

Data are analyzed and summarized annually by the Cardno Project Team and submitted to the UNRBA Executive Director in April of each year. This submittal will include all data collected through December of the prior year. This report will include summaries of data collected at monitoring locations and recommendations for sampling in the following fiscal year. The report will also document the results of performance evaluations and audits and data quality assessments. The report may include further analyses as agreed upon by Cardno and the UNRBA.

Interim reports submitted in October of each year (except in Year 1) will include a data assessment report (description of data format, method codes, station codes, qualifier codes, and any known quality assurance or other issues) along with metadata summaries of data collected, results of field and lab audits as appropriate, and other related information.

In addition to these reports, the Project Manager will report any issues of concern to the UNRBA Executive Director as they arise.

SECTION D — DATA VALIDATION AND USABILITY

D.1 Data Review, Verification, and Validation

Data verification and validation occurs at every step of data generation and handling. Field staff, laboratory support staff, laboratory chemists, and data entry staff are each responsible for verifying that all records and results they produce or handle are completely and correctly recorded, transcribed, and transmitted. Each staff member is also responsible for ensuring that all activities performed (sampling, measurements, and analyses) comply with all requirements outlined in the following project documents:

- This QAPP
- The SOP documents identified in the QAPP and attached as Appendices 2, 3, and 4
- The laboratory's Quality Assurance Manual (Appendix 5)
- The laboratory's SOPs (Appendix 6)

The Quality Assurance Manager is responsible for final verification and validation of all results.

D.2 Verification and Validation Methods

Data verification and validation activities involve many steps and are performed at multiple stages along the process from sample collection to analysis to reporting. Data verification is done at the field and bench levels, by laboratory reviewers, by the Project Manager, and by the QA Manager.

Field staff

Field staff will visually check the following items as produced to ensure that they are complete and correct:

- Sample labels
- Sample submission documentation
- Field data worksheet (hard copy)
- Electronic field data spreadsheet submission (transcription of hard copy field worksheet)

Field staff will review measurements as they are collected to assess if temperatures, pH, dissolved oxygen, and conductivity readings seem reasonable. They will monitor sample storage in the field to ensure that samples are stored on ice and that temperatures in the cooler are maintained below 6 degrees Celsius by verifying the presence of ice.

Laboratories

Laboratory staff will verify that samples arrived at the lab at the proper storage temperatures and that lab analyses occur within the specified holding times. Individual analysts will verify the completion of their analyses and required bench sheets. The laboratory QA/QC Manager or designee will review calculations and inspect laboratory bench sheets and log books to verify their accuracy, completeness, and adherence to the specified method protocols. Calibration and QC data will be examined daily by the individual analysts. The laboratory QA/QC Manager or designee will verify that all instrument systems are working within specified guidelines and that the QA objectives for accuracy, precision, completeness, and adherence to the required detection and reporting limits are being met. A summary of

all the QA/QC results and any non-conformance issues will be included in the laboratory data report for each monitoring event and uploaded to the UNRBA's document management system.

Data Validation

According to U.S. EPA guidance, data validation is typically performed by someone independent of the project activity and not associated with the organization responsible for producing the dataset. However, the validator needs to be familiar with both the data validation requirements and the project objectives. The Quality Assurance Manager from Cardno will conduct the data validation since Cardno project staff are not typically involved in the field or laboratory operations.

The first step of data validation is to inspect the data and the verification and review records to ensure that no oversights were made during that process. A complete set of field and laboratory information will be provided to the data validator for this task. The planned uploads to the UNRBA's document management system described under section B.10 will provide the necessary documentation for this process.

The primary purpose of the data validation is to evaluate the data against the data quality objectives presented in section A.7 of this QAPP. These objectives include criteria for the accuracy, precision, representativeness, comparability, completion, and compliance with required data reporting limits. The following will be checked as part of the validation procedure:

- field measurements data collection
- field sample collection
- sample custody, transport, and preservation
- laboratory analytical results and case narrative
- data reviews
- quality control data

The QA Manager will conduct a systematic review of the data for compliance with the established quality control criteria based on duplicate, spiked, control, and blank data results provided by the laboratory. In addition, quality assurance evaluations of data accuracy, precision, and completeness will be performed for each monitored event. The data validation qualifiers listed in table D.2.1 will be used when validating the data.

Table D.2.1: Common Data Qualifier Codes (Flags)

J	Estimated value; value may not be accurate. J1. Surrogate recovery limits have been exceeded. J2. The reported value failed to meet the established QC criteria for either precision or accuracy. J3. The sample matrix interfered with the ability to make any accurate determination. J4. The data is questionable because of improper laboratory or field protocols. J5. Temperature limits exceeded (samples frozen or >6°C) during transport. Non-reportable for NPDES compliance monitoring. J6. The laboratory analysis was from an unpreserved or improperly chemically preserved sample. The data may not be accurate.
N	Presumptive evidence of presence of material; estimated value. This code is used if: N3. The level of analyte is too low to permit accurate quantification, but the estimated concentration is greater than the laboratory method detection limit, but below the laboratory practical quantitation limit.
P	Elevated PQL due to matrix interference and/or sample dilution.
Q	Holding time exceeded. These codes shall be used if the value is derived from a sample that was received, prepared, and/or analyzed after the approved holding time restrictions for sample preparation and analysis. Q1. Holding time exceeded prior to receipt by lab. Q2. Holding time exceeded following receipt by lab.
U	Indicates that the analyte was analyzed for but not detected above the reported PQL. The value reported with the "U" qualifier is equal to the PQL.
V	Indicates the analyte was detected in both the sample and the associated method blank. Note the values in the blank shall not be subtracted from the associated samples.
X	Sample not analyzed for this constituent. X1. Sample not screened for this compound. X2. Sampled, but analysis lost or not performed- field error. X3. Sampled, but analysis lost or not performed- lab error.
Y	Elevated PQL due to insufficient sample size.
Z	The sample analysis/results are not reported due to: Z1. Inability to analyze the sample. Z2. Questions concerning data reliability. The presence or absence of the analyte cannot be verified.

Project Quality Assurance Manager

Final review, validation, and verification duties of results reported by field staff and the laboratory are performed by the Project Quality Assurance Manager on an ongoing basis.

As received: Review electronic submissions of lab reports and any hard copy lab reports of anomalies. Consult Laboratory staff for clarification or corrections if needed. Review data entry of analytical results.

Monthly: Review electronic field data submissions. Consult individual Monitors for clarification or corrections if needed.
Quarterly: All results, field and analytical, compiled, reviewed, validated, and verified.

When errors or omissions are found or suspected, focused verification will be conducted. The available electronic field data submissions or hard copy lab reports will be consulted to rule out transcription or data entry errors. If no errors are found in these records, the field staff that conducted the sampling/measurement or the appropriate laboratory chemist will be contacted so they can consult original hard copy records. If the result in question is found to be in error as compared to the original documentation, it will be corrected by the QA Manager. In the case of "impossible" values (e.g., pH of 19) if a corrected value cannot be determined from original documentation, the result will be deleted. "Unusual" values (i.e., above or below the latest five year period's minimum or maximum for that station) that are confirmed by original documentation are left intact and unqualified.

Once these steps are completed, data and any accompanying information (comments from field staff, data qualifiers/flags) are considered finalized and are added to the data warehouse.

Data End-Users

Questionable data should be brought to the attention of the Project Manager for focused verification. For data collected within the past five years, original lab reports and field data submissions are available from the online Document Management System or in hard copy from the contract laboratory. Field data sheets and hard copy notes will be maintained at the field staff office and laboratory for 5 years following the conclusion of the monitoring program for access as needed. These will be consulted to determine if correction or deletion of any records in the main warehouse is required.

D.3 Reconciliation with User Requirements

The UNRBA will review reports from Cardno annually to assess whether the data collected will meet the anticipated needs of the Association. The monitoring program is designed to be adaptive; monitoring locations, frequency, and parameters can be adjusted as deemed necessary by the Association.

SECTION E — References

Cuthbert, I. D., and P. del Giorgio. 1992. Toward a standard method of measuring color in freshwater. Limnology and Oceanography 37:1319–1326.

Mitchell, P. 2006. Guidelines for Quality Assurance and Quality Control in surface water quality programs in Alberta. Report prepared by Patricia Mitchell Environmental Consulting for the Environmental Monitoring and Evaluation Branch of Alberta Environment, Edmonton, Alberta, Canada. July 2006.

NCDENR. 2009. Falls Lake Nutrient Response Model Final Report. Prepared by N.C. Department of Environment and Natural Resources, Division of Water Quality Planning Section, Modeling/TMDL Unit November 2009.

NCDENR. 2011. Study Plan for the Ongoing Assessment of Falls of the Neuse Reservoir. Version 2. March 25, 2011. http://portal.ncdenr.org/c/document_library/get_file?uuid=f565bb4f-8428-42f3-93b1-fa701d9d5b59&groupId=38364 (accessed June 29, 2016).

NCDENR. 2012a. Ambient Lakes Monitoring Program Quality Assurance Project Plan. Version 1.1. July 2012. Prepared by N.C. Department of Environment and Natural Resources, Division of Water Quality, Environmental Sciences Section, Intensive Survey Unit. Raleigh, NC.

NCDENR. 2012b. Monitoring Coalition Program Field Monitoring Guidance. Version 2.0. December 2012. Prepared by N.C. Department of Environment and Natural Resources, Division of Water Quality, Environmental Sciences Section, Ecosystems Unit, Raleigh, NC.

APPENDICES

Official copies of the Appendices are to be included with this QAPP as a separate electronic or hard-copy document. URLs to documents are provided here where available. These URLs are current as of the date of this document but are subject to change and are not intended to be official archives of these appendices.

APPENDIX 1: UNRBA Monitoring Plan
https://www.unrba.org/monitoring-program

APPENDIX 2: NCDENR Approved Procedures for the Analysis of Field Parameters, April 2013.
http://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/laboratory-certification-branch/technical-assistance-policies

APPENDIX 3: NC DENR Intensive Survey Branch Standard Operating Procedures, Version 2.1 (revised December 2013).
http://portal.ncdenr.org/c/document_library/get_file?uuid=516f1b7b-fbb6-419f-83c8-0c981b2e1f78&groupId=38364

APPENDIX 4: EPA Methods for SUVA
Method 415.3 – Specific Ultraviolet Absorbance (SUVA)
https://www.nemi.gov/methods/method_pdf/7228/
http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000D1TP.txt

APPENDIX 5: Environment 1, Inc. Laboratory Quality Assurance Manual (QAM)

APPENDIX 6: Environment 1, Inc. Standard Operating Procedures (SOPs)