Table 7 Water Quality Parameters to be Measured at Jurisdictional Boundary Sampling Locations

Field Measurements	Laboratory Analyses
Water temperature	Total Kjeldahl nitrogen
Air temperature	Nitrate + nitrite
Specific conductance	Ammonia
Dissolved oxygen	Total phosphorus
pH	Total organic carbon
	Total suspended solids

1.2 Special Studies Component of the Monitoring Program

In addition to routine monitoring as described in Section 1.1 of this Monitoring Plan, several short-term studies will provide critical data needed to support each of the UNRBA's monitoring objectives. Over the past several years, UNRBA members and Cardno ENTRIX have identified many special studies that would inform the program's monitoring objectives; however, the total cost of these studies exceeds the UNRBA budget. This section presents the special studies which have been ranked highly jointly by Cardno ENTRIX and the UNRBA Path Forward Committee and are selected for inclusion in the 4-5 year monitoring program.

Recommended special studies along with their timing are presented in Table 8 and are grouped according to the three UNRBA monitoring objectives: lake response modeling, jurisdictional loading and source allocation, and support for regulatory options. Not all recommended special studies occur every year, and several studies will only occur in one or two years. The Study ID number corresponds to further discussion of the study in Appendix A and follows the format SS.XX.#, where SS stands for "Special Study", XX refers to the monitoring objective the special study meets. The monitoring objectives are "LR" for "Lake Response Modeling", "SA" for "Source Allocation" or "RO" for "Regulatory Options". The final number distinguishes among special studies within a given category.

Table 8 Special Studies and Data Use, Importance, and Timing of Study Implementation

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration
Lake Response Modeling (Loading Estimation)			
SS.LR.1	Storm event sampling and comparison of loading methods	Determine which method (various LOADEST options or WQ statistical model) most accurately calculates nutrient loads to Falls Lake. The TN and TP load estimate doubles depending on the method used as shown in the Model Sensitivity TM. Estimating lake loads based on the most accurate method will result in substantially more accurate model predictions and increased confidence in resulting Stage II targets.	1-2 storms per year, each at one site. Sites will vary for each storm.
SS.LR.2	Obtain additional internal loading from lake sediments	Improve accuracy and calibration of EFDC model. If EPA cannot collect this data, the data collected by DWR will be used to revise model setup, applying the higher nutrient flux measurements in upper lake areas. Although DWR collected data at two sites and obtained different flux rates at each, the current model uses a single value for the entire lake.	UNRBA will seek DWR cooperation to petition EPA to conduct these surveys for Falls Lake.
Source Allocation: Determining Loading from Different Watershed Sources			
SS.SA.1	Tracking BMP Implementation, Inspections and Repairs	The following information should be collected: description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed. The Nutrient Scientific Advisory Board (NSAB) is currently establishing guidance regarding data collection efforts for BMPs that will be needed to calculate credits. To continue receiving nutrient loading credits from BMPs, local governments should inspect and repair BMPs on an annual basis.	This information should be tracked annually by member jurisdictions.
SS.SA.2	Measure cross sections and sediment concentrations at five locations previously monitored by USGS; estimate sediment and nutrient loading associated with stream bank erosion	Determine how much of the nutrient loading to the lake could be associated with stream bank erosion; used to support development of nutrient reduction credits assigned to stream restoration activities. Provides members the ability to prioritize implementation practices and reduce compliance costs.	Conduct in year 2. UNRBA will discuss with USGS to determine if they are interested in revisiting these studies.

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration
Support of Regulatory Options - Linkage of Water Quality with Designated Uses			
SS.RO.1	Water quality studies at three Center for Applied Aquatic Ecology (CAAE) diurnal stations (I-85, Highway 50, and Raleigh Intake) during high-chlorophyll periods.	Supports regulatory options and structural equation/ Bayesian modeling, and EFDC model calibration. Provides data needed to support development of site specific water quality criteria or a sub-classification use attainability analysis. Correlates chlorophyll *a*, nutrient, DO and pH concentrations with conditions that influence aquatic health.	Years 1, 2, 3, 4
SS.RO.2	Fish monitoring by WRC at DWR Lake monitoring stations (or at the three CAAE locations)	Support regulatory options and structural equation/ Bayesian modeling. Correlates fish population, size and length with water quality conditions in the three main segments of the lake.	Years 1, 2, 3, 4
SS.RO.3	Coordinate with the City of Raleigh to conduct paired water quality sampling (nutrients, chlorophyll *a*, TOC, DOC, SUVA, and color) at intake to correlate with finished water quality testing performed by Underwriters Laboratories (UL) (taste and odor and DBPs)	Support regulatory options and structural equation/Bayesian modeling. Provides data to identify how water quality at the intake is linked with disinfection byproduct formation and taste and odor issues in the finished water.	Years 1, 2, 3, 4
SS.RO.4	Recreational surveys and count models that link visitation with water quality parameters	Support regulatory options and structural equation/Bayesian modeling. Correlates lake water quality with recreational uses. These data are needed for development of a site specific criterion or a sub-classification use attainability analysis.	Years 2, 3, 4, and 5 if needed

2 List of References

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Cardno ENTRIX. 2013a. Task 1: Framework for a Re-examination of Stage II of the Falls Nutrient Strategy. Support of Long Term Planning and Regulatory Nutrient Activities in the Falls Lake Watershed. Prepared for the Upper Neuse River Basin Association.

Cardno ENTRIX. 2013b. Task 3: Estimation of Nutrient Loading to Falls Lake. Support of Long Term Planning and Regulatory Nutrient Activities in the Falls Lake Watershed. Prepared for the Upper Neuse River Basin Association.

Cardno ENTRIX. 2013c. Task 4: Review of Existing Models and Recommendations for Future Studies. Support of Long Term Planning and Regulatory Nutrient Activities in the Falls Lake Watershed. Prepared for the Upper Neuse River Basin Association.

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APPENDIX A

DESCRIPTION OF SPECIAL STUDIES

Appendix A

A.1 Studies to Support Revised Lake Response Modeling

The existing Falls Lake EFDC lake response model was developed based on lake and watershed data collected from 2005 to 2007. In addition to the routine monitoring described in the main text of this document to better characterize tributary loading of nutrients, carbon, and chlorophyll *a*, several potential special studies have been identified which could reduce the reliance on assumptions for model development and influence the model response.

The following special studies related to Lake Response Modeling are deemed high priority and may be conducted within the currently projected UNRBA monitoring budget. Future changes to the budget or monitoring priorities established by the UNRBA may influence whether these special studies can be completed.

SS.LR.1: Storm Event Sampling

In a recent TM describing the sensitivity of the EFDC lake response model, Cardno ENTRIX demonstrates several methods for estimating nutrient loads to the lake based on flow and water quality data. The loads resulting from each method were highly variable and a determination of which method was most accurate could not be made based on the data available. Conducting storm event sampling where flow and water quality samples are collected frequently over the course of a storm will provide the data needed to determine which of the methods is most accurate in determining loading to the lake. The following water quality parameters should be included: turbidity, NH3, NO2/NO3, TKN, Ortho-P, total P, TSS, TOC, field parameters, and sediment partitioning. Sampling frequency will vary based on the intensity and duration of the storm. These studies will be conducted initially where an existing 15-minute USGS flow gage is present. One to two sites will sampled, each for a single storm event, in each year of the monitoring program.

SS.LR.2: Internal Lake Loading

The assessment of nutrient loading to the lake should account for internal loading due to releases from lake sediment. Benthic flux rates should be measured for ammonia, nitrate plus nitrite, phosphate, and sediment oxygen demand (SOD). There are a small number of existing measurements of benthic flux in Falls Lake that were conducted in support of the EFDC lake response modeling, and these results suggest that different rates may apply to different locations within the lake. However, the existing Falls Lake EFDC model assumed a single rate for each parameter across the lake which was adjusted as a calibration factor. In addition, the existing measurements were conducted in the spring when hypoxic conditions at the sediment-water interface were likely not present. Low dissolved oxygen conditions stimulate the release of phosphorus from lake sediments, so the existing monitoring may not have characterized the actual variability in this nutrient loading source.

A better understanding of the spatial variability in these lake processes would improve model calibration and provide the data needed to simulate these processes spatially rather than assuming that one set of factors applies in all areas of the lake. Future model updates could account for the observed spatial variation at additional stations, and sampling events would provide greater characterization of the spatial and temporal variability across the lake as whole. Additional monitoring for benthic flux should include both temporal (seasonal) and spatial variation. These

measurements will provide additional information on the spatial variability of these rates, but as with any monitoring plan additional data collection does not eliminate all uncertainty.

Benthic nutrient flux and sediment oxygen demand are measured *in situ* using sealed chambers. Samples are extracted from the water above the sediments and changes in nutrient concentration are used to calculate flux (mass per time). Measurements are typically taken in triplicate at each site. Site locations will be selected to assess longitudinal changes in nutrient flux from the upstream end of the lake to the dam.

Because the sediment oxygen demand studies require the presence of dissolved oxygen at the sediment-water interface to measure rates of change in this parameter, these benthic studies will not be conducted under anoxic conditions when phosphorus flux is typically greatest.

The UNRBA will petition US-EPA Region 4 to conduct these studies. If EPA does not conduct these studies, then the model may be modified to use the higher flux rates obtained by DWR at I-85 to represent conditions in the lake upstream of Creedmoor Road. The lower flux rates will be used to represent conditions in the lake downstream of Creedmoor Road. Alternatively, the two spatial measurements could be used to define a linear change in benthic flux rates defined for several modeling segments. Both approaches could be tested during preliminary model revisions and the sensitivity of the model to these parameters could be assessed.

A.2 Source Allocation and Estimation of Jurisdictional Loading and Nutrient Transport within the Falls Lake Watershed

In order to achieve compliance with chlorophyll *a* water quality standards throughout the Lake, the State has determined that nutrient loading to the lake from the upper five tributaries should be reduced by 40 percent for nitrogen and 77 percent for phosphorus. The Falls Lake Nutrient Management Strategy rules identify the parties (municipalities, counties, agriculture, and state and federal entities) responsible for implementing the nutrient reductions, which are to be achieved by requiring stormwater controls and implementation of best management practices (BMPs) for new and existing development, point source discharges, and agricultural non-point sources. Due to the requirements specified in the Falls Lake Nutrient Management Strategy (.0275 5(b)(i)), nutrient loading to Falls Lake Reservoir must be evaluated and reported to the EMC every five years, beginning in 2016.

Current evaluations of the watershed model indicate that there is a high degree of uncertainty associated with the watershed loads predicted by the Falls Lake watershed loading (WARMF) model. Issues and uncertainties associated with the model have been described by Cardno ENTRIX (2013b).

Targeted monitoring within the watershed will reduce uncertainties associated with specific loading sources and jurisdictional allocations. This monitoring can be supplemented by the statistical models developed by Cardno ENTRIX in the Water Quality Estimation and Optimization TM (Cardno ENTRIX April 2014). The following studies would provide data that can be used to refine the watershed loading estimates to Falls Lake, validate and refine the statistical models, and increase the accuracy of jurisdictional load allocation. Future changes to the budget or monitoring priorities established by the UNRBA may influence whether these special studies can be completed as described.

SS.SA.1: Tracking BMP implementation, inspections, and repairs

Local governments in the Falls Lake watershed are required to track BMP implementation and estimate resulting nutrient load reductions. Local governments should begin collecting data to support this requirement and provide the data needed for credit accounting tools such as the Jordan/Falls Lake Stormwater Nutrient Loading Accounting Tool (NCSU-BAE and NCDENR 2011). The following information should be collected: description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed. The Nutrient Scientific Advisory Board (NSAB) is currently establishing

guidance regarding data collection efforts for BMPs that will be needed to calculate credits. To continue receiving nutrient loading credits from BMPs, local governments should inspect and repair BMPs on an annual basis. Cardno ENTRIX suggests that each UNRBA member document these efforts in an electronic database or spreadsheet. These efforts will be covered by individual local governments. The local governments should treat this as a high priority effort.

SS.SA.2: Streambank erosion and nutrient loading

Little is known regarding the contribution of streambank erosion to nutrient loading in the Falls Lake watershed. Monitoring to measure the relative importance of this source is recommended. There are several locations in the watershed where USGS obtained stream channel cross section measurements. Revisiting these sites and measuring the cross sections will provide an estimate of the mass of sediment lost. Collecting stream bank and stream bed sediment data for analysis of nutrient and carbon content will provide a corresponding estimate of loading for these parameters. Another option (more resource intensive) is to develop Bank-Stability and Toe-Erosion Models (BSTEM) that rely on additional field data and the use of bank erosion modeling to estimate sediment loading under baseline and management scenarios. Given the other priorities associated with this monitoring program, Cardno ENTRIX recommends the simpler option that relies on cross section and sediment nutrient concentration data. This is a high priority study because its results will provide the UNRBA with information needed to prioritize BMPs on upland areas versus stream bank restoration projects.

A.3 Support of Regulatory Options and Linkage of Water Quality to Designated Uses

Falls Lake is listed as impaired for chlorophyll *a* based on the water quality criteria of 40 µg/L. The framework for re-examining the Falls Lake Nutrient Management Strategy relies on a linkage between water quality and designated uses: wildlife enhancement and aquatic life, recreation, drinking water supply, and flood storage. To date, little data has been collected in Falls Lake to support this linkage, and even DWR staff have stated that "based on what DWR staff has read in files from the 1970s, Water Resources Research Institute (WRRI) did not have a specific designated use that they were trying to protect by utilizing the 40 µg/L chlorophyll *a* criteria" (August 29, 2005 Falls of the Neuse and High Rock Lakes Combined Technical Advisory Committee meeting). Several studies are needed to provide a better linkage between water quality and designated uses, particularly with respect to the chlorophyll *a* standard.

The following special studies related to supporting regulatory options are deemed high priority and may be conducted within the currently projected UNRBA monitoring budget. Future changes to the budget or monitoring priorities established by the UNRBA may influence whether these special studies can be completed as described.

SS.RO.1: Falls Lake diurnal pH and DO monitoring with water quality sampling

The purpose of this study is to obtain additional data throughout the water column to link the aquatic life use support category with concentrations of chlorophyll *a*, nutrients, and related fluctuations in dissolved oxygen (DO) and pH. An over-abundance of algae may cause diurnal variations in DO concentrations and pH levels as the processes of photosynthesis and respiration occur. Die-off and decay of algae also result in the consumption of DO.

North Carolina State University's Center for Applied Aquatic Ecology (CAAE) collects field data at three hour increments at three locations in Falls Lake with at least monthly water quality sampling. Diurnal sampling of DO, pH, and temperature at these three CAAE platform locations (at multiple depths) in the lake will provide an indication of whether aquatic organisms are likely experiencing stress due to elevated levels of algae in the water column. To supplement the CAAE field data collection, water quality samples should be collected during 2-3 high algal growth periods

and one lower algal growth period to link chlorophyll *a* and nutrient concentrations with fluctuations in DO and pH and document conditions which can impact support of the aquatic life use. Data will be collected once per day for a 4-day period as a photic zone composite and at three discrete depths. Sampling depths should be co-located at the depths monitored by the automated platform and be approximately one meter from the surface, one meter from the bottom (or at the deepest CAAE platform sampling depth), and near the middle of the water column. Monitoring will include the following parameters: chlorophyll *a*, NH3, NO2/NO3, TKN, Ortho-P, total P, TSS, color, SUVA, TOC, and DOC. Algal unit density (units/ml) and biovolume (mm^3/m^3) will also be obtained for the following three groups of algae: diatoms, green algae, and cyanobacteria.

The data from this study can be used to demonstrate support of the aquatic life use and for development of an alternative chlorophyll *a* criterion for sections of Falls Lake. This data will also be used to help calibrate the EFDC model and provide insight on day to day variability in nutrient and chlorophyll *a* concentrations. If day-to-day variability is found to be high, the time interval between water quality samples may be decreased for subsequent monitoring events. This is a high priority study.

SS.RO.2: Fish monitoring with water quality sampling

The NC Wildlife Resources Commission (WRC) conducts fish monitoring in Falls Lake once per year for either largemouth bass or black crappie. The majority of the fish monitoring occurs in the Lower Lake downstream of Highway 50 (94 percent of current surveys focus on the Lower Lake). Fish monitoring in the Upper Lake would provide information on the biological health in this part of the system. This effort would involve coordinating with the WRC so that the fish sampling occurs within a few days of the monthly lake sampling conducted by DWR. This will provide an indication of how water quality affects fish utilization of the lake. Coordination with the WRC will be required to develop this sampling plan. This is a high priority study.

SS.RO.3: Drinking Water Supply and Water Quality Monitoring

The City of Raleigh currently collects data on taste and odor, disinfection by-products, and other parameters associated with the quality of the raw water supply at several places below Highway 50 (Figure 2). Cardno ENTRIX recommends water quality sampling of raw water for additional parameters including nutrients, chlorophyll *a,* TOC, DOC, SUVA, and color to link water quality at the intake with quality measures for finished water.

SS.RO.4: Recreational Data and Water Quality Sampling

Weekly recreational count data are available from the State Park System for the period 2000 to 2011. Starting in 2012, daily data are available. User perception surveys conducted to supplement the State Park System counts will be implemented online to assess how water quality conditions (clarity, aesthetics, odor, etc.) impact the quality of the recreational experience and dictate choices regarding where and when people choose to recreate. These online surveys will provide a linkage between water quality and attainment of the recreational designated uses for the reservoir. Surveys should target a mix of recreational uses including fishing, swimming, and boating to determine if water quality affects these uses in different ways.

The following recreational survey and count model development is recommended:

- Year 2: analyze count data from State Parks and develop count model to assess trends with weather, lake water quality, etc. Present results as a power point presentation to the UNRBA and develop a user-perception survey if needed (this will depend on the trends and strengths of the count model)
- Year 3: implement the user perception survey via internet to 1000 participants during the summer months. Update the count model and draft a report that summarizes the count model and the results of the user perception survey. Determine if additional surveys are needed in Year 4.
- Year 4 as needed: implement the user perception survey via internet to 1000 participants during the summer months. Update the count model and update the report that summarizes the count model and the results of the user perception survey. Determine if additional surveys are needed in Year 5.
- Year 5 if needed: implement the user perception survey via internet to 1000 participants during the summer months. Update the count model and report that summarizes the count model and the results of the user perception survey.

Table A-1. Summary of Special Studies.

Study ID	Priority	Study	Year 1	Year 2	Year 3	Year 4	Year 5 (Optional)
SS.LR.1	High	Storm event sampling	2 events	1 event	2 events	2 events	2 events
SS.LR.2	High	Internal lake loading. Petition EPA to conduct these studies.	Work with DWR to petition EPA to conduct studies	Schedule studies	Schedule studies – Alternate Year		
SS.SA.1	High	Tracking BMP Implementation, Inspections, and Repairs	x	x	x	x	x
SS.SA.2	High	Measure cross sections and sediment nutrient concentrations at five previously monitored locations; estimate sediment and nutrient loading associated with stream bank erosion		x			
SS.RO.1	High	Quarterly water quality studies at three CAAE diurnal stations	x	x	x	x	x
SS.RO.2	High	Fish monitoring at seven stations	x	x	x	x	x
SS.RO.3	High	Drinking water quality and lake water quality monitoring	x	x	x	x	x
SS.RO.4	High	Recreational data		x	x	x	x

APPENDIX

B

DWR APPROVAL OF UNRBA MONITORING PLAN

Appendix B

B.1 DWR Approval of UNRBA Monitoring Plan

NCDENR
North Carolina Department of Environment and Natural Resources

Pat McCrory
Governor

John E. Skvarla, III
Secretary

July 16, 2014

Dear Mr. Westall:

DWR approves UNRBA's Monitoring Plan under the Falls Lake Rules 15A NCAC 02B .0275 (5) (f). This approval applies only to the parts of the plan that support the goal of "develop and submit for Commission approval supplemental nutrient response modeling of Falls Reservoir" as per the Falls Lake Rules. This approval is contingent on the submittal and DWR approval of any future changes to the monitoring plan.

DWR approval of UNRBA's Monitoring QAPP must be obtained before monitoring begins, as provided for in the Falls Lake Rules. If you have questions, please contact Kathy Stecker of DWR's Modeling and Assessment Branch. Thank you and UNRBA for your commitment to improving water quality in Falls Lake.

Sincerely,

T. C. Fransen

Tom Fransen, Chief
Planning Section
Division of Water Resources

cc: Tom Reeder
Dianne Reid
Kathy Stecker
Steve Kroeger

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