SUMMARY OF UNRBA MODEL DEVELOPMENT PROCESS:
COMPARISON TO THE ADAPTIVE MANAGEMENT PROVISION OF THE FALLS LAKE RULES

Executive Summary:

The NC Environmental Management Commission (EMC) adopted the Falls Nutrient Management Strategy in 2010 as the Falls Rules, and the Rules Review Commission (RRC) approved the Rules in 2011. The EMC acknowledged the uncertainty in the modeling used to develop the nutrient load reduction requirements. To address this uncertainty, the Rules include an adaptive management framework that requires that "a person" submitting additional information must follow specific provisions for updating models for the purposes of revising the Rules.

The Upper Neuse River Basin Association (UNRBA) began its re-examination effort in 2011. The Association met or exceeded each of the requirements for developing the re-examination information and secured the necessary approvals from the NC Division of Water Resources (DWR) both before work began and as work components were completed. Attachment A provides a summary of the studies and evaluations that were applied to the development of the UNRBA watershed and lake models including those funded by the NC Collaboratory. The UNRBA also provided model files and training sessions for DWR on each of mechanistic models developed. These models include 1) the Watershed Analysis Risk Management Framework (WARMF) which simulates the watershed and Falls Lake and 2) the Environmental Fluid Dynamics Code (EFDC) model for the lake. The EFDC model is not directly connected to the watershed model, but the watershed model is used to develop its input files. The detailed watershed model provides for assessment of scenarios that change nutrient input to the lake based on potential management actions. It also allows for evaluation of hypothetical watershed conditions that illustrate the difficulty of reducing nutrients in the watershed (an "all forest" watershed, for example).

The UNRBA submitted letters to DWR and the NC Environmental Management Commission (EMC) in December 2023 (regarding the watershed model) and December 2024 (regarding the lake model) requesting review and approval of its models and reports (Attachment B). DWR responded via email in July 2024 and February 2025 accepting the models under the provisions of the rule (Attachment C). The emails from DWR stated that the UNRBA's watershed and lake modeling, respectively, had been developed according to the DWR-approved UNRBA Modeling Assurance Project Plan and that no further questions or comments would be provided by the agency. This represents DWR's determination that the models developed are viable and can be used to assess the impacts of the watershed on the lake and the lake's response to nutrient inputs.

This document summarizes the efforts of the UNRBA to develop watershed and lake models according to the requirements in the Rules. The UNRBA greatly appreciates the local, state, and federal agencies and organizations that participated in development of these products.

The UNRBA re-examination effort began in 2011 and continues through the Rules readoption process. The local governments have invested more than $11 million in these efforts. In many areas, the UNRBA

has exceeded the requirements for a re-examination listed in the Rules under the adaptive management section (Item (5)(f)). This document also summarizes these additional elements.

Rule Requirements for Re-examination:

The Falls Lake Nutrient Management Strategy (the Rules) was passed by the EMC and approved by the Rules Review Commission (RRC) in 2011. The Rules require two stages of nutrient reduction relative to a baseline year of 2006. Due to the uncertainty associated with the modeling used to develop the Rules, an adaptive management provision was added to the Rules in Item (5)(f) of the Purpose and Scope Rule:

> (5) ADAPTIVE IMPLEMENTATION. The Commission shall employ the following adaptive implementation plan in concert with the staged implementation approach described in this Rule:
> …
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> (f) Recognizing the uncertainty associated with model-based load reduction targets, to ensure that allowable loads to Falls Reservoir remain appropriate as implementation proceeds, a person may at any time during implementation of the Falls nutrient strategy develop and submit for Commission approval supplemental nutrient response modeling of Falls Reservoir based on additional data collected after a period of implementation. The Commission may consider revisions to the requirements of Stage II based on the results of such modeling as follows:
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> (i) A person shall obtain Division review and approval of any monitoring study plan and description of the modeling framework to be used prior to commencement of such a study. The study plan and modeling framework shall meet any Division requirements for data quality and model support or design in place at that time. Within 180 days of receipt, the division shall either approve the plan and modeling framework or notify the person seeking to perform the supplemental modeling of changes to the plan and modeling framework required by the Division;
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> (ii) Supplemental modeling shall include a minimum of three years of lake water quality data unless the person performing the modeling can provide information to the Division demonstrating that a shorter time span is sufficient;
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> (iii) The Commission may accept modeling products and results that estimate a range of combinations of nitrogen and phosphorus percentage load reductions needed to meet the goal of the Falls nutrient strategy, along with associated allowable loads to Falls Reservoir, from the watersheds of Ellerbe Creek, Eno River, Little River, Flat River, and Knap of Reeds Creek and that otherwise comply with the requirements of this Item. Such modeling may incorporate the results of studies that provide new data on various nutrient sources such as atmospheric deposition, internal loading, and loading from tributaries other than those identified in this Sub-item. The Division shall assure that the supplemental modeling is conducted in accordance with the quality assurance requirements of the Division;
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> (iv) The Commission shall review Stage II requirements if a party submits supplemental modeling data, products and results acceptable to the Commission for this purpose. Where supplemental modeling is accepted by the Commission, and results indicate allowable loads of nitrogen and phosphorus to Falls Reservoir from the watersheds of Ellerbe Creek, Eno River, Little River, Flat River, and Knap of Reeds Creek that are substantially different than those identified in Item (3), then the Commission may initiate rulemaking to establish those allowable loads as the revised objective of Stage II relative to their associated baseline values;

UNRBA Re-examination Effort:

In 2011, the UNRBA determined that it would seek a re-examination of the Rules and began planning the process as allowed under Item (5)(f). This initial work included the compilation and evaluation of existing data and review of previous models to identify gaps and inform re-examination studies; development of a Monitoring Plan and Quality Assurance Project Plan (QAPP); selection of watershed and lake models; development of a modeling framework, conceptual modeling plan, and Modeling QAPP; and engagement of stakeholders. These extensive documents are summarized and hyperlinked in Table 1.

Significantly more research and data have been collected since the original Falls models were developed. Scientific evaluation of the reservoir was also undertaken beginning in 2019 under the provisions of the NC Collaboratory. The UNRBA has worked diligently to incorporate and develop the most comprehensive set of scientific information and research available to inform revised Falls Rules. Several organizations have contributed to this effort as indicated in Figure 1. More detail on how these studies were incorporated into the modeling is provided in Attachment A and the UNRBA Watershed Modeling Report and UNRBA Lake Modeling Report.

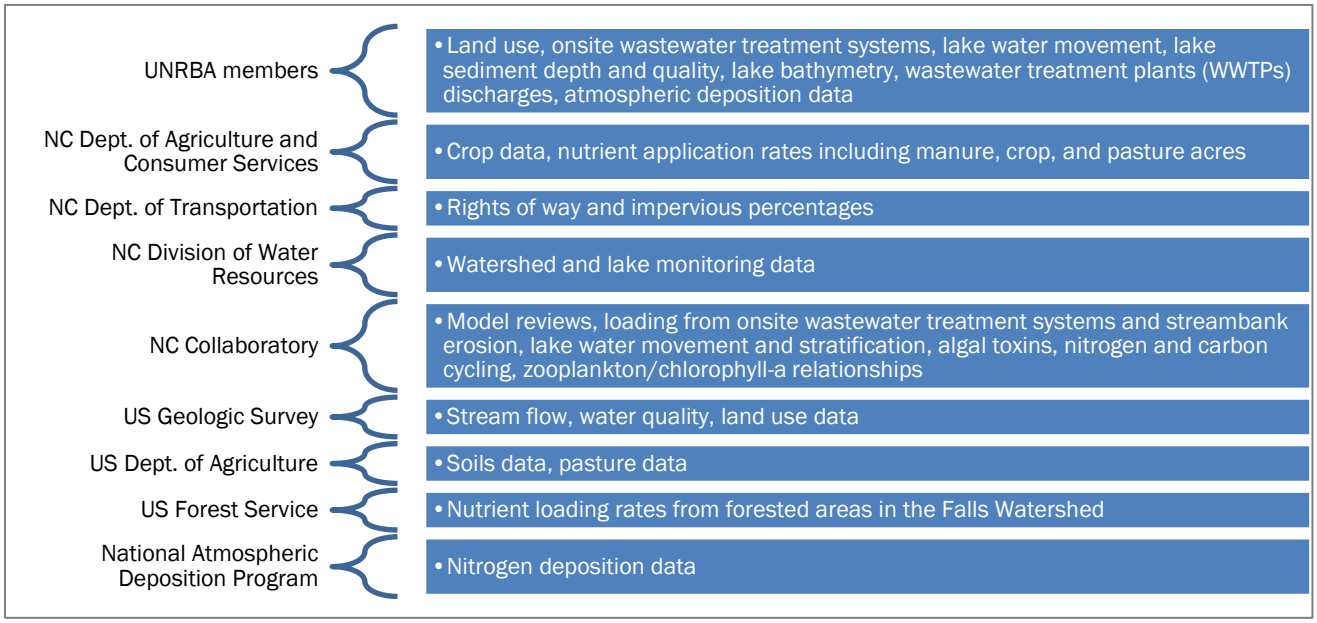

Figure 1. Organizations Providing Input Data to the UNRBA's Updated Models to Support Re-examination

Following the four-year monitoring program and development of the models, the UNRBA submitted the modeling files and reports to DWR and trained their staff on the use of the models. The UNRBA submitted watershed and lake modeling reports via letters to the EMC and DWR on December 20, 2023, and December 10, 2024, respectively (Attachment B). DWR confirmed that the UNRBA had developed its watershed and lake models according to the Modeling QAPP in emails provided in July 2024 and February 2025, respectively (Attachment C).

Table 1 abbreviates the list of requirements under Item (5)(f) of the Rules and documents the UNRBA's re-examination work products that satisfy each requirement. The UNRBA worked diligently to make sure that key elements of the re-examination exceeded the requirements of Item (5)(f). These efforts are also included as "additional" items in Table 1.

The modeling work done to support the UNRBA's recommendations for Falls Lake Rule revisions is extensive and represents a robust technical effort. The re-examination also included comprehensive outreach and vetting by stakeholders. This input was incorporated into the model development process. The input and participation in the process by DWR modelers is well documented and extensive. All modeling summary reports and documents were provided during the drafting stage, and input and questions were addressed (for example, Appendix H of the UNRBA Watershed Model Report).

Responsibilities of DWR:

The Rules also include responsibilities of DWR with respect to adaptive management. Several of these elements require the agency to consider the technical and financial feasibility of meeting the requirements and if alternative regulatory action or alternative water quality standards would protect the designated uses of the reservoir (see bold font text from Item (5) below).

(5) ADAPTIVE IMPLEMENTATION. The Commission shall employ the following adaptive implementation plan in concert with the staged implementation approach described in this Rule:

…

(b) The Division, to address resulting uncertainties including those related to technological advancement, scientific understanding, actions chosen by affected parties, loading effects, and loading effects of other regulations, shall report to the Commission and provide information to the public in January 2016 and every five years thereafter as necessary. The reports shall address all of the following subjects:

(i) Changes in nutrient loading to Falls Reservoir and progress in attaining nutrient- related water quality standards as described in Sub-Items (5)(a)(i) through (vi) of this Rule;

(ii) The state of wastewater and stormwater nitrogen and phosphorus control technology, including technological and economic feasibility;

(iii) Use and projected use of wastewater reuse and land application opportunities;

(iv) The utilization and nature of nutrient offsets and projected changes. This shall include an assessment of any load reduction value derived from preservation of existing forested land cover;

(v) Results of any studies evaluating instream loading changes resulting from implementation of rules;

(vi) Results of any studies evaluating nutrient loading from conventional septic systems and discharging sand filter systems;

(vii) Assessment of the instream benefits of local programmatic management measures such as fertilizer or pet waste ordinances, improved street sweeping and the extent to which local governments have implemented these controls;

(viii) Results of applicable studies, monitoring, and modeling from which a baseline will be established to address changes in atmospheric deposition of nitrogen;

(ix) Recent or anticipated changes in regulations affecting atmospheric nitrogen emissions and their projected effect on nitrogen deposition;

(x) Results of any studies evaluating nutrient loading from groundwater;

(xi) Updates to nutrient loading accounting tools; and

(c) The Division shall submit a report to the Commission in July 2025 that shall address the following subjects in addition to the content required elsewhere under this Item:

(i) The physical, chemical, and biological conditions of the Upper Falls Reservoir including nutrient loading impacts;

(ii) Whether alternative regulatory action pursuant to Sub-Item (5)(g) would be sufficient to protect existing uses as required under the Clean Water Act;

(iii) The impact of management of the Falls Reservoir on water quality in the Upper Falls Reservoir;

(iv) The methodology used to establish compliance with nutrient-related water quality standards in Falls Reservoir and the potential for using alternative methods;

(v) The feasibility of achieving the Stage II objective; and

(vi) The estimated costs and benefits of achieving the Stage II objective;

(d) The Division shall make recommendations, if any, on rule revisions based on the information reported pursuant to Sub-Items (b) and (c) of this Rule;

(e) In developing the reports required under Sub-Items (b) and (c) of this Rule, the Division shall consult with and consider information submitted by local governments and other persons with an interest in Falls Reservoir. Following receipt of a report, the Commission shall consider whether revisions to the requirements of Stage II are needed and may initiate rulemaking or any other action allowed by law;

DWR's most recent five-year status report for Falls Lake was issued in 2021 and the next is due in 2026. A 20-year report has not been issued. Through the re-examination effort, the UNRBA has been working on addressing the elements of the 20-yr report as described in the Rules:

- Items (5)(c)(i and iii):
  - UNRBA Watershed Modeling Report
  - UNRBA Lake Modeling Report
- Items (5)(c)(v and vi):
  - Task 1-Develop a Framework for a Reexamination of Stage II of the Falls Lake Nutrient Management Strategy
  - Concepts and Principles for the UNRBA Recommendations for a Revised Falls Lake Nutrient Management Strategy
  - Consensus Principles II
- Items (5)(c)(ii and iv):
  - UNRBA continues to work on these sub-items through the development of draft Falls Lake Rules and the compiling of economic information for development of a summary document to support development of a fiscal note and regulatory impact analysis. This document is under development and will be submitted following development of a final draft set of rules.

Key Findings of the UNRBA's Re-examination and Implications for Revised Falls Rules

Water quality models are useful tools for guiding policy decisions for the development of regulatory requirements. In some cases, the conditions and pollutant sources for a waterbody result in a straightforward approach for meeting water quality goals. In some cases, like Falls Lake, they demonstrate how feasible management actions and available technology constrain the outcomes.

The UNRBA's recommendations for revised Falls Lake Rules were filed with the EMC, Division, and General Assembly in 2023. These recommendations propose continuation of a 4B alternative (with appropriate revisions) to address these challenges and work toward meeting the chlorophyll-a standard. The proposed revised framework relies on an integrated watershed health approach, implementation of currently available technologies, and continued implementation of stormwater controls on new development. The UNRBA worked with stakeholders to document critical aspects of this framework in its Concepts and Principles for the UNRBA Recommendations for a Revised Falls Lake Nutrient Management Strategy and Consensus Principles II.

The UNRBA's key findings and implications for revised rules are summarized in Table 2. The findings support an integrated approach to nutrient management that recognizes the complexity of the system, aims to continue progress in the watershed, improves and promotes watershed health, and considers the scientific realities of this watershed and lake. The findings of the re-examination have identified specific challenges that must be recognized and considered in adopting a revised long-term strategy for the lake:

- The upstream, shallow areas and arms of Falls Lake will never meet the NC chlorophyll-a water quality standard as currently applied.
    - The UNRBA developed an "All Forest" scenario that predicted impacts under the following conditions: the entire watershed was converted to forests, all wastewater sources were removed (centralized and onsite), nutrient application to land surfaces ceased, and those conditions persisted for 25 years. Under this hypothetical scenario, the chlorophyll-a standard in the upper part of Falls Lake (near Interstate 85) would be exceeded more than 30 percent of the time. Under the calibrated model representing conditions from 2015 to 2018, this segment of the lake exceeded the chlorophyll-a standard 37 percent of the time. Thus, even this drastic change in watershed conditions does not achieve the standard (less than 10 percent exceedances). (See results for Segment 1 on page 14 of Key Findings of the Lake Modeling and page 9-19 of the UNRBA Lake Modeling Report.)
    - The UNRBA modeling also shows that to possibly meet the chlorophyll-a water quality standard (simulating no more than 10 percent exceedance of the standard), the nitrogen loading from all sources in the watershed, including forests and other natural and unmanaged lands, would have to be reduced by 50 percent. If converting the entire watershed to forests and removing wastewater and nutrient application cannot meet the standard (the "All Forest" scenario), there is no feasible way to reduce nitrogen loading by this amount. The UNRBA evaluated pump-and-treat systems to meet this reduction level in Concepts and Principles for the UNRBA Recommendations for a Revised Falls Lake Nutrient Management Strategy. This evaluation showed that 138 algal floways would be required to reduce nitrogen loading to the lake by 825,000 pounds per year. If it were feasible to construct 138 systems, it would cost $1.1 billion to construct and $23.4 million per year to operate and maintain. However, there is not sufficient water in the watershed to run this number of systems. The City of Durham has been unable to site even one of these facilities in the watershed.
- The designated uses of Falls Lake are being met. The City of Raleigh provides safe drinking water to over one-half million customers. The lake is used for swimming, boating, and recreation with no closures associated with nutrients or algae. The NC Department of Environmental Quality has

not had a report of a nutrient-related fish kill since the 1980s after the lake was filled. For more information, see Table 1 of Key Findings of the Lake Monitoring.

- The three major wastewater treatment plants (WWTPs) in the watershed are limited by the nitrogen allocations in the Falls Rules to discharging approximately 60 percent of their permitted flow capacity under the Stage I nitrogen allocations. The nitrogen allocations for the WWTPs should be increased to allow use of their permitted capacity and correct previous errors in setting the allocations:
    - The nitrogen allocations in the Falls Rules are based on loads discharged in 2006 when facilities were discharging one-fourth to one-third of their permitted flow capacity. These allocations are based on DWR's models that represent a historic drought for the area. The upper part of Falls Lake dried to the historic river channel during this period. The allocations for the Neuse Estuary were based on permitted flows and an assumed effluent nitrogen concentration of 3.5 milligrams nitrogen per liter (mg-N/L).
    - Tributary chlorophyll-a data was not available when DWR developed their model. The modelers assumed that the chlorophyll-a concentrations in the tributaries were the same as the nearest lake station. This assumption resulted in overestimation of chlorophyll-a concentrations entering Falls Lake and limited the ability of the models to predict changes in chlorophyll-a from nutrient load reductions, particularly during drought conditions. As chlorophyll-a is the regulatory driver for the Falls Lake Rules, the UNRBA prioritized collection of this data and confirmed concentrations in the free-moving tributaries are much lower than those in the lake.
    - Requiring nitrogen reductions of 20 percent under Stage I and 40 percent under Stage II when flows were a small fraction of permitted capacity results in untenable limitations to service. Sufficient nitrogen credits are not available to offset the difference in loading between the allocations and their permitted capacity. A moratorium on growth is not economically or politically viable.
    - The WWTPs were designed and constructed decades ago to treat their permitted hydraulic capacity. The local governments and utilities are still financing the original construction loans.
    - As a result of the Falls Rules, the WWTPs were upgraded to five-stage biological nitrogen removal (BNR, currently the best available technology). The local governments and utilities are still financing these upgrades. The largest facility upgraded to BNR in 1995 to comply with the Neuse Estuary Rules. This upgrade to BNR prior to the Falls Rules limits the additional reductions that could be achieved to comply with the Falls Rules have a baseline year of 2006.
    - DWR's 2010 Fiscal Note for the Falls Rules assumed that the WWTPs would be able to meet the allocations at permitted flow capacity because new, more efficient technology would be developed. This assumption has not been realized. The characteristics of nutrients in wastewater and the available treatment processes limit how low effluent concentrations can be treated. The WWTPs are currently achieving a very high level of treatment that represents best achievable treatment efforts (greater than 96 percent

nitrogen removal). The only theoretically available treatment technology is reverse osmosis (RO), but it is not feasible for the following reasons:

- RO generates a waste stream that contains high concentrations of nutrients, metals, "forever" chemicals, and other pollutants. The waste stream is approximately 10 percent of the treated flow, or nearly 3 MGD for these facilities at their combined permitted flow capacity.
- In other locations, where the primary application of this technology is used for salinity removal for the development of water supplies, the waste stream is discharged to the ocean for its dilution capacity. The Falls facilities are too far away for that to be an option, and ocean outfalls in NC are generally prohibited.
- Constructing RO plants would cost at least $300 million in construction costs and approximately $10 million per year in operating costs.
- The UNRBA lake water quality modeling shows that at permitted capacity, implementing RO versus BNR offers insignificant reduction in chlorophyll-a. Even in the upper lake where chlorophyll-a concentrations are the highest and most responsive to nutrient inputs, the model usually predicts the same chlorophyll-a concentrations whether assuming RO or BNR effluent concentrations. There are some periods in the upper lake where the chlorophyll-a is marginally higher under BNR compared to RO, but these differences are short term and do not impact the lower half of the lake (slides 27 to 55 of the September 2025 PFC Meeting).

  - The projected increase in nitrogen loading to Falls Lake at permitted flow using BNR compared to the conditions observed in 2015 to 2018 is approximately 167,000 pounds of nitrogen per year. The annual variability in nitrogen loading caused by rainfall is over 1.1 million pounds per year (comparing delivered load to the lake in 2017 to 2018). The simulated increase in nutrient loading from the WWTPs and the expected impacts on chlorophyll-a are dwarfed by the changes in non-point source loading.
  - The increase in loading from the WWTPs would occur incrementally over time. Following BNR, most of the nitrogen discharged is not biologically available. DWR will continue to monitor nutrients and chlorophyll-a in Falls Lake. If monitoring indicates that lake water quality is worsening as loading increases, the Rules provide the opportunity to revise the nutrient management strategy. Given that the loading is a fraction of rainfall-driven variability, it is unlikely that impacts will be detected considering the inherent variability of environmental data.

- Prior to the next rules readoption cycle, a Falls Lake site-specific chlorophyll-a standard should be developed. The standard should reflect attainment of designated uses and should consider the feasibility, costs, and benefits of attaining both the current and a site-specific chlorophyll-a standard.

Table 1. Components of the UNRBA's Re-examination Relative to the Requirements of the Falls Lake Rules	
UNRBA Work Products	Required under Item (5)(f) or Additional: Description of Work Product
INITIAL EVALUATIONS TO SUPPORT PLANNING FOR THE RE-EXAMINATION	
Task 1-Develop a Framework for a Reexamination of Stage II of the Falls Lake Nutrient Management Strategy	ADDITIONAL: The UNRBA's Task 1 TM summarized the conditions of Falls Lake with respect to its designated uses. It also included an evaluation of DWR's 2010 Fiscal Note for the Rules. The fiscal evaluation showed that many aspects of the current Falls Rules are not feasible. For example, the existing development rule requires treatment of each acre by at least two stormwater control measures. Site constraints on existing development often limit treatment by even one stormwater control measure. The 2010 Fiscal Note also assumed that the three largest WWTPs would be able to meet the Stage I and Stage II nutrient allocations at their permitted flow capacity due to development of new treatment technologies. This assumption has not been realized. The best current technology is five stage biological nitrogen removal (BNR) and chemical coagulation to treat phosphorus. These technologies rely on physical, biological, and chemical processes that can only reduce effluent concentrations down to a certain level.
Task 2-Review Existing Data and Reports to Summarize Knowledge of Falls Lake and the Falls Lake Watershed	ADDITIONAL: The Task 2 TM summarized the available data and information for Falls Lake from 1999 to 2012. It compared data distributions by year, organization, analysis method, lake unit, and sampling depth. Annual distributions showed that water quality in the lake cycles up and down, particularly for chlorophyll-a and total organic carbon. Data gaps to address prior to future modeling by UNRBA were also identified.
Task 3-Review Methods for Delivered and Jurisdictional Nutrient Loads	ADDITIONAL: The Task 3 TM reviewed methods to estimate the existing development nutrient load reduction requirements to meet the Stage I and Stage II requirements for each jurisdiction in the Falls Watershed. The Task 3 TM also identified sources of nutrient loading to Falls Lake that would benefit from additional research including onsite wastewater treatment systems, streambank erosion, and internal loading from lake sediments. The NC Collaboratory conducted research studies on these three sources of loading. UNRBA, NC Collaboratory, and US EPA conducted research studies on internal loading from lake sediments.
Task 4-Recommend Future Monitoring and Modeling Approaches	ADDITIONAL: The Task 4 TM reviewed existing Falls Lake and watershed models and summarized recommendations for future studies to support the re-examination. The lack of chlorophyll-a data in the tributaries draining to Falls Lake was identified as an important data gap. When DWR developed their models, this data was not available. DWR assumed that tributary concentrations were equal to the nearest lake station. This assumption resulted in overestimation of chlorophyll-a concentrations entering Falls Lake and limited the ability of the models to predict changes in chlorophyll-a from nutrient load reductions. As chlorophyll-a is the regulatory driver for the Falls Lake Rules, the UNRBA prioritized collection of this data and confirmed concentrations in the free-moving tributaries are much lower than those in the lake. This TM also reviewed estimates of delivered nutrient loading to Falls Lake from three models. Two of the available models included similar estimates (USGS SPARROW model and the time series inputs for DWR's Environmental Fluid Dynamics Code (EFDC) model). A third model developed by DWR was the Watershed Analysis Risk Management Framework (WARMF) model. DWR's WARMF model under predicted nitrogen and phosphorus loading to Falls Lake by almost half and could not be used to develop the inputs for DWR's Falls Lake EFDC model. Subsequent evaluations by the UNRBA showed that DWR's nutrient loading estimates were likely low due to underprediction of loading from forested areas which comprise most of the watershed and deliver about half of the nutrient loading to Falls Lake. Monitoring studies conducted in the Falls Watershed by the US Forest Service (USFS) provide estimates of nutrient loading. When UNRBA developed its WARMF watershed model, the modelers used the USFS studies to ensure that the model predicts reasonable nutrient loads from forested areas. The Task 4 TM also described several watershed and lake models for consideration by the UNRBA to develop for the re-examination.

Table 1. Components of the UNRBA's Re-examination Relative to the Requirements of the Falls Lake Rules	
UNRBA Work Products	Required under Item (5)(f) or Additional: Description of Work Product
OBTAIN DIVISION REVIEW & APPROVAL OF ANY MONITORING STUDY PLAN & DESCRIPTION OF THE MODELING FRAMEWORK	
DWR-Approved UNRBA Monitoring Plan (2014)	REQUIRED: The UNRBA Monitoring Program document describes the purpose of the monitoring program, the locations of 38 monitoring stations in the watershed, the frequency of monitoring, and the parameters. It also describes the special studies the UNRBA was planning or considering. The monitoring plan was revised when data showed strong correltions between parameters that could result in cost savings for the Association.
DWR-Approved UNRBA Monitoring Quality Assurance Project Plan (2014)	REQUIRED: The UNRBA Monitoring Quality Assurance Project Plan (QAPP) specified the quality assurance procedures required for the field and laboratory activities and specified the tolerances for accepting reported data.
DWR-Approved UNRBA Description of the Modeling Framework (2014)	REQUIRED: The 2014 Description of the Modeling Framework helped guide the development of the UNRBA Monitoring Program and how it would support modeling.
Conceptual Modeling Plan (2017)	ADDITIONAL: The 2017 Conceptual Modeling Plan described the linkages among the UNRBA's multi-modeling approach and how they would be used to support the re-examination.
Model Selection Criteria (2016) and Model Selection Package (2017)	ADDITIONAL: The UNRBA began its intensive stakeholder engagement process during the planning phase of the re-examination. For example, stakeholders identified model selection criteria and used weighting to select the models to be developed by the UNRBA. The WARMF watershed model was ultimately selected because it is the same model that had been used by DWR and because it is capable of estimating nutrient loading from streambank erosion. Another benefit of the WARMF watershed model is that the modeler does not specify the nutrient loading parameters for each land use. Rather, the modeler specifies the amount and timing of nutrient application, plant growth and harvesting cycles, and the rates of physical, chemical, and biological processes in the system. Most other watershed models require the user to specify pollutant build-up by land use, nutrient concentrations running off the land surfaces, or concentrations moving through the groundwater system. Without monitoring data to confirm these assumptions are valid at the land use scale, the models are based on assumptions that rely on literature values for other areas of the country. The WARMF model also includes a lake modeling component to simulate the large impoundments in the Falls Watershed as well as Falls Lake. This direct linkage allows the WARMF model to test the impacts that changes in the watershed may have on lake water quality. The UNRBA opted to develop multiple lake models to provide multiple lines of evidence to support revised rules. The EFDC lake model was selected as a more complex hydrodynamic, water quality model. This model was partly selected because it had been used previously by DWR to establish the required nutrient load reductions for Falls Lake.
MODELING CONDUCTED IN ACCORDANCE WITH THE QUALITY ASSURANCE REQUIREMENTS OF THE DIVISION	
DWR-Approved UNRBA Modeling Quality Assurance Project Plan (2018)	REQUIRED: The UNRBA Modeling QAPP described the development and calibration approach for each model including the monitoring locations, parameters, and acceptable differences between the model predictions and observations.
SUPPLEMENTAL MODELING SHALL INCLUDE A MINIMUM OF THREE YEARS OF LAKE WATER QUALITY DATA	
UNRBA 2019 Monitoring Report (4+ years of data which exceeds the 3-year minimum)	ADDITIONAL: The 2019 UNRBA Monitoring Report summarizes the data collected by the UNRBA over its four-year monitoring program as well as data collected by other organizations. The report also includes summaries of the special studies that the UNRBA conducted in the watershed and the lake (studies plans available here: https://unrba.org/resource-library). The monitoring program confirmed that chlorophyll-a concentrations entering the lake from tributaries are generally much lower than that in the nearest lake station except for small tributaries discharging from wetlands on the north side of Falls Lake where water is often stagnant.

Table 1. Components of the UNRBA's Re-examination Relative to the Requirements of the Falls Lake Rules	
UNRBA Work Products	Required under Item (5)(f) or Additional: Description of Work Product
UNRBA Database and links to other organizations that collect data in the Falls Watershed: https://unrba.org/resource-library)	The monitoring program also confirmed that most of the total organic carbon loading to Falls Lake originates from the watershed, not growth of algae in the reservoir. The 2019 Monitoring Report also summarizes the impacts of reservoir residence time on chlorophyll and provides estimates of nutrient loading from the lake sediments. The report also demonstrates that most of the nutrients in Falls Lake are contained in algal cells, not as available nutrients in the water column. The 2014 to 2018 nutrient concentrations observed during the UNRBA study period were relatively low and decrease in the downstream direction. The 2019 monitoring report also summarized the algal species data and available algal toxin data for Falls lake. Algal toxins are not present in Falls Lake at concentrations that exceed recreational or drinking water standards. Two key findings documents have been developed to summarize the watershed and lake monitoring data. Dr. Martin Lebo has also developed an evaluation of lake monitoring data with respect to a potential site specific chlorophyll-a standard (link).
SUBMITTAL OF SUPPLEMENTAL MODELING DATA, PRODUCTS, AND RESULTS	
UNRBA Watershed Modeling Report (2023)	REQUIRED: The UNRBA Watershed Modeling Report summarizes the model development, processing of input data, model calibration, and performance compared to observed flows and water quality in the tributaries. Several scenarios testing the impacts of changing rainfall, atmospheric deposition, and converting all of the land to forests are also summarized. Key findings of the watershed modeling are summarized here.
UNRBA Lake Modeling Report (2024)	REQUIRED: The UNRBA Lake Modeling Report summarizes the model development, processing of input data, model calibration, and performance compared to observed lake water quality data for WARMF Lake and EFDC. Long-term data and nutrient loading estimates were also input into a statistical/Bayesian model that is summarized in the UNRBA Lake Model Report. Results of the watershed model scenario and reductions in nutrient loading as percentages are also summarized. Key findings of the lake modeling are summarized here.
Submittal of modeling files to DWR (2023)	REQUIRED: The WARMF watershed and lake modeling files were submitted to DWR in May 2023. The EFDC lake modeling files were submitted to DWR in December 2023.
DWR Model Trainings	ADDITIONAL: UNRBA hosted a WARMF watershed and lake model training for DWR in February 2023 and an EFDC lake model training in November 2023.
Letters requesting approval of the watershed and lake models by the EMC and DWR (Attachment B)	REQUIRED: UNRBA watershed model report submittal letter dated December 20, 2023 UNRBA lake model report submittal letter dated December 10, 2024
STAKEHOLDER ENGAGEMENT TO INFORM RE-EXAMINATION STUDIES	
UNRBA Modeling and Regulatory Support Workgroup (MRSW)	ADDITIONAL: In 2019, the UNRBA began to hold MRSW meetings to discuss model development with internal and external stakeholders on a more frequent basis. The MRSW included modeling staff from DWR and subject matter experts funded through the NC Collaboratory. Modeling assumptions, processing of input data, model calibration, and development of scenarios were coordinated through the MRSW. These meetings continued through early 2023 until the models (watershed and lake) were finalized and approved by the MRSW.
UNRBA Path Forward Committee (PFC) and Board of Directors (BOD)	ADDITIONAL: The UNRBA PFC meets once per month, and the BOD meets six times per year (https://unrba.org/meeting). The PFC and BOD meetings are open to the public. Throughout the re-examination, status updates, modeling progress, and model approval for submission to DWR and the EMC have been vetted through these UNRBA groups.

Table 1. Components of the UNRBA's Re-examination Relative to the Requirements of the Falls Lake Rules	
UNRBA Work Products	Required under Item (5)(f) or Additional: Description of Work Product
UNRBA Nutrient Study	ADDITIONAL: In 2014, the UNRBA began a project to expand the types of projects and activities that receive nutrient reduction credits. The Association worked with subject matter experts and stakeholders to develop credit documents. The UNRBA submitted these documents for review and approval by the State. The project included development of a Nutrient Credit Tool and User Guide to help local governments track compliance with nutrient reduction requirements. The Association also developed an analysis to understand how nutrients from different parts of the watershed reach Falls Lake. The UNRBA invested over $300,000 in this project. State agencies provided $70,000 in grant funds to support this work.
Developing An Innovative Approach to Nutrient Management	ADDITIONAL: The 2011 Rules require that local governments reduce nutrient loading from sites developed before 2012. This older development is difficult to treat. Roads, water lines, and buildings limit the use of newly constructed treatment devices. In the original 2011 Rules, only devices with NC-approved nutrient reduction credits counted toward compliance. Many beneficial actions improve water quality and reduce nutrients that do not have approved credits. In the past, these actions did not count toward compliance. In 2018, the UNRBA began exploring an alternative based on an idea proposed by environmental interest groups that proposed that beneficial actions should "count" toward compliance even without NC-approved credits. Their idea shifted the focus from tracking nutrients to implementing beneficial projects. The UNRBA worked with stakeholders and DWR for three years to develop the investment-based compliance program called the Stage I Existing Development Interim Alternative Implementation Approach (IAIA). This program was approved by the EMC in 2021. UNRBA members have exceeded investment requirements during every year of implementation as illustrated by the Year 4 Annual Summary Report.
2016 Technical Stakeholder Workshop	ADDITIONAL: Reviewed past efforts, current efforts, and future activities regarding Falls Lake monitoring and modeling studies.
2017 Technical Stakeholder Workshop	ADDITIONAL: UNRBA described the watershed models and necessary data to build the models. UNRBA reviewed its data acquisition request form, and stakeholders provided feedback on available data and transmittal methods to support the UNRBA modeling.
2018 Technical Stakeholder Workshop	ADDITIONAL: UNRBA presented the status of model development and requested feedback from stakeholders on what questions they wanted the models to be able to answer. This feedback helped guide how model results were summarized in the reporting and which scenarios were evaluated.
2020 Regulatory Forum.pdf	ADDITIONAL: The UNRBA hosted a forum for elected officials to summarize the current Falls Rules and provide a status update on the re-examination effort. Participants were asked what information would be needed to inform their decision-making regarding nutrient management.
2021 FLNMS Symposium Agenda and Video Links for Virtual Meeting	ADDITIONAL: The UNRBA provided a status update on the re-examination. Researchers funded through the NC Collaboratory presented on each of their Falls Watershed and Lake studies.
2022 Joint Symposium with the NC Collaboratory	ADDITIONAL: The UNRBA summarized findings from the monitoring and modeling studies. NC Collaboratory researchers provided updates on their research studies.
2023 Technical Stakeholders Workshop	ADDITIONAL: UNRBA summarized the watershed and lake modeling development, calibration, and results of model scenarios. The UNRBA also summarized key findings of the monitoring and modeling studies and shared their concepts and principles for developing revised Falls Lake Rules. Participants provided feedback on how the findings should be incorporated into a revised nutrient management strategy for Falls Lake.

Table 1. Components of the UNRBA's Re-examination Relative to the Requirements of the Falls Lake Rules	
UNRBA Work Products	Required under Item (5)(f) or Additional: Description of Work Product
2024 UNRBA and DWR Joint Forum on Falls Lake	ADDITIONAL: UNRBA and DWR hosted a joint forum for election officials. UNRBA summarized its re-examination efforts, key findings, and implications for a revised nutrient management strategy. The UNRBA presented its plan to draft rule language through an intensive workgroup process followed by review and approval by the PFC and BOD. DWR provided background and an anticipated schedule for the rules readoption process.
2024-2025 UNRBA Rule Workgroup Process	ADDITIONAL: In December 2024, the UNRBA formed four rule workgroups to draft language for broader stakeholder review. In addition to UNRBA members, the workgroups included key external stakeholders that would be impacted by the rules. The UNRBA hosted 19 working meetings through April 2025 during which the workgroups reviewed iterative drafts and provided feedback. At the conclusion of the workgroup process, the drafts were distributed to the PFC who reviewed iterative drafts from May to August 2025 and to the Board and PFC who reviewed iterative drafts in September through November 2025.
UNRBA RECOMMENDATIONS FOR REVISED FALLS LAKE RULES	
Concepts and Principles for the UNRBA Recommendations for a Revised Falls Lake Nutrient Management Strategy	ADDITIONAL: This document summarizes the history of Falls Lake and the Rules as well as pre-construction environmental assessments. The document summarizes the results of the UNRBA's monitoring and modeling studies as well as other organizations including DWR and the NC Collaboratory. The UNRBA and stakeholders framed a revised nutrient management strategy for the watershed and lake. The strategy builds on the EMC-approved Stage I Existing Development Interim Alternative Implementation Approach (IAIA). The strategy also recognizes the progress made to reduce nutrient loading to Falls Lake and the subsequent improvements to lake water quality. The infeasibility of further significant nutrient reductions is discussed.
Consensus Principles II	ADDITIONAL: Through its extensive stakeholder process, the UNRBA developed 16 "consensus principles" to guide the Association's efforts to draft revised Falls Lake Rules and to ensure long-term protection Falls Lake. The UNRBA Board of Directors and each member's local board or council **unanimously approved** Consensus Principles II.
THE DIVISION SHALL ASSURE THAT THE SUPPLEMENTAL MODELING IS CONDUCTED IN ACCORDANCE WITH THE QUALITY ASSURANCE REQUIREMENTS OF THE DIVISION	
DWR Confirmation that UNRBA Models Were Developed According to the QAPP (Attachment C)	REQUIRED: Email from Karen Higgins, DWR, July 31, 2024, confirming the DWR modeling staff had reviewed and confirmed the UNRBA watershed model and reporting followed the QAPP Email from John Huisman, DWR, February 12, 2025, confirming the DWR modeling staff had no further comment on the UNRBA lakes models or report and that his email closes the loop "officially"

Table 2. Key Findings of UNRBA's Re-examination and Implications for a Revised Falls Lake Nutrient Management Strategy	
Key Finding	Implication
Nutrient loading to Falls Lake was two to three times higher in the 1980s than it is today. Nutrient reductions resulting from the Clean Air Act, phosphate detergent ban, upgrades at WWTPs, and investment in watershed-health projects have resulted in reduced loading to Falls lake. Implementation of the New Development Rule since 2011 has mitigated loading increases from development.	Comparable reductions in nutrient loading to the reservoir are unlikely on the scale that has been seen since the 1980s. The UNRBA's proposed Falls Rules continue the new development rule, operation of the three largest WWTPs with five-stage biological nutrient removal and increased chemical coagulation, and investment in watershed health projects to incrementally improve water quality across the watershed.

Table 2. Key Findings of UNRBA's Re-examination and Implications for a Revised Falls Lake Nutrient Management Strategy	
Key Finding	**Implication**
Nutrient concentrations and chlorophyll-a concentrations in Falls Lake were much higher and more variable in the 1980s as a result of the higher nutrient loads to the lake. As nutrient loads to Falls Lake declined, water quality has improved and stabilized. However, loading to Falls Lake will always be a reality. Sediments in Falls Lake store, cycle, and release nutrients and take decades to respond to changing inputs from the watershed.	Falls Lake is stable, and conditions are unlikely to change dramatically unless loading reverts back to conditions from the 1980's. The UNRBA's proposed Falls Rules aim to maintain this stable condition and expand tracking and reporting of progress to include a stability metric and evaluation of designated uses in addition to water quality standards.
Land use in the Falls Watershed is 75 percent unmanaged including forests, wetlands, and unmanaged grassland.	Following the significant reductions that have already been achieved, few opportunities remain to further reduce nutrient loading to Falls Lake. The UNRBA's proposed rules include a multifaceted approach to invest in watershed health, conserve unmanaged lands, and mitigate impacts from new development.
Nutrient loading to Falls Lake is heavily driven by precipitation and antecedent moisture conditions. From 2017 to 2018, nitrogen and phosphorus loading to Falls Lake more than doubled when annual rainfall increased from 45 inches per year to 60 inches per year.	Nutrient load allocations from the watershed are only relevant with respect to hydrologic conditions. The 2011 Falls rules include load allocations that are based on conditions observed during a severe drought. The nutrient loading to Falls Lake during that period occurred when rainfall was as low as 37.5 inches per year. The UNRBA's proposed rules include an investment-based compliance approach that focuses on implementation of watershed health projects rather than estimating nutrient reductions and loading that varies from year to year.
There is little correlation between nutrient loading and chlorophyll-a concentrations in Falls Lake. The UNBRA compared long-term data and estimates of nutrient loading to Falls Lake to determine what factors best predicted chlorophyll-a levels. Nutrient loading to the lake and nutrient concentrations in the lake only improved chlorophyll-a predictions by less than four percent. High nutrient loads are often delivered by high rainfall events that move water through the reservoir quickly. Algae thrive in stagnant, warm conditions.	Further reducing nutrient loading to Falls Lake is unlikely to significantly impact chlorophyll-a concentrations. Hydrologic and climatologic conditions have more impact and are beyond the control of the regulated entities in the watershed. The UNRBA's proposed rules seek to manage nutrients to the best of their ability using currently available technologies and investment in watershed health.
The UNRBA used its watershed and lake models to evaluate lake water quality under an "all forest" scenario where all of the land was converted to forest, discharges from onsite and centralized wastewater treatment systems were removed, and no nutrient application except from atmospheric deposition was simulated. This hypothetical scenario showed that the chlorophyll-a standard would still not be met in all parts of Falls Lake. The UNRBA models also showed that reducing all nutrient loading to Falls Lake by 50% would be required to possibly meet the chlorophyll-a water quality standard. This 50% reduction would include treating loading from	Exceedances of the chlorophyll-a standard are due to hydrologic modification caused by construction of the dam. Removing the dam and returning Falls Lake to its natural condition is not an option for this region. The proposed rules developed by the UNRBA include a provision to develop a site-specific chlorophyll-a standard for Falls Lake. This standard development process should include the impacts of nutrient loading, residence time, and other factors on chlorophyll-a concentrations in Falls lake; the impacts of chlorophyll-a on designated uses; and the social and economic burden of further reducing nutrient loading to Falls Lake relative to the benefits including incremental changes in water quality.

Table 2. Key Findings of UNRBA's Re-examination and Implications for a Revised Falls Lake Nutrient Management Strategy	
Key Finding	Implication
forests. If converting all the land in the watershed to forests and removing nutrient inputs cannot meet the water quality standard, then water quality standard cannot be met in Falls lake under any condition.	
UNRBA modeling shows that increases in nutrient loading within a reasonable range do not negatively impact water quality. For example, increasing the nutrient loading from WWTPs in the watershed at levels that would allow for permitted flow and 3 milligrams per liter of total nitrogen (mg-N/L) and 0. 1 milligrams per liter of total phosphorus (mg-P/L) only cause slight increases in chlorophyll-a and only in the upper part of the lake. Comparing these predictions to a scenario where effluent nitrogen concentrations are around 1.1 mg-N/L and phosphorus concentrations are around 0.06 mg-P/L (Stage II requirements), the resulting difference in chlorophyll-a is less than the allowable tolerance range for duplicate samples. The differences in chlorophyll-a would have no impact on designated uses which are currently being met. The Falls Rules require further upgrades to reverse osmosis when WWTPs approach their permitted capacity to achieve both the Stage I and Stage II requirements in the Falls Rules. Reverse osmosis is not technically feasible because it generates a highly concentrated waste stream that cannot be reasonably disposed.	WWTPs are still financing construction of the original plants and subsequent upgrades to five stage biological nutrient removal. These facilities should be able to use their permitted flow capacity pursuant to 15A NCAC 02T .0118 at concentrations that are achievable with the current technology. The UNRBA's proposed rules currently include use of 100 percent of permitted flow capacity at currently achievable technology and investment of $500,000 per year in watershed health projects to offset incremental increases in nutrient loading. UNRBA and DWR continue to discuss the allowable wasteload allocations.

ATTACHMENT A:
SUMMARY OF STUDIES AND EVALUATIONS
APPLIED TO THE UNRBA WATERSHED AND LAKE MODELS

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	**Date Range and Location**	**Organization**	**Summary of Results or Link to Data**	**Applicability**
WATERSHED STUDIES, TRIBUTARY AND LAKE DATA, AND TRIBUTARY LOADING EVALUATIONS TO FALLS LAKE				
Compilation of watershed and lake data to support planning for the reexamination	1999 to 2012 Watershed and Falls Lake	DWR, USGS, Local Governments,	UNRBA review of water quality data for Falls Lake and the Watershed by organization, sampling depth, month, year, etc. (Task 2 Report)	While this evaluation period does not overlap with the UNRBA Study Period, previous DWR sampling included water quality sampling at deeper depths in the water column. Distributions of past water quality summarized by depth provide a reasonableness check on EFDC and WARMF Lake simulations relative to predicted water quality in the bottom layers.
Measurement of nutrients, TSS, and total organic carbon from forested areas	2008 to 2013, forested headwater catchments in the Falls Lake watershed	US Forest Service	Measured loading rates from forested areas and comparison to simulated loading rates under varying rainfall conditions is provided in the UNRBA WARMF Watershed Modeling Report. Published data are available in Boggs et al. (2012).	While this evaluation period does not overlap with the UNRBA Study Period, these studies were used to provide a reasonableness check on WARMF-simulated loading rates for forested areas. When WARMF was evaluated for similar rainfall conditions to the Forest Service monitoring studies conducted in the Falls Lake watershed, simulated rates were similar to measured rates (baseflow and storm event runoff).
Tributary water quality monitoring to support UNRBA watershed model development	Aug. 2014 to Oct. 2018, Watershed and Falls Lake	UNRBA Routine Monitoring	Data summarized in the UNRBA 2019 Annual Report Raw data are available on the UNRBA Resource Library.	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Tributary high flow sampling to support UNRBA watershed model development	Grab sampling targeting precipitation events on largest 5 tributaries or corresponding with routine monitoring events, Aug 2014 to Dec. 2018	UNRBA Special Study	Distribution of concentrations by flow percentile in the 2019 Annual Report in Section 3.4.1; and partial results summarized in a different format in Results summarized in the 2016 Annual Report, Section 4.2	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.
Tributary storm event sampling to support UNRBA watershed model development	Automated samplers deployed April, September, and October 2015 on Ellerbe Creek and Eno River capturing four or more distinct storm peaks for each tributary.	UNRBA Special Study	Results summarized in the 2016 Annual Report, Section 4.1	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.
Sediment and carbon inputs to Falls Lake	Flat River, Eno River, Little River and Ellerbe Creek August 2019 to March 2020	NC Collaboratory	Results summarized in McKee et al. (2023)	This study concludes that most of the particulate organic matter entering Falls Lake originates from soil organic matter, freshwater algae (likely from upstream impoundments) and fertilizer. The cores from Falls Lake only indicate soil organic matter in the carbon signature. Average sedimentation rates in Falls Lake from 0.7 cm/yr to 1 cm/yr. The study concludes that "If other reservoirs are similar in nature to Falls Lake, then the organic carbon accumulating in reservoirs (to offset growing CO2 concentrations in the atmosphere) is primarily from the carbon from reservoir watersheds which are better preserved and stored in reservoir bottom sediments. This conclusion is contrary to the idea that the source of the sedimentary carbon in bottom sediments results from the input of excess nutrients to reservoirs that results in large seasonal algae blooms and low oxygen waters." For Falls Lake,

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
				the dominant source of carbon is from the watershed, and that is comprised mostly of soil organic matter.
Empirical estimates of loading to Falls Lake	1980's to present at four tributaries with historic data (Flat River, Eno River, Knap of Reeds, and Ellerbe Creek	DWR water quality data and USGS stream flow data	Summarized in the UNRBA Lake Modeling Report	Provides historic loading (total nitrogen and total phosphorus) to the UNRBA Statistical/Bayesian model
Historic water quality measurements.	Several locations in Falls Lake and the watershed	DWR and USGS data	EPA Water Quality Portal	Historic lake data used to evaluate long-term trends in Falls Lake. Historic water quality data from the watershed used to develop annual average ratios of total organic carbon to total nitrogen to develop historic loading estimates of total organic carbon from the historic loads of total nitrogen described in the previous row.
WARMF simulated loading to Falls Lake	2014 to 2018 for seventeen tributary inputs	UNRBA Watershed Model	Summarized in the UNRBA Watershed Modeling Report	Simulated stream flows and water quality concentrations provide input to EFDC, WARMF Lake, and the UNRBA Statistical/Bayesian model
CBOD5 in lake loading in lake samples	August 2014 to December 2015 for seventeen tributary inputs	UNRBA Routine Monitoring	Data summary provided in the UNRBA 2016 Annual Report, Section 3.2 (parameter discontinued the following year) Raw data are available on the UNRBA data portal available in the UNRBA Resource Library.	Approximately 95 percent of the organic material entering Falls Lake is in the dissolved form; see description of development of labile and refractory constituents for EFDC model in Appendix A
Falls Lake profile data	2014 to 2018	DWR, CAAE, City of Durham	DO summarized in the 2019 Annual Report in Section 5.1.7.4;	Profile data used in EFDC and WARMF Lake for model calibration to ensure appropriate simulation of thermal stratification
Falls Lake UV254 and absorbance data	August 2014 to - October 2018	UNRBA Routine Monitoring	Included each year with 2014 to 2018 summarized in the 2019 Annual Report in Section 3.3.2	Provides additional lake data to support the evaluation of disinfection byproduct formation simulated in the UNRBA Falls Lake Statistical/Bayesian model

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
LAKE BATHYMETRY, LAKE SEDIMENT EVALUATIONS, INTERNAL LOADING FROM LAKE SEDIMENTS, and ATMOSPHERIC DEPOSITION TO SURFACE OF FALLS LAKE				
UNRBA Falls Lake bathymetry and sediment depth study (Water Cube)	Falls Lake, 2016	UNRBA Special Study	Results summarized in the UNRBA 2019 Annual Report in Section 5.4	Data used to establish the EFDC model grid and the WARMF Lake segments and to estimate the thickness of sediment across the bottom of Falls Lake
Quantifying sediment nutrient processing in Falls Lake (Dr. Michael Piehler)	Between July 2019 and August 2022, a series of sampling campaigns were conducted along a transect of 6 main channel stations and at 10 creek arm sites to measure N2 fixation and the biological, physical, and chemical characteristics at each site.	NC Collaboratory	Results summarized in final report (NC Collaboratory 2023), Piehler (2020), and Smiley et al. (2023). Researchers conclude that 1) policies aimed at reducing anthropogenic nitrogen inputs could mitigate water quality degradation to some extent but will likely not prevent algal blooms completely and that 2) excess nitrogen may be a characteristic of urban reservoir systems, and water quality standards should reflect that.	Data informs simulation of nutrient processing in the EFDC and WARMF Lake models for Falls Lake. Research confirmed that nitrogen fixation was an insignificant component of the Falls Lake nitrogen balance (~1 percent) and omission of this source from the Falls Lake models would not introduce significant uncertainty. Researchers indicated that most of the nitrogen and phosphorus within Falls Lake are bound up in plankton biomass and that neither nitrogen nor phosphorus is available in great excess. The three lake models for Falls Lake developed by the UNRBA also indicate that nutrient concentrations are relatively low.
Falls Lake sediment nutrient release (DWR)	June 2006	DWR	Results summarized in the 2019 Annual Report	Similar results to more recent sediment flux evaluations conducted by DWR and UNRBA when adjusted for temperature
Falls Lake sediment quality and nutrient release study (Dr. Marc Alperin)	June 8 and 10, 2015; 27 locations in Falls Lake	UNRBA Special Study	Alperin (2018) summarized in the 2019 Annual Report in Section 5.5.	Data provides initial conditions of lakebed sediments for simulation in the EFDC and WARMF Lake models for Falls Lake; nutrient release estimates provide a reasonableness check on model simulations

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Falls Lake sediment nutrient release	June 2018	EPA	Flexner (2019) summarized in the 2019 Annual Report in Section 5.5.	Nutrient release estimates provide a reasonableness check on model simulations
Atmospheric deposition to the lake surface for the UNRBA Study Period	2014 to 2018 for nitrogen, phosphorus, and total organic carbon	UNRBA based on data from CASTNET, NADP, and NC State Climate Office	Summarized in the UNRBA Watershed Modeling Report	Provides estimates of wet and dry deposition for WARMF Lake and EFDC models. See UNRBA Lake Modeling Report for long-term estimates used for the UNRBA statistical/Bayesian model.
WATER BALANCE AND WATER MOVEMENT IN FALLS LAKE				
Flow and water quality at two Falls Lake constrictions	January 2016; Oct./Nov. 2016	UNRBA Special Study	January 2016 event: 2016 Annual Report, Section 4.5 Oct/Nov 2016 event: 2017 Annual Report, Section 4.2	Provides water movement and water quality data for comparison to simulated values during high flow conditions
In situ observational study of falls lake	ADCPs were deployed at 4 locations: I-85, Fish Dam/Cheek Road, Hwy 50, Hwy 98; Nov 2019 to Dec 2020 Temperature profilers deployed at 3 downstream locations; also collected PAR data and YSI measurements at deployment/ redeployment 11/2019 and 6/2020	NC Collaboratory	Results summarized by Luettich et al. (2023). The researchers report that residence time in Falls Lake can be as short as weeks and as long as 5 years. Residence times in the side arms due to the exchange flow vary between 4.6 to 16.4 days, with the shorter residence times more common during the summer months.	EFDC modelers compared simulated water movement and velocities for 2015 to 2018 to those measured by Dr. Luettich in 2019 and 2020 to confirm the general patterns, directions, and magnitudes of flow were consistent with observations.

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Evaluation of Falls Lake residence time	2014 to 2018	UNRBA	2014 to 2018 data summarized in the 2019 Annual Report in Section 5.8	Provides reasonableness check for EFDC and WARMF Lake and provides inputs to UNRBA Statistical/Bayesian model.
Precipitation, UNRBA study period	2015 to 2018 6-hour rainfall	NC State Climate Office	Summarized in the UNRBA Watershed Modeling Report	Provides 6-hour rainfall at 78 locations in the watershed for the watershed and lake models
Precipitation, historic record	1990 to 2020 at 60 stations with variable periods of collection	National Oceanic and Atmospheric Administration (NOAA)	Global Historical Climatology Network	Used to evaluate rainfall trends over time (rainfall depth, number of days of rain, wet and dry periods, identification of extreme events) for the UNRBA Statistical/Bayesian model.
Falls Lake water supply withdrawals	2005-2007, 2014-2018	City of Raleigh	Daily data provided by City of Raleigh	Used to develop daily time series of withdrawals for EFDC and WARMF Lake
Falls Lake water level	1991 to 2022, gages located at Beaverdam Dam and Falls Lake Dam	USGS	Beaverdam Creek at Dam Near Creedmoor, NC – 0208706575 Falls Lake Above Dam NR Falls, NC - 02087182	Both gages were used for hydrodynamic calibration of the EFDC model for the UNRBA Study Period (2015 to 2018); the Falls Lake gage was used for hydrologic calibration of WARMF Lake for the UNRBA Study Period. The long-term record at the Falls Lake Dam was used by the UNRBA Statistical/Bayesian model to generate daily average, annual average, monthly variation, 30-day rolling average, and daily change in water level data inputs.
Falls Lake dam releases	1983 to 2023	USGS	Neuse River Near Falls, NC - 02087183	Used to specify the discharge from Falls Lake to the Neuse River for the WARMF Lake and EFDC models
LIGHT EVALUATION AND PHOTOSYNTHESIS				
Light attenuation and Secchi depth data collected within Falls Lake	Mid 1980s to early 1990s and 3 locations in Falls Lake, October 2015	DWR	Results summarized in the 2016 Annual Report, Section 4.7; Light Attenuation Falls of the Neuse Reservoir 10-2015.pdf; Model Evaluation Report, Section 3.1.3	Confirms assumption that the photic zone can be reasonably approximated as twice the Secchi depth; provides information on background light extinction in Falls Lake for EFDC and WARMF Lake

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Jordan Lake - Effects of nutrient and light limitation on phytoplankton dynamics	Jordan Lake, July 2017 to June 2018	NC Collaboratory	Results summarized by Paerl and Hall (2019)	While this study was not conducted on Falls Lake, this evaluation of photosynthesis rates, light saturation, and shade adaptation provides a reasonable starting point for calibration of these rates for the Falls Lake EFDC and WARMF Lake models.
LAKE PROCESSES, ALGAL SPECIES, AND ALGAL GROWTH				
Cyanobacterial N2 fixation and denitrification in Falls Lake	July 2019 and early July 2020: Profiles of temperature, conductivity, dissolved oxygen, pH; Photosynthetically active radiation (PAR); Photic zone composite nutrient and silicate samples; chlorophyll-a, taxa, POC and PON	NC Collaboratory	Results summarized by Hall and Paerl (2023): "Based on the mass balance and direct core measurements of denitrification it appears that denitrification exceeds N2 fixation and that the balance of these microbial processes result in a net loss of N from Falls Lake. Net loss of N could help maintain N limited phytoplankton which is consistent with N limited growth observed in nutrient addition experiments conducted in spring and summer 2021. Most of the N and P within Falls Lake are bound up in plankton biomass. P is not available in great excess and appears to be an important constraint on N2 fixation. This situation of N limitation but with the potential for stimulation of N2 fixation by P suggests that dual management of N and P is warranted for preventing undesirable levels of phytoplankton biomass in Falls Lake.	Provides information to set initial reaction rates in WARMF Lake and EFDC pertaining to nitrogen reactions
Evaluation of nutrient limitation	Using UNRBA routine monitoring data (2014 to 2018)	UNRBA	Data summarized in the 2019 Annual Report in Section 5.9	Provides context for evaluating simulations by WARMF Lake and EFDC along with NC Collaboratory research studies
Evaluation of DWR EFDC model sensitivity to lability	The lability of POC was an assumed parameter for DWR's 2006 EFDC model, along with the assumption that 50 percent of all	UNRBA evaluation of DWR model	Model Evaluation Report, Section 3.1.2	Provides information regarding previous EFDC model. UNRBA routine Monitoring has since shown that POC accounts for only about 5 percent of the organic carbon entering Falls Lake.

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
	incoming carbon was delivered in particulate form (as POC). Assumptions used by DWR to build their Falls Lake EFDC model and relevant data to consider			
Algal species data	Three locations in Falls Lake monthly	DWR	2014 to 2018 data summarized in the 2019 Annual Report in Section 3.3.2; historic data summarized in Appendix D	Provides algal cell densities and biovolumes to determine seasonal trends in algal groups and support calibration of WARMF Lake and EFDC.
Assessment of Zooplankton-Phytoplankton Relationships in Falls Lake	Zooplankton data from Falls Lake were provided by Dr. Sandra Cooke. Zooplankton samples were collected at ten CAAE monitoring stations approximate monthly from 2009 to 2012. Chlorophyll-a was measured by CAAE using fluorometry.	NC Collaboratory	Results summarized by Hall and Piehler (2023)	In 2021, EPA issued proposed models to calculate site-specific chlorophyll-a standards based on the relationship between phytoplankton (algae) and zooplankton (small organisms that eat algae and are eaten by small fish). The UNRBA had requested the raw zooplankton data for incorporation into the statistical/Bayesian model but was not able to obtain the data. Dr. Nathan Hall was able to obtain the data and evaluate the relationship proposed by EPA for Falls Lake and other southeastern reservoirs. He found the approach was not appropriate Falls Lake. For this reason, the statistical modeling team did not further pursue the raw zooplankton data.

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
ALGAL TOXIN DATA				
Falls Lake algal toxin data	Six locations, three toxins, 2007-2012, raw intake measurements; Monthly data collected at multiple stations from 2016 to 2018	City of Raleigh	2016 to 2018 data summarized in the 2019 Annual Report in Section 5.10	Provides data for the Statistical/Bayesian model regarding conditions in Falls Lake and concentrations of algal toxins
Cyanotoxin presence and year-round dynamics in Falls Lake	2019-2021 (toxin adsorption to SPATTs, toxin concentrations, field parameters)	NC Collaboratory	Results summarized by Schnetzer and Pierce (2023): "Maximal toxin concentrations from monthly collections did not exceed regulatory thresholds established by the World Health Organization. However, accumulated dissolved toxins were detected by passive in situ samplers. Algal biomass alone is not a reliable indicator of cyanotoxin exposure risk in Falls Lake."	Provides data for the Statistical/Bayesian model regarding conditions in Falls Lake and levels of algal toxins
One Health Harmful Algal Bloom System	Voluntary reporting by States, launched in 2016; data through 2020	Center for Disease Control (CDC)	Provides data on reported events in terms of environmental conditions, water quality and algae monitoring data, human health, and animal effects	Provides data for the Statistical/Bayesian model regarding conditions in other states that have reported human health events or animal incidents associated with harmful algal blooms and environmental conditions during the event
ADDITIONAL DESIGNATED USE DATA AND EVALUATIONS				
Reported fish kills	1986 to 2020, statewide database	NCDEQ	See additional description in UNRBA Lake Modeling Report	Used in the UNRBA Statistical/Bayesian model to understand water quality conditions when fish kills have been reported and to evaluate the aquatic life designated use
In lake fish type and quantity	Black crappie and largemouth bass every other year, alternating spring and fall depending on the	Wildlife Resource Commission (WRC)	Data provided to Ashton Drew via personal communication (K. Rundle, November 2021)	Data are collected every other year for each species, so not directly included in the UNRBA Statistical/Bayesian model which has been developed with monthly data. This data provides

Table A-1. Relevant Studies and Reports to Support UNRBA Falls Lake Modeling				
Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
	species; primarily in deeper part of lake			context when evaluating output from the UNRBA Statistical/Bayesian model.
Additional raw water characteristics (turbidity, manganese, pH, temperature)	2013 to 2018	City of Raleigh	Data discussed with E. Buchan on May 2022 and summarized in the UNRBA Lake Modeling Report; originally acquired by UNRBA for 2019 Annual Report	Used in the UNRBA Statistical/Bayesian model to understand how water quality conditions affect drinking water treatment.
Boat ramp study	2000; Falls, Jordan, and Kerr Lakes	Colorado State University	The purposes included documenting current use of the lake, determining boater perceptions of their visits, and identifying the nature and magnitude of boating conflicts (2013 USACE Falls Lake Master Plan)	The study found that boater experiences were being negatively impacted at peak periods of use by the high level of motorboat traffic on the reservoir. Provides context and background to the statistical/Bayesian model; not directly applied given it is a single survey.
Falls Lake recreational use assessment	2005 to 2015	UNRBA	Trips and trip types (2005 to 2015), facility limitations, summarized in the 2016 Annual Report, Section 4.9; Different data are summarized in the 2019 Annual Report in Section 5.11	Data are summarized annually, so not directly included in the UNRBA Statistical/Bayesian model which has been developed with monthly data. This data provides context when evaluating output from the UNRBA Statistical/Bayesian model.

ATTACHMENT B:
SUBMITTAL LETTERS FROM UNRBA TO EMC AND DWR FOR THE WATERSHED AND LAKE MODELS

UPPER NEUSE RIVER BASIN ASSOCIATION

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Town of Hillsborough

Orange County

Person County

City of Raleigh

Wake County

Town of Wake Forest

South Granville Water and Sewer Authority

Soil and Water Conservation Districts

Town of Stem

December 20, 2023, Submitted via email

Mr. John (JD) Solomon, Chair
NC Environmental Management Commission (EMC)
1611 Mail Service Center
Raleigh, N.C. 27699 -1617
e-mail: pamlicojd@gmail.com

Mr. Richard Rogers, Director
Division of Water Resources (DWR)
1611 Mail Service Center
Raleigh, NC 27699-1611
e-mail: richard.rogers@ncdenr.gov

Reference: UNRBA Submittal of the Falls Lake Watershed Model Report

Dear Mr. Solomon and Mr. Rogers:

The UNRBA is pleased to submit our Watershed Analysis Risk Management Framework (WARMF) model report for the Falls Lake watershed. This modeling effort and documentation support our previously submitted recommendations for a revised Falls Lake Nutrient Management Strategy and readoption of the Falls Lake Rules. Due to the file sizes of the report and appendices, please use this link to access the UNRBA Watershed Model Report. The UNRBA hosted a model training for staff at the Division of Water Resources (DWR) on the use of the model in February 2023 and provided the final modeling files and executable in April 2023. We note and appreciate the time and energy the DWR modeling and planning staff invested in this model development process. They attended multiple meetings and provided helpful input and comments.

Submittal of this report marks an important milestone in the UNRBA re-examination of the Falls Lake Nutrient Management Strategy (the "Strategy" or the "Rules"). This watershed modeling report serves the following purposes:

- Provides documentation that the development of the WARMF Watershed Model followed the UNRBA Modeling Quality Assurance Project Plan (QAPP) approved by DWR for this modeling effort.
- Supports the review and approval by DWR and the EMC of this WARMF Watershed model development report under Falls Lake Rule 15A NCAC 02B .0275.
- Provides an evaluation of the modeling results relative to the impacts of land use in the watershed, the distribution of nutrient loading, and the implications of those findings for a revised strategy.

The UNRBA has spent considerable resources to obtain data, work with subject matter experts, and build a calibrated model that reasonably simulates stream flows and nutrient loading to Falls Lake. The report and appendices document these

efforts in detail. The UNRBA presented the model development, calibration, and scenario analyses at least monthly at its status meetings from 2018 to 2023. The UNRBA hosted several technical stakeholder workshops to present findings to interested stakeholders. These status meetings and workshops were well attended by staff from member local governments, utilities, DWR, NC Department of Transportation, NC Department of Agriculture and Consumer Services, US Forest Service, researchers from the NC Collaboratory, and representatives from agricultural and environmental interest groups. The modeling report was reviewed and commented on several times by the stakeholders. The UNRBA and its consultant team worked diligently to address questions and input from all of these stakeholders. Based on this input, we refined and improved the watershed model. We also provided the draft modeling report to our stakeholders and this final report reflects their feedback. This committed level of vetting and transparency in addressing input on the modeling development process is reflected in Appendix H. This substantial component of the report reflects detailed and well-researched responses to all input provided.

Based on the significant coordination with stakeholders, the transparent model development process, and the iterative reviews and revisions to the watershed model report, the UNRBA respectively requests timely review and decision on approval of this submittal by DWR and the Commission.

The UNRBA submitted its recommendations for a revised nutrient management strategy to DWR and the Commission on November 15, 2023. The NC Collaboratory will submit its recommendations in December 2023. Receipt of these two sets of recommendations establishes the schedule for the DWR Falls Lake rules readoption process which must begin within six months of receipt of recommendations. Timely review and approval of the technical documents are critical for moving the rules readoption process forward.

If there are any questions about the watershed modeling report or information therein, please contact our Executive Director, Forrest Westall, using the contact information on this letterhead.

Sincerely,

Forrest Westall
Executive Director, UNRBA

Copy: UNRBA Board Members
Mr. Rich Gannon
Mr. John Huisman
Ms. Julie Grzyb
Ms. Karen Higgins
Ms. Pam Behm
Ms. Jing Lin
Mr. Adugna Kebede

UPPER NEUSE RIVER BASIN ASSOCIATION

Forrest Westall
Executive Director
forrest.westall@unrba.org
PO Box 270
Butner, NC 27509
Phone: 919. 339. 3679

On the Web:
http://unrba.org

Town of Butner

City of Creedmoor

City of Durham

Durham County

Franklin County

Granville County

Town of Hillsborough

Orange County

Person County

City of Raleigh

Wake County

Town of Wake Forest

South Granville Water and Sewer Authority

Soil and Water Conservation Districts

Town of Stem

December 10, 2024, Submitted via email

Mr. John (JD) Solomon, Chair
NC Environmental Management Commission (EMC)
1611 Mail Service Center
Raleigh, N.C. 27699 -1617
e-mail: jd.solomonemc@deq.nc.gov

Mr. Richard Rogers, Director
Division of Water Resources (DWR)
1611 Mail Service Center
Raleigh, NC 27699-1611
e-mail: richard.rogers@deq.nc.gov

Reference: UNRBA Submittal of the Falls Lake Model Report, Consistent with the Adaptive Implementation of the Falls Lake Rules (15 NCAC 02B .0275 (5) (f))

Dear Mr. Solomon and Mr. Rogers:

The Upper Neuse River Basin Association (UNRBA) is pleased to submit our lake model report for Falls Lake. Three different lake models were developed and are documented in this report:

- The Watershed Analysis Risk Management Framework (WARMF) Lake Model
- The Environmental Fluid Dynamics Code (EFCD) hydrodynamic/water quality model
- A statistical/Bayesian model

This modeling effort and documentation supplements and supports our previously submitted (November 2023) recommendations for a revised Falls Lake Nutrient Management Strategy and readoption of the Falls Lake Rules. For reference, those recommendations are summarized in the Concepts and Principles document and Consensus Principles II. While the lake modeling results and conclusions were completed and used to support the submitted recommendations, final documentation required additional time. Please note that due to the extensive work related to this effort, file sizes of the report and appendices necessitate access using this link: UNRBA Lake Model Report.

The UNRBA has made a concentrated effort to provide a robust model development process that has been thoroughly vetted through coordination with DWR and other stakeholders. This included our hosting of a model training for DWR staff on the use of the WARMF Lake model in February 2023 and submittal of the final modeling files and executable code in April 2023. We provided a model training on the EFDC model in November 2023 and provided those modeling files and executable code in December 2023. We are developing an application and user guide to review the statistical/Bayesian modeling results.

This has been a detailed and extensive effort by the UNRBA, and we appreciate the time and energy the DWR modeling and planning staff invested in this development and vetting process. DWR was represented at many meetings where modeling efforts were presented, and status reports provided. DWR staff provided extensive input and comments that improved these modeling products. The UNRBA presented the model development, calibration, and scenario analyses monthly at its status meetings while these models were under development. The UNRBA also hosted several technical stakeholder workshops to present findings to interested stakeholders.

The status meetings and workshops were well attended by staff from member local governments, utilities, DWR, NC Department of Transportation, NC Department of Agriculture and Consumer Services, US Forest Service, researchers from the NC Collaboratory, and representatives from agricultural and environmental interest groups. The modeling was reviewed and comments were received on numerous occasions by the stakeholders. The UNRBA and its consultant team worked diligently to address questions and input from all stakeholders. Based on this input, we refined and improved the lake models. We also provided the draft modeling report to our stakeholders, and this final report reflects their feedback. This lake modeling report serves the following purposes:

- Provides documentation that the development of the lake models followed the UNRBA Modeling Quality Assurance Project Plan (QAPP) approved by DWR.
- Supports the review and approval by DWR and the EMC of this lake model development report under the Falls Lake Rules (15A NCAC 02B .0275).
- Provides an evaluation of the modeling results relative to the impacts of nutrient loading from the watershed, improvements in the distribution of lake water quality monitoring data since the reservoir was constructed, and the implications of those findings for revised Falls Lake Rules.

Submittal of this report and the detailed materials already submitted provides the full documentation of the UNRBA's scientific re-examination of the Falls Lake Nutrient Management Strategy under the Falls Lake Rules (15 NCAC 02B .0275 (5) (f)).

The UNRBA has invested significant local government resources to obtain data, work with subject matter experts, and build calibrated models that effectively simulate Falls Lake and the watershed, providing the ability to assess water quality response to stream flows and delivered nutrient loading. The report and appendices document the lake modeling efforts and results in detail.

Based on the significant coordination with stakeholders, the transparent model development process, and the iterative reviews and revisions to the lake model report, the UNRBA respectively requests timely review and approval of this submittal by DWR and the Commission under the rules. Review and approval of the technical documents are needed as confirmation that the work completed meets the requirements for providing a reexamination of the Falls Lake Rules. We are using this information and working with DWR to jointly move the rules readoption process forward.

In accordance with this effort, DWR has developed a timeline for the rules readoption process and is coordinating this effort with the UNRBA and other stakeholders. On November 20th, the UNRBA and DWR held a joint Forum to summarize the UNRBA's work and outline the plan for successful readoption of a revised set of Falls Lake Rules. We are also working with DWR to coordinate several workgroups to discuss concepts for revised rule language and develop drafts for a larger stakeholder

audience to review prior to formal consideration by the EMC. To review this effort, we plan to jointly present the status to the full EMC or the Water Quality Committee at an upcoming meeting.

If there are any questions about the lake modeling report or next steps in the rules readoption process, please contact me.

Sincerely,

Forrest Westall
Executive Director, UNRBA

Copy: UNRBA Board Members
Mr. Rich Gannon
Mr. John Huisman
Ms. Julie Grzyb
Ms. Karen Higgins
Ms. Pam Behm
Ms. Jing Lin
Mr. Adugna Kebede

ATTACHMENT C:
EMAILS FROM DWR APPROVING THE UNRBA WATERSHED AND LAKE MODELS AND REPORTS

Alix Matos

From: Alix Matos
Sent: Friday, November 21, 2025 2:39 PM
To: Alix Matos
Subject: FW: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

---

From: Higgins, Karen <karen.higgins@deq.nc.gov>
Sent: Wednesday, July 31, 2024 2:12 PM
To: Forrest Westall <Forrest.Westall@mcgillassociates.com>
Cc: Gannon, Rich <rich.gannon@deq.nc.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; haywood@unrba.org
Subject: RE: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

> You don't often get email from karen.higgins@deq.nc.gov. Learn why this is important

Hi Forrest-

Thank you for the message. I apologize as it is my fault you did not get a response re the watershed model. There were several emails about the watershed and lake models earlier this spring and I thought the comments I referenced in the April email covered everything, not realizing the watershed model comments were provided to me separately.

Regarding your request for confirmation of the December 20 submittal of the UNRBA's Watershed Model Development Report, under the Falls Lake Rules' adaptive management provisions as defined under 15A NCAC 02B .0275 (5)(f)(iii), "*The Division shall assure that the supplemental modeling is conducted in accordance with the quality assurance requirements of the Division;*" the Modeling and Assessment Branch **confirm** that the Falls Lake WARMF Watershed model development process, described in the UNRBA Falls of the Neuse Reservoir (Falls Lake) Watershed Modeling Report that was submitted to DWR on December 20, 2023, in general followed the DWR approved Quality Assurance Project Plan (UNRBA, 2018).). It should be noted that some level of flexibility was exercised to include elements that were not directly reflected in the QAPP but was included to enhance the model development process.

Again, I apologize and appreciate you bringing this to my attention.

Karen

Karen Higgins *(she/her/hers)*
Water Planning Section Chief
Division of Water Resources
Department of Environmental Quality

(919) 707-3630 office
karen.higgins@deq.nc.gov (Updated)

512 N. Salisbury St., #1106-X, Raleigh, NC 27604
1611 Mail Service Center, Raleigh, NC 27699-1611

From: Forrest Westall <Forrest.Westall@mcgillassociates.com>
Sent: Wednesday, July 31, 2024 7:11 AM
To: Higgins, Karen <karen.higgins@deq.nc.gov>
Cc: Gannon, Rich <rich.gannon@deq.nc.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; haywood@unrba.org
Subject: RE: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

Hi Karen,

Hope you are well.

I write again to request action by the Division on our submittal of the Falls Lake Watershed Model Development Report. The previous emails outline, with reference to the Falls Lake Rules adaptive management provisions, the review sought by the UNRBA.

[*Personal information deleted.*] Nevertheless, our submittal was provided after an exhaustive effort to seek, respond to, and incorporate revisions to the modeling effort and report itself provided by subject matter experts engaged to provide an ongoing review of the effort and, most importantly for the purpose of this email, your modeling staff. The staff has been engaged in this process from the outset and have had access to our contractors and the model information in complete detail. I specifically directed our contractor from beginning to end to seek DWR's input and engagement to assure that they were and are fully familiar with our work. The UNRBA has provided a level of documentation and engagement that is extremely extensive, including summaries and reviews at each of our Modeling and Regulatory Support sub-committee, Path Forward Committee meetings, special meetings with subject matter experts and DWR modelers, the UNRBA Board, and even a training session on the WARMF watershed model set up specifically for DWR modeling staff (it was very well attended).

I do not want to have to detail all of the ways we have worked to make sure your staff is fully informed and engaged on the model development process and the development of the report itself. It has been a concentrated effort to make review simple and timely. It has now been 7 months since it was submitted for which is clearly a limited review supported in a host of ways. It has been 3 months since my last reminder of this pending review. I am at a loss to understand the delay. If there is a more complete, coordinated, and documented watershed modeling effort based on a huge and comprehensive database and watershed information-gathering process to support developing a nutrient management strategy in this state, I do not know of it.

We continue to look at our effort as a partnership with DEQ/DWR, stakeholders, and interested public to provide the most well-developed scientific evaluation possible on this watershed and lake. The watershed modeling has been essential to this process. It is critical that we move on to the important work of updating the rules. We have worked with John and Rich and have reached the conclusion well before we submitted our recommendations last November that we should proceed with the rules development process on the basis of our completed watershed and lake mechanistic models and the scientific observations and conclusions reached.

I seek your help to complete this review process.

Thanks for your time and consideration.

Forrest

Forrest R. Westall, Sr.
Executive Director
Upper Neuse River Basin Association
415 Central Ave. Suite A
Butner, NC 27509
Phone: 828.231.6840|
Email: forrest.westall@mcgillassociates.com
|**Website:** https://unrba.org/

From: Forrest Westall
Sent: Thursday, April 18, 2024 10:21 AM
To: Higgins, Karen <karen.higgins@deq.nc.gov>
Cc: Gannon, Rich <rich.gannon@deq.nc.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; haywood@unrba.org
Subject: RE: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

Thanks Karen.

Forrest

Forrest R. Westall, Sr.
Executive Director
Upper Neuse River Basin Association
415 Central Ave. Suite A
Butner, NC 27509
Phone: 919.339.3679 |
Email: forrest.westall@mcgillassociates.com |**Public Website**: https://upperneuse.org/
|**Technical Website:** https://unrba.org/

From: Higgins, Karen <karen.higgins@deq.nc.gov>
Sent: Thursday, April 18, 2024 9:51 AM
To: Forrest Westall <Forrest.Westall@mcgillassociates.com>
Cc: Gannon, Rich <rich.gannon@deq.nc.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; haywood@unrba.org
Subject: RE: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

Forrest-

[*Personal information deleted.*] UNRBA should receive combined comments from both Pam's group and Rich's group shortly.

Thanks-
Karen

Karen Higgins
Water Planning Section Chief
Division of Water Resources
Department of Environmental Quality

(919) 707-3630 office
karen.higgins@deq.nc.gov (Updated)

512 N. Salisbury St., #1106-X, Raleigh, NC 27604
1611 Mail Service Center, Raleigh, NC 27699-1611

From: Forrest Westall <Forrest.Westall@mcgillassociates.com>
Sent: Monday, April 15, 2024 3:08 PM
To: Behm, Pamela <pamela.behm@deq.nc.gov>
Cc: Higgins, Karen <karen.higgins@deq.nc.gov>; Gannon, Rich <rich.gannon@deq.nc.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; haywood@unrba.org
Subject: [External] FW: UNRBA Submittal of its WARMF Watershed Modeling Report

Hi Pam,

I hope all is well with you.

Attached and below is our December 20, 2023 submittal of the UNRBA's Watershed Model Development Report. We requested review under the Falls Lake Rules' adaptive management provisions as defined under 15A NCAC 02B .0275. I know we touched base on the many demands on you and the modeling staff's time. We acknowledged those demands when we sent in our final document. I wanted to check with you on your review of the watershed model development effort. With reference to the rule cited, section (5) (f) (iii) includes language referencing the modeling information developed as part of the supplemental study and modeling effort allowed under the rule. The Watershed Model, as you know, is an essential component of both the EFDC and WARMF-Lake models. We have worked hard to follow the approved Modeling QAPP, which represents the modeling procedures established and adopted for the UNRBA's efforts. The cited rule section includes the following statement: "The Division shall assure that the supplemental modeling is conducted in accordance with the quality assurance requirements of the Division." Because the Division-approved QAPP represents the quality assurance requirements for this effort, our report documents the steps taken to make sure the model development process was conducted in accordance with that plan. I believe the Division's determination relates to the model development process only and not to modeling results or the UNRBA's use of the developed model to test certain scenarios. DWR's assurance would only speak to the development of the model. We have worked closely with the modeling staff to develop the watershed model and we have addressed the Division's comments on the draft of the report before it was finalized. I would request again that DWR provide a finding under the rule on our model development effort. Much work still remains to readopt the Falls Lake Rules. So, having confirmation that the model development process followed quality assurance guidelines is important as we work cooperatively with DWR and all of our stakeholders to update the rules and strategy for Falls Lake.

We are working with Rich and John to promote moving forward with readoption of the Falls Lake Rules. We met last week, and we briefly discuss the status of the modeling work review.

Related to the lake modeling effort, I understand that you all have completed a review of the draft EFCD and WARMF-Lake model development report. I believe that those comments are being reviewed prior to submittal to the UNRBA. Thank your for that effort. We anticipate receiving those comments soon.

Thank you for your time and consideration.

Forrest

Forrest R. Westall, Sr.
Executive Director
Unrba
Upper Neuse River Basin Association
415 Central Ave. Suite A
Butner, NC 27509
Phone: 919.339.3679 **|**
Email: forrest.westall@mcgillassociates.com **|Public Website**: https://upperneuse.org/
|Technical Website: https://unrba.org/

From: Forrest Westall
Sent: Wednesday, December 20, 2023 11:11 PM
To: pamlicojd@gmail.com; Richard Rogers <richard.rogers@ncdenr.gov>
Cc: Grzyb, Julie <julie.grzyb@ncdenr.gov>; 'Higgins, Karen' <karen.higgins@ncdenr.gov>; Behm, Pamela <pamela.behm@deq.nc.gov>; Gannon, Rich <rich.gannon@ncdenr.gov>; Lin, Jing <jing.lin@ncdenr.gov>; Kebede, Adugna <Adugna.Kebede@ncdenr.gov>; Huisman, John <john.huisman@deq.nc.gov>; Alix Matos <AMatos@BrwnCald.com>; Haywood Phthisic <haywood@unrba.org>
Subject: UNRBA Submittal of its WARMF Watershed Modeling Report

Hello Chair Solomon and Director Rogers,

Attached is the transmittal letter for submission of the UNRBA's watershed model, Watershed Analysis Risk Management Framework (WARMF) model, under the adaptive management provisions of the Falls Lake Rules. Because of the size of the report and its appendices, the letter provides a link to the UNRBA website for access to the main report and the appendices.

The cover letter provides a very brief introduction to the model development process and the exhaustive supporting documentation developed during the building of this model. Obviously the report provides a comprehensive review of the development effort. It has been a multi-year process and we greatly appreciate the engagement of DWR, our member representatives, the Collaboratory reviewers, and other stakeholders. The model development process was directed by the DWR-approved Quality Assurance Project Plan and the report references this document throughout.

I realize that the Division has many priorities and much work to perform to meet its obligations. I emphasized throughout the model development process the importance of providing review and input as the model was being built and as critical decisions on the model were being made. We opened up the process with deliberate transparency so that the modeling and our work would be well understood from beginning to end. I certainly understand the obligations and responsibility of the Division and EMC to consistently apply the provisions of all rules, including the Falls Lake Rules. In recognizing these obligations, I would note that the ongoing and progressive management actions to address

nutrient impacts in Falls Lake need to proceed in a timely way. We plan to work collaboratively with DWR and the EMC to assist with the development of revised Falls Lake Rules. Review of this modeling information is an important part of our ability to see rules readoption proceed as quickly as possible.

The UNRBA will submit its Lake Modeling report as soon as the documentation has been finalized. As the Division and staff know, the lake modeling using EFDC and WARMF-Lake are completed and those efforts comprehensively reviewed and vetted. The lake modeling report preparation is to provide documentation of the process, comments provided and addressed, calibration, confirmation and finalization of the models.

We look forward to continuing working with DWR and the EMC in developing an effective and progressive management strategy for Falls Lake. If you have any questions, please let me know.

Thank you and I hope everyone has an enjoyable Holiday Season.

Forrest

Forrest R. Westall, Sr.
Executive Director
Unrba
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Butner, NC 27509
Phone: 919.339.3679 **|**
Email: forrest.westall@mcgillassociates.com **|Public Website**: https://upperneuse.org/
|Technical Website: https://unrba.org/

Alix Matos

From: Alix Matos
Sent: Tuesday, November 18, 2025 3:03 PM
To: Alix Matos
Subject: FW: [External] RE: Workgroup & Workshop Schedule

From: Huisman, John <john.huisman@deq.nc.gov>
Sent: Wednesday, February 12, 2025 11:09 AM
To: Forrest Westall <Forrest.Westall@mcgillassociates.com>; Alix Matos <AMatos@BrwnCald.com>
Subject: RE: [External] RE: Workgroup & Workshop Schedule

Yes, I have confirmed with Modeling Unit that there is no more review or comments. This will close the loop "officially".

John

From: Forrest Westall <Forrest.Westall@mcgillassociates.com>
Sent: Wednesday, February 12, 2025 11:07 AM
To: Alix Matos <AMatos@BrwnCald.com>; Huisman, John <john.huisman@deq.nc.gov>
Subject: RE: [External] RE: Workgroup & Workshop Schedule

Yes, thanks John. I hope that "completion of the process" is the focus! 😊

Forrest

From: Alix Matos <AMatos@BrwnCald.com>
Sent: Wednesday, February 12, 2025 10:58 AM
To: Huisman, John <john.huisman@deq.nc.gov>; Forrest Westall <Forrest.Westall@mcgillassociates.com>
Subject: RE: [External] RE: Workgroup & Workshop Schedule

Wonderful news, thanks!

Alix Matos, PE
Principal, Environmental Engineering
Brown and Caldwell | Raleigh, NC
AMatos@brwncald.com
T 919.424.1458, 2235 | **C** 919.961.7658

From: Huisman, John <john.huisman@deq.nc.gov>
Sent: Wednesday, February 12, 2025 10:32 AM

To: Forrest Westall <Forrest.Westall@mcgillassociates.com>; Alix Matos <AMatos@BrwnCald.com>
Subject: RE: [External] RE: Workgroup & Workshop Schedule

Thanks for the feedback. I just discovered our internal "pre-emc" prep meeting for the March WQC/EMC is tomorrow afternoon so I anticipate getting some additional direction from the Director. I will circle back with you after that meeting to share the outcome.

Also wanted to let you know I finally got my hands on the updated DWR letterhead. I plan to draft up a letter recognizing receipt of the UNRBA models and model reports and completion of that process. It will take a few days to work its way up to the Director for his signature, but I am shooting to get it over to you in the next week or so – that way we can close that loop on the model tasks. Thanks!

John Huisman
Environmental Program Consultant, Division of Water Resources
North Carolina Department of Environmental Quality
Office: (919) 707-3677
john.huisman@deq.nc.gov